How dispersed are new technologies in the Australian job market?

Prepared by Elif Bahar and Oscar Lane[*]

The diffusion of new technologies is an important driver of productivity growth, particularly in Australia − a small open economy that tends to adopt innovations from the global frontier. Using Lightcast job ad data, we show that Australia's adoption of emerging technologies has increased over the past decade. Job ads referencing cloud computing, machine learning and artificial intelligence − innovations most likely to become general-purpose, productivity-enhancing technologies − have increased strongly and become more evenly spread across industries. However, the prevalence of these technologies appears to be lower in Australia than in the United States.

Diffusion of new technologies is a key driver of productivity growth

Innovation and the use of new technologies are important determinants of firm performance and aggregate productivity. Typically, new technologies are developed by frontier firms and then diffused through the economy as they are adopted by other firms.

Previous Treasury analysis has demonstrated a slowdown in the rate at which Australian firms reached the global productivity frontier between 2002 and 2016, suggesting slower adoption of cutting-edge technologies and processes (Andrews et al. 2022). This article builds on this evidence by examining the extent to which Australian job advertisement data referenced cutting-edge technologies between 2012 and 2020.

We focus particularly on technologies that may become 'general-purpose'. General-purpose technologies are widely used across industries and spark widespread innovation and productivity growth across the whole economy. Electricity and the internet are examples of previous general-purpose technologies. While complementary investments are necessary, general-purpose technologies will ultimately produce significant productivity gains (Brynjolfsson et al. 2021).

Emerging technologies

We use a list of 29 emerging global technologies identified by Bloom et al. (2021). These authors selected technologies based on how frequently they are mentioned in patents, job postings and earnings conference calls in the US. They argue that each of the 29 technologies has significantly disrupted businesses and jobs in the US in the past 2 decades. They also had significant global implications. All these technologies had emerged (at least in the US) by the 2000s or early 2010s.

We pay particular attention to cloud computing, machine learning and artificial intelligence. It has been argued that these technologies have the most potential to become the next general-purpose technologies (Goldfarb et al. 2022).

Text analysis of job ads

Lightcast[1] scrapes online company job boards and makes that data available for analytical purposes. The data used here are individual online job ads collected by Lightcast for 2012 to 2020.[2] This provides us with a sample of about 8.5 million Australian job ads over this period. The data contains the full text of the job ads, as well as some pre-defined characteristics of each job such as the industry, occupation and location.

We take two approaches to examining the job ad data. First, we use text analysis techniques to search for keywords related to each technology within the job description, similar to Bloom et al. (2021). For example, searches for the 'autonomous cars' technology also includes searches for 'self-driving car', 'robot car', and 'driverless truck'. Second, we use the skills identified by Lightcast to compare the adoption of technologies in Australia and the US.

Figure 1: References to emerging technologies in Australian job ads
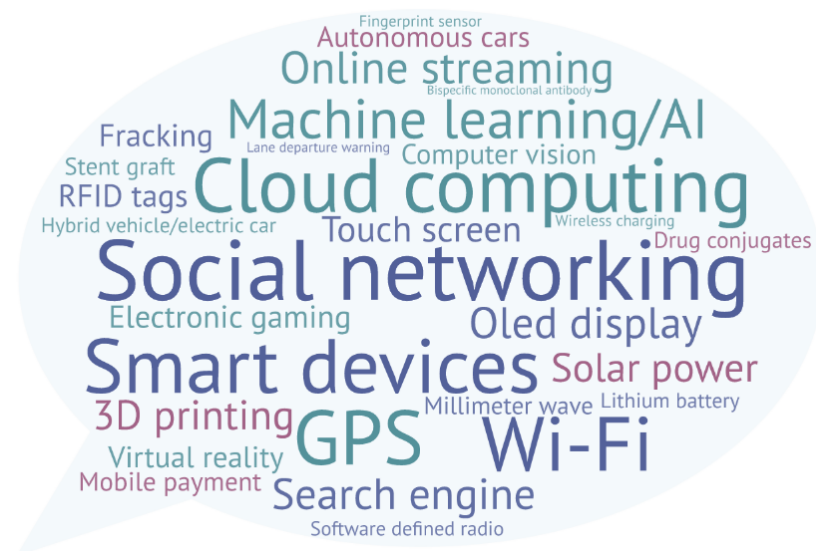
Notes*: Size of font refers to frequency of jobs ad references.
Source*: Treasury analysis of Lightcast data for Australia (2012-2020).

[1] Lightcast was previously known as Emsi Burning Glass.
[2] Data will necessarily only include job ads posted online and will not perfectly represent the number of new hires in the economy.

Emerging technologies are becoming more prevalent in Australia

Figure 1 maps how frequently each of the 29 emerging technologies is mentioned in Australian job ads, with the size of each word indicating how often they are referenced by employers. Overall, the top 3 referenced emerging technologies by employers in Australia were social networking, cloud computing, and smart devices. Other top demanded skills are related to GPS, online streaming, and machine learning/artificial intelligence. Table 1 in the Appendix enumerates all 29 technologies.

Our text analysis suggests that references to the top 29 emerging global technologies in job ads have become more prevalent over time, indicating demand for these technologies has become more prominent in the Australian labour market. The share of job ads referencing any of the 29 emerging technologies increased from 4 per cent in 2012 to 7 per cent in 2020 (Figure 2).

Figure 2: Share of job ads that reference emerging technology, Australia
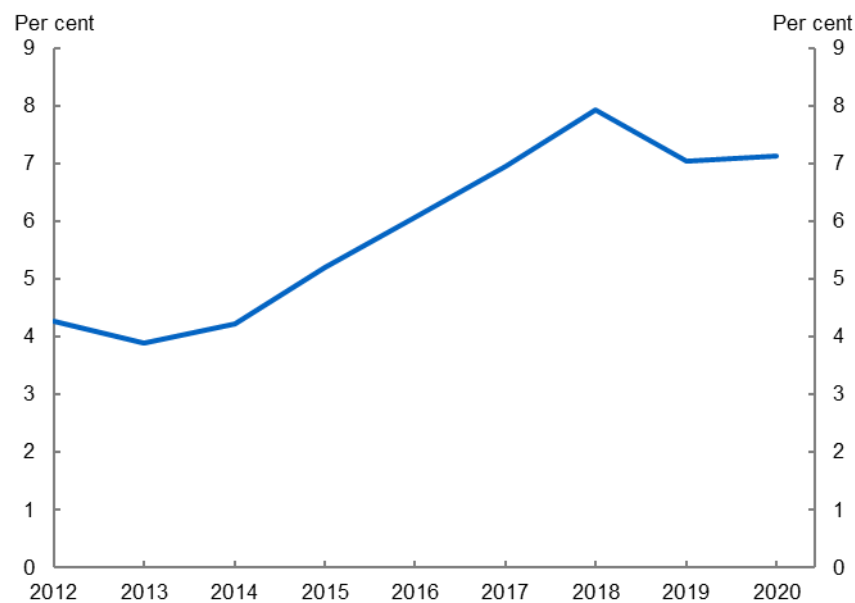
Notes: One job ad may correspond to multiple vacancies. Emerging technology job ads refer to any instance where a technology is mentioned in the job description. A list of the 29 emerging technologies is in Table 1 in the Appendix.
Source: Treasury analysis of Lightcast data for Australia (2012-2020).

The share of total job ads that reference cloud computing, machine learning or artificial intelligence – technologies most likely to become general-purpose – have increased over the past decade in Australia and the US (Figure 3). Adoption of these technologies particularly strengthened from around 2017. Despite strong growth in the past decade, the share of job ads referencing these technologies remains lower in Australia than in the US.

In 2020, the share of job ads referencing machine learning and artificial intelligence was broadly flat in Australia. There was a slight increase in the share of job ads referencing cloud computing, consistent with Australian Bureau of Statistics analysis reporting greater use of these services (Australian Bureau of Statistics 2021). However, more data are required to understand how the pandemic impacted technological adoption.

Figure 3: Share of job ads requiring technological skills
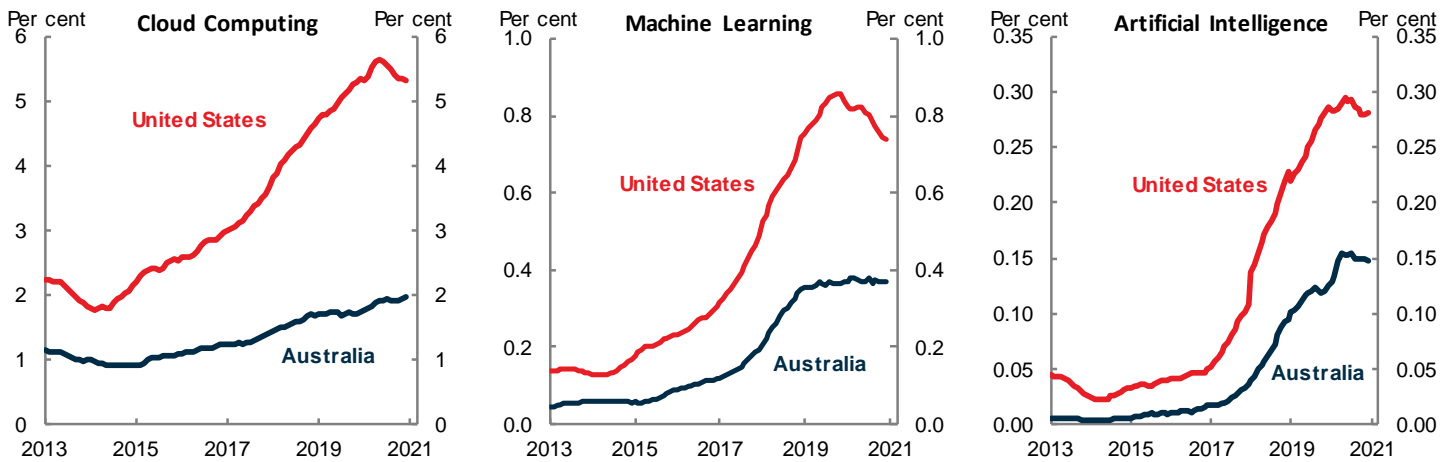
Notes: 12-month rolling average of monthly share of job ads that require each technology skill. These charts use Lightcast's predefined skill categories, rather than the text analysis approached used in Figure 2. Cloud Computing also includes Cloud Storage and Cloud Solutions. Source: Treasury analysis of Lightcast data for Australia and the United States (2012-2020).

Diffusion across industries for general-purpose technologies has increased

Initially, disruptive general-purpose technologies tend to be produced and used by a single industry. They diffuse to other industries over time, helping them modernise and improve their production processes. Stronger diffusion of general-purpose technologies across multiple industries will help support improved productivity growth over time.

We measure cross-industry diffusion by calculating the Coefficient of Variation (CoV). This metric captures the take-up of these technologies across industries, with a lower CoV indicating a more evenly distributed take-up across industries. The CoV is measured as the ratio of the standard deviation and mean of the share of job ads referring to the technology, calculated across all industries.

Cloud computing and machine learning/artificial intelligence have become more evenly dispersed across industries over the sample, suggesting firms across a range of industries have increased their adoption of these technologies in recent years (Figure 4).

Figure 4: Diffusion of technologies across industries
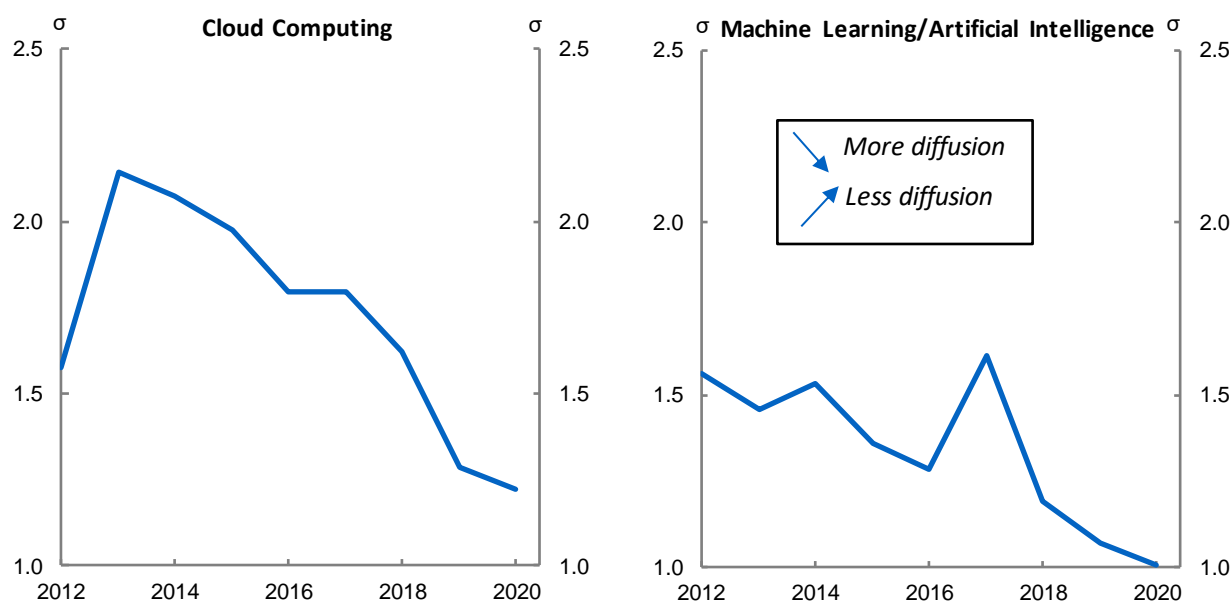
Notes: Series charts average yearly Coefficient of Variation (CoV) across 1-digit divisions. The CoV takes the share of job ads that mention each technology and calculates the ratio of the standard deviation to the mean across all divisions. In a hypothetical economy with 10 industries where every industry had the same share of job ads with a technology, the CoV would be 0. If the technology was only used by 1 out of the 10 industries (regardless the exact share in that industry), the CoV would be 3.16.
Source: Treasury analysis of Lightcast data for Australia (2012-2020).

Conclusion

Adoption of new technologies has increased over the past decade. However, Australia remains behind the US, which is one factor likely contributing to the growing gap between Australian and global frontier firms (Andrews et al. 2022).

The lower adoption of emerging technologies in Australia relative to the US could reflect the fact that some technologies are still quite new to the Australian market,[3] or that we are yet to develop the technological or human capability required to use them. Different industry make-up, management capabilities, and investment in research and development between the 2 countries may also contribute to the different diffusion rates.

Investment in new technologies also comes with a delay as firms often need to make complementary investments in other areas like high-speed internet or intangibles like organisational change. Brynjolfsson et al. (2021) argue that productivity slowdowns often accompany the rise of general-purpose technologies as firms are delayed in making the required complementary investments. These implementation lags have been noted as the biggest reason why advanced technologies like artificial intelligence have been slow to instigate mass productivity growth (Brynjolfsson et al. 2017).

Policy can support greater technological adoption through the provision of appropriate infrastructure (for example, high-speed internet) and skills training. Incentivising and facilitating investment in new technologies, particularly those most likely to become general-purpose, has the potential to increase the speed of technological diffusion and ultimately boost Australia's productivity.

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[3] A recent report by the National Skills Commission indicates that digital skills are growing in Australia, and that this demand is creating new occupations. However, the report also notes Australia remains behind Singapore, the US and Canada (Hope et al. 2022).

References

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Appendix

Table 1: Total job postings (2012-2020) by technology

Technology	Count
Social networking	150,830
Cloud computing	122,426
Smart devices	92,986
GPS	44,729
Machine learning/artificial intelligence	19,994
Online streaming	19,211
Wi-Fi	14,155
Search engine	11,818
Oled display	9,897
Solar power	6,852
Electronic gaming	3,714
Virtual reality	2,248
Touch screen	2,063
Hybrid vehicle/electric car	1,868
3d printing	1,800
Autonomous cars	1,492
Computer vision	1,380
RFID tags	887
Mobile payment	875
Lithium battery	607
Fracking	241
Software defined radio	109
Drug conjugates	38
Stent graft	25
Millimeter wave	20
Wireless charging	16
Fingerprint sensor	6
Bispecific monoclonal antibody	0
Lane departure warning	0

Notes: Count of jobs postings will not necessarily equal the count of new hires. Each technology is identified by a list of related keywords. For example, Machine Learning/Artificial Intelligence jobs can refer to any of the following keyword pairs: neural network; deep learning; language processing; machine learning; machine intelligence; natural language; artificial intelligence; ai technology; supervised learning; learning algorithms; unsupervised learning; reinforcement learning; ai machine. For a full list of keywords for each technology, see Appendix in Bloom et al. (2021).
Source: Treasury analysis of Lightcast data for Australia (2012-2020).