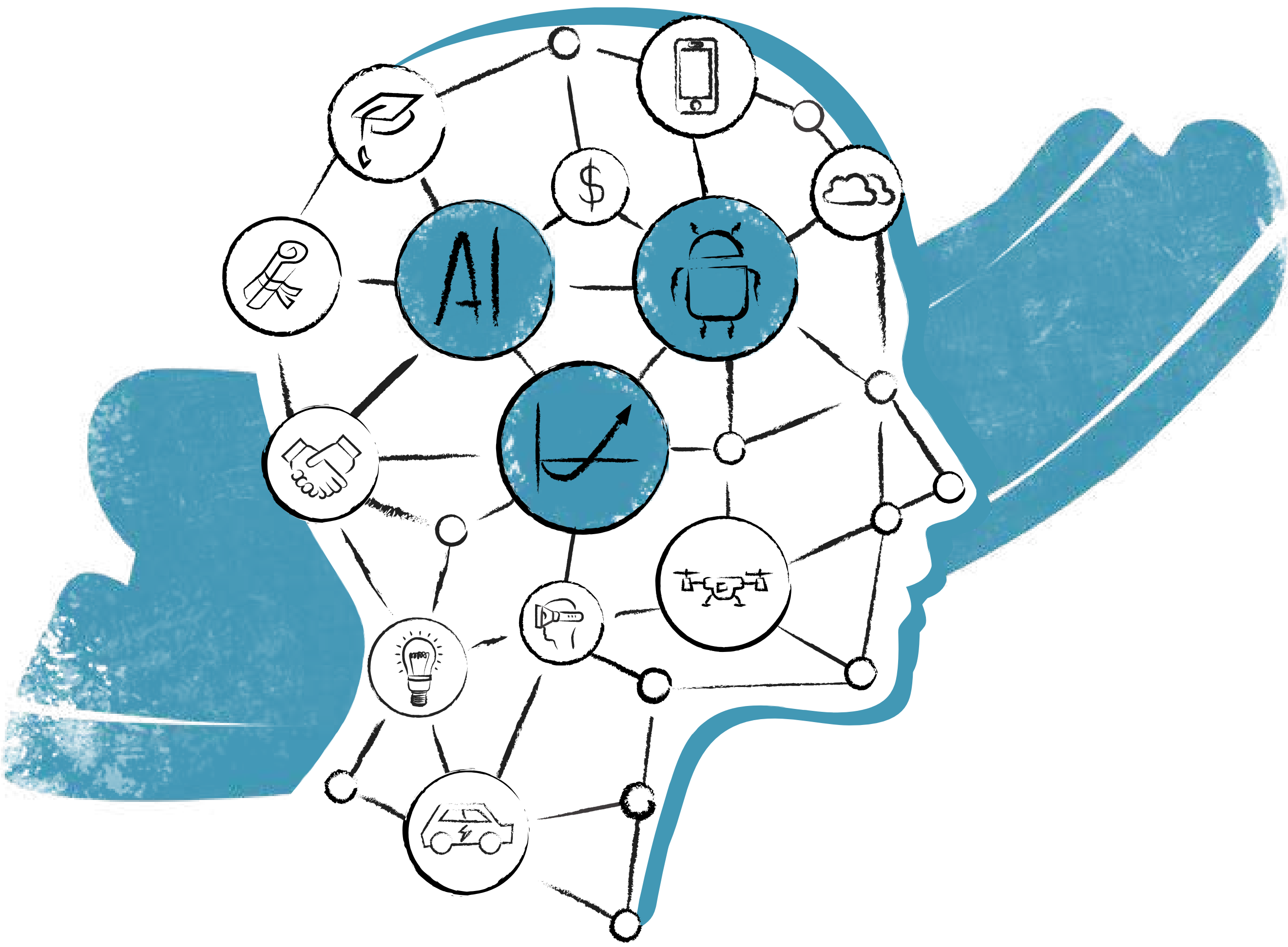
NEW ZEALAND
PRODUCTIVITY COMMISSION
Te Kōmihana Whai Hua o Aotearoa



New Zealand, technology and productivity

Technological change and the future of work

Draft report 1
September 2019

The Productivity Commission aims to provide insightful, well-informed and accessible advice that leads to the best possible improvement in the wellbeing of New Zealanders. We wish to gather ideas, opinions, evidence and information to ensure that our inquiries are well-informed and relevant. The Commission is seeking submissions on the draft findings and recommendations and the questions contained in this report by 20 January 2020.

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The Commission – an independent Crown entity – completes in-depth inquiries on topics selected by the Government, carries out productivity-related research and promotes understanding of productivity issues. The Commission aims to provide insightful, well-informed and accessible advice that leads to the best possible improvement in the wellbeing of New Zealanders. The New Zealand Productivity Commission Act 2010 guides and binds the Commission.

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[1] The Commission that pursues abundance for New Zealand.

Terms of reference

New Zealand Productivity Commission Inquiry into Technological Change, Disruption and the Future of Work

Issued by the Minister of Finance, the Minister of Education, the Minister for Economic Development, the Minister for Workplace Relations and Safety and the Minister for Government Digital Services (the "referring Ministers"). Pursuant to sections 9 and 11 of the New Zealand Productivity Commission Act 2010, we hereby request that the New Zealand Productivity Commission ("the Commission") undertake an inquiry into how New Zealand can maximise the opportunities and manage the risks of disruptive technological change and its impact on the future of work and the workforce.

Context

Technology, and its rapid development and adoption, is one of the critical dynamics in the changing world of work. The transition to a low-emissions economy has begun and will accelerate, providing scope for New Zealand to increase its focus on technology and changing economic opportunities. While technological innovation and disruption is nothing new, the increasingly pervasive nature of disruptive technologies and the pace of change will create significant opportunities for New Zealand to achieve a productive, sustainable, and inclusive economy. However, systemic, rapid change can be daunting and it is important for government to understand and respond to this prospective change so that these opportunities are realised and the risks managed. The opportunities and risks also need to be communicated in a clear and accessible way to New Zealanders. Technology is changing how government interfaces with the public and business, so government needs to be ready to respond to change in an agile and adaptive manner.

It is difficult to predict exactly what technological change will mean for New Zealand and how widespread disruption will be, but impacts are being felt already in the form of changing business models and some jobs being replaced or transformed by automation. While non-government parties (businesses, consumers and communities) will to a large extent drive change, government also has an important role to play by actively managing the impacts on different groups (positive and negative), and using policy and regulation to promote the innovative and beneficial use of technology across the public, business and not-for-profit sector.

New Zealand has had much success in labour market participation and employment on the whole but some groups are under-represented in labour market participation and employment. While technological disruption may pose fresh challenges in terms of policy and regulatory changes needed to help workers and firms adjust, it also provides opportunities to reduce barriers for participation. The government must actively manage a just transition, such as through its range of initiatives that support workplace productivity, regional labour markets and filling skills gaps. Finally, the government has a vital role in how it chooses to promote the innovative use of technology in the public sector and business community and to ensure a level playing field for different technologies.

Well-designed and coordinated government responses could allow New Zealand to:

- fully realise the potential of disruptive technologies for economic productivity and social prosperity;
- improve the services provided by government and increase the efficiency and effectiveness with which government functions; and
- provide an enabling environment without unnecessary barriers to desirable change, while effectively managing risks.

Together, these would also help to prepare New Zealand for any rapid labour displacement and distributional impacts.

Scope and Aims

The purpose of this inquiry is to provide an independent assessment of the scale and potential impacts of rapid technological change and its disruptive impact on the future of work and the workforce in New Zealand. The overriding aim is to harness changes to maximise the wellbeing of New Zealanders. The assessment should provide material for future government policy development and other initiatives to prepare the country for a productive, sustainable, and socially-inclusive future, despite uncertainties around the impact of technology.

For this inquiry, 'disruption' is primarily about the impacts of technological change. The inquiry should acknowledge the potential for disruption to have both positive and negative impacts.

Two broad questions should guide the inquiry:

- What are the current and likely future impacts of technological change and disruption on the future of work, the workforce, labour markets, productivity and wellbeing?
- How can the Government better position New Zealand and New Zealanders to take advantage of innovation and technological change in terms of productivity, labour-market participation and the nature of work?

We encourage the Commission to break the inquiry down into a series of shorter, related reports, published throughout the term of the inquiry, with a final report summarising findings and providing recommendations. For example, the topics could be as follows:

1. A scene setter:
   - A definition of disruption;
   - An analysis of the status quo in New Zealand, including the government's institutional and regulatory ability to flexibly adapt to a rapidly changing environment, and to support the diffusion of innovation;
   - The likely nature and scale of the impact of technology change on labour- market participation, under-employment, productivity, wages, education and skill requirements, and the nature of jobs (e.g. the gig economy);
   - The likely scale and pace of technology change, including across regions and industries, and the distributional impacts within the population; and
   - New Zealand's distinctive features in this space, and its comparative advantages and disadvantages (e.g. relatively flexible labour market and high employment, significant incidence of low skills).
2. How can active labour market policies, including their interaction with the welfare system, assist (or hinder) displaced workers to transition to different types of work and work places?
3. How can New Zealand's education and training systems be more effective in enabling adaptation to technological disruption?
4. How can we address the digital divide in New Zealand?
5. Identifying how technological change will affect different groups of workers, and therefore what are the appropriate types and levels of support required.
6. How can the regulatory environment enable adaptation to change, provide opportunities for new technologies to be tested and understood in New Zealand, and become more responsive to disruptive change?
7. How can government best encourage technology innovation and uptake, with a focus on wage growth and the development of appropriate high-engagement, high- performance actions and behaviours in New Zealand workplaces and industries?

8. How can New Zealand firms improve their employees' management capability in terms of adapting to technological change?

Report and Recommendations

The inquiry should explore New Zealand and international research and experience related to the questions above. However, the focus should be on practical applications relevant to New Zealand's circumstances.

Given the uncertainty around future technology and its impact, the inquiry is not expected to make detailed, quantified predictions of impacts. Rather, it should give a sense of the nature and relative scale of impacts in different scenarios.

The inquiry should have a long-term focus, with recommendations that can be implemented in the short- to medium-term. It should provide a resource for government to develop policies and programmes that make the most of the technological opportunities on offer and allow New Zealanders to face an uncertain future with confidence.

The report should build on previous relevant inquiries undertaken by the Productivity Commission.

The final report should provide recommendations for how New Zealand should manage a transition to a more technically advanced economy in relation to both technology's upside and downside risks, while still maintaining or improving incomes and wellbeing across all groups in the population, through recommendations on appropriate policy settings.

Consultation

Given that technological change is an issue of national significance, the Commission should consult with a broad range of stakeholders including: central and local government; the Future of Work Tripartite Forum, Future of Work Ministerial Group, the Just Transitions Unit in MBIE, and any new Future of Work groups established in Government agencies; relevant industry and NGO groups, including the NZCTU and Business NZ; academic bodies, businesses, Iwi, and the general public.

This inquiry is intended to complement and take account of existing policy work and other current work by evidence-gathering groups on the future of work and the impacts of technological change. The groups include the Law Commission, the AI Forum, and the OECD.

Timeframes

The Commission should present a final report to referring Ministers by 31 March 2020.

About this inquiry

This inquiry explores the impacts of new and changing technology on the quantity and nature of work. It builds on research and modelling carried out by governments, academics and other organisations in New Zealand and throughout the world. The inquiry aims to answer two main questions:

- What are the current and likely future impacts of technological change and disruption on the future of work, the workforce, labour markets, productivity and wellbeing?
- How can the Government better position New Zealand and New Zealanders to take advantage of innovation and technological change in terms of productivity, labour-market participation and the nature of work?

This first draft report sets the scene for the inquiry and for subsequent publications. It aims to:

- examine what factors affect the adoption of technology, and how technology adoption affects the labour market (Chapter 1);
- survey how technology affected work in the past, including in New Zealand (Chapter 2);
- lay out scenarios for future productivity growth and labour-market change (Chapter 3); and
- examine how best to prepare for an uncertain future (Chapter 4).

What the four draft reports will cover

The Commission will publish four draft reports addressing different aspects of the inquiry's terms of reference.

Report 1 **New Zealand, technology and productivity**	• Defining technology, technological change and disruption • What factors affect technology adoption and diffusion? • What are the labour-market effects of technology diffusion to date? • What might future technology adoption and labour market change look like? • Preparing for an uncertain future
Report 2 **Employment, labour markets and income**	• How has technology affected New Zealand's labour market? • How well do current employment laws balance protections & flexibility? • Are there opportunities to improve the current income support systems and better support unemployed workers into jobs? • How well-matched are New Zealand workers and jobs? How mobile are workers? Can current policies be improved?
Report 3 **Education and skills**	• How can the education system best prepare young people for an uncertain future? • How can the education system best respond to the needs of people in work to retrain and acquire new skills over time? • How can the digital divide best be closed?
Report 4 **Preparing New Zealand for the future**	• How can governments better encourage technology uptake – and hence productivity growth – in New Zealand? • What policy areas should be the priority?

Timetable

Draft report	Scheduled release
1. New Zealand, technology and productivity	September 2019
2. Employment, labour markets and income	October 2019
3. Education and skills	November 2019
4. Preparing New Zealand for the future	December 2019

The Commission will deliver a **final report to the Government in March 2020**, bringing together themes, findings, recommendations and participant feedback from the draft reports.

Register your interest

The Commission seeks your help in gathering ideas, opinions and information to ensure this inquiry is well informed and relevant. The Commission will keep registered participants informed as the inquiry progresses. You can register for updates at www.productivity.govt.nz/have-your-say/subscribe, or by emailing your contact details to info@productivity.govt.nz.

Make a submission

The Commission is interested in hearing comment, feedback and other evidence on the draft reports, and is conscious that different people and groups will have differing levels of interest in each of them. The Commission therefore welcomes separate submissions on each of the reports, submissions that respond to cross-cutting themes in multiple reports, or a single submission that covers all four of the reports. Please pick the format and approach that suits you best.

Due date for submissions

The due date for submissions on this report and on the three subsequent draft reports is **20 January 2020**.

Anyone can make a submission. Your submission may be written or in electronic or audio format. A submission may be a short note on one issue or a substantial response covering multiple issues. Please provide relevant facts, figures, data, examples and documents where possible to support your views. Multiple, identical submissions will not carry more weight than the merits of your arguments. Your submission may incorporate relevant material provided to other reviews or inquiries.

Your submission should include your name and contact details and the details of any organisation you represent. The Commission will not accept submissions that, in its opinion, contain inappropriate or defamatory content.

Sending in your submission

Please make a submission via www.productivity.govt.nz/have-your-say/make-a-submission. The Commission appreciates receiving submissions in PDF format.

What the Commission will do with submissions

The Commission wants to have as much information as possible on the public record. Submissions will become publicly available documents on the Commission's website. This will occur shortly after receipt, unless your submission is marked "in confidence" or you wish to delay its release for a short time. Please contact the Commission before submitting "in confidence" material.

Other ways you can participate

The Commission welcomes feedback about this inquiry. Please email your feedback to info@productivity.govt.nz or contact the Commission to arrange a meeting with inquiry staff.

The inquiry team is running a blog on technological change and future of work topics until December 2019. Individual staff members post regularly at www.productivity.govt.nz/futureworknzblog/. You can subscribe at www.productivity.govt.nz/have-your-say/subscribe. Comments and guest posts welcome.

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Overview

Technology is the lifeblood of productivity growth and improvements in human wellbeing. The emergence and spread of technologies over the past 250 years have allowed people to have longer, safer and healthier lives; enjoy more abundant and cheaper food; and reduced the prevalence of dangerous, back-breaking labour. People today have more leisure, more income and more choice over how to spend their money and free time.

New technologies also involve change to existing firms, goods and services, and jobs. Once successful companies, products and occupations can face reduced demand or obsolescence.

These changes raise understandable concerns about the impacts on people whose skills or investments have been made redundant, and each major technological era has seen debate about its possible negative impacts on work and jobs. But technology does not have a single, negative effect on jobs and work. It has many different effects, some of which create demand for more workers and new skills. Widespread and large-scale technological change over the last two and a half centuries has not reduced the overall quantity of work and employment in any country, nor the centrality of work to society.

This report looks at the factors affecting technology adoption and how technological adoption affects the labour market. It also examines how technology affected work in the past, including in New Zealand.

There are many recent predictions of the labour-market impact of new automation technologies. Their headline results vary from minor impacts through to significant, perhaps unprecedented, disruption. This report surveys these predictions and contrasts them with the most recent data on labour markets and economic conditions. The report's draft findings are summarised below:

- There is little, if anything, in the available data to suggest imminent disruption to work. In an environment of rapid technological change and diffusion, one would expect to see high rates of firm start-ups, high productivity growth and high levels of job churn. Yet across the developed world, the data indicates the opposite.
- The likely pace and scale of technological change in New Zealand will depend to a significant extent on developments overseas. The vast majority of technologies used by New Zealanders in business, work and everyday life were created offshore, and that is likely to remain the case. If technological progress speeds up overseas, it will also do so here. Likewise, New Zealand will not be immune to an overseas slowdown in technological development.
- Technological and labour-market trends in New Zealand will tend to lag behind those overseas and will be more muted, if recent history is anything to go by. This country is small, far from its trading partners, and has historically done a poor job of adopting new technologies. While poor adoption may mean less disruption to work, it also results in lower productivity growth, lower income growth and fewer resources to pay for the things New Zealanders value.
- New Zealand needs to embrace technology, not treat it as a threat. The problem is not that there is too much technological change and adoption; there is too little. More and faster technology adoption will open up opportunities to improve New Zealanders' living standards. Embracing technology implies supporting people who are less able to adjust, preparing young people for the future, and setting policies and institutions that encourage the entry and uptake of new knowledge, processes, goods and services by firms. There are things New Zealand can do now to support smoother transitions and to seize these opportunities.

The Commission will provide further analysis and advice in three upcoming draft reports: *Employment, labour markets and income*, *Education and skills* and *Preparing New Zealand for the future*.

1 Technology diffusion and its impacts on work

Key points

- Technology is the application of knowledge that makes the production of goods and services cheaper or higher-quality, creates new goods and services, and changes relationships between consumers and producers. Technological progress was behind the dramatic growth in incomes, productivity and wellbeing over the past 250 years.
- The spread (or 'diffusion') of a technology throughout an economy occurs when firms and individuals decide to adopt it. Many factors affect the decision to adopt a technology, including:
  - how certain and large the returns are from investment in the technology;
  - access to the information, skills and tools needed to successfully implement the technology;
  - changes in a firm's operating costs, and whether the technology will reduce those costs or increase revenue;
  - labour-market dynamics, employment relationships and institutional settings;
  - how competitive markets are; and
  - barriers and incentives created by government policy.
- Technological progress and diffusion have many effects on the labour market, both positive and negative, and more than one effect can occur at the same time. Because of this complexity, it is difficult to predict the impact of a specific technology.
- The impact of technology on the labour market has changed over time. In the earlier years of the Industrial Revolution, mechanisation replaced skilled artisans, increased the demand for lower-skilled labour and suppressed wage growth. From the second half of the 19^{th} century, the demand for higher-skilled labour and incomes increased, reflecting the needs of large and complex factories and new production methods. More recently, the advent of information technology has increased returns for higher skills and non-routine cognitive tasks, while displacing routine tasks. In many developed countries this has led to 'job polarisation', with growth in (non-routine) low-skilled and high-skilled jobs but not in (more routine) middle-skilled jobs.
- New Zealanders have adopted and applied technology since the early days of human settlement, especially in agriculture (eg, the development of kumara pits). Technological progress in the form of refrigerated shipping increased New Zealand incomes and encouraged the development of new firms and industries. However, high levels of industry protection between the 1930s and 1980s discouraged technology adoption and innovation. The economic reforms of the 1980s and 1990s opened up the economy and allowed domestic resources to move to more productive uses. This period saw large shifts in the New Zealand labour market towards the service sector and high-skilled jobs, and especially towards Auckland.
- New Zealand's poor productivity growth is due in part to the weak diffusion of technology across the economy.

1.1 What is technology and why does it matter?

Defining technology, technological change and disruption

'Technology' is central to economic thinking, yet the concept itself is often defined very broadly and imprecisely.

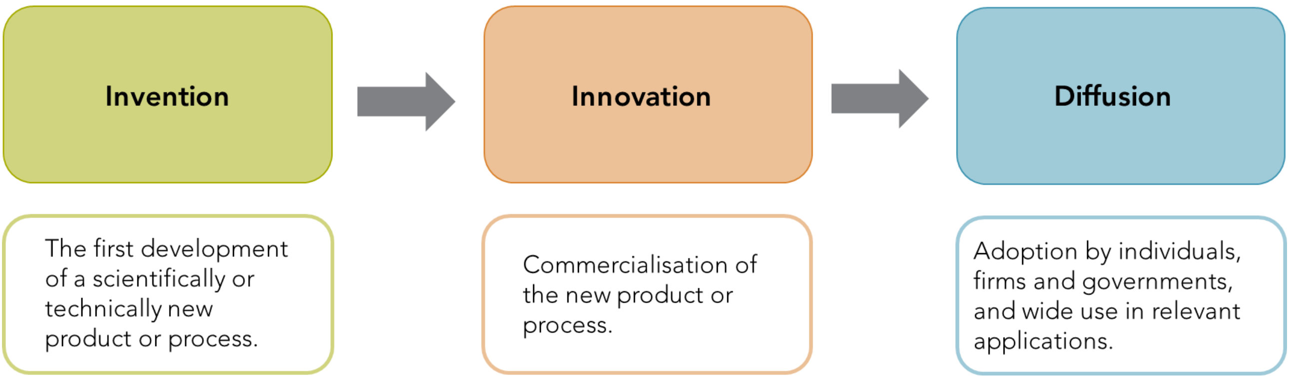
- The *Dictionary of Economics* describes technology as "the application of human knowledge to create machines and methods [that] improve products and their production and marketing" (Collin, 2006, p. 200).
- Jones and Vollrath (2013) define technology as "the way inputs to the production process are transformed into output" (p. 80).

These definitions often focus on the production of goods and services for sale in markets. However, technology and technological improvement are equally important for the delivery of goods and services by governments and not-for-profit entities (NZPC, 2015a, 2017b). Technology, especially its recent manifestations, can also change production, consumption, and the nature of the transaction between producers and consumers. For example, consumers now undertake some activities once done by employees, such as checking in at an airport.

The Commission will adopt the following definitions for this inquiry.

- Technology is the application of knowledge to improve the production, quality or delivery of goods and services, or to create new goods and services. This knowledge can be embodied in products, physical assets (eg, machinery) or in intangible assets (eg, software, product designs, business processes).
- Technological change is the overall process of invention, innovation and diffusion of technology (Figure 1.1).
- Technological disruption is when new or existing technologies make existing firms, business models, skills or occupations obsolete, at a pace and scale that is both unexpected and larger than ordinary rates of change.

Figure 1.1 Three stages of technological change



Source: Adapted from Jaffe, Newell and Stavins (2000)

The Commission defines technology broadly because of the many forms it can take. However, this inquiry has been motivated in part by technologies predicted to automate human tasks and change the quantity and nature of work, such as artificial intelligence (AI), machine learning, robots and predictive analytics. Later sections consider these technologies in more detail, and their possible impacts on labour markets.

Although the creation and commercialisation of new technologies are critical to technological change, for this inquiry the Commission is more interested in how technologies spread throughout the economy (ie, diffusion). New Zealand firms and researchers will only invent a small share of the total number of technologies that are going to affect labour markets in this country. Accordingly, diffusion is of more importance than invention or innovation in the context of this inquiry.

While individual events and changes can cause disruption to the lives of specific people and the fortunes of specific firms, the Commission believes the term 'technological disruption' is best reserved for unexpected change that creates significant adjustment costs across the economy. This reinforces the idea that technological change is both normal and ongoing, and that planning for and adapting to it should be 'business as usual' for individuals, firms and governments. A desirable feature of an economy is its ability to cope with technological change without disruption.

How far away is the future?

The further into the future one peers, the less reliable one's predictions become. Those looking forward in 1970 predicted flying cars and humans on Mars by 2020. Others predicted global famines and running out of oil. It is unlikely that anyone predicted social media or Brexit.

Most of the studies of automation and labour markets that motivated this inquiry make predictions for the next 10 to 20 years. Accordingly, the Commission adopted the midpoint (15 years) as the forecasting timeframe for this inquiry. The draft reports present the Commission's best judgement as to what will feasibly happen over the years 2020–2035, but this will not correspond exactly with events up to 2035. Technological effects on labour markets will interact with – and may be swamped by – political, social and economic changes that are outside the scope of this inquiry.

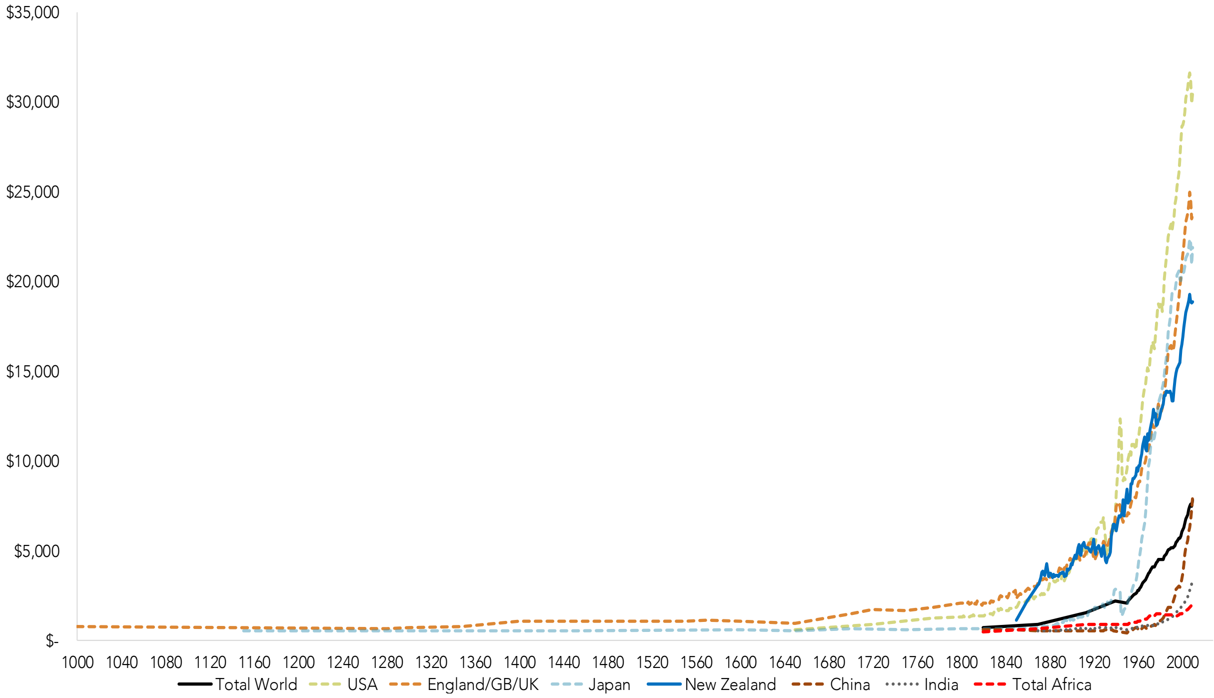
The nature of work

The inquiry's terms of reference also refer to, but do not define, the 'nature of work'. This term could encompass everything from the role of work in society, the sense of personal identity associated with a job, the process by which work is arranged, regulated and unregulated work conditions, salary levels, hours and the tasks undertaken. It is conceivable that technology could affect all of these over the long run. Having said that, social norms and culture change more slowly than technology. This report concentrates on those aspects of work more likely to change between now and 2035.

Technology adoption grows incomes and lifts wellbeing

Economic models and studies typically attribute a large part of the dramatic growth in incomes experienced over the past 250 years (Figure 1.2) to technological progress.

Figure 1.2 Estimated average per-capita GDP, total world and selected countries, 1000–2000



Source: Bolt and van Zanden (2014)

Note:

1. Per-capita world GDP in 1990 international dollars.

By increasing productivity, technological progress has freed increasing numbers of people from drudgery, hunger, disease and back-breaking labour, and created the incomes and wealth to support higher living standards. Nobel Economics Laureate Angus Deaton (2013) described these dramatic lifts in health and longevity as "the Great Escape" from widespread death and deprivation.

Technology has radically improved human wellbeing, as can be seen in greater food availability (Box 1.1), longer life expectancy (Box 1.2) and more leisure time (Box 1.3).

Box 1.1 **Technology allowed food production to increase faster than population**

Worries about the ability of food production to keep pace with population growth have fuelled pessimistic predictions about the future for centuries. Paul Ehrlich famously predicted in 1968 that the:

> … battle to feed all of humanity is over. In the 1970s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate (1968, p. xi).

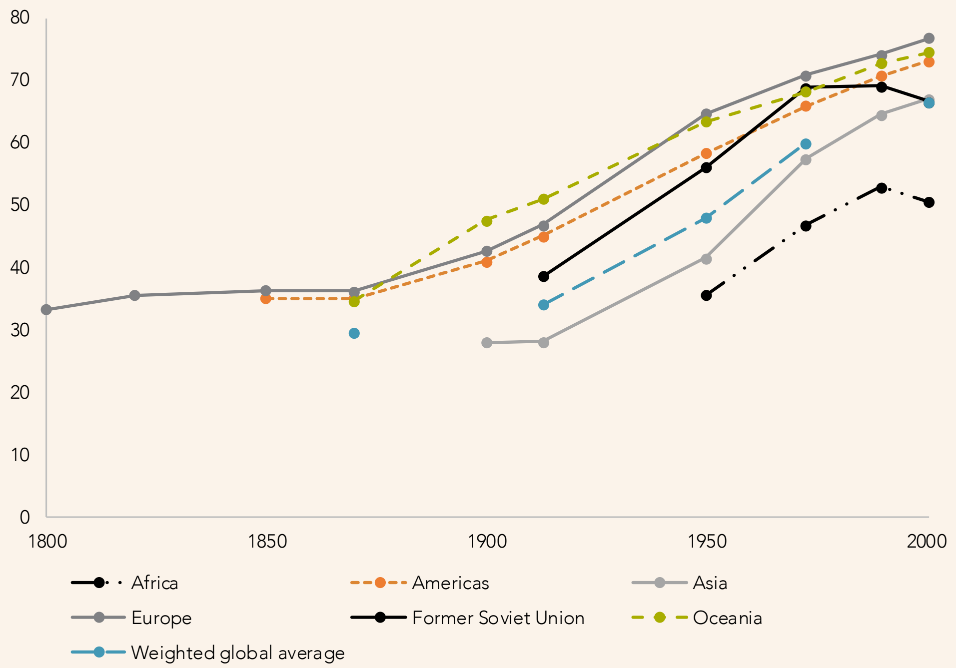
Despite this prediction, agricultural productivity in many developing countries dramatically increased from the mid-1960s to the 1980s, due in large part to the development and diffusion of higher-yielding and more robust crop varieties, especially rice and wheat. Estimates of the impact of this 'Green Revolution' have found that without these crop improvements:

> … food production in developing countries would have been almost 20% lower (requiring another 20–25 million hectares of land under cultivation worldwide). World good and feed prices would have been 35–65% higher, and average calorific availability would have declined by 11–13% (Pingali, 2012, p. 12303).

Box 1.2 **Technology supported a strong rise in life expectancy**

Improvements in nutrition and access to food, rising living standards, falls in the relative prices of other health-promoting goods, and the application of knowledge to improve medicine, food safety and public works have seen life expectancy rise strongly in most regions of the globe, especially since the turn of the 20th century (Mokyr, 1993) (Figure 1.3).

Figure 1.3 Estimated life expectancy by region, 1800–2001



Source: Riley (2005)

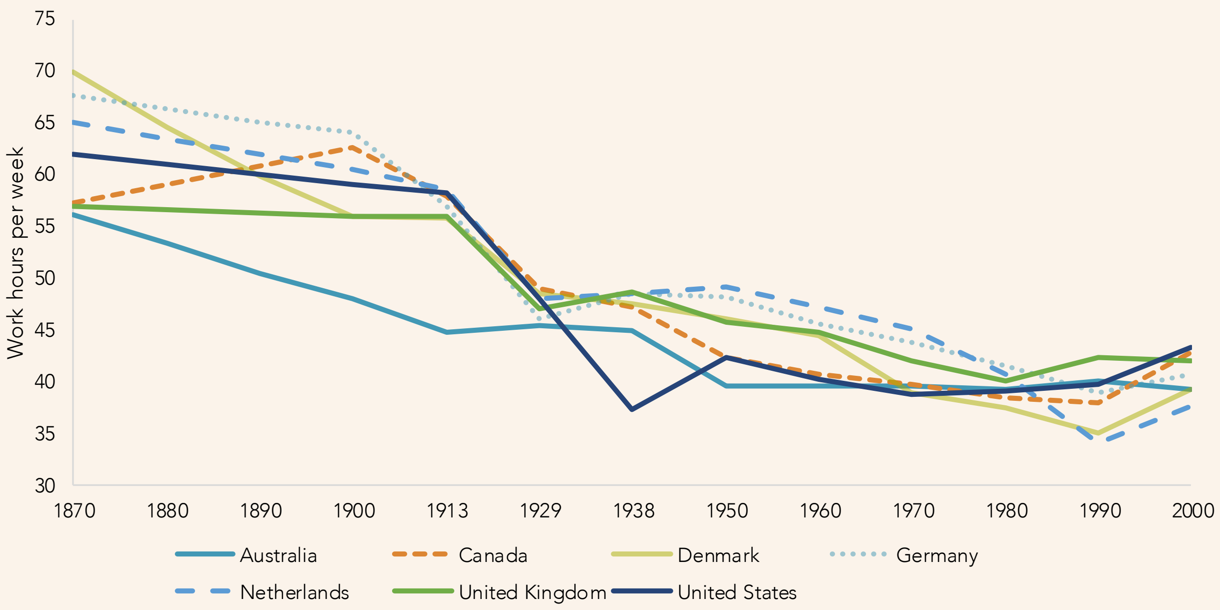
Box 1.3 **Technology reduced work hours and increased leisure time**

Technology-driven productivity growth frees up more time for leisure and reduces the burden of work. As a report prepared for President Obama commented, one of the:

> … main ways that technology increases productivity is by decreasing the number of labor hours needed to create a unit of output. Labor productivity increases generally translate into increases in average wages, giving workers the opportunity to cut back on work hours and to afford more goods and services. Living standards and leisure hours could both increase (Executive Office of the President, 2016, p. 9).

The effect of technology (and greater regulation of workplaces) on access to leisure can be seen in the large falls in average working hours across developed countries between 1870–2000 (Figure 1.4).

Figure 1.4 Hours of work per week, 1870–2000



Source: Huberman and Minns (2007)

Note:

1. Work hours per week for full-time production workers. Netherlands data for 1960 interpolated.

These undoubted advances in living standards have brought with them some challenges, including increased pressure on the environment. The relationship between technology and the environment is complex. Technology has become essential for both environmental monitoring and remediation; indeed further technological development is necessary to adapt to and limit human-induced climate change (NZPC, 2018).

Technological change creates adjustment costs, which fall unevenly

The technological progress of the past two centuries has been overwhelmingly positive for human wellbeing, at least when measured over time and in aggregate. Technological progress is, however, the ongoing adoption and interaction of individual technologies. These typically displace or at least devalue older technologies, and their associated skills and assets.

Importantly, the costs and benefits from change may fall unevenly across people and across time. Those who anticipate bearing the costs – and those for whom societal costs are more salient than benefits – will quite understandably oppose such change. For example, it is little more than a century since cars were banned in favour of horses in parts of the South Island (Queenstown Historical Society, 2016), reflecting opinions such as the following published in 1900 in the *New Zealand Herald*:

> Think how impassable the streets will be when thousands of motor cars are rushing along at the high rate of speed which they invariably adopt … A horse does not run a man down if he can help it, but … the path of a runaway motor will be strewn with dead and mangled citizens, and when it finally runs into a lamp post and blows up the explosion will be worse than that of a fifteen-inch shell … Regarded as a machine, it is one of the noisiest and most objectionable that has ever been invented. (Yarwood, 2003)

Such concerns about technological change, and the language in which they are expressed, are not unusual. They may, however, be an unreliable guide to the aggregate and longer-term effects of new technology. Technology adoption, over time, makes a society richer and better able to support those facing adjustment costs. And knowing that such support will be forthcoming can mitigate the fears of those who anticipate adjustment costs.

1.2 What affects the adoption and diffusion of technology?

Technology is not an independent force that sweeps over societies and economies. Instead, the adoption of technologies, and their spread across the economy, is the result of a multitude of individual decisions made by firms and consumers. The emergence of a commercialised technology is no guarantee it will be widely adopted (Box 1.4).

Box 1.4 **New, innovative technologies can fail to fly**

In 1998, Michelin launched the PAX intelligent tyre system, which had a hard, internal wheel and electronic sensors that notified drivers – via a light on the dashboard – when there was a puncture. The PAX tyre allowed drivers with a punctured tyre to continue driving for up to 200km at 90km/h. This offered greater safety (less risk of crashes from blow-outs) and convenience (no need for roadside tyre changes or waiting for tow trucks), as well as creating more space in cars (no need to store a spare tyre). Michelin built an alliance with Goodyear to reach 40% of the global tyre market, and signed up Mercedes, Audi and Honda as partners.

Yet by 2007, the PAX system was such a proven failure that Michelin abandoned it. PAX failed because it created additional costs for consumers and other firms in the supply chain, without clear and larger benefits. Car manufacturers had to redesign the underbodies of their vehicles to accommodate the new tyres, and mechanics had to acquire specialised equipment to replace damaged PAX tyres. Neither saw reasons to incur these costs, especially when the price of replacement tyres to consumers was very high (US$1 200), compared with ordinary tyres.

Source: Adner (2012); Allen (2012); McGrath (2010)

Many factors affect the decisions made by firms and consumers about technology adoption. The remainder of this section explores these factors.

Uncertainty, relative costs and benefits

Decisions about adopting a new technology typically take place under uncertainty. A firm or individual may not know what the total benefits or costs of adoption could be, nor how the technology might change over time.[2] Because the decision to adopt a technology involves expense that cannot always be recovered, firms may wait until the likely benefits exceed the costs by a reasonable margin (Hall & Khan, 2003). High degrees of uncertainty about the benefits of a technology will tend to discourage its adoption (Luque, 2002). For example, Dairy NZ partly attributed the relatively low take-up of automated milking systems and on-farm data-gathering sensors in New Zealand to "the lack of a clear value proposition for farmers" (sub. 20, p. 3).

[2] 'Firm' in this report refers to for-profit businesses, not-for-profit organisations, cooperatives and government entities that employ (or could employ) people, whether motivated by profit or by mission.

One way for firms to reduce uncertainty about the likely benefits of introducing new technologies is to learn from the experience of other firms. Research into New Zealand firms' practices has shown that adopting and adapting practices or products from other businesses is an important driver of innovation (Pells & Howard, 2019). This ability to learn is greatest in large cities where there are more firms nearby, and in tradable industries where there is more scope for competition. Most New Zealand cities are very small by international standards, and many markets are made up largely of small firms that only trade their output locally (Conway & Zheng, 2014; Zheng, 2016). New Zealand's geographic distance from other markets further limits interactions with other firms and customers and restricts opportunities for learning and knowledge transfer.

However, where New Zealand firms do make international connections (eg, through exporting, being foreign-owned, or owning offshore companies), the payoffs can be significant. Wakeman and Conway (2017, p. 25) found such firms "experience higher returns from product and organisational innovation", as they used their connections "to obtain better information and guidance on how to exploit their innovation". Harris and Le (2018, p. 1) similarly found that New Zealand firms with foreign interests had higher levels of "absorptive capacity"; that is, the ability to use "knowledge from the external environment to improve their productivity".

Firms facing a decision about whether to adopt a new technology also have to consider alternative investment opportunities, including extending the life of their existing assets. Improvements in older technologies therefore discourage the uptake of new assets, processes or knowledge (Hall & Khan, 2003).

Access to complementary skills and inputs

Firms adopting new technology typically require specialised skills and other capital goods to gain the full benefits of that technology. Such skills and capital are described as 'complementary' to the technology.

For example, large productivity gains in US rail in the 19th century from advances in locomotive engineering depended on the invention and adoption of other tools and techniques, such as "the control of train movements through use of the telegraph, block signalling, air brakes, automatic couplers, and the substitution of steel rails for iron" (Rosenberg, 1972, p. 21).

Skills play a central part in technology adoption, and the importance of education levels to technology diffusion has been supported by international studies. For example, Caselli and Coleman's (2001, p. 331) cross-country study of the adoption of computers since 1970 found that "high levels of educational attainment are important determinants of computer-technology adoptions, even after controlling for a variety of other macroeconomic variables, including per capita income". Pells and Howard (2019, p. 5) found that a lack of "staff with the right skills" was a frequently cited barrier to innovation in New Zealand firms.

Specialisation can be harder in small markets because their potential customer base and profits are lower. This could limit access to the skills and other inputs needed to successfully introduce new technologies in New Zealand. Salmon (2019, p. 55) argued that the lack of specialisation makes some industries unviable in New Zealand:

> … to design and manufacture the ATR 72 plane that Air New Zealand flies between my home town of Nelson and Auckland requires huge teams of people with deep and specific know-how. We simply don't have that know-how in New Zealand. This gets to the heart of the challenge.

Access to foreign skills is one way around local limits on specialisation. McLeod, Fabling and Maré (2014, p. iii) found that:

> … firms that hire more recent migrants and firms that hire more recent returnee New Zealanders tend to innovate more than other firms. Firms with more recent migrants are more likely to introduce new goods and services, new processes, and new marketing methods, as well as being more likely to enter new export markets. Firms that hire more recent returnees are more likely to introduce new products that are new to New Zealand, new organisational or managerial practices, and new marketing methods.

However, high housing costs can constrain firms' access to the right skills. House and rental prices have increased significantly in many New Zealand cities over the past two decades, putting financial pressure on low-income households and raising barriers to worker mobility (NZPC, 2012, 2015b, 2017a).

Changes in input prices

Increases in the price of a firm's inputs may prompt technology adoption should it either reduce the need for a pricier input or completely substitute for it. Similarly, falls in the price of technology encourages its adoption.

Increases in the cost of labour can drive innovation. High wages have been cited as contributing to the Industrial Revolution, and the reason why technological progress and mechanisation was more rapid in the 19th century United States (where labour was scarcer) than in Britain (Allen, 2015; Habakkuk, 1962; Hicks, 1932). More recently, Acemoglu and Finkelstein (2008) explored the impact of changes to the public funding of US hospitals that increased the relative price of labour. These changes led to "a significant increase in the adoption of a range of new health care technologies" (2008, p. 873). Hospitals reduced their overall demand for labour but, consistent with the importance of complementary skills and inputs, they sought higher-skilled staff.

The prices of some products in New Zealand are high compared to equivalents in other countries, particularly those that are inputs to the production of other goods and services. Gemmell (2014, p. 20) identified investment goods and services, property, construction, utilities (eg, gas, electricity), transport and telephone services as "relatively expensive". These higher prices are due in part to the lack of economies of scale in a small market (and the resulting need to spread fixed costs over a smaller number of clients) and to high 'at the border' costs, such as international transport (ibid).

Although higher input prices may prompt local firms to innovate and introduce new technologies to reduce costs and improve productivity, Gemmell (2014, p. 21) concluded that this:

> … might generally be expected to ameliorate, rather than eliminate, the disadvantage NZ firms face via higher intermediate prices. It can also encourage the out-migration of firms and industries for which these high-priced inputs are a large fraction of their total costs.

Labour-market dynamics, employment relationships and institutional settings

Employment conditions within firms and across the broader labour market may affect firms' willingness and ability to invest in new technologies.

Contractual or regulated employee protections may have both positive and negative effects on the pace of technology adoption and productivity growth (OECD, 2013, p. 70).

- Employee protections and strong employment relationships may encourage employers to invest in training, increase workers' willingness to train in job-specific skills, raise productivity and increase workers' support for the adoption of new technologies in the workplace.
- Policies and contracts that raise the cost of workforce adjustments (restructuring, lay-offs and hiring), or reduce flexibility to negotiate work arrangements, can inhibit firms' investment in new technologies and job creation. Reduced labour force mobility slows the redeployment of workers and skills across the economy to higher-productivity jobs.

Workers' economic security and wellbeing depends less on security of employment in their current job if unemployment is low and if policy settings support fast, effective matching of people to new job opportunities, or provide income security in the event of a job loss. This can reduce the welfare impact of losing a job, reduce the depreciation of human capital through unemployment, and speed structural change and technology adoption.

New Zealand's employment policies provide relatively low barriers to workforce adjustments,[3] and re-employment rates are high by international standards. Displaced New Zealand workers do not face the risks and costs of losing healthcare, childcare and pension entitlements because these are not generally tied to jobs and tenure as they are in some countries.

[3] There are comparatively few restrictions on individual dismissals (eg, no statutory definition of justified or unfair dismissals, relatively short maximum times in which to make claims, low notice and severance pay requirements for no-fault dismissals) and no special regulations for collective dismissals.

However, unemployment comes with comparatively high and sustained income reductions for New Zealand workers (Hyslop & Townsend, 2017; OECD, 2017). Government support for displaced workers lacks some features available in other countries, such as time-limited social insurance entitlements linked to prior earnings.

Management practices matter for the successful adoption of new technologies and for productivity growth. New Zealand firms have scored poorly on international comparisons of management capability, with people management identified as an area of particular weakness (Bloom, Genakos, Sadun, & Van Reenen, 2012; Green & Agarwal, 2011).

Strong customer relationships

Firms with stable and secure customer bases are more likely to adopt new technologies, as such firms face lower uncertainty about the ability to recoup their investment. As Hall and Khan (2003, p. 5) observed, in the presence of customer commitment, "firms can more accurately predict the demand for their product and the profit from production, and this helps give them incentives to adopt a technology if it is profitable for them to do so". The importance of customer relationships has been investigated in the US automotive industry, where Helper (1995) studied the adoption of computer-programmable machine tools. She found that firms with little commitment from their customers (eg, expressed in terms of longer-term contracts) were unlikely to adopt the tools, even where they would improve the firm's efficiency.

The nature of the customer base can also affect technology adoption. Sophisticated and wealthy customers are more likely to adopt new technologies early (eg, internet banking), and thus may exert a 'pull' on firms serving these groups (Anderson & Kumar, 2019; Kennickell & Kwast, 1997). Sophisticated business customers play a particularly important function in promoting technology adoption by other firms. Firms that participate in global value chains (GVCs),[4] or supply multinational enterprises with goods and services, are more likely to acquire new technologies and complementary inputs as "lead firms … demand more or better quality inputs from suppliers and may directly share knowledge and technology and encourage the adoption of new practices to achieve this" (Criscuolo & Timmis, 2017, p. 71). New Zealand firms have low levels of participation in GVCs, reducing the economy's exposure to new, cutting-edge technologies and business improvement processes (ibid).

Firm size

Larger firms can better manage the risks associated with new technologies because they can "be more diversified in their technology choice and are in a position to try out a new technology while keeping the old one operating at the same time in case of unexpected problems" (Hall & Khan, 2003, p. 10).

New Zealand markets generally lack the large firms seen in other developed countries. Large firms are more likely to have the resources to devote to R&D and the introduction of new technologies and business processes, and can spread the associated costs across a larger number of sales. Larger firms can also scale up more quickly. As Salmon (2019, pp. 70–71) noted, if:

> … a single large company, like Amazon, starts using aerial drones to deliver packages the ramp-up in drone deliveries will be extremely rapid. If, on the other hand, we had to rely on every local garden centre, dairy and boutique clothing store to decide to buy a drone and implement a drone delivery system, the uptake would be far slower… New Zealand's large numbers of small businesses suggest adoption may be slower for many technologies.

Competition

Firms facing competition may adopt new technology as a way of gaining market share or improving profitability. There is some debate about the nature of the relationship between competition and technology innovation or adoption. Aghion et al. (2005) argued that the relationship is best described as an inverted U, with innovation rates low when there is too much or too little competition. Too little competition provides

[4] 'Global value chain' describes the international fragmentation of production, "with various parts of the production process, from design to distribution, segmented across different countries" (Criscuolo & Timmis, 2017, p. 61).

little incentive to innovate or improve. Firms with market power may be better placed to capture more of the benefits from adopting new technologies, as profits tend to erode with greater competition.

Studies of the adoption of automated teller machines in US banks in the 1970s found that market concentration (ie, markets that have a small number of suppliers) had a positive effect on technological diffusion and that larger banks (measured in terms of deposit value) adopted new technologies sooner (Hannan & McDowell, 1984; Saloner & Shepard, 1995). However, research into mobile telecommunications markets in the European Union indicated that greater competition tends to encourage adoption and diffusion (Gruber & Verboven, 2001). The Bell telephone monopoly in the United States famously suppressed a number of innovations, including the answering machine in the 1930s, because of concerns they would reduce company revenue (Wu, 2011).

Local research indicates that competition is an important spur to innovation for New Zealand and Australian firms (Pells & Howard, 2019; Soames, Brunker, & Talgaswatta, 2011). However, competition levels in some New Zealand industries – and especially in the services sector – are low.

- Service industries in New Zealand face less competition than the goods-producing and primary industries (NZPC, 2014). Industries with less intense competition included finance and insurance; rental, hiring and real estate; retail; and professional, scientific and technical services.
- Gardiner (2017) similarly noted that competition levels in New Zealand appeared highest in manufacturing, construction and hospitality, and lowest in finance and insurance, wholesale trade, and property and business services.
- New Zealand has low competition levels compared to some other small countries, when measured in terms of profit elasticity and average profitability (Gardiner, 2017; Ministry of Business, Innovation and Employment, 2016).
- New Zealand's small and isolated markets tend to lack competitive intensity, especially at the regional level (Maré & Fabling, 2019; Schiff & Singh, 2019).

New goods and services enabled by digital technologies hold out the possibility of creating greater competition in industries with few firms. For example, the New Zealand and Australian Productivity Commissions (2019) noted the potential competition benefits offered by open banking and fintech in their joint report on the digital economy.[5]

Access to capital

Firms seeking to introduce new technology need access to capital. More capital per worker – known as 'capital deepening' – is often associated with higher productivity.

Looking at large firms (those with a turnover of over NZ$1 billion), two organisational forms (cooperatives and state-owned enterprises) are more prevalent in New Zealand than internationally. A common factor with these types of firms is "a reluctance to provide capital for growth and a strong aversion to risk" (Conway, 2018, p. 50).

High levels of inward migration, such as have been experienced in this country, may contribute a higher cost of capital for New Zealand firms. With low levels of national savings, high migration inflows may put pressure on existing infrastructure, prompting higher investment to meet excess demand and pushing up interest rates (Reddell, 2013). Higher capital costs could discourage technological investment by firms. High migration can also mean that population growth exceeds business investment rates, leading to falls in the amount of capital per worker, even though overall capital levels are growing.

Regulatory restrictions on foreign direct investment (section 1.2) may also contribute to a higher cost of capital for local firms.

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[5] Fintech is short for 'financial technology' and includes new technologies and innovations that challenge traditional methods of delivering financial services (such as banking). Open banking is a system in which customers can securely access information held by a bank about them and share that data with third parties.

Wider government policy

Government policy can encourage, facilitate or block the adoption of technology, either deliberately or inadvertently. Queen Elizabeth I refused to issue a patent for William Lee's stocking frame because of concerns about the effect it would have on the employment of hand knitters (Hills, 1989). Recent examples of deliberate blockages of technology include bans on ridesharing services such as Uber in some US cities. Inadvertent barriers to technology adoption include out-of-date regulation that does not adequately reflect the requirements of new technology users. For example, intellectual property laws in Australia and New Zealand limit beneficial uses of AI technologies (APC & NZPC, 2019; Crampton & Ting-Edwards, 2017).

Wider policy settings affect the incentives for firms to take up new technologies. Policies that make labour in easily automatable jobs more expensive may encourage businesses to adopt labour-replacing technologies. Alternatively, policies that make capital more expensive may discourage the uptake of new technologies and thereby reduce opportunities for productivity gains. More stringent regulation can, in some circumstances, induce technological innovation and adoption. For example, the introduction of 'clean air' legislation in the United States that limited the emission of sulphur dioxide from power plants led to improvements in 'scrubbing' processes that reduced their cost and improved their effectiveness, encouraging adoption by firms (Taylor, Rubin, & Hounshell, 2005).

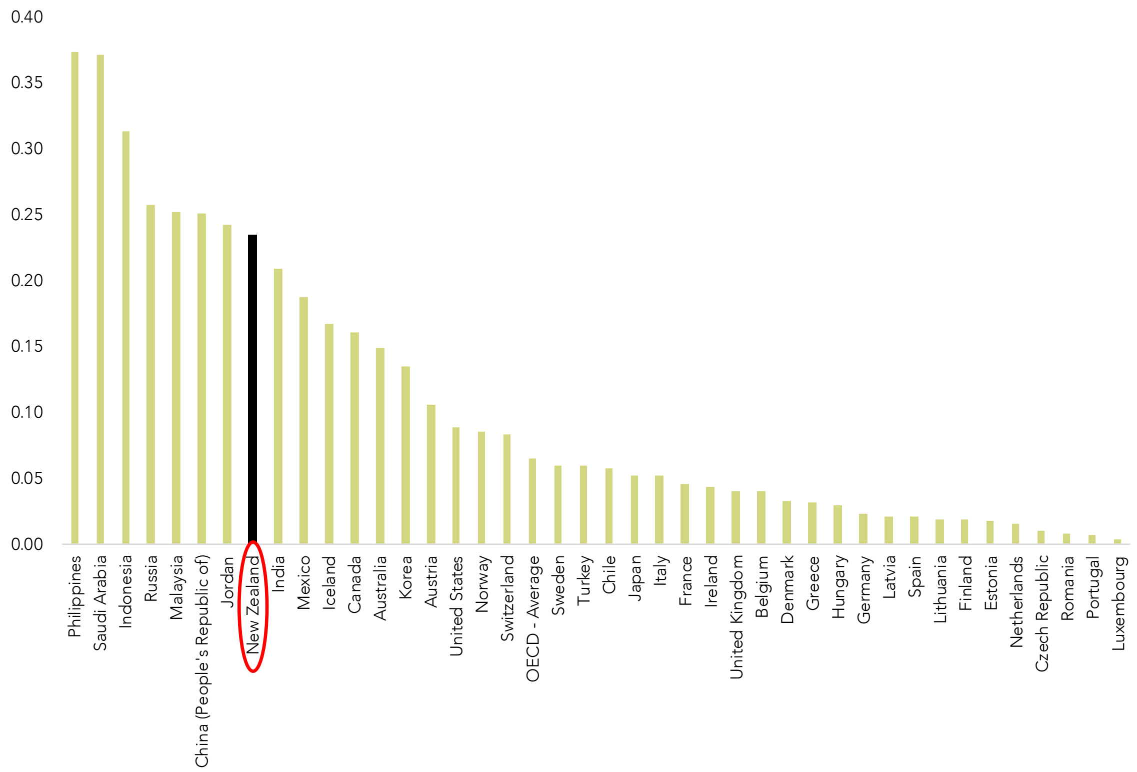
New Zealand has low regulatory barriers in most product and input markets, which should make it easier for firms and individuals to adopt new technologies, adjust their processes, or set up different organisations to suit new technologies.

- According to Ferracane, Lee-Makiyama and van der Marel (2018), New Zealand has the lowest barriers to digital trade of 64 countries.
- New Zealand has a lower score on the OECD's Services Trade Restrictiveness Index than the average in 20 out of 22 sectors, explained by an overall favourable regulatory framework (OECD, 2018).
- New Zealand has relatively low scores on OECD measures of regulatory restrictiveness, but its relative advantage has eroded over time (Conway, 2011).

One significant exception to these patterns is openness to foreign direct investment. As assessed by the OECD, New Zealand has high barriers (Figure 1.5), reflecting equity restrictions in some sectors and the country's broad-based screening regime (Wilkinson & Acharya, 2014). New Zealand's investment screening concentrates on limiting the foreign control of "sensitive land", as defined in the Overseas Investment Act 2005. These restrictions apply regardless of business size (Heatley & Howell, 2010).

Most other OECD countries focus their screening efforts on a small selection of industries, usually where there is a defined national security interest. New Zealand policy has become more restrictive over time.

Figure 1.5 OECD Foreign Direct Investment Restrictiveness Index, 2018



Source: Productivity Commission analysis of OECD data

Note:

1. Restrictiveness is measured on a 0–1 scale, where zero indicates the least restrictions and 1 the highest.

Table 1.1 presents the factors that affect technology-adoption decisions, and specific features of New Zealand markets relevant to these factors.

Table 1.1 Factors affecting technology-adoption decisions by New Zealand firms

Decision factor	Effect on technology adoption	New Zealand features
Uncertainty, relative costs and benefits	Discourages adoption	Small local markets, and geographic distance from other countries, may limit the ability of NZ firms to learn from others.
Access to complementary skills and inputs	Encourages adoption	Skills specialisation is riskier in small markets, so firms may need to recruit migrants or those outside the local labour market. However, expensive housing can limit labour mobility. Some important inputs (eg, utilities, transport, construction) are expensive by international standards.
Changes in input prices	Tends to encourage adoption of technologies that reduce demand for pricier inputs. Falls in the price of a technology promotes adoption.	Some inputs (especially related to investment, property, construction and utilities) are expensive in NZ, reflecting the lack of scale economies and high 'at the border' costs.
Labour-market dynamics, employment relationships and institutional settings	Overly restrictive settings to protect current jobs and limit flexibility can discourage adoption. Settings that strengthen trust and commitment by employers and workers can boost skills training and willingness to support adoption of new technologies.	NZ has low barriers and costs to hiring and firing staff, and more flexibility for temporary contracts, compared to most other developed countries. Government support for displaced workers lacks some features available in other countries. NZ management capability is middling to poor by international standards.
Strong customer relationships	Stable customer bases, and more sophisticated and wealthy customers, encourage adoption. Sophisticated customers (especially business customers such as multinational enterprises) can promote adoption by demanding higher production standards.	NZ firms have low levels of engagement with global value chains. The legal form of many of NZ's large firms (ie, cooperatives, state-owned enterprises) tends to promote risk aversion.
Firm size	Larger firms are better placed to manage technology risks	There is a low presence of large firms in NZ domestic markets.
Competition	The subject of some debate, but low levels of competition will tend to discourage technology adoption.	Low levels of competition in many NZ industries, particularly in the services sector.
Access to capital	Firms needs access to capital to adopt (most forms of) technology	The legal form of many of NZ's large firms (ie, cooperatives, state-owned enterprises) makes capital more difficult to obtain. NZ firms face a relatively high cost of capital.
Wider government policy	Depends on the nature of the policy – may encourage, facilitate or block adoption.	NZ generally has low regulatory barriers, with the exception of barriers to foreign direct investment.

Note:

1. Not all of these effects or features are discussed in this report. The Commission intends to address them in subsequent draft reports.

F1.1

Technological diffusion is the result of a multitude of decisions by individuals, firms and governments. Many factors influence the likelihood of adoption, and hence diffusion, including:

- uncertainty about the relative costs and benefits of adoption;
- access to complementary skills and inputs, including capital;
- changes in input prices;
- labour-market dynamics, employment relationships and institutional settings;
- the strength of customer relationships;
- the size of markets and levels of market competition; and
- government policy.

1.3 How technological diffusion affects the labour market

Popular debate on the impact of technology on jobs typically focuses on the question of whether a new machine, process or computer will replace human labour, and concern about the displacement of people by machines is one of the motivations behind this inquiry. While displacement is one possible effect of technology adoption, actual impacts are often more complicated, and may play out over some time and have multiple effects that work in different directions.

First-, second- and third-round effects

One way to think about the impact of technological diffusion on the labour market is sequentially, or in terms of first-, second- and third-round effects.[6] The net effect of a new technology on jobs can be different from the effects at individual stages. Box 1.5 describes the separate but interacting labour-market effects of technological change using the case of Amazon, a multinational technology company based in the United States, which provides e-commerce, cloud computing, digital streaming and AI services.

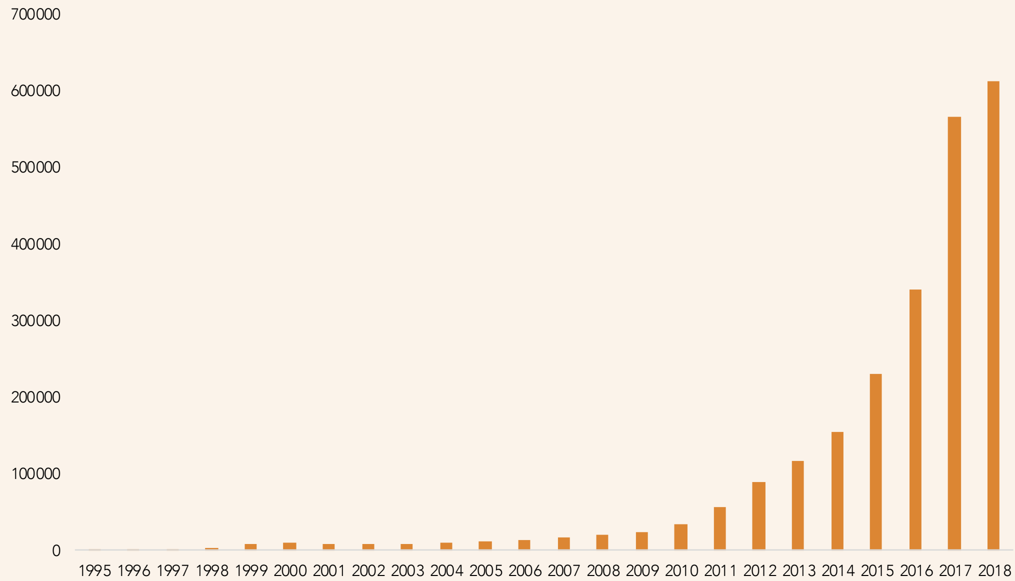
[6] This is a stylised representation of how technology affects the labour market. More than one effect can occur at the same time.

Box 1.5 **The labour-market effects of Amazon**

Amazon began in 1994 as an online book retailer, but has progressively expanded into other consumer goods, internet services, movie production, logistics, supermarkets, renewable energy and other services. Amazon is an increasingly important part of the US and global retail sector, with its net sales increasing from US$11 billion in 2006 to $107 billion in 2015 (Houde, Newberry, & Seim, 2017).

First round effects: As Amazon grew and took a larger market share, it sought more labour, both as employees (Figure 1.6) and as independent contractors. The growth in Amazon's employment has prompted fierce debate. Morgan Stanley analysis concluded that the establishment of Amazon distribution warehouses was "both a net job creator and catalyst for stronger job growth", offsetting the negative impact on employment in brick-and-mortar retail stores (Rooney, 2018). Others, however, have criticised Amazon for using local market power to offer low wages and harsh working conditions (Burin, 2019; Hamilton & Cain, 2019).

Figure 1.6 Amazon employees, 1995–2018



Source: McCracken (2019)

In addition to directly employing or contracting workers for its own operations, Amazon's platforms create income-earning opportunities for individuals and firms and, through that, create demand for labour. Over 300 000 US-based small and medium enterprises sold their goods using Amazon's Marketplace platform in 2017 (Bezos, 2017).

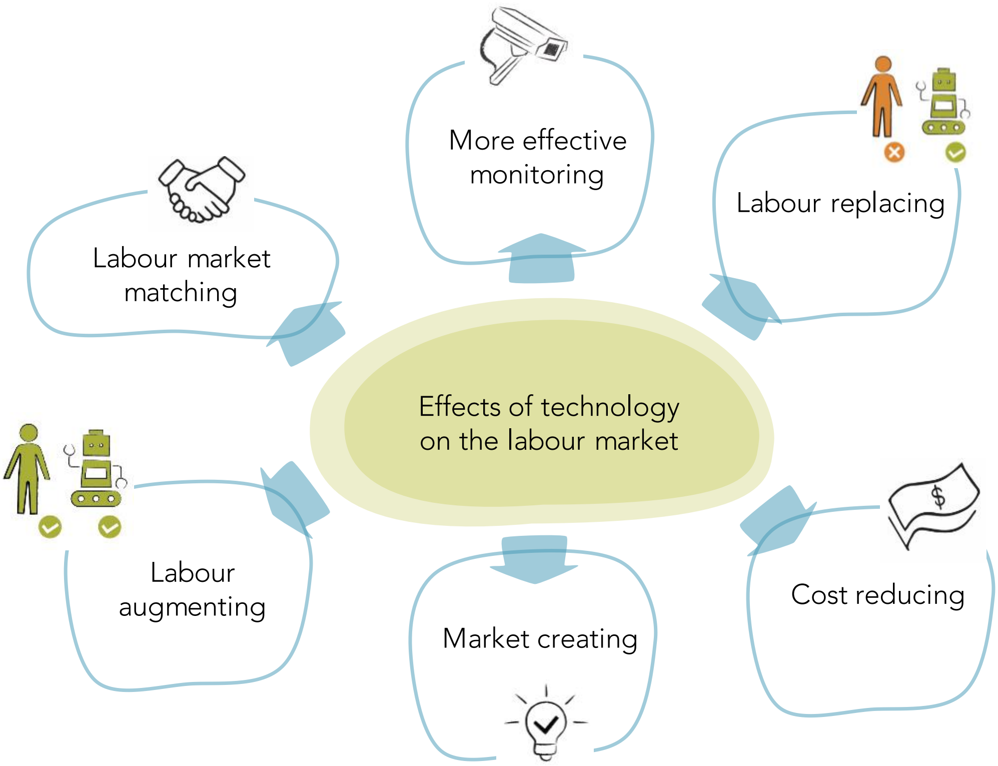
Second round effects: Amazon's expansion disrupted traditional brick-and-mortar retail stores, contributing to the rationalisation or collapse of once-significant chains and the consequent loss of jobs. Part of this 'Amazon effect' can be seen in the decline of employment in competing firms across the United States – department store employee numbers fell 28% over 2000–2017, while book store and news retail employee numbers declined more than 55% over 2001–2019.

Third round effects: Amazon's focus on achieving scale economies, competing fiercely and driving down logistical costs has put downward pressure on prices. Lower prices mean more discretionary income for households, which they can spend on other goods and services – creating demand for labour in the firms supplying those goods and services. Amazon reduced its total shipping costs by more than 50% over 2006–13 and its prices fell by around 40% over the same period (Houde et al., 2017). This effect on prices is not exclusive to the United States. The Japanese central bank estimated that by putting downward pressure on consumer prices, Amazon and other e-commerce firms reduced annual rates of inflation in Japan by 0.1 to 0.2% (Deutsche Welle, 2018).

Six effects of technology on the labour market

As can be seen in the Amazon example, technology can have many distinct effects on the labour market. These can be broadly categorised into six groups (Figure 1.7). The net effect of adopting a specific technology in a particular firm is the sum and interaction of potentially all of these effects. Further, the net effect for the firm may be different from the aggregate effect on the economy. This section explains the six direct effects. The following section further explores the distinction between direct and aggregate effects.

Figure 1.7 Effects of technology on the labour market



Labour-augmenting applications

Labour-augmenting applications of technology are those that directly boost the productivity of workers and increase the demand for labour able to use the new assets or processes. In recent years, the spread of computers and electronics across workplaces in the developed world has seen firms demand better-educated workers across a diverse range of sectors, including banking, automotive repair and valve manufacturing (Autor, Levy, & Murnane, 2002; Bartel, Ichniowski, & Shaw, 2007; Levy, Beamish, Murnane, & Autor, 1999; Levy & Murnane, 1996).

Labour-replacing applications

Labour-replacing applications of technology are those that allow jobs or tasks that were once carried out by people to be undertaken by machines, computers or other assets. Labour replacement can create disruption in the short term for workers whose skills and experience are devalued. In recent years, jobs involving routine tasks (eg, checking goods on production lines) have been increasingly replaced by AI. Labour replacement can also alleviate skill shortages, enabling labour-constrained firms and industries to grow faster.

Cost reducing

Cost-reducing technologies permit existing goods or services to be produced at a lower cost. In a competitive market, such cost reductions get passed onto consumers in the form of lower prices. The impacts of cost-reducing technologies on the labour market take three main forms.

The first form is where technological advances reduce the cost of a good or service, increasing demand for that product and the labour that delivers it. Van Reenen (2018) cited the examples of ridesharing services such as Uber and Lyft, which introduced a cheaper alternative to taxis. While the number of traditional taxi trips in New York city fell between 2015–2018, this was more than offset by a dramatic increase in trips using ridesharing apps. History provides further examples.

- Advancements in weaving technology during the Industrial Revolution automated 98% of the labour needed to produce a yard of cloth but increased the number of weaving jobs. As Bessen (2015, p. 5) noted, automation "drove the price of cloth down, increasing the highly elastic demand, resulting in net job growth despite the labor saving technology".
- Improvements in the production of Ford Model T cars saw their price fall from US$950 in 1909 to US$440 in 1915. As a result, the number of cars sold "increased 30-fold, and employment at Ford rose from 1 655 to 18 892" (Manyika et al., 2017, p. 38).

The second form of cost-reducing technologies is where reductions in the prices of goods and services free up consumer incomes for spending on other products, creating labour demand elsewhere in the economy. Van Reenen (2018) dubbed it the 'Walmart effect' after the low-cost US retail giant that achieved significant productivity improvements and price reductions in the late 1990s and early 2000s, giving consumers more disposable income.

This effect could equally well be named after other firms, particularly digital platform companies. The emergence of zero-price digital services such as internet search, email, maps and online videos has created substantial consumer gains (APC & NZPC, 2019).

The third form of cost-reducing technologies is price reductions for products and services consumed by other businesses. Lower prices on business inputs benefit firms directly, thereby affecting employment. Productivity improvements in steel production over 1980–2017 lowered costs and prices, boosting jobs in 'metal using' industries such as manufacturing, machinery, motor vehicle and aerospace production (Van Reenen, 2018).

The effects of cost-reducing technological progress on aggregate employment can be significant, according to European research. Gregory, Salomons and Zierahn (2016) looked at the impacts of 'routine-replacing technological change' in 27 European countries over 1999–2010. They found that while technology had displaced 9.6 million jobs (largely through automation), it had increased the demand for labour by 21 million jobs (through reductions in the costs of goods and services and the resulting growth in disposable incomes), resulting in net employment growth of 11.6 million jobs.

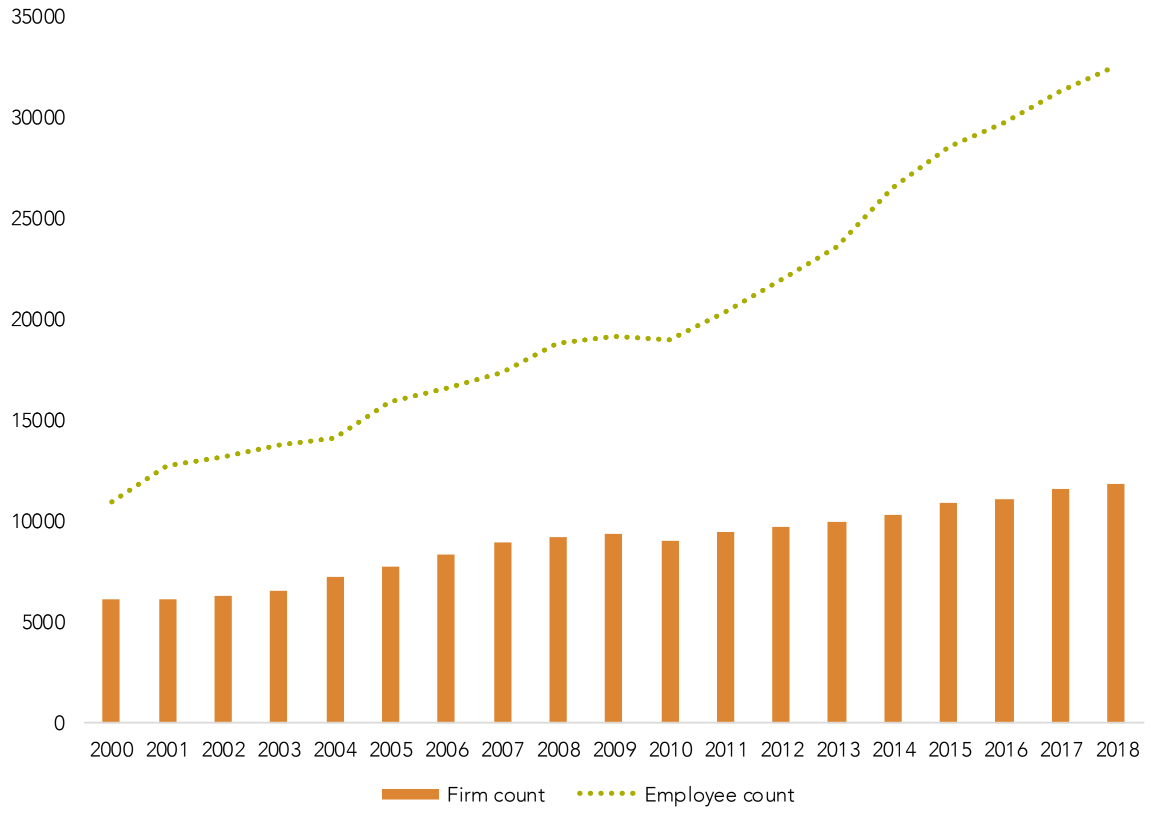
Market creating

Technology can create new goods and services and, through that, demands for new types of skills and jobs. Acemoglu and Restrepo (2019, pp. 205–206) noted that:

> … periods of intensive automation have often coincided with the emergence of new jobs, activities, industries and tasks. In nineteenth-century Britain, for example, there was a rapid expansion of new industries and jobs ranging from engineers, machinists, repairmen, conductors, back-office workers, and managers involved with the introduction and operation of new technologies (eg, Landes 1969; Chandler 1977; and Mokyr 1990). In early twentieth-century America, the mechanization of agriculture coincided with a large increase in employment in new industry and factory jobs (Kuznets 1966) among others in the burgeoning industries of farm equipment (Olmstead and Rhode 2001) and cotton milling (Rasmussen 1982).

In New Zealand, the spread of information technology across the economy in 2000–2018 saw a large increase in the demand for people skilled in designing and maintaining computer systems (Figure 1.8).

Figure 1.8 Firms and employees in New Zealand computer system design & related services, 2000–2018



Source: Productivity Commission analysis of Stats NZ Business Demography Statistics data

This shift mirrors labour-market developments in other countries; Manyika et al. (2017) concluded that computers had created almost 16 million new jobs in the United States, despite displacing 4 million. Demand fell for typists, accountants and secretaries, but grew for jobs in the computer manufacturing and supply industries, computer science and e-commerce.

Labour-market matching

Technology has changed the operation of the labour market itself, with new platforms and new tools for matching workers to jobs. Examples include Seek, LinkedIn and AI services that find suitable candidates for jobs (eg, Ziprecruiter), and algorithmic tools that vet job applications for employers. Careers NZ's website links to more than 100 job listing websites.

Matching workers to jobs

Research into the impacts of online job searches has found that "Internet searchers' unemployment durations are about 25% shorter than comparable workers who search offline only" (Kuhn & Mansour, 2014, p. 1213). Both employers and workers benefit from higher-quality matches: "matching outcomes of online job seekers are superior along several dimensions, including making better use of [their] own skills, being more content with the type of work, having higher changes of promotion, and enjoying greater job security" (Mang, 2012, p. 17). Internet-based job searches were an "especially important tool for job seekers distant from the labor market" and mothers with children (ibid).

Better job matching can lift productivity, improve worker wellbeing and satisfaction, and increase labour-market dynamism. Some, however, have warned that digital matching technologies (eg, hiring and vetting algorithms) may "inadvertently reinforce discrimination in hiring practices" (Mann & O'Neil, 2018).

Digital platforms also open up more of the labour market to international exchange, with New Zealand firms able to source workers offshore and New Zealanders (individuals and firms) able to work for international clients and employers.

Matching contractors to tasks

One reason why organisations hire staff as employees is the high transaction costs involved with independent contractors – that is, finding someone available and capable, specifying the work that needs to be undertaken, monitoring performance and enforcing the terms of a contract (Coase, 1937). Digital platforms have reduced these costs for some activities by allowing for more detailed specification of work, standardising contracts, simplifying payment and strengthening incentives for performance (eg, through ratings features). Reducing the transaction costs of contracting should support more of this form of work, all else being equal. This would be to the benefit of workers preferring to be contractors, and to the detriment of those preferring employment.

Outsourcing can reshape supply chains, business models and employment patterns for existing firms and workers, while also creating new opportunities for self-employment and for firms with specialised skills. The emergence of digital on-demand work platforms in the so-called gig economy (Box 1.6) has expanded opportunities for people in thin labour markets and for those seeking flexible work. It has also raised concerns that an increasing share of work in the future will be conducted through non-standard employment arrangements that lack traditional legal protections and other benefits such as retirement savings (eg, Stewart & Stanford, 2017).

Box 1.6 **On-demand internet work platforms**

Internet-based platforms such as Uber, Fiverr, Taskrabbit, Airtasker and 99designs allow firms or individuals to specify tasks they want carried out and then buy these services from on-demand labour. Each platform has different characteristics; for example, some permit direct negotiation around tasks and pay between customers and suppliers, while others set standardised pay rates and conditions. In general, however, internet-based work platforms share these features:

- suppliers only work when their services are required, and there is no guarantee of continuing engagement;
- suppliers are paid per task or unit of output, rather than for their time;
- suppliers provide their own capital equipment (eg, car, computer);
- the platform is distinct from both customers and suppliers; and
- the platform intermediates between customers and suppliers in commissioning, supervising and delivering the work, and in arranging payment.

Source: Stanford (2017)

More effective monitoring

Technological advances may make it easier for firms to monitor and direct the performance of workers, including those who are not employees.

Better monitoring technologies may lead to improved workplace and public safety. The heavy equipment company Caterpillar has been trialling facial recognition software that monitors truck drivers for signs of fatigue. The software:

> … uses a camera, speaker and light system to measure signs of fatigue like eye closure and head position, When a potential 'fatigue event' is detected, the system sounds an alarm in the truck and sends a video clip of the driver to a 24-hour 'sleep fatigue center' at Caterpillar headquarters in Peoria, Illinois. At that point, a safety advisor contacts them via radio, notifies their site manager, and sometimes recommends a sleep intervention (Varagur, 2016).

Such technologies hold out the potential to reduce road accidents and may be more effective and efficient than current regulatory tools (eg, driver logbooks and maximum driving hour rules).

On the other hand, greater monitoring may reduce worker agency, workers' trust in fair treatment and job quality. Media reports about work practices associated with major digital firms highlight some of these risks, for example Kantor and Streitfeld (2015) and Newton (2019).

The New Zealand Council of Trade Unions (sub. 41, p. 9) observed that there is:

> … potential for social disruption through surveillance (such as cameras facing truck drivers, increasingly ubiquitous use of surveillance cameras in retail and the ability to monitor employees' productivity by counting keystrokes or other metrics), the use of artificial intelligence and psychometric testing to make or assist decisions on the suitability of a person for a job … and the use of customer 'likes' or dislikes through social media to judge performance. They have potential benefits but also potential grave dangers to fair treatment of employees and the trust which is the basis for 'decent work'.

Workers may also benefit from improved monitoring. For example, it has become easier to research potential employers. And employer rating schemes can strengthen incentives for better treatment of workers. Videos of interactions between employees and consumers can inform investigations into consumer complaints, allowing unfounded allegations to be quickly resolved in the employee's favour.

Distinguishing direct and aggregate effects

The net effect of adopting a specific technology in a particular firm is the sum and interaction of potentially all of the above effects. Further, the net effect for the firm may be different from the aggregate effect on the economy as a whole. Indeed, these effects may extend beyond the borders of a country.

So, it is important to clearly distinguish between the direct effects of technology adoption and their aggregate effect. Direct effects will always be more obvious, and likely to capture the headlines. But even a worker displaced by technology has an interest in the aggregate effect. A net increase or decrease in jobs in their local labour market could affect how easy it is for them to obtain a new job, and could influence the salary and conditions of that job.

It can be misleading to characterise *specific* technologies as labour replacing or labour augmenting. The introduction of computer programs, for example, displaced bookkeepers and the manual preparation of spreadsheets but increased the demand for people who were able to carry out spreadsheet-based financial analysis (Kestenbaum & Goldstein, n.d.).

In other instances, technologies that initially augment workers may end up lowering their wages. Dellot, Mason and Wallace-Stephens (2019, p. 22) cited the example of a "healthcare algorithm that makes it easier to diagnose rare diseases [which] could lower the barriers to entry for esteemed clinical roles, and thus reduce the bargaining power of highly skilled professionals".

In practice, it may be impossible to predict *in advance* whether the direct effects of a specific technology are labour replacing or labour augmenting. This classification can only be clear in specific applications. Job losses from labour-replacing applications will, in most cases, be partially or fully offset by job creation due to the cost-reducing and market-creating effects.

F1.2

Technology can have many distinct effects on the labour market, and more than one effect can occur. Technology can replace human labour, augment human labour, increase the demand for labour by reducing the cost of goods and services, create new markets and jobs, and improve matching between workers and employers. Because of this complexity, it can be difficult to predict in advance the aggregate impact of a specific technology on work and labour.

2 How has technology affected work in the past?

Key points

- In the early years of the First Industrial Revolution, mechanisation replaced skilled artisans, increasing the demand for lower-skilled labour and leading to slow wage growth. Demand for higher-skilled labour increased from the mid-1800s, reflecting the needs of large and complex factories and production methods. Wage growth accelerated as a result. Since the 1970s, technological change has rewarded occupations devoted to complex non-routine tasks and penalised those with mostly routine and automatable tasks.
- New Zealanders have adopted and adapted technologies since the first days of human settlement. The country's economic fortunes were transformed by the entry of technology – refrigerated shipping – in the 1880s. However, a shift to protectionism in the 1930s discouraged technology adoption by limiting competition and sheltering inefficient, high-cost industries. This led to a difficult and painful adjustment in the 1980s and 1990s.
- Protectionist policies delay rather than eliminate adjustment costs. Such policies create additional costs due to investment misallocation, placing an even higher burden on the generation in which adjustment occurs.
- The impact of technology on the labour market has changed over time, as has its impact on income inequality. The current nature of the relationship between technology adoption and inequality is unclear.
- Recent labour market changes in New Zealand have favoured people with higher skills, the services sector and Auckland. There has not been the increase in low-skilled jobs seen in the United States. Instead, the share of low-paid and low-education jobs has declined.
- New Zealand's poor productivity performance is due in part to the weak diffusion of technologies across the economy.

2.1 The distributional impacts of technological progress

The introduction and diffusion of new technologies creates both costs and benefits. Typically, people who have invested in older technologies and associated skills bear the short-term costs. Benefits accrue in part to investors in successful new technology, but mainly to the wider community. Nobel Laureate William Nordhaus (2004, p. 34) estimated that innovators only captured a very small fraction of "the total social surplus from innovation". Historically, different technologies have varied in who they affected, and how they were affected. Impacts have also varied across time and countries.

The First Industrial Revolution initially suppressed skills; living standards grew slowly

The diffusion of water and steam power throughout Europe in the First Industrial Revolution (1760–1850) tended to have a 'deskilling' effect. Jobs that were previously undertaken by (or under the supervision of) skilled artisans were replaced by mechanised processes that could be overseen or carried out by less-skilled workers. This reduced the demand for skilled labour relative to unskilled labour (Goldin & Katz, 1998). As a result, jobs that were once socially and economically valued were either fundamentally transformed or eventually disappeared. Atack, Margo and Rhode (2019, p. 67) noted that:

> Faced with such competition, blacksmith shops either shifted away from making objects to fixing them by offering repair services, or simply disappeared. The job of blacksmithing was once considered

> sufficiently numerous to warrant its own industry classification, but by the very end of the nineteenth century it was dropped from the manufacturing census as no longer worth the trouble to enumerate.

The implications of the First Industrial Revolution for living standards were not straightforward. While most British workers and their families did not experience a deterioration in their standard of living during and after the Industrial Revolution, neither did they enjoy rapid progress (Feinstein, 1998). Real wages in Europe increased only slowly over the first half of the 19th century. Drawing off English primary data, Feinstein (1998, p. 649) calculated that "over the 75 years from 1778/82 to 1853/57 the increase in real weekly earnings, allowing for unemployment and short-time working, was less than 30 percent".

Furthermore, wage gains were partly offset by higher costs from other factors such as disease, pollution, food adulteration and falling unemployment relief payments (Feinstein, 1998). Others have cited falls in the recorded heights of European adults (indicating malnourishment), increases in child mortality, and very long working days as evidence of stagnant living standards (Komlos, 1998; Voth, 2001).

Technology in the second half of the 19th century rewarded skills and lifted incomes

Average incomes in Europe and the United States began to increase more rapidly in the second half of the 19th century. One factor contributing to higher incomes was an increase in the relative demand for skilled labour. This increased demand reflected the increasing size and complexity of factories, changes in production methods, and the move from steam to electrical power.

- Larger factories required people with the skills to manage and oversee them. Katz and Margo (2013) found that the "white collar" share of the US workforce increased from 3% in 1850 to 12% in 1910. Most of this growth was due to increases in the number of managers, rather than clerical or sales staff.

- Larger factories sometimes also required higher-skilled operators on the shop floor. Bessen (2012, p. 46) attributed about a quarter of labour productivity growth in the US weaving industry between 1802 and 1902 to "better quality labor". Higher-skilled workers could effectively monitor more machines and better anticipate and detect errors in production. Human capital investment and wages for skilled weavers increased markedly over this period.

- New factory production methods increased the demand for managers, professionals and skilled blue-collar operators. Goldin and Katz (1998) cited the shift to batch or continuous process production in manufacturing as contributing to these higher skill demands through greater capital-skill complementarity.[7]

- The shift to electrical power in factories also increased demand for skills. Purchased electricity permitted more factories to automate the conveying and hauling tasks traditionally carried out by unskilled labour, and "encouraged a more intensive use of machines thereby increasing demand for the skilled personnel who maintained them" (Goldin & Katz, 1998, p. 713). Falls in the price of electricity permitted capital-intensive industries to grow faster, further contributing to higher skill demand (Acemoglu, 2002).

The shift to electric power also enabled the creation of safer, more pleasant working environments.

> Lighter, cleaner workshops were made possible by the introduction of skylights, where formerly overhead transmission apparatus had been mounted; and also by the elimination of the myriad strands of rotating belting that previously swirled dust and grease through the factory atmosphere, and, where unenclosed within safety screening, threatened to maim or kill workers who became caught up in them (David, 1990, p. 359).

Overall, the economic impacts of technological change on the labour market tended to favour higher skills, especially from the mid-to-late 1800s to the early 1900s. Katz and Margo (2013, pp. 2–3) characterised the wider impacts on the US economy.

> … although de-skilling in the conventional sense did occur overall in nineteenth century manufacturing, a more nuanced picture is that the occupation distribution 'hollowed out.' By hollowing out we mean

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[7] Batch methods involve the processing of bulk material in batches. Processing of subsequent batches waits until the current batch is finished. Continuous methods, on the other hand, involve moving one unit through each stage of the process with no breaks in time or sequence.

> the share of 'middle-skill' jobs – artisans – declined while the shares of 'high-skill' – white collar, non-production workers – and 'low skill' – operatives and laborers increased. Second, unlike the pattern observed in manufacturing, de-skilling did not occur in the aggregate economy; rather, the aggregate shares of low skill jobs decreased, middle skill jobs remained steady, and high skill jobs expanded from 1850 to the early twentieth century. It is incorrect, in other words, to infer the pattern of occupational change in the economy at large from that occurring in manufacturing.

F2.1 The impact of technology on the labour market has changed over time. In the earlier years of the First Industrial Revolution, mechanisation replaced skilled artisans, increasing the demand for lower-skilled labour. Wage growth was slow. From the mid-1800s, the demand for higher-skilled labour increased, reflecting the needs of large and complex factories and new production methods. Wages grew more rapidly.

From the 1970s, technologies have increased returns to complex, analytical tasks and lowered them for routine tasks

Beginning in the late 20th century with the introduction of computers and the internet, technological change began to favour higher-skilled (especially university-educated) cognitive workers, while displacing the middle-skilled. Autor, Levy and Murnane (2003, p. 1284) argued that this development "marks an important reversal" and was related to the nature of the tasks conducted.

> Previous generations of high technology capital sharply increased demand for human input of routine information-processing tasks, as seen in the rapid rise of the clerking occupation in the nineteenth century … Like these technologies, computerization augments demand for clerical and information-processing tasks. But in contrast to its nineteenth century predecessors, it permits these tasks to be automated … Over the last three decades, computers have substituted for the calculating, coordinating, and communicating functions of bookkeepers, cashiers, telephone operators, and other handlers of repetitive information-processing tasks.

What drove these patterns was not the skill requirements of jobs, but how routine and predictable the tasks that made up those jobs.[8] Tasks that were highly routine and predictable in nature could be more easily automated, while less routine or predictable tasks (including those that are largely manual rather than cognitive) could not (Table 2.1).

Table 2.1 Direct employment impacts of computerisation on different types of workplace tasks

	Routine tasks	Non-routine tasks
Analytic tasks	Human labour can be substantially replaced by computers	Computers augment, rather than replace, labour
Examples	Record-keeping, calculation	Managing others, persuading/selling, forming/testing hypotheses
Manual tasks	Human labour can be substantially replaced by computers/robots	Currently only limited opportunities for computers to either replace or augment labour
Examples	Repetitive assembly, picking and sorting	Truck driving, janitorial services

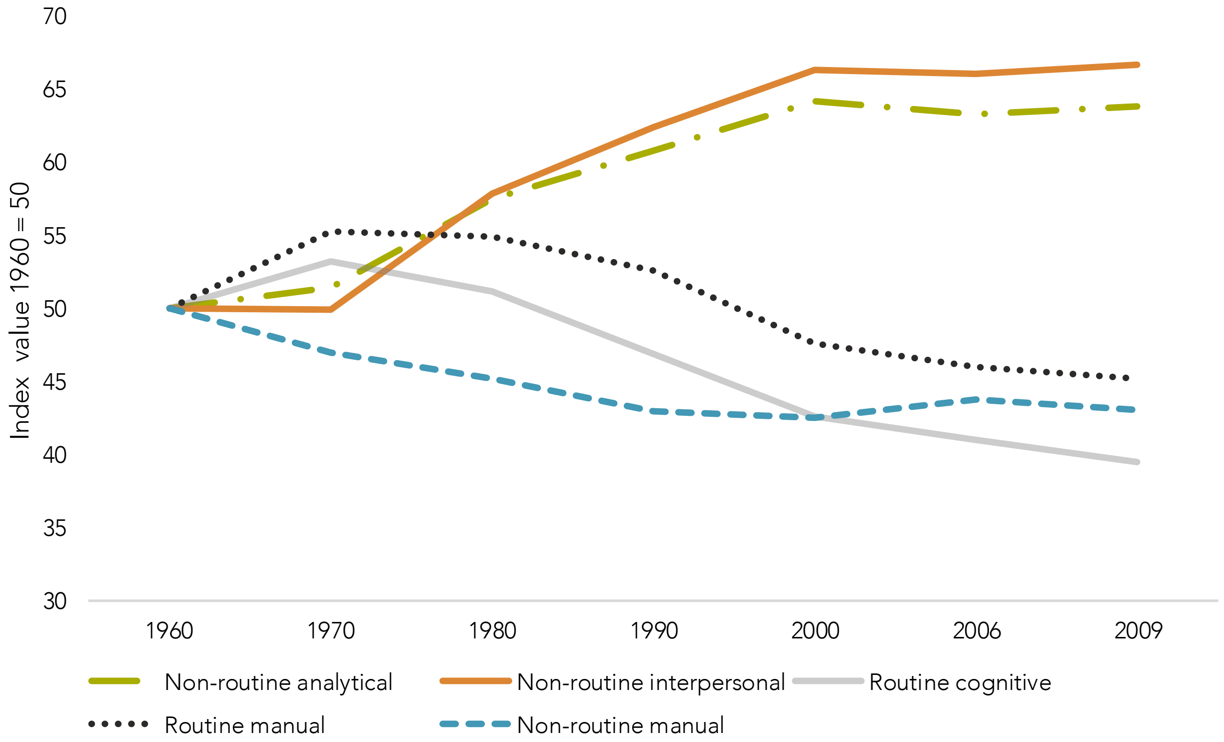
Source: Adapted from Autor, Levy and Murnane (2003)

Improved communications and transport have supported the offshoring of some routine tasks. Labour markets in developed countries have been affected by both automation and offshoring, and it is difficult to disentangle the relative contributions of each.

[8] While it can be analytically convenient to split tasks from jobs, in practice a *job* is bundle of related and often interdependent tasks. This makes it infeasible (or at least uneconomic) to automate or offshore all the routine and predictable tasks within a typical job.

Autor and Price (2013) found that worker tasks that were routine (both cognitive and manual) declined as a share of all tasks carried out in the US labour market fairly steadily from 1970 onwards, while non-routine manual tasks fell from 1960 and then stabilised around 1990 (Figure 2.1).

Figure 2.1 Index of changing work tasks in the US economy, 1960–2009



Source: Autor and Price (2013)

F2.2 From the 1970s, technological change has rewarded occupations devoted to complex non-routine tasks and penalised those that largely have routine and automatable tasks.

The relationship between technology and inequality is unclear

Some researchers have argued that technological progress has led the owners of capital (eg, investors, entrepreneurs, self-funded retirees) to capture a disproportionate share of the income gains from economic growth over the past four decades (Bassanini & Manfredi, 2012; European Commission, 2007; International Monetary Fund, 2017; Sachs, 2019).

Much of this debate centres around declines in the labour income share (LIS). The LIS measures "the returns to labour (wages, salaries, etc) divided by the total income of a nation … In other words, the labour income share measures how the 'income pie' is split between labour and capital" (Fraser, 2018, p. 2).[9] However, there are many ways to calculate the LIS in practice. Researchers report both declines and increases in the LIS, depending on the methodology, country and time period studied (Gutiérrez & Piton, 2019; Partridge & Wilkinson, 2019).

The LIS is not a direct measure of income inequality. Capital income tends to be more unequally distributed than labour income, both within and between countries, as wealth inequality tends to exceed income inequality. So, everything else constant, sustained falls in the LIS might lead one to conclude that income inequality was widening over time. However, everything else does not stay constant.[10] The LIS would, for

[9] The LIS splits national income across inputs to production (ie, labour and capital) rather than across distinct groups of people, and overstates actual divergences in income since many people earn income both by supplying labour and owning capital.

[10] The LIS is sensitive to: changes in the prices of exports and imports; changes in the relative quantities of labour and capital; policy changes; and other factors.

example, rise as labour-market participation increases or the unemployment rate falls – changes not normally associated with widening inequality.

Neither is the LIS a direct measure of technological progress.[11] Technological diffusion involves changes to labour and capital stocks, and to the productivity of labour and capital. The LIS cannot distinguish between changes in the quantity of labour and capital, and changes in their productivity.

The LIS in New Zealand has increased since 2002, while income inequality has been broadly stable,[12] and technology adoption and productivity growth have been slow.

F2.3 The impact of technology on income inequality has differed over time, and the nature of the current relationship between technology and inequality is unclear.

2.2 Technology diffusion in New Zealand

Technology – especially technology from overseas – has made a significant contribution to the development of New Zealand's industries and labour markets. However, government policies over the middle of the 20th century created barriers to technology adoption and distorted prices, contributing to difficult adjustments in the 1980s and 1990s.

Early technologies were primarily agricultural

New Zealanders have adopted and adapted technologies since the first days of human settlement, particularly in agriculture. Initial technologies were embodied in imported plants and seeds (eg, kumara, grass) and cultivation methods. Early technology adoption by Māori was driven by the need to feed local communities and adapt to local conditions.[13] Contact with Europeans and Americans in the 18th and 19th centuries saw increased production for export to Australia, to service visiting ships, and for the growing non-Māori resident communities. Considerable technology adoption occurred before the signing of the Treaty of Waitangi. Hawke and Lattimore (1999, p. 15) observed that "European grasses and legumes, fruit trees, crop seeds, livestock and basic horse drawn machinery all entered the country … by the 1820s and facilitated the transformation of northern and eastern New Zealand".

New Zealand's economic fortunes were transformed by the introduction of refrigerated shipping in the 1880s. This created new markets (eg, dairy for export), encouraged producers to adopt technologies to manage market risks (eg, crossbreeding sheep to create animals that provided both good meat and wool), and prompted the emergence of ancillary firms, industries and employment opportunities (eg, freezing works, milk processors) (Hawke & Lattimore, 1999).

Starting in the 1930s, protectionism discouraged technology adoption

High unemployment and the economic misery resulting from the Great Depression led successive governments to introduce controls to shield New Zealand from external shocks, maintain its balance of payments, develop domestic industry and ensure full employment. These controls included high tariffs, import licensing, financial subsidies to industry, and regulations that directed firm activities (eg, requirements to use trains to transport goods over distances longer than 30 miles).[14]

These protectionist policies discouraged technology adoption by protecting inefficient and high-cost industries, limiting competition and reducing flexibility (OECD, 1983; Reserve Bank of New Zealand, 1981,

[11] It is worth noting that a fall in the LIS can occur alongside rising real wages (when capital incomes are growing at an even faster rate).

[12] At least before housing costs. See, for example, Fair Pay Agreement Working Group (2018).

[13] Downs and Wojasz (2019, p. 6) cite the example of the kumara pit as an early agricultural innovation: "Finding the climate too temperate for growing their favoured crop, the sweet potato, [Māori] created a way to build small walls around the pits the kumara were grown in. This allowed the rays of the sun to be absorbed during the day, and warm the earth in the evening, elongating the growing period".

[14] Road transport of most goods was limited to 30 miles from 1936 and subsequentially increased to 150 km in 1977 (Heatley, 2009). Entry to the road transport business was also restricted, and freight prices were controlled. The regulatory protection of rail was removed between 1983 and 1986.

2007). These policies also reinforced a 'breadwinner model' based on full male employment and an industrial relations system that kept full-time (male) wages high.[15]

The skill demands of the economy were low, and few adults acquired post-school qualifications. A review of continuing education in 1987 found that New Zealand had the lowest tertiary education participation rate for 18-year olds in the OECD, and the second lowest for 17-year olds (Butterworth & Butterworth, 1998, p. 63). Māori, Pasifika and people from lower socio-economic backgrounds were underrepresented in tertiary education, and there was a widespread view at the time that overall levels of participation were too low to match the needs of a rapidly changing environment (Crawford, 2016). Concerns were also expressed about the structure of the school curriculum and examinations, which were judged as being unresponsive and increasingly out of touch with the needs of the labour market (Butterworth & Butterworth, 1998).

New Zealand's economic circumstances began to deteriorate from the late 1960s when the country's terms of trade fell:

> Private and public sector foreign debt combined rose from 11 percent of GDP to 95 percent between March 1974 and June 1984. Net public debt increased from 5 percent of GDP to 32 percent during the same period. Annual inflation remained in double digits for the entire December 1973 to March 1983 period (and was subsequently controlled only through an extensive wage-price freeze). The current account deficit in the balance of payments climbed to 8.7 percent of GDP, while the government's financial deficit amounted to 6.5 percent of GDP in 1983/84 (Evans, Grimes, Wilkinson, & Teece, 1996, p. 1860).

Technological change contributed to falling export prices; for example, the development of synthetic fibres reduced demand for crossbred wool. In 1973, the United Kingdom joined the European Economic Community, further reducing demand for New Zealand exports.[16]

A difficult adjustment in the 1980s and 1990s

Wide-ranging reforms in the 1980s and 1990s led to high unemployment and economic disruption in many regions. Formerly protected firms and industries closed or reduced their workforce, and displaced workers often faced significant financial hardship.

The 1930s to 1990s is a controversial period in New Zealand's history, and there are competing and divergent narratives. An economic interpretation is that new technologies change prices, and changing prices create adjustment costs for firms and individuals. Protectionist policies can shield locals from price changes in the wider world. However, they defer rather than eliminate the consequential adjustment costs (NZPC, 2018). Should local and world prices diverge, a reckoning is all but inevitable when protectionism ends. The economy is then faced with adjustment costs accumulated over the period of protectionism. Furthermore, the economy must deal with the devaluation of investments made that were profitable based on protected prices, but not world prices.

F2.4 Protectionist policies delay rather than eliminate adjustment costs. Such policies create additional costs due to investment misallocation, placing an even higher burden on the generation in which adjustment occurs.

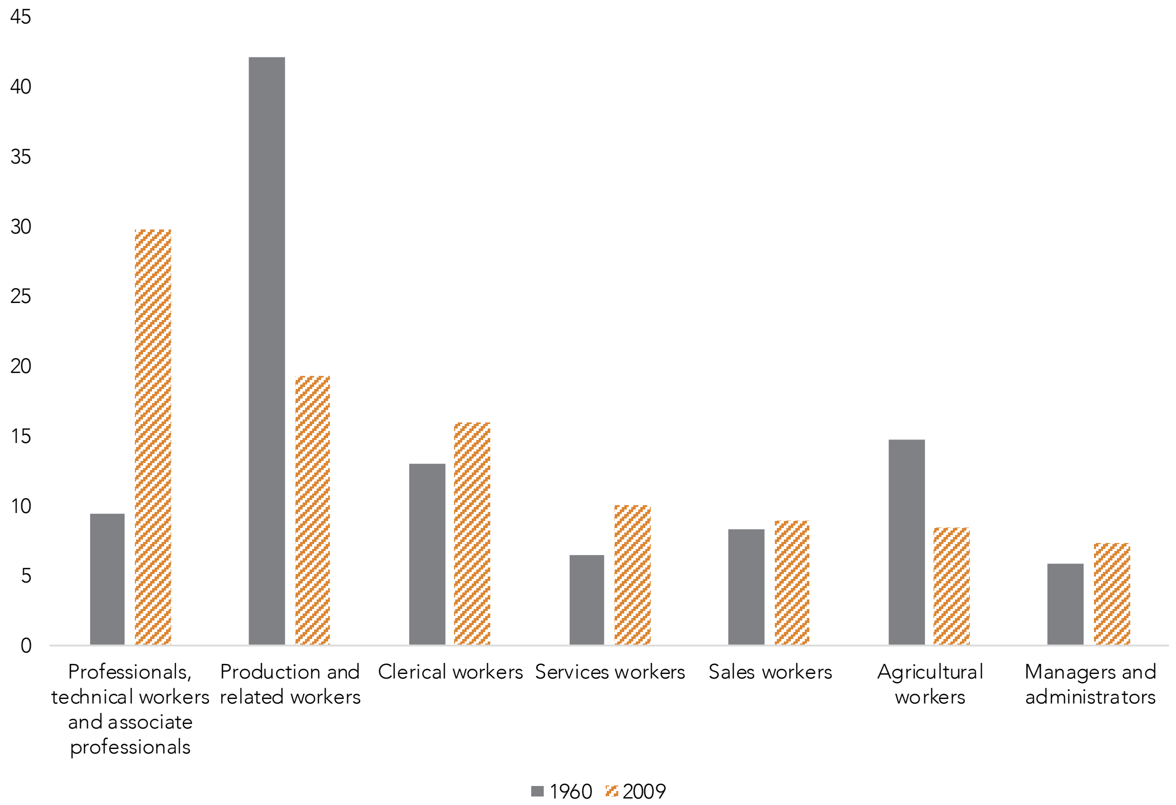
A shift towards higher skills, service industries and Auckland from the 1990s

In line with the experience of other developed countries, changes in New Zealand's economy prompted rapid shifts in the labour market towards the service sector, away from manufacturing (Figure 2.2) and towards higher-paid and higher-skilled positions.

[15] Described for Australia by Castles (1994), but also applicable to New Zealand.

[16] Britain first began talks to join the EEC in July 1961.

Figure 2.2 Occupational shares of the New Zealand labour force, 1960 and 2009



Source: Handel (2012)

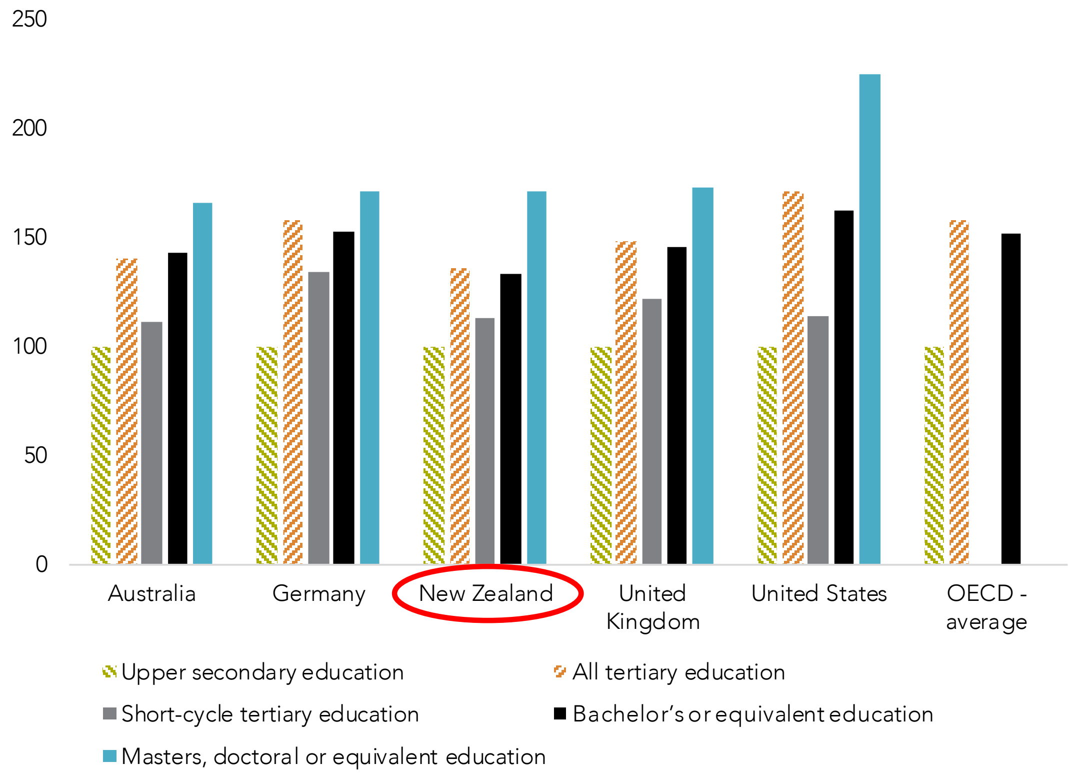
Note:

1. The task content and skills required for these occupations will have evolved over these 50 years. However, the occupational categories are still recognisably the same.

These changes in the occupational shares of the labour force also favoured New Zealand's larger cities and those with desirable amenities. The bulk of new work created over 1976–2013 in information-intensive and skill-intensive sectors, such as finance and professional and business services, took place in Auckland. As manufacturing employment declined in regional centres, some smaller towns and cities struggled to adjust and diversify. Those centres that adjusted most successfully tended to have other attractions, such as favourable climates. Employment growth in these cities was concentrated in non-tradable sectors that provide services to local consumers (eg, health and education) (Coleman & Zheng, forthcoming).

Like most developed countries, there has been a shift towards jobs requiring a higher education level. Wage growth in New Zealand over the past 30 years has been more evenly distributed across education levels than in, for example, the United States. The income premium for tertiary education is lower in New Zealand than the OECD average, and much lower than that in the United States (Figure 2.3). And the median wage for a university graduate has been rising more slowly, in percentage terms, compared with workers without a degree (Ministry of Education, 2018).

Figure 2.3 Earnings of full-time full-year workers by level of educational attainment, 2015



Source: Productivity Commission analysis of data from Ministry of Education (2018)

Notes:

1. Earnings for upper secondary education is set at 100 units for each country.
2. "Short cycle tertiary education" programmes are "usually occupationally-specific and prepare students to enter the labour market" (OECD, Eurostat, & UNESCO Institute for Statistics, 2015, p. 74). Their content is more complex than secondary school education, but less so than Bachelor's level programmes.
3. Education levels are defined using international standard classifications (ISCED). In New Zealand 'upper secondary' generally means completion of 12 years of primary and secondary schooling (ISCED Level 3).

Research into employment patterns in Australia, Canada, the United Kingdom, Germany and a number of European countries has found job 'polarisation', where "there is an increase in the share of employment in high skill jobs, a decrease in the share of middle skill jobs, and an increase in the share of low skill jobs" (Coelli & Borland, 2016, p. 1). Job polarisation is also apparent in the United States, where the employment share of middle-skilled jobs has fallen (Autor, 2015).[17] Middle-skilled jobs fell by 17.9 percentage points over 1979–2016; roughly two-thirds of this share moved into higher-skilled jobs and one-third into lower-skilled jobs (Autor, 2018; cited in Van Reenen, 2018).

Job polarisation is not apparent in the New Zealand data. The employment share of both low-paid and middle-paid occupations has declined, while the share of high-paid occupations has increased (Table 2.2). This pattern also holds for occupations classified by required education level.

But poor productivity performance due to slow diffusion of new technologies

Economic reform appears to have halted the long-term decline in New Zealand's productivity relative to high-income OECD countries. However, a sizeable productivity gap remains, and there is no evidence of it closing (Conway, 2018).

[17] Autor uses occupational category as a proxy for skill level.

Table 2.2 Levels and changes in occupation employment shares in New Zealand, 1991–2011

Occupations	Average employment share in 1991 (%)	Percentage point change in employment share, 1991–2011
High paid	19.5	7.3
Middle paid	50.2	-5.5
Low paid	30.3	-2.5
High education	35.4	9.5
Middle education	48.6	-7.1
Low education	16.0	-2.5

Source: Carey (2017)

Notes:

1. Occupations defined at the two-digit level of the classification system in use up until 2011.
2. High-paid (low-paid) occupations have median earnings one standard deviation above (below) the average for the New Zealand labour force, while middle-paid occupations have median earnings within one standard deviation of this average.
3. High-education occupations typically require tertiary education (eg, teachers, managers, public servants), middle-education occupations call for upper secondary attainment (eg, builders, clerks, salespeople), and low-education occupations have limited educational requirements (eg, drivers, machine operators).
4. The percentage point changes by pay level sum to 0.7%. The Commission expects that this sum should have been zero, or ±0.1% after allowing for rounding. The source report does not explain this apparent discrepancy.

New Zealand's poor productivity performance has been attributed in part to the weak and slow diffusion of new technologies. In a dynamic economy, the top firms quickly adopt the technologies used by their international equivalents. Yet New Zealand's leading firms tend to have lower multifactor productivity growth than firms at the global frontier (Conway & NZPC, 2016). Salmon (2019, p. 52) argued that:

> New Zealand is just not very good at adopting technology and productivity improvements in general. … We don't learn very quickly from what the best businesses are doing overseas. Even the crème de la crème of businesses in New Zealand produce about a third less per hour than the best businesses globally in the same industry. We are ineffective international copycats. Not only that, we are getting less effective at copying each year.

In a dynamic economy, low-productivity firms lift their performance, or exit the market and thus reallocate their resources to stronger firms. However, there is a wide and stable distribution of productivity performance across New Zealand firms. In the services sector – New Zealand's largest – there is little sign of productivity convergence between the top- and bottom-performing firms within industries (Conway, 2018).

Sherwin (2019, p. 10) summarises the New Zealand condition:

> Our best firms have productivity performance that is well short of the levels of firms at the global frontier. Our laggard firms are well behind our best. More particularly, our laggards hold a surprisingly large share of our labour and capital resources, and don't give them up quickly. In small and quite isolated markets, our low productivity firms remain in business for a long time.

F2.5

Recent economic and labour-market changes in New Zealand have favoured people with higher education, the services sector and Auckland. While there have been reductions in the employment share of middle-skilled jobs in New Zealand, there has not been an increase in low-skilled jobs as seen in the United States. Instead, the share of low-paid and low-education jobs has declined.

F2.6

New Zealand's poor productivity performance is due in part to the weak diffusion of technologies across the economy. New Zealand's leading firms are slow to adopt world-leading technologies, and the poorest-performing firms are not driven out by competition.

3 Global influences and local impacts

Key points

- Artificial intelligence (AI) and related technologies could potentially increase productivity and displace human labour. However, there is no consensus on the pace of current and future progress in AI, its effect on specific occupations, its aggregate impact on employment, nor its likely effects on the nature of work. US data suggests that technology-induced structural change to the labour market has not been historically associated with mass unemployment.
- The pace of technological change (and any consequential labour-market change) does not appear to be accelerating. Rather, local and international statistics point in the opposite direction, towards declining labour market and business dynamism.
- Models that predict what technology will do to specific occupations and industries can inform thinking about the future. But such models have inherent limitations, and their predictions are prone to misuse or misinterpretation. They can create an artificial sense of certainty to governments over desirable policy action and the likelihood of its success.
- Scenario building offers an alternative to modelling that better reflects uncertainty. This chapter presents four scenarios, reflecting differing views of the pace of technological change and its aggregate labour-market impacts.
- Most technologies that could affect work and employment in New Zealand will be developed in other countries. The pace of technological and employment change in New Zealand will therefore be affected by the global pace of change.
- A continuation of existing trends seems the most likely scenario in the next 10–15 years, including further automation of routine tasks and the concentration of knowledge-intensive jobs in major cities.
- Increased technology with fewer jobs is a low-likelihood but high-consequence outcome. However, a Stagnation scenario of low productivity growth and a significant risk of high unemployment is more likely. Neither outcome should be completely discounted.
- Regardless of the pace of technological change overseas, productivity growth and direct labour-market effects are likely to lag, and be more muted than, overseas trends unless New Zealand overcomes its poor track record in adopting and diffusing technology. Although poor technological diffusion in New Zealand may imply less direct risk to employment here, poor technological diffusion implies lower productivity growth, with the result that workers' incomes grow more slowly.

Overall, New Zealand is a technology taker (with some notable niche exceptions of local firms creating and exporting technology). This is particularly the case for digital technologies (APC & NZPC, 2019), and it is these technologies that underly recent predictions of technological disruption of labour markets. This means that the pace of technology invention and innovation elsewhere in the world will likely define the upper limit of technological change experienced by New Zealand.[18,19]

[18] The adoption of such technologies could, in principle, be faster or slower in New Zealand than elsewhere. It could be faster if policy settings were more accommodating; the scale benefits of the technology diminished above "New Zealand scale"; and/or complementarities between invention, innovation and adoption were low. Only policy settings are under the direct influence of New Zealand.

[19] This chapter uses the term 'global' as a shorthand for technologically advanced economies, and the more technologically advanced parts of less developed economies.

3.1 Will artificial intelligence lead to technological disruption of the labour market?

A specific set of emerging technologies that could automate a wide set of human activities has fuelled debate about the future of work. These technologies include robots, autonomous vehicles and artificial intelligence (AI).

AI is arguably the most important, as it has many uses and underpins improvements in the performance of robots, autonomous vehicles and software bots.

AI breakthroughs – and concomitant increases in business investment – have raised concerns about the potential for accelerating progress in AI to lead to "sustained periods of time with a large fraction of people not working" and to erode "both the labor force participation rate and the employment rate" (Furman, 2016, p. 7). Several technology investors (including Tesla CEO Elon Musk and Virgin founder Richard Branson), politicians and researchers have argued that universal basic income policies will be needed to respond to AI-induced large-scale unemployment (Clifford, 2018; Ford, 2015).

For AI to have highly disruptive effects on the labour market, the following would need to happen: a fast and continuing pace of AI development; the predominant direct effects of AI would be labour replacing; and the aggregate effects of AI would also need to be labour replacing. There is no general agreement on any of these points.

AI – an unstoppable rise or an impending plateau?

AI arguably has the characteristics of a general-purpose technology, which can be applied in many contexts, improves over time and prompts complementary innovations elsewhere (Bresnahan & Trajtenberg, 1995). Earlier general-purpose technologies – such as steam and electric power – had revolutionary effects on economies and societies.

There have been several recent breakthroughs in AI, as evidenced by these examples:

- British AI company DeepMind announced in 2018 that it had developed a healthcare algorithm that could detect over 50 eye diseases as accurately as a doctor (Vincent, 2018).
- Oxford University researchers reported in November 2016 that an AI system had achieved 95% accuracy in reading lips, considerably outperforming human lip readers (who were only right 52% of the time) (Manyika et al., 2017, p. 140).
- An IBM program took part in a live debate with humans in 2018 in "what was described as a ground-breaking display of artificial intelligence" (D. Lee, 2018). Attendees at the debate "made clear their thoughts when voting on who did best. While the humans had better delivery, the group agreed, the machine offered greater substance in its arguments" (ibid).
- Image recognition software now exceeds human accuracy levels, and the time taken to train an AI network to classify pictures accurately from the ImageNet database fell from an hour to 4 minutes in a year and a half (Shoham et al., 2018, pp. 47–48).

Improvements in the ability of AI technologies to make autonomous decisions reflect four developments over the past decade:

- better algorithms that allow systems to 'learn' from large datasets, and then apply this training to making decisions about data not previously encountered;
- better and cheaper hardware (including special-purpose hardware for training and classification);
- large, more reliable and cheaper datasets to use for training; and
- the commodification of the preceding three developments as on-demand services, allowing low-cost experimentation and widespread application.

There has been a recent surge in AI-related investment and business acquisitions. *The Economist* magazine reported that companies in 2017 "spent around [US]$22bn on AI-related mergers and acquisitions, about 26 times more than in 2015" (2018, p. 15).

There is no consensus about the pace of current and future progress in AI. Some scholars, for example Marcus (2018), are sceptical about the likely future speed and trajectory of development in AI technologies. Rather than speeding up, Marcus posited that AI variants like deep learning "may well be approaching a wall" (2018, p. 3) due to some inherent limitations.

> Deep learning systems work less well when there are limited amounts of training data available, or when the test set differs importantly from the training set, or when the space of examples is broad and filled with novelty (Marcus, 2018, p. 15).

AI has previously experienced large increases in investment and activity, only to be followed by 'winters' during which funding and interest in AI research dried up (1974–1980 and 1987–1993). Rather than a smooth curve of improvement, the development of AI in the past has been described as a process of "fits and starts" (Snow, 2018). And while there have been dramatic improvements in some aspects of AI performance, there have also been prominent failures.

- Doctors at Memorial Sloan Kettering Cancer Center in New York partnered with IBM to train the supercomputer Watson to diagnose and treat patients. However, the computer frequently gave bad or dangerous advice, "like when it suggested a [hypothetical] cancer patient with severe bleeding be given a drug that could cause the bleeding to worsen" (Chen, 2018). Doctors told IBM executives that "[t]his product is a piece of s---" (ibid). Applications of Watson in other health centres were equally dire. In South Korea, doctors "reported that Watson did poorly with older patients, didn't suggest certain standard drugs, and had a bug that caused it to recommend surveillance instead of aggressive treatment for certain patients with metastatic cancer" (Strickland, 2019).
- Driverless cars have failed to deliver on earlier expectations. Despite predictions in 2016 that autonomous vehicles would be on the road within a couple of years, trials of driverless cars have run into numerous problems, including deaths and accidents in test vehicles (Browne, 2019; Lee, 2018). The CEO of Aurora, a company that makes software for self-driving cars, recently stated that while there will be some small-scale adoption over the next 5–10 years, it "will be about 30 to 50 years … until they're everywhere" (Glaser, 2019).

The direct and aggregate effects of artificial intelligence on employment are uncertain

Some assessments of the impacts of AI on employment argue that it will tend to change and augment, rather than fully replace, human labour. Brynjolfsson, Mitchell and Rock (2018, p. 44) evaluated "the potential for applying machine learning [a form of AI] to tasks to the 2 069 work activities, 18 156 tasks, and 964 occupations in the O*NET database". They found that most occupations had tasks that were suitable for replacement by machine learning ('SML'), but "few if any occupations have all tasks that are SML", and concluded that:

> … a shift is needed in the debate about the effects of AI on work: away from the common focus on full automation of many jobs and pervasive occupational replacement toward the redesign of jobs and reengineering of business processes (2018, p. 44).

Others have argued that the diffusion of AI will most likely follow the paths of earlier general-purpose technologies such as steam power, electricity and computers. Comparing their predictions of job creation and destruction with earlier eras, the McKinsey Global Institute concluded that, even with fast rates of AI adoption, "future rates of labour displacement from automation within specific sectors are not unprecedented" (Manyika et al., 2017, p. 34). They went on to argue that "little is new about the breadth of impact of automation technologies" (ibid, p. 50).

Acemoglu and Restrepo (2018) found that industrial robots were labour replacing in aggregate within local labour markets in the United States between 1990 and 2007. However, they did not find the same effect for information (IT) capital in general. Industrial robots are a very specific technology whereas IT is a general-purpose technology. The labour-market effects of AI might be expected to be closer to those of IT capital than industrial robots.

Bloom et al. (2019) looked at the outsourcing of manufacturing from the US to China between 2000 and 2017. They found that outsourcing redistributed jobs from manufacturing in lower-income areas to services in higher-income, high human-capital areas. Outsourcing, in economic terms, is equivalent within a country to the adoption of a cost-saving technology. Jobs created in China also add to the total, suggesting that this "technology" is, in aggregate, labour augmenting.

Inquiry participants offered differing perspectives on how new technologies will influence existing industries and occupations in New Zealand (Box 3.1).

Box 3.1 **Submissions on emerging technologies and their labour-market impacts**

Submitters on the inquiry's issues paper expected the increasing use of data-based tools to improve productivity and customer service, with associated requirements on current workers to gain the skills to use these tools effectively. The Building and Construction Industry Training Organisation (BCITO) (sub. 25, pp. 2–3) outlined some of the technologies and tools currently "on the horizon".

> These include more extensive automated stock management and logistics such as Building Information Modelling (from Four- to Seven-Dimensional) and Virtual Reality, and – at the more distant end – potential use of robotics (both actual robots and exoskeleton-style technologies). Some of these directly impact on firm activity or organisation, while others are more related to customer service and relationships. For example, in sectors such as Kitchen Installation, clients are increasingly expecting access to self-design tools and processes that allow for direct personalisation of the products being purchased.

The Motor Trade Association (sub. 31, p. 5) commented that "we expect that motor vehicle technicians will continue to be in demand, albeit with a more technology-heavy diagnostic process".

The New Zealand Nurses Organisation (sub. 26, p. 2) cited a range of emerging technologies that would affect nursing practice (including genetics, genomics, 3D printing, robotics, biometrics, electronic healthcare records and computerised decision support tools) but concluded that:

> … technology cannot replace the bedside vigilance provided by nurses, nor does it have the capability to respond to patient changes in condition. Like nurses in other clinical settings, critical care nurses will move and progress with technology rather than be replaced by technology.

Dairy NZ noted the increased "digitalisation of farm advisory roles", which was likely to change the nature of the relationship between farmers and advisors (sub. 20, p. 3).

In their assessment of the possible impacts of AI on New Zealand, the AI Forum (2018) concluded that it was unlikely to have dramatic and negative effects on employment, because of:

- the relatively long lag times required both for businesses to adjust their processes once AI technology was a viable proposition; and
- expected changes in the labour market, which would see new occupations emerge and people shift towards jobs in which their skills and talents are more in demand.

F3.1 Artificial intelligence (AI) could potentially increase productivity and displace human labour. However, there is no consensus on the pace of current and future progress in AI, its effect on specific occupations, its aggregate impact on employment, nor its likely effects on the nature of work.

3.2 Recent data suggests global technological change is slowing, not accelerating

Several commentators have argued that technological change in general is accelerating. Some of these observations are based primarily on developments in AI, while others cite the adoption of other technologies. Chartered Accountants Australia and New Zealand (CAANZ) and the New Zealand Institute of Economic Research (NZIER) (2015, p. 16) pointed to apparent increases in the speed of technology uptake in the United States (Table 3.1).

Table 3.1 Technology adoption in the United States

Technology	First commercially available year	Years until used by 25% of US population
Electricity	1873	46
Telephone	1876	35
Radio	1897	31
Television	1926	26
Computer	1975	16
Mobile phone	1983	13
World wide web	1991	7

Source: CAANZ and NZIER (2015)

However, a McKinsey Global Institute report on workforce transitions in a time of automation noted that while technology adoption rates were probably faster than was the case 100 years ago, there was no evidence of acceleration over the last six decades.

> Looking at only the last 60 years, our review of the historical rates of adoption of 25 previous technologies shows that the time from commercial availability to 80 percent adoption has tended to fall within a relatively constant range: between approximately eight and 28 years. For 50 percent adoption, the range is five to 16 years. The technologies reviewed date back to TVs in the 1950s, and include recent examples of cell phones, customer relationship management software, and lithium-ion cell batteries. This range of times for adoption was observed for both hardware-based technologies that are capital-intensive and require physical installation; and technologies that are available purely online…Even highly popular and widely-used social media applications do not achieve a high level of adoption faster than technologies in previous eras. Facebook is one example: it was launched in 2004 and quickly achieved worldwide success. Yet even by mid-2016, when it had about 1.7 billion users globally, it was still far from full adoption, even outside China. Moreover, it was not the first social network, and so the adoption period could be calculated as being even longer – since the advent of the first modern social network, Six Degrees, which launched in 1997, or Classmates.com, which launched in 1995. (Manyika et al., 2017, p. 50)

It is not necessarily valid to compare diffusion rates of technologies that rely on significant new infrastructure (eg, telephones) with those that build off existing infrastructure investments (eg, dial-up internet) (APC, 2016). Similarly, it:

> … makes little sense to compare the spread of consumer goods and services to technologies being used in production. The latter requires the reconfiguration of production processes while the former does not. (Frey, 2019, p. 328)

An environment of rapid or increasing technological diffusion and disruption would be characterised by high productivity growth, higher rates of job churn and reallocation, and increases in new business creation. But data across several countries show the opposite trend – declining productivity growth and lower rates of job churn and business creation.

Slowing productivity growth

Productivity growth rates in many developed countries have fallen to very low levels (Figure 3.1 and Figure 3.2).

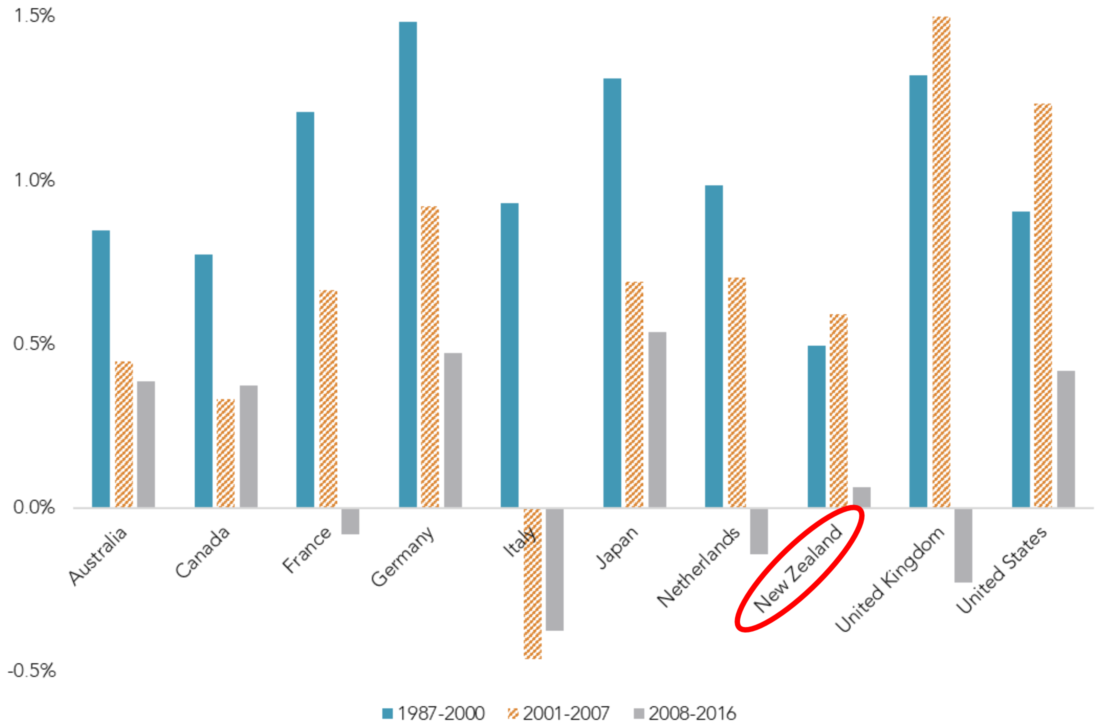
Figure 3.1 Average growth rates in labour productivity, 1971–2017

Source: APC (2019, p. 45)

Note:

1. Growth rates are based on averages of annual changes in real GDP per hour (PPP adjusted) for each year in the span shown.

Figure 3.2 Average growth rates in multifactor productivity, 1985–2017



Source: Productivity Commission analysis of OECD data.

Part of these declines in economic and productivity growth has been attributed to measurement problems – in particular, the inability of GDP measures to account for the welfare benefits from zero price goods such as free digital services (Brynjolfsson & Oh, 2012).

This argument is not universally accepted. Others have agreed that mismeasurement can explain part of the productivity slowdown, but argue it only accounts for a relatively minor share (Pells, 2018). Byrne, Fernald and Reinsdorf (2016, p. 109) found "little evidence that this [productivity] slowdown arises from growing mismeasurement of the gains from innovation in information technology-related goods and services". They concluded that:

- mismeasurement issues with information and communication technology (ICT) goods and services preceded the productivity slowdown and hence could not be its cause;
- the estimated gains from zero-priced services such as Google search and Facebook "are too small to compensate for the loss in overall well-being from slower market sector productivity growth"; and
- other measurement issues (eg, with fracking or globalisation) were "also quantitatively small relative to the slowdown" (ibid).

Syverson (2017, p. 167) was similarly sceptical of mismeasurement explanations, noting that the productivity slowdown occurred "with similar timing across at least two dozen other advanced economies", despite large differences in ICT "intensities" across these countries. He also agreed that the estimated surpluses from free digital goods are "modest" and could not account for the substantial loss in productivity and output that has occurred.

Less job churn, slower occupation churn and longer tenure

Borland and Coelli (2017, p. 388) reviewed a number of Australian job market indicators over the 1970s to 2000s to "evaluate the pace of structural change and job turnover". They concluded that there was "no evidence that increasing use of computer-based technologies has been associated with a higher rate of job destruction or a faster pace of structural change in the Australian labour market" (ibid). Evidence for this conclusion included:

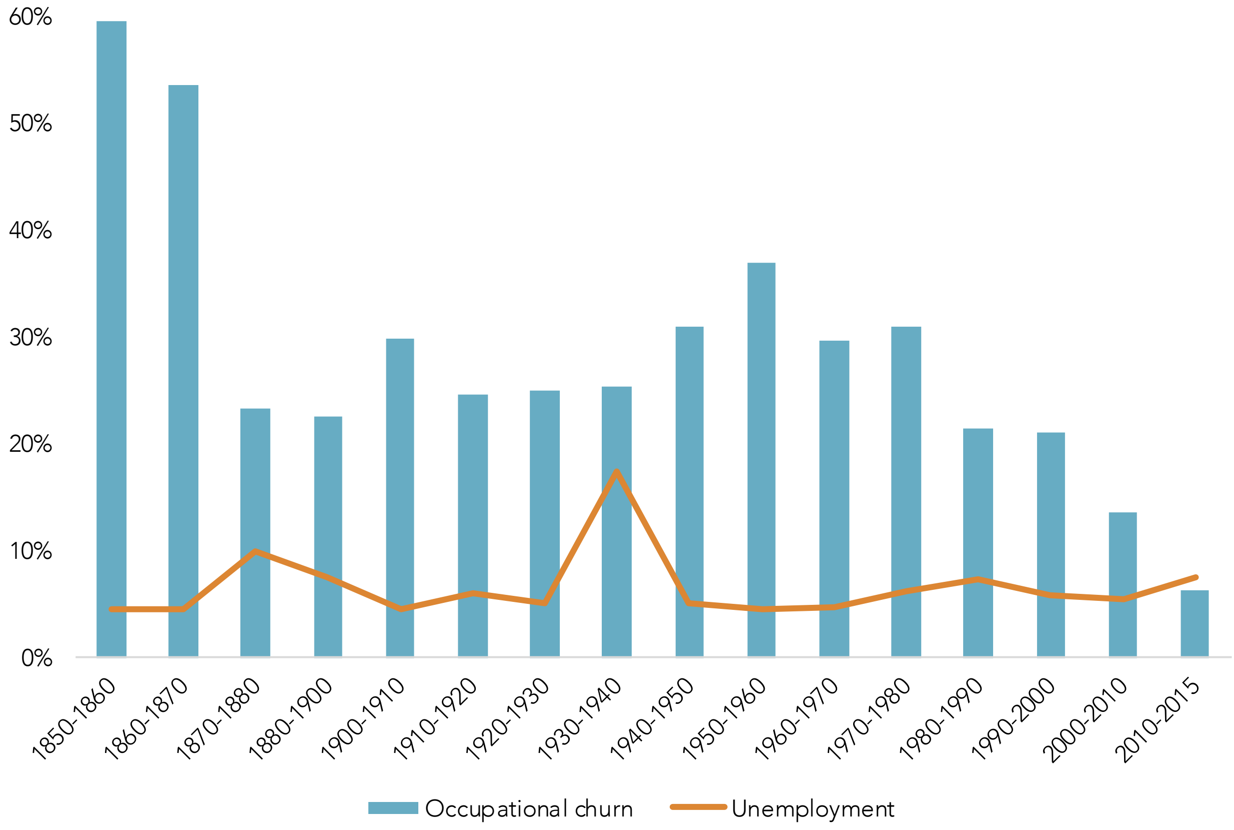
- rising average job tenure, due in part to an aging workforce: the "proportion of workers in very long duration jobs has increased from 19.3% in 1982 to 26.7% in 2016, and there has a corresponding decrease in the proportion of workers in their jobs for less than a year" (2017, p. 389);
- no obvious increase for men in the outflow to unemployment or out of the labour market since the early 1980s, and a steady decrease in this outflow for women;
- some increase in job destruction rates over the 1980s and 1990s, but a return to low levels from the 2000s onwards; and
- a steady decrease in the demand for workers to perform routine tasks , which "commenced at least as far back as the mid-1960s, and has been happening at a fairly steady rate since that time" (2017, p. 387).

US data also shows an increase in job tenure. The proportion of US workers with five or more years of tenure on their main job increased from 44% to 51% over 1998–2014, and the share of workers with one year or less fell from 28% to 21% (Hyatt & Spletzer, 2016). Much of this shift was attributed to workers aging and declining business births, which in turn led to falls in hiring rates.

Drawing on 165 years of data, Atkinson and Wu (2017, p. 2) concluded that "the rate of occupational churn in recent decades is at the lowest level in American history – at least as far back as 1850" (Figure 3.3). The Office of the Chief Economist (2018) repeated this analysis for Australia using a shorter time period, and they similarly found falling occupational churn from 2000 onwards.

When US unemployment data is overlaid on occupational churn data (Figure 3.3), no clear relationship emerges between occupational churn and unemployment. This observation fits with the idea that cyclic change (measured by the unemployment rate) and structural change in the economy (measured by the occupational churn rate) are independent. There is no reason to believe that a technology-induced structural change to the labour market will be associated with mass unemployment.

Figure 3.3 Rates of occupational churn and unemployment by decade in the United States, 1850–2015



Source: Atkinson and Wu (2017)

Notes:

1. The report characterised occupational change as "change in each occupation relative to overall occupational change … Absolute values were taken of negative numbers, and the sum of employment change was calculated for all occupations. This was then divided by the number of jobs at the beginning of the decade to measure the rate of churn" (2017, p. 12).
2. This figure uses 1950 occupational classifications. Analysis using 2010 occupational classifications found a similar general pattern over a shorter time period, with higher churn rates over 1950–1980 and declining churn from 2000 onwards.
3. Unemployment data based on 10-year averages, drawn off Lebergott (1964), Romer (1986) and Bureau of Labor Statistics figures.

F3.2 Data for the United States suggests that technology-induced structural change to the labour market is not historically associated with mass unemployment.

Declining business creation

Self-employment in New Zealand is declining, with working-proprietor labour input falling from 28.6% of all full-time equivalent labour in 2005 to 21% in 2015 (Fabling, 2018). Self-employment accounts for a substantial number of jobs and can be viewed as an indicator of the vibrancy of the wider business environment.[20]

Business start-up rates have been declining across many OECD countries (Figure 3.4). The New Zealand start-up rate fell by around 30% between 2001–2004 and 2009–2013. This may not bode well for future employment nor for wider technology adoption and diffusion. Young firms make a disproportionate contribution to job creation (Figure 3.5) and start-ups firms are more likely to take on new technologies.

[20] To the extent that people are self-employed by choice, their numbers reflect their belief that their expected total returns from self-employment exceed those from normal employment, even accounting for increased risk. An increase in self-employment (all else being equal) indicates an increased ability or willingness of individuals to take on business risk, which should reflect conditions in the wider business environment.

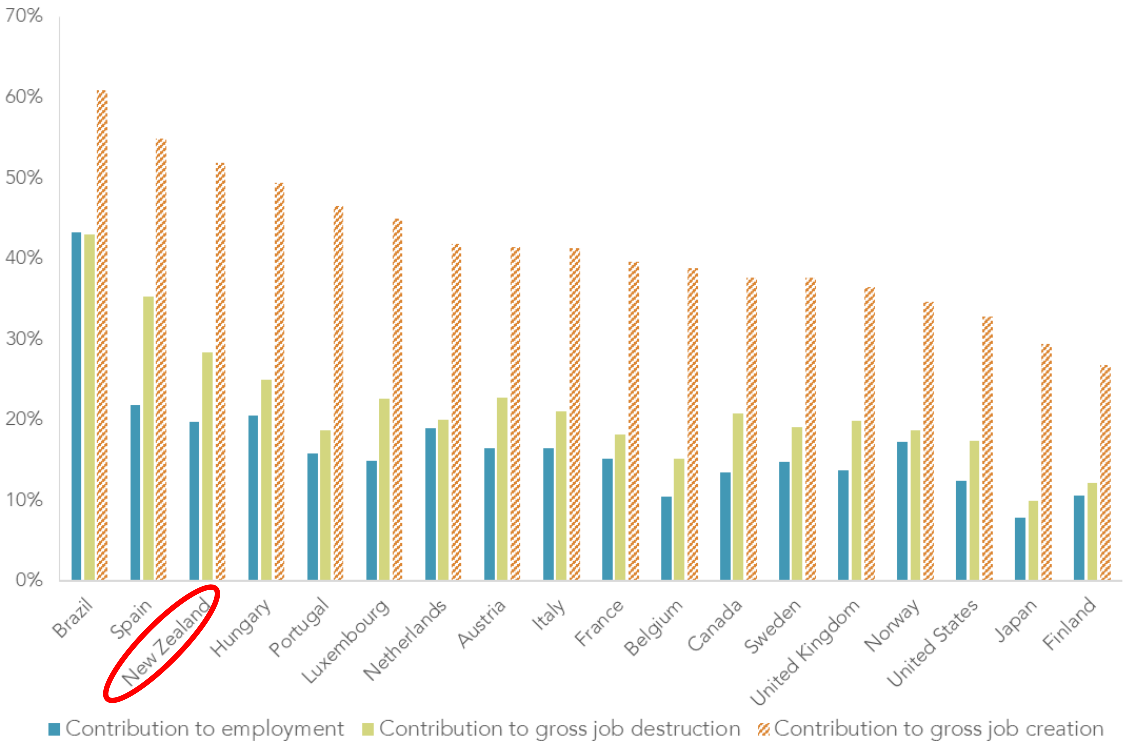
Figure 3.4 Business start-up rates in OECD countries, 1998–2013

Source: OECD (2016)

Notes:

1. Entry rates are calculated as the number of entrants with positive employment over the total number of units with positive employment.
2. Sectors covered are manufacturing, construction and non-financial business services.

Figure 3.5 Employment, job creation and job destruction by young small and medium firms, 2001–2011



Source: Criscuolo, Gal and Menon (2014)

Note:

1. 'Young' firms are less than six years old. Sectors covered are manufacturing, construction and non-financial business services.

F3.3 The pace of technological change (and any consequential labour-market change) does not appear to be accelerating. Rather, local and international statistics point in the opposite direction, towards declining labour market and business dynamism.

3.3 Predictive modelling

There are various ways to think about what future labour markets might hold, and thus what governments, firms and individuals might need to prepare for. One approach is to develop predictive models that forecast the extent and timing of the effects of forthcoming technologies on the labour market (Box 3.2). Such models typically look at a country's labour market in aggregate over a forecast period of 10–20 years. A few models disaggregate the effects by different job types, industries or regions, but disaggregated models can be expected to be less reliable than aggregate ones.

Box 3.2 **Some models predicting future job disruption**

Many forecasts have been made about the number, types and locations of jobs that will be lost to automation. One of the earliest, and most frequently cited, was by Frey and Osborne (2013). They categorised occupations "according to their susceptibility to computerisation" and examined the "expected impacts of future computerisation on US labour market outcomes" (2017, p. 254). They grouped occupations into those at 'high', 'medium' and 'low' risk of automation. They concluded that around 47% of total US employment was in the high-risk category, "ie, jobs we expect could be automated relatively soon, perhaps over the next decade or two" (p. 268). Particularly at risk were "most workers in transportation and logistics occupations, together with the bulk of office and administrative support workers, and labour in production occupations" (ibid).

CAANZ and NZIER adapted the Frey and Osborne model in 2015 to assess the impacts of disruptive technologies on New Zealand (CAANZ & NZIER, 2015). They concluded that 46% of the overall New Zealand workforce faced a high risk of automation, ranging from 75% for labouring jobs to around 12% of professional jobs.

Others looked at job tasks, rather than occupations, and came to less pessimistic conclusions about the risks posed to employment by automation. This approach recognises that occupations are made up of many distinct tasks, only some of which may be automatable. Arntz, Gregory and Zierahn (2016, p. 3) found that "on average across the 21 OECD countries, 9% of jobs are automatable". As a result, they concluded that "automation and digitalisation are unlikely to destroy large numbers of jobs" because "the utilisation of new jobs is a slow process" and workers adjust by switching tasks (ibid).

More recently, McKinsey prepared a forecast of job creation and destruction in New Zealand out to 2030 for the Future of Work Tripartite Forum (McKinsey & Company, 2019). This forecast included three main labour demand scenarios based on the pace of technology adoption ('early', 'mid-point' and 'late') and broke the results down by region, occupation type and industry. McKinsey found that:

- The earlier automation technologies are adopted, the more jobs will be lost – and the worse aggregate employment levels fare. Under the 'early adoption' scenario, there is a net job loss of 600,000. In comparison, under the 'late adoption' scenario, net employment increases by 1 million.
- Under their 'mid-point' scenario, 21% of work activities would be automated by 2030.
- Most regions benefit from net employment growth (except Southland and the West Coast), although the largest growth rates are expected to occur in Auckland and Wellington.
- Employment growth would be concentrated in managerial, technical and associated professional, service and retail jobs. There would be an overall reduction in administrative, trade and manual work jobs.

The Commission decided not to conduct a similar exercise for this inquiry due to the inherent limitations and methodological issues with modelling of this type. It is also hard to know what change is normal, and there are difficulties in knowing how the results should be interpreted or acted on.

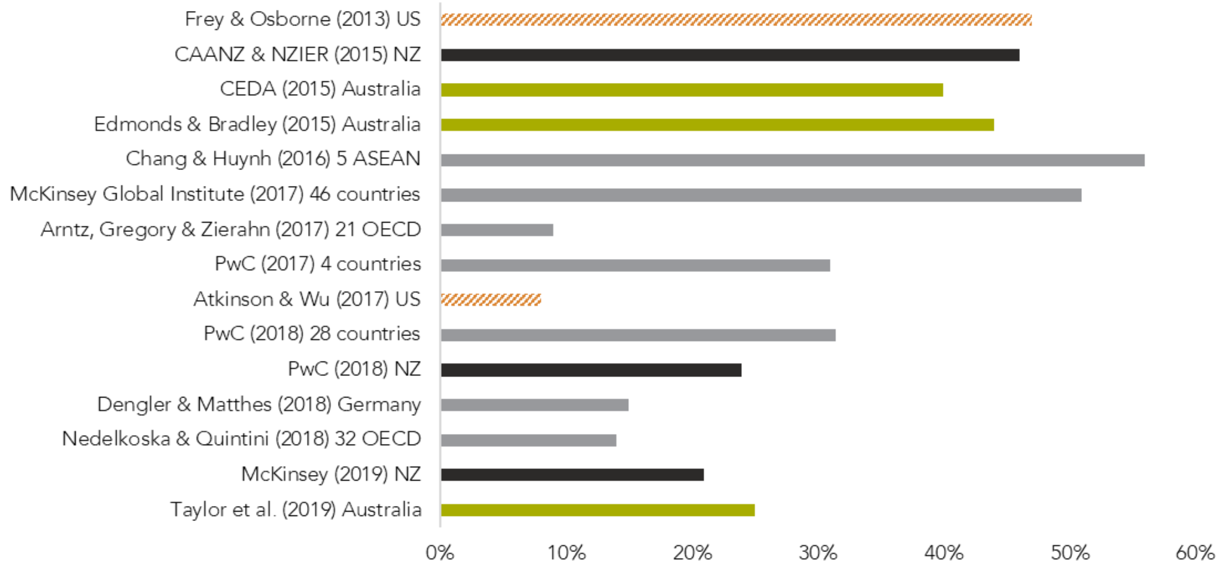
The inherent limitations of predictive models

Predictive modelling is an inherently difficult exercise. The frame of the analysis is crucial; depending on the frame used, models can produce very different results. Models tend to assume that what's technologically possible will be successfully commercialised and diffused widely and that the labour-market effects of technological change are known.

- *The frame of analysis matters.* As can be seen in Box 3.2 and in Figure 3.6, different models predict very different outcomes – even for the same country – depending on the unit of analysis (eg, tasks vs occupations), underlying datasets (eg, O*NET, PIAAC), assumptions made and other methodological choices.
- *Modelling is based on "known" technologies.* McKinsey's predictions, for example, define "automation potential according to the work activities that can be automated by adapting currently demonstrated technology" (McKinsey Global Institute, 2017, p. 5). A quickly developed and adopted but unexpected technology, or unexpected interactions between expected technologies, could create effects in excess of those predicted in these models. Similarly, unexpected technologies or interactions could mute or reverse predicted effects.
- *Modelling assumes that new technologies will be successfully commercialised and diffused widely.* Basing forecasts on the known examples of successful and proven technologies may overstate forthcoming automation. Salmon (2019, p. 66) argued that this is making the same mistake as "using the rugby careers of only Dan Carter and Richie McCaw to predict how quickly each of the Manawatu under-16s rugby team will make the All Blacks".
- *Assumptions about technology uptake, or the risks of automation, may not reflect economic realities.* All forecasts make assumptions about how quickly a technology will spread. However, as Nedelkoska and Quintini (2018, p. 8) observed, estimates of risks to jobs from automation "refer to technological possibilities, abstracting from the speed of diffusion and likelihood of adoption". Faster or slower diffusion or adoption would mean different impacts on job numbers and characteristics. The fact that a task or job is technically automatable does not mean that it necessarily will be automated. Many factors affect the decision by firms to adopt a technology and, at its most basic level, adoption needs to hold out a reasonable prospect of greater profits (Borland & Coelli, 2017).

Figure 3.6 appears to show a declining proportion of jobs at risk over time. One plausible explanation is progressive refinements to the models. Another is that the modellers are incorporating knowledge that automation technologies are not diffusing as quickly, or that labour market effects are more muted, than prior modellers had assumed. It is unclear which, if any, of these explanations is responsible.

Figure 3.6 Forecast jobs at risk from automation over following 10–20 years, selected models



Source: Productivity Commission

Notes:

1. The research paper by Frey and Osborne has appeared in multiple forms with publishing dates varying between 2013 and 2017. This report generally cites the 2017 version, but Figure 3.6 lists it as 2013 to preserve the chronology.
2. PwC (2019) covered 29 countries. The New Zealand result is split out.
3. Taylor et al. (2019) is published by McKinsey (Australia), and uses the same methodology as McKinsey (2019).

There are significant methodological issues with these predictive models

Existing predictive models, such as those in Figure 3.6, have significant methodological issues.

- *Some models only include job destruction effects.* But technological change also leads to job creation, through creating new tasks, new goods and services, and increased demand for existing goods and services. Yet, as Salmon (2019, p. 113) observed, some predictions fail to account for this effect.[21]
- *Many models are based on US job descriptions, industries and rates of technology uptake.* Other countries may have different occupations, bundles of tasks, industry structures and technology uptake rates, and hence different future automation impacts.
- *Many of these models are proprietary.* This makes it impossible for outsiders to understand and evaluate the assumptions and data the models rely on.
- *It is unclear what the best unit of analysis is.* Some predictions use jobs as the unit of analysis, others use tasks or work activities. Using jobs leads to crude estimates, as many jobs contain both automatable and non-automatable tasks. Using tasks addresses this problem, but typically makes another unrealistic assumption – that the tasks that make up a job are completely separable.

What degree of change is "normal"?

These types of models typically do not calculate a baseline of normal labour-market change against which predictions of future change should be compared. Labour-market change due to technology and other factors is normal and jobs are created and destroyed all the time. A study of New Zealand job trends found that the annual job creation rate over 2001–2009 averaged 14.8%, while the job destruction rate over the same period averaged 12.9% (Page, 2010).

[21] Frey and Osborne (2017) do not include effects that are positive for employment. The predictions for New Zealand by CAANZ & NZIER and PwC acknowledged that new jobs will be created, but they only modelled displacement. McKinsey's models include direct job creation. None of the models listed in **Error! Reference source not found.** include indirect job creation due to price effects.

Atkinson and Wu (2017) studied occupational churn in the United States. Using their estimates, 26% of US occupations churned over the period 2000–2015.[22]

Given an average working life of 40 years, around 2.5% of people retire each year. This equates to a low-disruption workforce adjustment of 37.5% over 15 years due to retirement. This number alone exceeds the 30% average technological job losses predicted for New Zealand (average of the three studies listed in Figure 3.6).

According to the AI Forum (2018, p. 53), in New Zealand:

> Over the next 40 years more than 10 million jobs will be displaced by normal market changes, so even in a worst case scenario of a million jobs lost to AI, this only represents 10% of the total change. Even if AI related job elimination were additional to the existing churn, it would be a relatively modest influence.

How should policy makers interpret model results and act on them?

Quantitative predictions give an artificial sense of certainty about the future and can encourage governments to make poor policy choices, or act too slowly or swiftly. One of the most prominent authors in this field, Carl Benedikt Frey, has expressed concern about the way in which his work with Michael Osborne has been interpreted, emphasising that *actual* job automation levels "will depend on many other things, such as cost, regulatory concerns, political pressure and social resistance" (The Economist, 2019, p. 66).

Frey is not alone in doubting the veracity of the conclusions of the jobs at risk from automation models. Box 3.3 summarises some other sceptical authors.

Modelling job losses from future automation has developed into something of an industry over the past six years. Figure 3.6 presents the headline results from 15 such models, but this is by no means an exhaustive list. The countries modelled are now up to 40% of the way through the forecast period yet the forecast job loss effects have not appeared in the labour-market data (see section 3.2). This creates a quandary for policy makers and the government. Perhaps the models have simply mis-predicted the *timing* of automation adoption and consequent job losses or they have mis-predicted the *magnitude* of job losses from automation. Another possibility is that the models have correctly predicted the timing and magnitude of job losses from automation, and these changes *are in progress,* but the changes are not identifiable in the data.

The Commission does not know which one or more of these explanations explains the quandary (although this report further considers the idea of a delayed timing of impacts below). Given the issues outlined above with these models, the Commission believes that it would be imprudent to plan for the future based on the predictions of any one, or group, of such models.

F3.4

There are inherent difficulties in undertaking predictive modelling of the employment effects of technological change. There are many 'jobs at risk from automation' models, yet the predicted job loss effects have not appeared in labour-market data. It would be imprudent to plan for the future based on the predictions of any one, or group, of these models.

[22] Atkinson and Wu provided two methods of calculating churn and results for both the 1950 and 2010 occupational classifications. 26% is the average of the results of their two methods using 2010 occupation classifications.

Box 3.3 **Sceptical commentary on technological change and the future of work**

Karen Chester (2018), then deputy chair of the Australian Productivity Commission, said in a speech that perhaps the future of work is "simply not so different".

> We know from history that soothsayers abound when it comes to opining on the future of work. Indeed history is littered with the foretelling of a dystopia of jobless woe … or a utopia of little need to work at all. And the only universal truth seems to be that they were all wrong – both happily and unhappily so. (p. 1)
>
> Overall, the evidence suggests that labour markets have been pretty well resilient to 'shocks' posed by new technologies of the past century and even the most recent, modern bit.
>
> Occupations, skills and jobs come … and they go. No matter how transformative the technology (be it the telephone, electricity, indoor plumbing, refrigeration, air transport, the personal computer, and today's digital). No technology has removed people's capacity to work. (p. 4)

Labour economist David Autor (2015) wrote in a provocatively titled paper *Why are there still so many jobs?*

> Clearly, the past two centuries of automation and technological progress have not made human labor obsolete: the employment-to-population ratio rose during the 20th century even as women moved from home to market; and although the unemployment rate fluctuates cyclically, there is no apparent long-run increase. (p. 4)
>
> Automation does indeed substitute for labor — as it is typically intended to do. However, automation also complements labor, raises output in ways that lead to higher demand for labor, and interacts with adjustments in labor supply. Indeed, a key observation of the paper is that journalists and even expert commentators tend to overstate the extent of machine substitution for human labor and ignore the strong complementarities between automation and labor that increase productivity, raise earnings, and augment demand for labor. (p. 5)

Robert Atkinson and John Wu (2017) of the Information Technology & Innovation Foundation wrote that it "has recently become an article of faith that workers in advanced industrial nations face almost unprecedented levels of labor-market disruption and insecurity." (p. 1) They challenged their readers to:

> Take a deep breath, and calm down. Labor market disruption is not abnormally high; it's at an all-time low, and predictions that human labor is just one tech "unicorn" away from redundancy are likely vastly overstated, as they always have been. (p. 3)

Economic historian Joel Mokyr, with Chris Vickers and Nicolas Ziebarth (2015), reminded readers that technological anxiety has a long history.

> From generation to generation, literature has often portrayed technology as alien, incomprehensible, increasingly powerful and threatening, and possibly uncontrollable. …
>
> So it is surely not without precedent that the developed world is now suffering from another bout of such angst. In fact, these worries about technological change have often appeared at times of flagging economic growth. (p. 31)

Mokyr et al. concluded that:

> … the more extreme of modern anxieties about long-term, ineradicable technological unemployment, or a widespread lack of meaning because of changes in work patterns seem highly unlikely to come to pass. As has been true now for more than two centuries, technological advance will continue to improve the standard of living in many dramatic and unforeseeable ways. However, fundamental economic principles will continue to operate. Scarcities will still be with us, most notably of time itself. The law of comparative advantage strongly suggests that most workers will still have useful tasks to perform even in an economy where the capacities of robots and automation have increased considerably. (p. 47)

3.4 Scenarios and productivity paths

An alternative approach is to explore the future consequences of 'drivers' – those factors that are expected to strongly influence the future, and for which the timing, direction and magnitude of variation is uncertain. Such analysis quickly becomes unwieldy and complex with too many drivers. Most practical applications consider two or three drivers, and the choice of drivers strongly influences the resulting scenarios.

Labour-market scenarios for 2035

The Commission presented four labour-market scenarios for New Zealand in the inquiry issues paper. These were based on plausible variation in two drivers of change with significant uncertainties: the rate of adoption of new technology; and the degree to which adopted technology is net labour-augmenting or net labour-replacing. Figure 3.7 positions the four scenarios relative to these drivers.

Figure 3.7 Labour-market scenarios for 2035

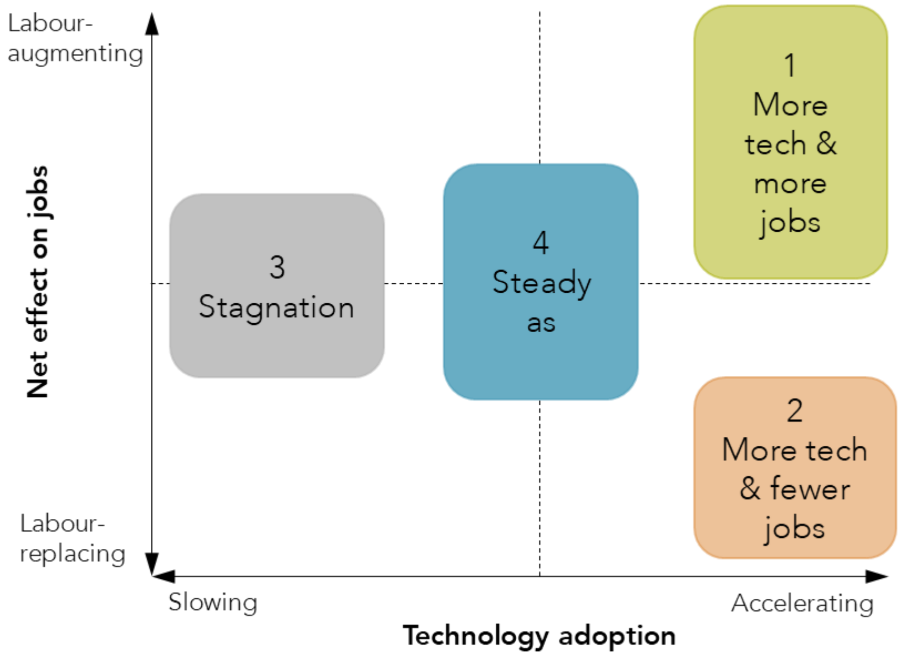
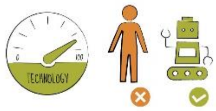
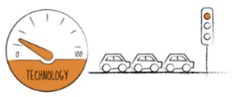
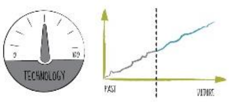


Table 3.2 lists the main characteristics of the four scenarios.

Table 3.2 Main characteristics of the four labour-market scenarios

Scenario	Characteristics
More tech, more jobs 	Technology adoption accelerates, creating at least as many jobs as it destroys • Capital and labour productivity rise, perhaps substantially • High levels of employment • Higher rates of occupational churn, leading to increased demand for mid-career training • Jobs lost are likely to be routine, while jobs gained will be those that are more complex
More tech, fewer jobs 	Technology adoption accelerates, with the overall effect of replacing labour • Capital productivity rises, as firms adopt productivity-enhancing technologies • Widespread unemployment and falls in average incomes as labour supply exceeds demand • Lower job churn as those in the remaining jobs seek to hold onto them for longer
Stagnation 	Technology adoption slows, with less job churn and less change in the nature of work • Less change in the volume, churn and nature of work • Very slow or flat growth in productivity and incomes • Significant risk of high unemployment
Steady as 	Technology adoption continues at a pace similar to the last 15 years • The pace of technology adoption by firms continues at recent levels • Slow productivity and income growth • Ongoing high levels of employment and stable levels of income inequality

The scenarios, as outlined in the issues paper, elicited considerable and diverse feedback from inquiry participants (Box 3.4).

No single set of scenarios could satisfy the full scope of this feedback. This draft report further develops the scenarios to improve their usefulness. This report:

- evaluates the likelihood of each of the scenarios, based on current data;
- recognises that the scenario drivers (ie, the new technology adoption rate and aggregate effects on jobs) are not specific to New Zealand – they are global drivers; and
- clarifies what New Zealand has control over, and what it does not.
- The AI Forum (sub. 10, p. 3) argued that the scenarios were "useful to discuss as endpoints, but less so as trajectories", and that it was important to also consider the journeys to these endpoints. This report adopts the Forum's suggestion, developing three productivity paths for New Zealand, each of which links to particular scenarios by 2035.

Box 3.4 **Submitter views on the four scenarios**

Some submitters believed that the Commission should select a preferred scenario, which government policy could then aim for (Northland Innovation Centre, sub. 3; AI Forum New Zealand, sub. 10; MacMahon et al., sub. 23; InternetNZ, sub. 24). To the extent that submitters selected a likely or preferred scenario, they tended to favour More tech, more jobs (Water New Zealand, sub. 19; Victoria MacLennan et al., sub. 23; Geoff and Esther Meadows, sub. 37).

Others felt that the coverage of the scenarios was too narrow.

> For example, another scenario could be one where there is significant technological uptake, an initial massive disruption in jobs, but the labour market settles, and after appropriate retraining, into a state with a similar number of jobs as today. (AI Forum, sub. 10, p. 3)

Chartered Accountants Australia and New Zealand similarly recommended adding a further scenario "in which economic and labour market outcomes diverge widely amongst different parts of the economy or society and which may be hidden by a net-economy wide approach." (sub. 15, p. 1)

InternetNZ felt that the scenarios could consider a wide range of variables, such as

> (a) The type and quality of jobs created by technological change …
>
> (b) The underlying landscape, including the technological infrastructure that facilitates the creation of new technology, the regulatory environment, etc.
>
> (c) The variable impacts of technological uptake, with some technologies (such as deep learning) likely to have huge impacts while others will be comparatively minor. (sub. 24, p. 5)

The Marlborough District Council (sub. 8) and the Employers and Manufacturers Association (sub. 5) said that the scenarios should pay more attention to aging populations, the likelihood of skills shortages and the potential for technology to alleviate these shortfalls.

The BCITO saw the most likely outcome for New Zealand as being an "uneven mixture of all four [scenarios], with each being represented to different degrees not just in different sectors of the economy, but within different industries and potentially different regions. In practice, this will likely smooth out to a fundamentally 'Steady As' scenario for the economy as a whole." (sub. 25, p. 2) The BCITO therefore recommended that the Commission "couch its future work in terms of specific aspects or dimensions of the workforce (many of which have been outlined in the issues paper) and the potential positive and negative effects of technology in those areas." (p. 2)

The Public Service Association welcomed "the idea of developing future scenarios", but recommended that the Commission add "a reflection of values and principles that should underpin our vision for the future" that included "social, cultural and environmental impacts." (sub. 33, p. 5)

How to think about the scenarios and existing predictions about the future

The Commission's four scenarios reflect four different 'camps' of future predictions of the labour-market impacts of automation.

- More tech, more jobs reflects a techno-optimist position (eg, McKinsey Global Institute, 2017).
- More tech, fewer jobs reflects a techno-pessimist position (eg, Acemoglu, 2019).
- Stagnation reflects the views of Gordon (2014, 2018) and others that current and forthcoming technology is not as transformative as previous rounds, and that a productivity and income growth slump might ensue as a result of technological change reaching natural limits or bottlenecks.
- The Steady as scenario forms a reference point for the other three. It is a continuation of economic conditions that have seen substantial technological change, including the ICT revolution, but little sign of technology-induced labour-market disruption (eg, Chester, 2018).

Global outcomes will constrain local outcomes

The New Zealand economy is entwined with the economies of other countries through trade in goods and services; investment flows; asset and commodity prices; labour mobility; global, multilateral and bilateral agreements; and knowledge flows. The labour-market outcomes of automation technologies will be strongly influenced – and perhaps largely determined – by what happens elsewhere.

The largely international sources of technology mean that New Zealand does not have unrestricted choice over which scenario will play out here. The creation and adoption of technologies overseas is outside New Zealand's control. However, the New Zealand Government has some control – through regulation, subsidies, taxes and other policy interventions – over local technology adoption and its impacts on the labour market.

But there are limits to the effectiveness of such tools. The entry and diffusion of technology is ultimately the result of a multitude of decisions by individual firms, people and households. Policy tools can either encourage or discourage adoption, but not completely determine those decisions. And while it is possible to ban specific technologies, the undesired effects of those technologies can 'leak' across borders and undermine the intent of the ban (Box 3.5)

Box 3.5 **New Zealand can ban a technology, but can it ban the technology's effects?**

New Zealand could ban or restrict a technology, aiming to protect local firms or workers. But such bans may have little protective effect on the labour market if the country is exposed to the impacts of that technology through international prices and competition. Indeed, local restrictions on technology could make things worse by limiting the ability of New Zealand firms and workers to adjust.

This reasoning applies to both bans on production technologies and bans on products themselves:

- A ban on automation technology that reduces the cost of production for an internationally traded good could make local producers uncompetitive and lead to their closure, reducing local employment. For example, a ban on kiwifruit-picking robots here might make New Zealand kiwifruit uncompetitive on world markets.
- Similarly, an import or local production ban on a new, cheaper-to-produce product might seem an attractive way to support local producers of 'traditional' products. However, if those products are at least partial substitutes in global markets, producers of the traditional product will still face downwards price pressures. New Zealand's Margarine Act 1895, for example, regulated the local production and sale of margarine, but probably had neglible effect on world butter prices.

Many digital services and technologies are effectively 'borderless', making it difficult for any single government (or group of governments) to regulate them (APC & NZPC, 2019).

Global drivers will set the environment that New Zealand policy will be responding to. Should the world move towards something like the Stagnation scenario, for example, there is no feasible path for New Zealand to More tech, more jobs. It may well be possible for New Zealand, through its policy decisions, to engineer a scenario less favourable than global conditions allow. However, it is difficult to see how that would be desirable.

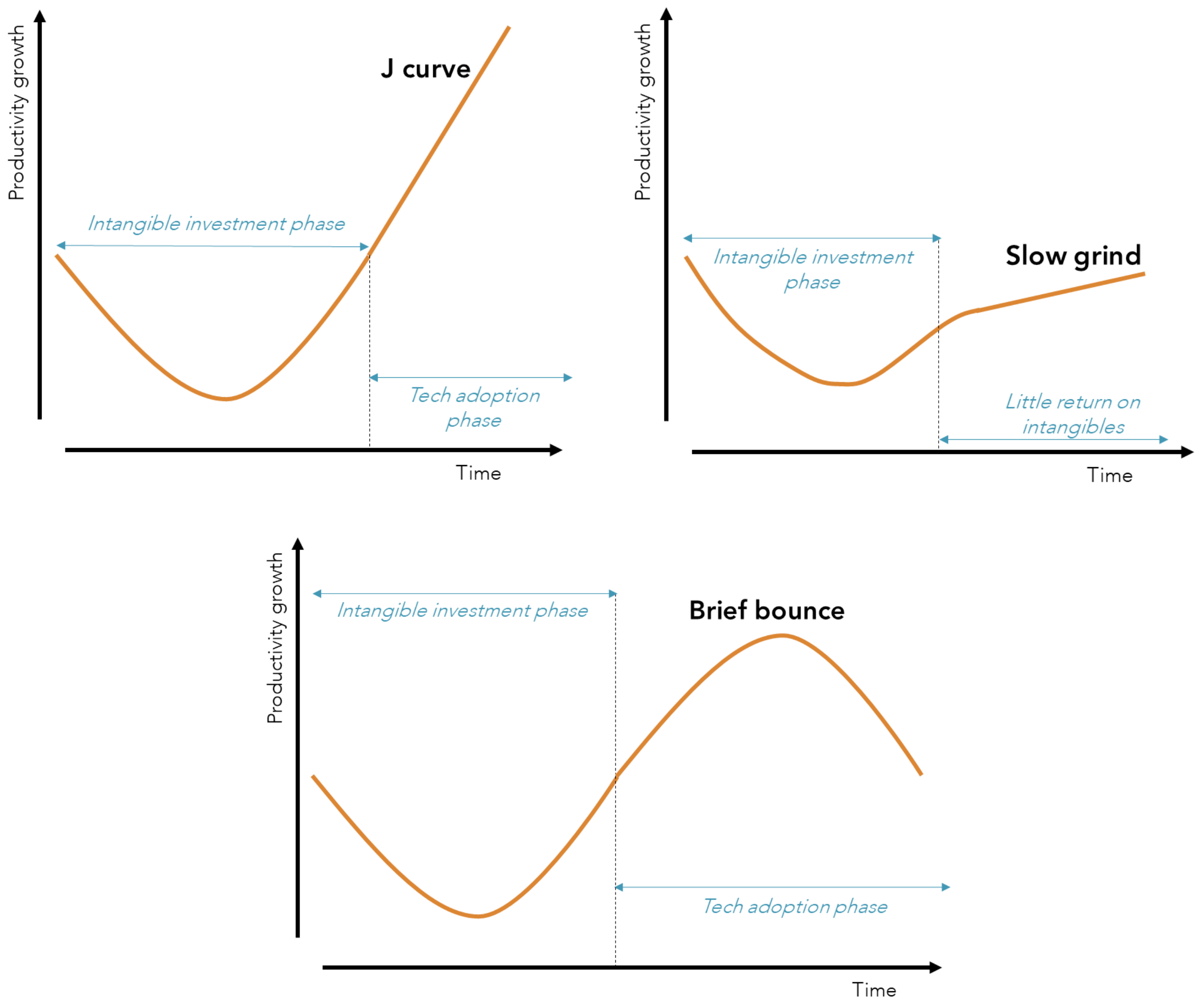
Global productivity paths to 2035

This section explores the idea that societal costs exceed benefits during the start-up phase of a new technology, and it takes some time before a reversal occurs. Such an idea would allow for both slowing productivity growth and falling business dynamism in the present (as per section 3.2), followed by a reversal and path towards a different outcome – for example the labour-market scenarios described above.

To develop this idea, this section develops three global 'productivity paths', each drawing off different historical examples (Figure 3.8).

- *J curve:* Recent developments are but a temporary pause, as firms invest heavily in the technology and organisational changes that they believe will realise benefits for them (Brynjolfsson, Rock, & Syverson, 2018). Over time, poor investments will be written off, and successful investments will drive substantial productivity growth.
- *Slow grind:* Recent developments are a harbinger of future trends. The rewards from current investments will turn out to be elusive. Technological change will be undramatic and productivity growth will remain low.
- *Brief bounce:* Recent developments may herald an effect similar to the 'ICT revolution', whose productivity benefits arrived late and lasted but a decade. The economy will realise large, but also temporary, gains from new technology.

Figure 3.8 Global productivity paths



J curve

The J curve path draws off previous experience with technologies, which often took time to diffuse through the economy and make their full effect felt in productivity and wage growth. For example, it took four decades after the first central power station opened for business in the United States for half of American factory mechanical drive capacity to be electrified (David, 1990). The diffusion and full exploitation of electricity was delayed because of an absence of complementary inputs (especially expertise in reorganising factories to best suit the new power source), uncertain returns from investments in electrical power, and the continued viability of non-electric power sources.

Economists Brynjolfsson, Rock and Syverson (2018) argued that the diffusion of general-purpose technologies such as steam engines, electric motors and semiconductors typically involves a productivity slowdown, as firms have to make "larger intangible and often unmeasured investments and [undertake] a fundamental rethinking of the organization of production itself" in order to realise the full potential of the technology. This pattern leads to a 'productivity J curve', whereby "measurable resources are committed (and measurable output foregone) to build new, unmeasured inputs that complement [the new technology]" (ibid). Many of these investments fail to pay off, further depressing productivity growth. Once firms discover and implement the appropriate investments and organisational changes, productivity growth increases. The J curve scenario posits that the leading firms are currently in the 'intangible investment phase' of AI adoption, and that productivity and income growth will pick up in the future once successful investments begin to pay off.

Slow grind

The Slow grind path similarly reflects the large investments in intangible assets by leading firms, but concludes that these investments will ultimately not recover their accumulated costs. The path draws off the work of scholars such as Gordon (2018), who have argued that:

- "… it is becoming ever more resource-intensive to find ideas that have a major impact" (p. 17);
- progress in automation technologies has been slow in the past and is likely to remain so; and
- there are many economic and social forces (ie, falling fertility, stagnant life expectancies for lower income groups, rising inequality, slowing increases in educational attainment rates) that will lean against future productivity gains.

Bloom et al. (2017, p. 2) similarly report an ongoing decline in the productivity of research effort by firms. The report notes that:

> Economic growth arises from people creating ideas. As a matter of accounting, we can decompose the long-run growth rate into the product of two terms: the effective number of researchers and their research productivity. We present a wide range of empirical evidence showing that in many contexts and at various levels of disaggregation, research effort is rising substantially, while research productivity is declining sharply. Steady growth, when it occurs, results from the offsetting of these two trends.

They reported that research productivity, averaged across the firms studied, was declining by around 10% per year. Following this path, productivity (and income) growth would remain poor for the foreseeable future.

Brief bounce

Alternatively, global technological change and productivity growth may be following the pattern of ICT over the 1980s to 2000s.

The apparent widespread adoption of computers, combined with a lack of any obvious improvement in economic performance, led Nobel Laureate Robert Solow to comment in 1987 that one "can see the computer age everywhere but in the productivity statistics" (p. 36) and others to muse over the apparent 'productivity paradox'. An ICT-based productivity boost ultimately occurred in the United States in the mid-1990s to early 2000s, driven in large part by changes to business processes by large retailers that improved efficiencies and drove higher profits (NZPC, 2014). However, the productivity growth increases over this period soon dissipated and were much less pronounced outside the United States.

Consistent with this productivity path, leading global firms are currently in the 'intangible investment' phase. Payoffs from these investments will see a future boost in productivity growth, but this will be temporary.

What about New Zealand's productivity path to 2035?

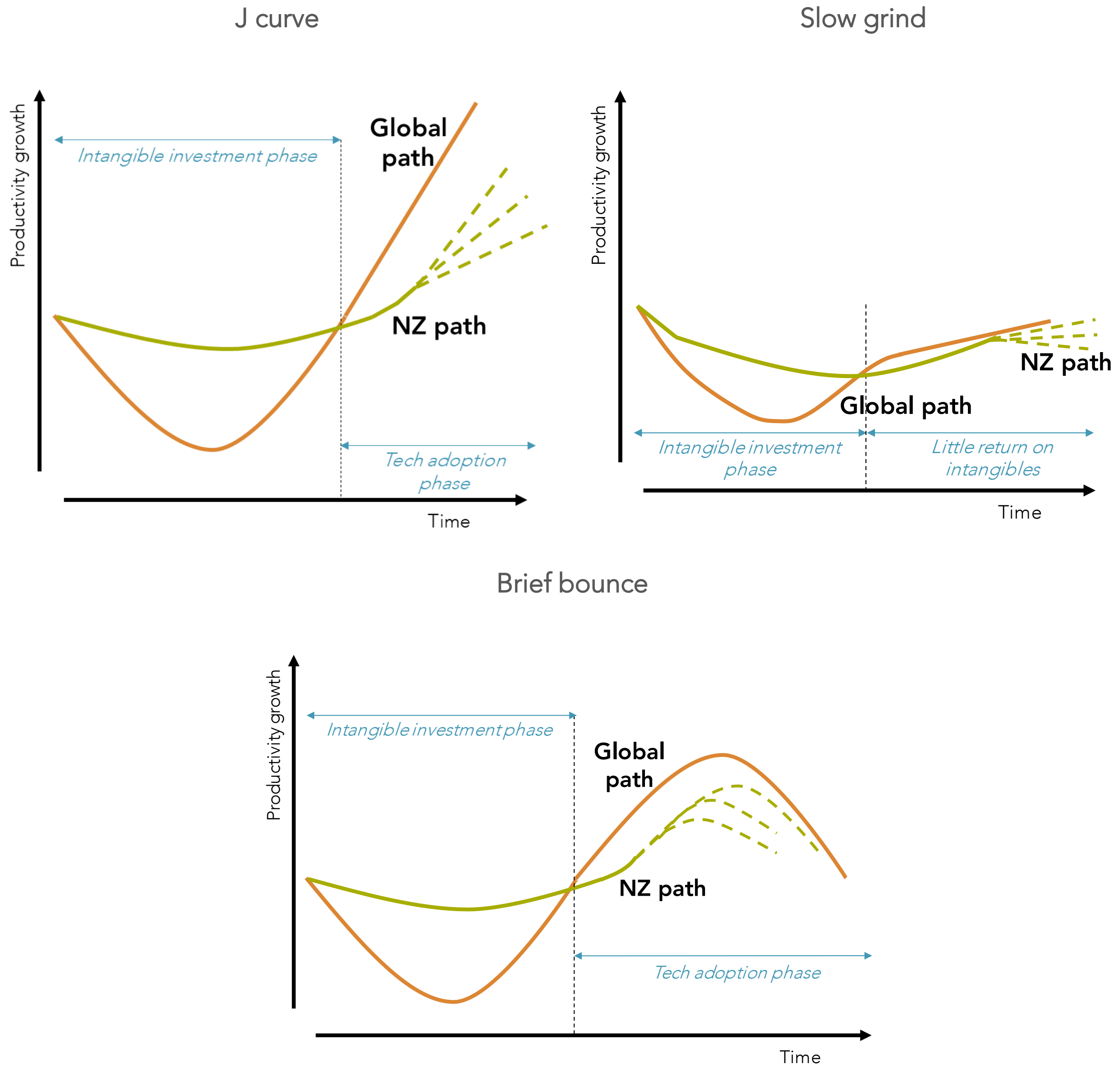
For each of the possible global productivity paths, the path of New Zealand's productivity would likely be slower and more muted:

- New Zealand firms are not making the investments in intangible assets that could generate large productivity gains (AI Forum, 2018; Chappell & Jaffe, 2016; Conway & NZPC, 2016; de Serres, Yashiro, & Boulhol, 2014). Hence local firms will neither make the same losses or reap the same returns from the intangible investment phase.

- Technology-induced changes in New Zealand's productivity growth are likely to lag behind other countries because of this country's relatively slow and low diffusion rates (section 2.2).

Figure 3.9 represents possible New Zealand paths alongside the global paths. The dotted green lines reflect lower certainty and that the path is more able to be influenced by New Zealand's policy settings. The inquiry's forthcoming draft reports, specifically the fourth report, will discuss those policy settings.

Figure 3.9 New Zealand productivity under the three global productivity paths



F3.5

The scale, pace and direction of technology-induced change to New Zealand's labour market will depend, to a significant extent, on how quickly technology develops and diffuses overseas. Productivity growth and direct labour-market impacts from technology are likely to lag, and be more muted than overseas trends, unless New Zealand overcomes its poor track record in adopting and diffusing technology.

Labour-market effects of poor diffusion in New Zealand

Although poor technological diffusion in New Zealand may imply less risk of disruption to employment, this is not necessarily the case. As can be seen in the example of kiwifruit-picking robots in Box 3.5, failure to adopt leading technologies in New Zealand could make local firms and industries uncompetitive, leading to a fall in demand for their products and displacement of their workers. More broadly, poor technological diffusion implies lower productivity growth, with the result that workers' incomes grow more slowly.

F3.6

Poor technological diffusion may imply less direct risk to employment in New Zealand, but it also implies lower productivity growth, with the result that workers' incomes grow more slowly.

The three productivity paths lead to the scenarios

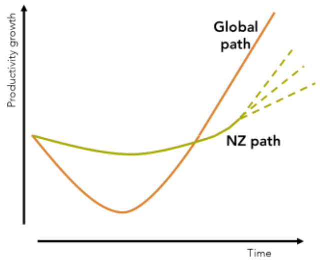
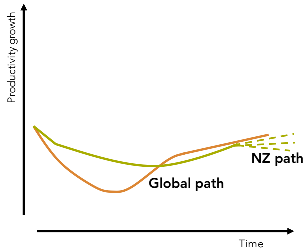
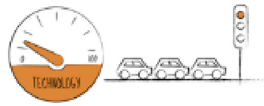
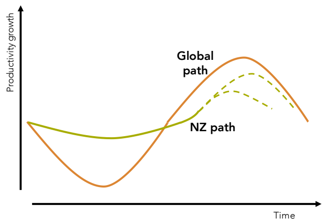
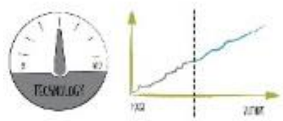
Table 3.3 presents the Commission's view on the expected impacts on work and employment of the three productivity paths to 2035. In summary, the:

- J curve will most likely lead to More tech, more jobs, but could conceivably lead to More tech, fewer jobs;
- Slow grind leads to the Stagnation scenario; and
- Brief bounce leads to the Steady as scenario.

These are the *aggregate* effects of technology on the labour market. Disruption of employment (both positive and negative) at a local or industry level could still occur in each, reflecting the application and diffusion of specific new technologies. The effects of Brief bounce may also be concentrated in specific sectors. For example, the productivity impacts of ICT, and the resulting productivity boost, were felt most strongly in the US retail sector (Triplett & Bosworth, 2004).

Slow grind would most likely lead to the least amount of change in the volume, churn and nature of work, accompanied with slow productivity and income growth, and could involve less change to work than the status quo. Brief bounce entails more change than Slow grind, but on a time-limited basis. Of the three paths, the J curve would clearly have the largest impact on work, both in terms of scale and breadth.

Table 3.3 New Zealand labour-market effects of the three productivity paths

Productivity path	Productivity growth	Job creation and destruction	Job tenure	Job churn	Occupational churn	Business creation	Resulting scenario
J curve  	Initial slump and then sustained and broad-based increase in productivity growth.	Sustained increase in job creation and destruction rates. The increases in the two rates may occur at different times, and at different paces.	Stabilisation/ possible reduction	Sustained increase	Sustained increase	Sustained increase	Most likely a More tech, more jobs scenario. However, a More tech, fewer jobs scenario cannot be discounted. 
Slow grind  	Slow	Low/declining	Lengthening	Stable/declining	Low/declining	Stable/ declining	Stagnation scenario 
Brief bounce  	Initial slump and then surge in productivity growth. The surge may be concentrated in specific sectors and fade over time.	Time-limited increase in both creation and destruction rates, although one effect may dominate. Increases may be concentrated in specific sectors.	Temporary stabilisation in average tenure	Time-limited increase	Time-limited increase	Time-limited increase	Steady as scenario 

These paths and scenarios are not equally likely

This analysis has informed the Commission's preliminary view of the likely effect of technological change on employment. In coming to a view, the Commission has taken into consideration that:

- the rate of adoption of new technology is slowing, not accelerating (section 3.2);
- it is difficult to predict which automation technologies are more likely to augment or replace specific tasks, jobs or occupations;
- there is little evidence that new or previous technologies are strongly labour replacing in aggregate; and
- previous diffusion of general-purpose technologies has led to more employment, and there is no clear association between technology-induced occupation churn and unemployment (Figure 3.3).

These factors do not suggest that future technological change will lead to fewer jobs for human labour. Nevertheless, there are uncertainties about how quickly and far technologies such as AI will develop. Dramatic improvements in the ability of AI to replicate 'general intelligence' (ie, the ability to think and reason across different areas and apply knowledge to unfamiliar tasks) could make large-scale displacement of human labour feasible should it become commercialised and widely diffused in the next few years. The Commission considers this to be a low probability but high consequence outcome. For this reason, it should not be discounted.

Within the time period considered by this inquiry (ie, the next 10–15 years), some continuation of existing trends seems likely.

- *Further automation of routine tasks*. Even if AI and other automation technologies do not make much progress towards general intelligence, existing and emerging tools (eg, chatbots, virtual assistants etc) already permit computers to carry out repetitive and predictable tasks. Their prices are likely to continue falling, and their quality should continue rising. The extent to which this leads to displacement will depend on the pace of these price falls and quality improvements.
- *Concentration of knowledge-intensive jobs in major cities*. As data becomes an increasingly important input to business decisions, the demand for people with the skills to collect, interpret and utilise this information is likely to grow. Recent experience, reflecting the importance of agglomeration benefits, suggests that these people and jobs will be located primarily in large cities.

Table 3.4 presents the Commission's preliminary judgement of the likelihoods of the labour-market scenarios, as informed by current data and historical experience.

Table 3.4 Labour-market scenario likelihood

Scenario	Current data suggests	History suggests
More tech, more jobs	Unlikely	Most likely outcome from transformative technology
More tech, fewer jobs	Very unlikely	No precedent
Stagnation	Possible	No recent example
Steady as	Probable	Disruptions (ie, large, unexpected shocks) are rare

The More tech, fewer jobs is very unlikely; yet would have adverse consequences. The Stagnation scenario would also have adverse consequences but is somewhat more likely than large-scale technological displacement of work. It should be treated seriously.

F3.7

A continuation of existing trends seems the most likely scenario, including further automation of routine tasks and the concentration of knowledge-intensive jobs in major cities. It is unlikely that, in the next 10–15 years, automation technologies will widely displace human labour in New Zealand.

Increased technology with fewer jobs is a low-likelihood but high-consequence outcome. However, a Stagnation scenario of low productivity growth and a significant risk of high unemployment is more likely than large-scale technological displacement of work. Neither outcome should be completely discounted.

4 Preparing for an uncertain future

Key points

- There is time to prepare for significant impacts of technological change on labour markets in New Zealand. Labour-market change is likely to lag, and be more muted than, overseas trends. New Zealand could usefully:
  - improve systems to monitor labour-market and technological changes internationally and locally;
  - examine current policy settings and look for improvements that assist people to adjust to labour-market changes or prepare for a different future of work; and
  - widen the economy's capacity to adjust to change without incurring disruptive consequences.
- Policy changes that will widen the economy's capacity to adjust to change include those that:
  - promote the fast adoption of technology;
  - reduce uncertainty for firms and for workers;
  - better support workers and others adversely affected by technology adoption; and
  - support the efficient allocation of capital and other resources to productive enterprises and away from less-productive ones.
- New Zealand's poor productivity performance is long-standing. Actions to improve productivity will enhance the ability of the economy to deal with shocks from whatever source. Such measures will also raise incomes and wellbeing.

How should governments best respond to uncertainty that surrounds technological development and the future of work?

4.1 There is time to prepare for change but not time to waste

The path analysis presented in the previous chapter, along with an examination of existing data, suggests that there is time to prepare for significant impacts of technological change on labour markets. In New Zealand, labour-market change is likely to lag, and be more muted than, overseas trends. However, that comes with a warning that faster adoption of technology overseas could see New Zealand fall behind, with consequences for jobs and incomes.

The analysis presented in this report also suggests that a useful course of action is to monitor global (and local) developments. The productivity paths reflect investment in intangibles in the hope of achieving a productivity payoff, but no-one can know whether these investments will pay off and to what extent. That uncertainty is the key difference between the J curve, Brief bounce and Slow grind paths. Each of these assumes that technological change is *in progress* but is not yet identifiable in the data. This points to some important trends and labour-market statistics to watch.

Monitor trends …

Monitoring labour-market and business statistics can identify divergence from current trends. Indicators that could be monitored include:

- job creation and destruction rates,
- the structure of employment,

- distribution of incomes,
- job displacement rates,
- business starts and exits,
- the performance of leading New Zealand firms relative to their international peers,
- domestic diffusion rates, and
- occupational churn rates.

Further information on these indicators is available in Table 4.1. These trends would best be monitored, both domestically and internationally (particularly in countries with faster technology adoption or more flexible labour markets than New Zealand).

Current official statistics do not fully cover the labour-market trends that governments should take a close interest in. For example, New Zealand does not currently have a reliable measure of the size and make-up of the gig or contract labour market.[23]

F4.1 Monitoring labour-market and business statistics can identify divergence from current trends. Such divergence will most likely be evident in other countries, particularly those with faster technology adoption, before it is evident in New Zealand.

… and expand New Zealand's capacity to adjust to change

New Zealand has undergone significant labour-market changes over the last few decades, as described in this report's companion paper *New jobs, old jobs and the evolution of work in regional New Zealand* (Coleman & Zheng, forthcoming).

Changes over the last 10–15 years have been within New Zealand's overall capacity to adjust. These changes include the decline of some industries and occupations; new jobs in service industries, especially in knowledge-intensive industries in Auckland; and an increasing need for workers with tertiary qualifications and skills. However, these changes have disrupted the lives of some individuals, and their families and whānau.

Could New Zealand, under current policy settings, cope with a faster rate of change in the future? Existing policy settings relevant to the future of work in the next 10–15 years fall into three domains:

- employment and incomes;
- education and skills; and
- technology, innovation and productivity.

The inquiry's forthcoming draft reports will address policies in these domains. Preliminary observations that will guide the development of these reports include the following:

- Agility and adaptability – of people, firms and governments – are valuable in adjusting to change.
- The costs and benefits of change – whether driven by technology or by other factors – can fall unevenly.
- Government policies can help or hinder those affected by change. Existing policies and programmes could do a better job of helping those most disadvantaged.
- Support policies should not treat those affected by technology any differently from those similarly affected by different underlying causes.

[23] Accurately measuring the gig labour market is a complex task, as US researchers have found (Abraham, Haltiwanger, Sandusky, & Spletzer, 2018). The Commission is researching the desirable features of a gig labour-market indicator, which should help inform the development of future metrics.

- Maximising mobility, resilience and employment opportunities will allow faster and smoother adjustments to change.
- There are opportunities to improve the effectiveness of New Zealand's education and training system in enabling existing and future workers to adapt to technological change.
- The nature and impacts of technology can be dispersed, context-dependent and hard to distinguish from the impact of other influences. Regulation that is based on specific technology can easily and quickly become obsolete; and delay or prevent technology adoption.
- 'Lumpy' events, in which the adverse effects of change are concentrated, are unusual. They may require specially designed policy responses to support those affected. But these should spring from institutions that are well designed to cope with broad change.
- Protecting declining industries or artificially inflating new ones can delay, magnify or create future adjustment costs.

4.2 Pursue policies that will help New Zealand embrace change

The benefits of technological progress are many and significant including higher productivity, higher incomes, and more effective public services. Turning away from technological change or attempting to tightly control its entry and diffusion offers at best temporary relief. Previous attempts to insulate New Zealand from economic and technological change were not successful and created large and painful adjustment costs. New Zealand's problem has not been *too much* technological change and progress; it has been *too little*. By failing to pick up and spread the world's best technologies, New Zealand has lost opportunities to gain higher living standards. The path to greater wellbeing lies with more technology adoption and diffusion.

Faster adoption of technology increases the economy's ability to adjust to change without disruption. But it will require policy changes that support and encourage faster adoption and address likely objections to change. These changes should:

- reduce policy uncertainty for firms and for workers;
- better support workers and others adversely affected by technology adoption;
- better prepare New Zealanders for potential changes to the nature of work and the skills required; and
- support the efficient allocation of capital and other resources to productive enterprises and away from less-productive ones.

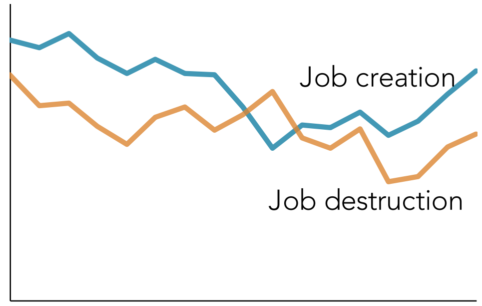
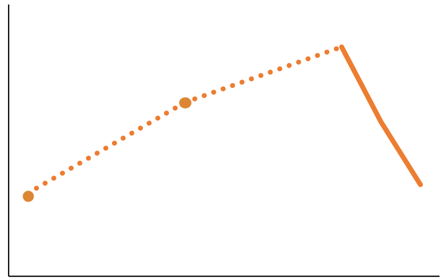
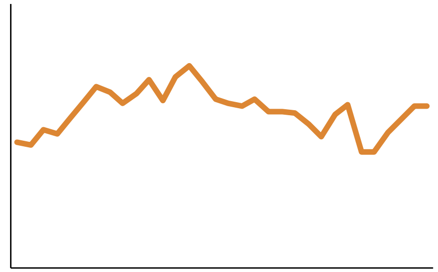
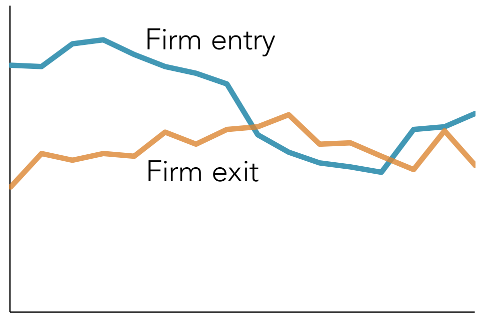
F4.2

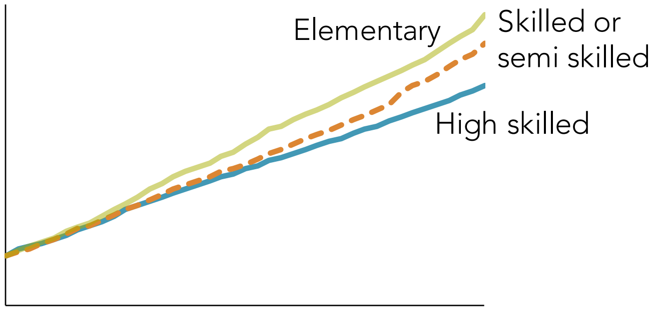
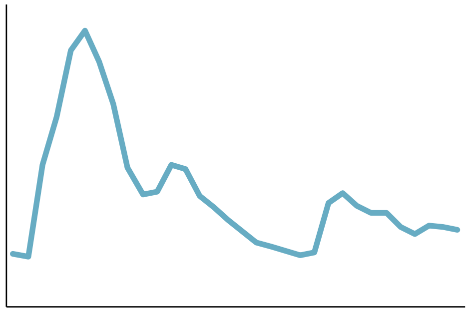
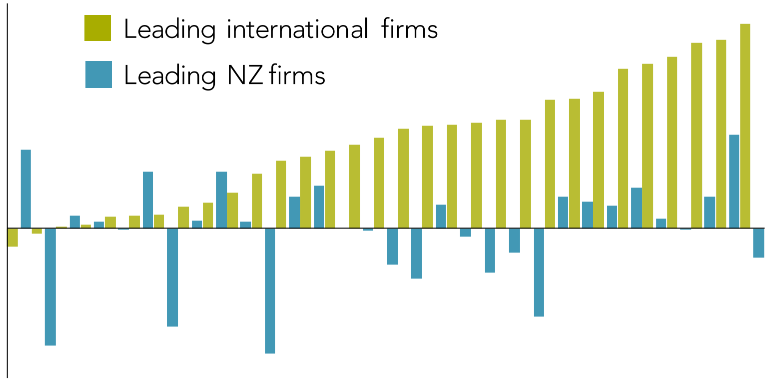
Faster adoption of technology increases the economy's ability to adjust to change without disruption. This requires policy changes that support and encourage faster adoption, and address objections to change, by:

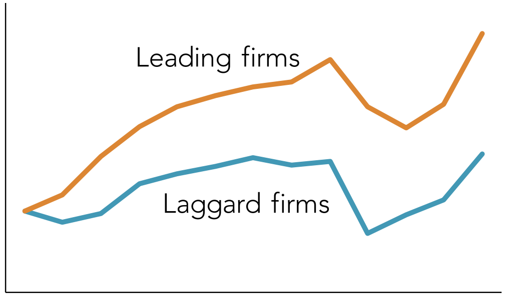
- reducing policy uncertainty for firms and for workers;
- better supporting workers and others adversely affected by technology adoption;
- better preparing New Zealanders for potential changes to the nature of work and the skills required; and
- supporting the efficient allocation of capital and other resources to productive enterprises and away from less-productive ones.

New Zealand's poor productivity performance is long-standing. Actions to improve productivity will enhance the ability of the economy to deal with shocks from whatever source. Such measures will also raise the incomes and wellbeing of New Zealanders.

Table 4.1 Indicators of the impacts of technology on the labour market and economy

Indicator	Description	Trend
Job creation and destruction rates	Job creation is the gross number of filled jobs created since the last measurement point, as a share of all jobs. Job destruction is the the gross number of filled jobs lost since the last measurement point, as a share of all filled jobs. Sustained divergences between the two rates may indicate growing technological impacts on employment.	Job creation and destruction as a share of total jobs, 2000-16 
The structure of employment	This measures changes in the make up of work, by the type of employment relationship (eg, permanent employee, fixed-term and temp agency, seasonal and casual) and contract status (eg, employee or contractors). Large shifts towards self-employment or non-permanent arrangements may signal technology-enabled disintermediation of employment relations	Casual and fixed-term jobs as a share of total jobs, 2008-18  Self-employed as a share of total jobs, 1987-2017 
Business starts and exits	New businesses established, and existing business closed, during a period. New firms create an outsized proportion of new jobs, and start-up and exit rates are good proxies for the dynamism of the business environment. Business starts and exit rates would be expected in increase in an environment of faster technological progress or diffusion.	Firm entry and exit rates, 2001-15 

Indicator	Description	Trend
Distribution of incomes	The rates of wage and salary growth across different occupational and skill levels. Falling or stagnant growth rates for some groups of workers may indicate falling demand or the introduction of labour-replacing technologies.	Wage growth across occupation skill groups, 2009-19 
Job displacement rates	The rate of workers who lose their jobs involuntarily (ie, because of redundancy/lay-offs/business restructuring). Higher rates of job displacement may indicate a larger labour-replacing effect of technology on the labour market.	Rate of involuntary job loss for non-employed workers, 1987-2017 
The performance of leading firms, relative to their international peers	The productivity performance of New Zealand's best-performing firms, relative to equivalent leading global firms. Faster technological diffusion in New Zealand should lead to a closing gap beween local and global leading firms' performance.	Labour productivity growth rates by industry, leading NZ and international firms, 2000-12 

Indicator	Description	Trend
Domestic diffusion rates	The productivity performance of New Zealand's best performing firms, relative to the poorest-performing firms. Faster technological diffusion in New Zealand should lead to a closing gap between the performance of the best and worst local firms.	Multi-factor productivity growth rates, leading and laggard firms, 2000-12 
Occupational churn rates	Change in each occupation relative to overall occupational change. Faster occupational churn may indicate growing technological impacts on the nature of jobs and their tasks	Occupational churn rates have not yet been estimated for New Zealand. Estimating this indicator would likely require analysing Census data on changes in the number of workers in different occupations (at a detailed level). This data is not publicly available in New Zealand. As noted earlier, work has been conducted in the United States and Australia on measuring occupational churn.

Notes:

1. Data on casual and fixed term jobs was initially sourced from the four-yearly Survey of Working Life (run in 2008 and 2012). More recently, it has been sourced from the Household Labour Force Survey, which is run quarterly (ie, every three months).
2. Occupational groups in the 'wage growth' figure are defined drawing on MBIE definitions. For example, 'elementary' is the lowest-skill grouping and includes machinery operators, drivers and labourers.
3. Figures on the performance of leading firms and domestic diffusion rates are drawn from Conway (2016).

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Summary of findings

Chapter 1 – Technology diffusion and its impacts on work

F1.1

Technological diffusion is the result of a multitude of decisions by individuals, firms and governments. Many factors influence the likelihood of adoption and hence diffusion, including:

- uncertainty about the relative costs and benefits of adoption;
- access to complementary skills and inputs, including capital;
- changes in input prices;
- labour-market dynamics, employment relationships and institutional settings;
- the strength of customer relationships;
- the size of markets and levels of market competition; and
- government policy.

F1.2

Technology can have many distinct effects on the labour market, and more than one effect can occur. Technology can replace human labour, augment human labour, increase the demand for labour by reducing the cost of goods and services, create new markets and jobs, and improve matching between workers and employers. Because of this complexity, it can be difficult to predict in advance the aggregate impact of a specific technology on work and labour.

Chapter 2 – How has technology affected work in the past?

F2.1

The impact of technology on the labour market has changed over time. In the earlier years of the First Industrial Revolution, mechanisation replaced skilled artisans, increasing the demand for lower-skilled labour. Wage growth was slow. From the mid-1800s, the demand for higher-skilled labour increased, reflecting the needs of large and complex factories and new production methods. Wages grew more rapidly.

F2.2

From the 1970s, technological change has rewarded occupations devoted to complex non-routine tasks and penalised those that largely have routine and automatable tasks.

F2.3

The impact of technology on income inequality has differed over time, and the nature of the current relationship between technology and inequality is unclear.

F2.4

Protectionist policies delay rather than eliminate adjustment costs. Such policies create additional costs due to investment misallocation, placing an even higher burden on the generation in which adjustment occurs.

F2.5 Recent economic and labour-market changes in New Zealand have favoured people with higher education, the services sector and Auckland. While there have been reductions in the employment share of middle-skilled jobs in New Zealand, there has not been an increase in low-skilled jobs as seen in the United States. Instead, the share of low-paid and low-education jobs has declined.

F2.6 New Zealand's poor productivity performance is due in part to the weak diffusion of technologies across the economy. New Zealand's leading firms are slow to adopt world-leading technologies, and the poorest-performing firms are not driven out by competition.

Chapter 3 – Global influences and local impacts

F3.1 Artificial intelligence (AI) could potentially increase productivity and displace human labour. However, there is no consensus on the pace of current and future progress in AI, its effect on specific occupations, its aggregate impact on employment, nor its likely effects on the nature of work.

F3.2 Data for the United States suggests that technology-induced structural change to the labour market is not historically associated with mass unemployment.

F3.3 The pace of technological change (and any consequential labour-market change) does not appear to be accelerating. Rather, local and international statistics point in the opposite direction, towards declining labour market and business dynamism.

F3.4 There are inherent difficulties in undertaking predictive modelling of the employment effects of technological change. There are many 'jobs at risk from automation' models, yet the predicted job loss effects have not appeared in labour-market data. It would be imprudent to plan for the future based on the predictions of any one, or group, of these models.

F3.5 The scale, pace and direction of technology-induced change to New Zealand's labour market will depend, to a significant extent, on how quickly technology develops and diffuses overseas. Productivity growth and direct labour-market impacts from technology are likely to lag, and be more muted than overseas trends, unless New Zealand overcomes its poor track record in adopting and diffusing technology.

F3.6 Poor technological diffusion may imply less direct risk to employment in New Zealand, but it also implies lower productivity growth, with the result that workers' incomes grow more slowly.

F3.7

A continuation of existing trends seems the most likely scenario, including further automation of routine tasks and the concentration of knowledge-intensive jobs in major cities. It is unlikely that, in the next 10–15 years, automation technologies will widely displace human labour in New Zealand.

Increased technology with fewer jobs is a low-likelihood but high-consequence outcome. However, a Stagnation scenario of low productivity growth and a significant risk of high unemployment is more likely than large-scale technological displacement of work. Neither outcome should be completely discounted.

Chapter 4 – Preparing for an uncertain future

F4.1

Monitoring labour-market and business statistics can identify divergence from current trends. Such divergence will most likely be evident in other countries, particularly those with faster technology adoption, before it is evident in New Zealand.

F4.2

Faster adoption of technology increases the economy's ability to adjust to change without disruption. This requires policy changes that support and encourage faster adoption, and address objections to change, by:

- reducing policy uncertainty for firms and for workers;
- better supporting workers and others adversely affected by technology adoption;
- better preparing New Zealanders for potential changes to the nature of work and the skills required; and
- supporting the efficient allocation of capital and other resources to productive enterprises and away from less-productive ones.

Appendix A Public consultation

Submissions on issues paper

Individual or organisation	Submission number
AI Forum New Zealand	010
Alexia Hilbertidou	001
Blind Foundation	017
Building and Construction Industry Training Organisation	025
Business Hawke's Bay	021
Career Development Association of New Zealand	035
Chartered Accountants Australia and New Zealand	015
Counties Power Consumer Trust	012
DairyNZ	020
Economic Development New Zealand	028
EdTech New Zealand	013
Energy Trusts of New Zealand Inc	018
Engineering Leadership Forum	030
Engineering New Zealand	047
Federated Farmers of New Zealand	037
Geoff and Esther Meadows	034
Göran Roos	046
Grant White	044
Greg van Paassen	007
Industry Training Federation	029
Institute of Directors	004
InternetNZ	024
Jeanette Thorne	014
Kim Stevenson	045
Marlborough District Council	008
Microsoft	043
Ministry of Education	048
Motor Trade Association	031
National Council of Women of New Zealand	022
National Library of New Zealand	036
New Zealand Council of Trade Unions Te Kauae Kaimahi	041
New Zealand Nurses Organisation	026
New Zealand Qualifications Authority	039
NGO Health & Disability Network	006
Perce Harpham	002
Powerco	032
Public Service Association	033
Tertiary Education Commission	042
The Employers and Manufacturers Association (EMA)	005
The Northland Innovation Centre (NIC)	003
Uber	027
Unboxed Performance	038
Victoria MacLeannan	023
Water New Zealand	019
Watercare Services Limited	016
WeCreate Incorporated	009
Young Enterprise Trust	011

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