Appendix, “Automation and the Workforce: A Firm-Level View from the 2019 Annual Business Survey,” by Daron Acemoglu, Gary W. Anderson, David N. Beede, Catherine Buffington, Eric E. Childress, Emin Dinlersoz, Lucia S. Foster, Nathan Goldschlag, John C. Haltiwanger, Zachary Kroff, Pascual Restrepo, and Nikolas Zolas. In Technology, Productivity, and Economic Growth, Studies in Income and Wealth volume 83, edited by Susanto Basu, Lucy Eldridge, John Haltiwanger, and Erich Strassner. Chicago, IL: University of Chicago Press, 2025.

Appendix A: Development of the ABS 2019 Module

Work on the development of the 2019 ABS module began in the Spring of 2018. The questions for the module were developed over a period of several months in cooperation with NCSES, and with input from economists at Massachusetts Institute of Technology and Boston University.

The initial technologies included in the 2019 ABS module consisted of those relevant for automation: specialized software, specialized equipment, robotics, and artificial intelligence. Cloud computing was added later in the process, as it complements some of these technologies, particularly AI, and facilitates automation.

The initial draft of the module only considered technology adoption and use within the context of the processes for producing goods or services. When confronted with the fact that there is little up-to-date information on which firms actually provide these technologies as their products and services, it was decided to duplicate the questions for firms which identify themselves as sellers of the goods or services embedding the technologies (e.g. providers of machine learning software, or robot producers).

Cognitive testing of the module on a sample of potential respondents took place in late summer and fall of 2018. The testing process revealed some minor changes to the definitions of each of the technologies to make them transparent for respondents, and streamlined parts of the module.

Appendix B: Additional Empirical Results for the 2019 ABS

This appendix provides additional empirical results:

- Tables A.1 and A.2 reproduce the findings from Table 5 separately for manufacturing and non-manufacturing firms. To protect confidentiality, these table uses a coarser definition of size and age brackets than Table 5.
- Tables A.3 and A.4 reproduce the findings from Table 6 separately for manufacturing and non-manufacturing firms.
- Tables A.5 and A.6 reproduce the findings from Table 7 separately for manufacturing and non-manufacturing firms.
- Figure A.1 reports firms' assessments on the effects of technology on their employment level and demand for skills by size. The estimates come from a generalized ordered logit model (controlling for size, age, and sector).
- Figure A.2 reports firms' assessments on the effects of technology on their employment level and demand for skills by age. The estimates come from a generalized ordered logit model (controlling for size, age, and sector).

Table A.1: Regressions accounting for the variation in the use of advanced technologies for 2016–2018, ABS data for manufacturing firms.

Dependent variable:	Artificial intelligence	Robotics	Dedicated equipment	Specialized software	Cloud computing
Employment percentile 50th-90th	0.015	0.062	0.156	.173	0.142
	(0.003)	(0.004)	(0.007)	(0.008)	(0.007)
Employment percentile 90th-95th	0.026	0.146	0.262	0.274	0.204
	(0.006)	(0.011)	(0.016)	(0.016)	(0.016)
Employment percentile 95th-99th	0.046	0.242	0.336	0.335	0.292
	(0.008)	(0.012)	(0.016)	(0.015)	(0.016)
Employment percentile 99th+	0.108	0.403	0.409	0.372	0.380
	(0.015)	(0.023)	(0.023)	(0.023)	(0.025)
Age percentile 10th-50th	-0.009	-0.016	-0.043	-0.042	-0.061
	(0.005)	(0.006)	(0.012)	(0.012)	(0.011)
Age percentile 50th-75th	-0.013	-0.029	-0.072	-0.064	-0.104
	(0.005)	(0.007)	(0.012)	(0.013)	(0.012)
Age percentile 75th-95th	-0.012	-0.030	-0.094	-0.104	-0.130
	(0.005)	(0.008)	(0.013)	(0.015)	(0.013)
Age percentile 95th+	-0.003	0.000	-0.024	0.015	0.011
	(0.005)	(0.008)	(0.013)	(0.014)	(0.013)
log of average wage in 2015	0.007	0.015	0.050	0.066	0.057
	(0.002)	(0.003)	(0.006)	(0.007)	(0.005)
R-squared	0.016	0.097	0.086	0.098	0.090
Observations (rounded)	22,500	23,500	23,000	22,500	23,000

Notes: The table reports results from a regression of firm-level adoption on firm characteristics, 6-digit industry dummies, and employment shares by state. The sample includes firms in the ABS in the manufacturing sector. Column 1 reports results for the adoption of artificial intelligence. Column 2 reports results for the adoption of robotics. Column 3 reports results for the adoption of dedicated equipment. Column 4 reports results for the adoption of specialized software. Column 5 reports results for the adoption of cloud computing. To protect confidentiality, these table uses a coarser definition of size and age brackets than Table 5. Robust standard errors are reported in parenthesis.

Table A.2:Regressions accounting for the variation in the use of advanced technologies for 2016–2018, ABS data for non-manufacturing firms.

Dependent variable:	Artificial intelligence	Robotics	Dedicated equipment	Specialized software	Cloud computing
Employment percentile 50th-90th	0.009	0.007	0.064	0.129	0.115
	(0.001)	(0.001)	(0.003)	(0.004)	(0.004)
Employment percentile 90th-95th	0.015	0.019	0.099	0.217	0.204
	(0.003)	(0.003)	(0.008)	(0.009)	(0.009)
Employment percentile 95th-99th	0.014	0.018	0.110	0.245	0.250
	(0.004)	(0.003)	(0.009)	(0.011)	(0.010)
Employment percentile 99th+	0.029	0.031	0.161	0.304	0.321
	(0.005)	(0.004)	(0.022)	(0.023)	(0.023)
Age percentile 10th-50th	-0.001	-0.002	-0.007	-0.013	-0.026
	(0.002)	(0.002)	(0.005)	(0.006)	(0.006)
Age percentile 50th-75th	-0.005	-0.004	-0.026	-0.041	-0.070
	(0.002)	(0.002)	(0.005)	(0.006)	(0.006)
Age percentile 75th-95th	-0.007	-0.007	-0.029	-0.044	-0.089
	(0.002)	(0.002)	(0.005)	(0.006)	(0.006)
Age percentile 95th+	-0.006	-0.006	-0.026	-0.053	-0.077
	(0.003)	(0.002)	(0.008)	(0.009)	(0.008)
log of average wage in 2015	0.003	0.002	0.013	0.047	0.051
	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
R-squared	0.017	0.036	0.111	0.141	0.142
Observations (rounded)	94500	97000	95000	94000	95000

Notes: The table reports results from a regression of firm-level adoption on firm characteristics, 6-digit industry dummies, and employment shares by state. The sample includes firms in the ABS in the non-manufacturing sector. Column 1 reports results for the adoption of artificial intelligence. Column 2 reports results for the adoption of robotics. Column 3 reports results for the adoption of dedicated equipment. Column 4 reports results for the adoption of specialized software. Column 5 reports results for the adoption of cloud computing. To protect confidentiality, these table uses a coarser definition of size and age brackets than Table 5. Robust standard errors are reported in parenthesis.

Table A.3: Regressions explaining firm labor productivity in 2018 as a function of technology use in 2016–2018 for the manufacturing sector, ABS data for 2016–2018.

	Dependent Variable: Log of Labor Productivity in 2018				
	(1)	(2)	(3)	(4)	(5)
Employment percentile 0th-50th	-0.086	-0.069	-0.064	-0.063	0.332
	(0.012)	(0.012)	(0.012)	(0.012)	(0.014)
Employment percentile 75th-90th	0.126	0.114	0.108	0.108	-0.133
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Employment percentile 90th-95th	0.284	0.269	0.257	0.256	-0.207
	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)
Employment percentile 95th-99th	0.388	0.363	0.342	0.339	-0.343
	(0.021)	(0.021)	(0.021)	(0.021)	(0.026)
Employment percentile 99th+	0.524	0.494	0.459	0.454	-0.550
	(0.034)	(0.034)	(0.034)	(0.035)	(0.040)
Age percentile 10th-50th	-0.053	-0.043	-0.041	-0.040	-0.115
	(0.020)	(0.020)	(0.020)	(0.020)	(0.019)
Age percentile 50th-75th	-0.101	-0.086	-0.082	-0.081	-0.191
	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)
Age percentile 75th-90th	-0.129	-0.113	-0.109	-0.108	-0.232
	(0.025)	(0.025)	(0.025)	(0.024)	(0.024)
Age percentile 90th-95th	-0.130	-0.106	-0.097	-0.093	-0.217
	(0.064)	(0.065)	(0.065)	(0.065)	(0.061)
Age percentile 95th-99th	0.062	0.090	0.090	0.090	-0.046
	(0.128)	(0.129)	(0.128)	(0.128)	(0.111)
Age percentile 99th+	-0.150	-0.135	-0.131	-0.132	-0.279
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Technology user		0.115			0.053
		(0.010)			(0.010)
One technology			0.055		
			(0.016)		
Two technologies			0.120		
			(0.013)		
Three technologies			0.128		
			(0.014)		
Four technologies			0.229		
			(0.022)		
Five technologies			0.249		
			(0.041)		
Artificial intelligence				-0.002	
				(0.028)	
Cloud computing				0.071	
				(0.012)	
Robotics				0.091	
				(0.018)	
Specialized software				0.081	
				(0.014)	

Dedicated equipment				-0.006	
				(0.013)	
log average wage 2015					0.273
					(0.006)
R-squared	0.204	0.209	0.211	0.212	0.300
Observations (rounded)	20,500	20,500	20,500	20,500	20,500

Notes: The table reports results from a regression of firm labor productivity in 2018 on size and age groups, 6-digit industry dummies, employment shares by state, and measures of technology use from the 2019 ABS for 2016–2018. The relationship is estimated for manufacturing firms. To protect confidentiality, the number of observations has been rounded. Robust standard errors are reported in parenthesis.

Table A.4: Regressions explaining firm labor productivity in 2018 as a function of technology use in 2016–2018 for the non-manufacturing sector, ABS data for 2016–2018.

	Dependent Variable: Log of Labor Productivity in 2018				
	(1)	(2)	(3)	(4)	(5)
Employment percentile 0th-50th	0.053 (0.007)	0.065 (0.007)	0.067 (0.007)	0.068 (0.007)	0.397 (0.008)
Employment percentile 75th-90th	0.025 (0.008)	0.019 (0.008)	0.018 (0.008)	0.017 (0.008)	-0.187 (0.008)
Employment percentile 90th-95th	0.056 (0.013)	0.044 (0.013)	0.042 (0.013)	0.039 (0.013)	-0.353 (0.013)
Employment percentile 95th-99th	0.126 (0.015)	0.109 (0.015)	0.104 (0.015)	0.100 (0.015)	-0.493 (0.016)
Employment percentile 99th+	0.218 (0.033)	0.197 (0.032)	0.191 (0.032)	0.186 (0.032)	-0.789 (0.034)
Age percentile 10th-50th	-0.015 (0.011)	-0.011 (0.011)	-0.011 (0.011)	-0.009 (0.011)	-0.049 (0.011)
Age percentile 50th-75th	-0.045 (0.011)	-0.037 (0.011)	-0.036 (0.011)	-0.034 (0.011)	-0.091 (0.011)
Age percentile 75th-90th	-0.054 (0.012)	-0.045 (0.012)	-0.042 (0.012)	-0.039 (0.012)	-0.118 (0.012)
Age percentile 90th-95th	-0.116 (0.018)	-0.106 (0.018)	-0.103 (0.018)	-0.098 (0.018)	-0.175 (0.018)
Age percentile 95th-99th	-0.098 (0.031)	-0.083 (0.031)	-0.078 (0.031)	-0.074 (0.031)	-0.164 (0.028)
Age percentile 99th+	-0.082 (0.015)	-0.072 (0.015)	-0.069 (0.015)	-0.066 (0.015)	-0.175 (0.014)
Technology user		0.107 (0.006)			0.058 (0.006)
One technology			0.063 (0.009)		
Two technologies			0.120 (0.008)		
Three technologies			0.138 (0.010)		
Four technologies			0.155 (0.020)		
Five technologies			0.168 (0.036)		
Artificial intelligence				0.024 (0.016)	
Cloud computing				0.105 (0.008)	
Robotics				0.029 (0.021)	
Specialized software				0.044 (0.008)	

Dedicated equipment				-0.010	
				(0.009)	
log average wage 2015					0.278
					(0.004)
R-squared	0.329	0.332	0.332	0.333	0.399
Observations (rounded)	82,500	82,500	82,500	82,500	82,500

Notes: The table reports results from a regression of firm labor productivity in 2018 on size and age groups, 6-digit industry dummies, employment shares by state, and measures of technology use from the 2019 ABS for 2016–2018. The relationship is estimated for non-manufacturing firms. To protect confidentiality, the number of observations has been rounded. Robust standard errors are reported in parenthesis.

Table A.5: Regressions explaining firm labor share in 2018 as a function of technology use in 2016–2018 for the manufacturing sector, ABS data for 2016–2018.

	Dependent Variable: Labor share in 2018				
	(1)	(2)	(3)	(4)	(5)
Employment percentile 0th-50th	-0.029	-0.031	-0.031	-0.032	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Employment percentile 75th-90th	-0.010	-0.009	-0.009	-0.008	-0.028
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Employment percentile 90th-95th	-0.033	-0.032	-0.030	-0.029	-0.068
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
Employment percentile 95th-99th	-0.047	-0.045	-0.042	-0.040	-0.099
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)
Employment percentile 99th+	-0.079	-0.077	-0.070	-0.067	-0.155
	(0.008)	(0.008)	(0.008)	(0.008)	(0.010)
Age percentile 10th-50th	0.022	0.022	0.021	0.021	0.016
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Age percentile 50th-75th	0.038	0.037	0.036	0.036	0.029
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Age percentile 75th-90th	0.058	0.057	0.056	0.056	0.048
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Age percentile 90th-95th	0.066	0.064	0.063	0.061	0.056
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Age percentile 95th-99th	0.064	0.062	0.062	0.061	0.052
	(0.029)	(0.029)	(0.029)	(0.029)	(0.031)
Age percentile 99th+	0.062	0.061	0.060	0.060	0.050
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Technology user		-0.008			-0.013
		(0.002)			(0.002)
One technology			-0.002		
			(0.004)		
Two technologies			-0.006		
			(0.003)		
Three technologies			-0.009		
			(0.003)		
Four technologies			-0.028		
			(0.005)		
Five technologies			-0.036		
			(0.010)		
Artificial intelligence				0.002	
				(0.006)	
Cloud computing				-0.007	
				(0.003)	
Robotics				-0.027	
				(0.004)	
Specialized software				-0.002	
				(0.003)	

Dedicated equipment				0.001	
				(0.003)	
log average wage 2015					0.021
					(0.002)
R-squared	0.110	0.111	0.112	0.113	0.121
Observations (rounded)	20,500	20,500	20,500	20,500	20,500

Notes: The table reports results from a regression of firm labor share in 2018 on size and age groups, 6-digit industry dummies, employment shares by state, and measures of technology use from the 2019 ABS for 2016–2018. The relationship is estimated for manufacturing firms. To protect confidentiality, the number of observations has been rounded. Robust standard errors are reported in parenthesis.

Table A.6: Regressions explaining firm labor share in 2018 as a function of technology use in 2016--2018 for the non-manufacturing sector, ABS data for 2016–2018.

	Dependent Variable: Labor share in 2018				
	(1)	(2)	(3)	(4)	(5)
Employment percentile 0th-50th	-0.061	-0.062	-0.062	-0.062	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Employment percentile 75th-90th	0.023	0.024	0.024	0.024	-0.014
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Employment percentile 90th-95th	0.048	0.048	0.049	0.049	-0.025
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Employment percentile 95th-99th	0.052	0.053	0.053	0.053	-0.058
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Employment percentile 99th+	0.051	0.052	0.053	0.053	-0.129
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
Age percentile 10th-50th	0.002	0.001	0.001	0.001	-0.006
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Age percentile 50th-75th	0.010	0.010	0.009	0.009	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Age percentile 75th-90th	0.019	0.019	0.018	0.018	0.005
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Age percentile 90th-95th	0.032	0.032	0.031	0.031	0.019
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Age percentile 95th-99th	0.037	0.036	0.035	0.035	0.021
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Age percentile 99th+	0.037	0.037	0.036	0.036	0.018
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Technology user		-0.006			-0.015
		(0.002)			(0.002)
One technology			-0.002		
			(0.002)		
Two technologies			-0.005		
			(0.002)		
Three technologies			-0.013		
			(0.002)		
Four technologies			-0.018		
			(0.005)		
Five technologies			-0.025		
			(0.009)		
Artificial intelligence				-0.001	
				(0.004)	
Cloud computing				-0.006	
				(0.002)	
Robotics				-0.010	
				(0.005)	
Specialized software				-0.002	
				(0.002)	

Dedicated equipment				-0.005	
				(0.002)	
log average wage 2015					0.051
					(0.001)
R-squared	0.308	0.309	0.309	0.309	0.349
Observations (rounded)	82,500	82,500	82,500	82,500	82,500

Notes: The table reports results from a regression of firm labor share in 2018 on size and age groups, 6-digit industry dummies, employment shares by state, and measures of technology use from the 2019 ABS for 2016–2018. The relationship is estimated for non-manufacturing firms. To protect confidentiality, the number of observations has been rounded. Robust standard errors are reported in parenthesis.

Figure A.1: Reported changes in employment levels and skill demand by firms adopting advanced technologies, employment-weighted shares by size from 2019 ABS. The markers provide the employment-weighted responses for firms with 0–9 workers, 10–49 workers, 50–249 workers, and more than 250 workers. The estimates come from a generalized ordered logit model (controlling for size, age, and sector).

Figure A.2: Reported changes in employment levels and skill demand by firms adopting advanced technologies, employment-weighted shares by age from 2019 ABS. The markers provide the employment-weighted responses for firms of 0–5 years, 6–10 years, 11–20 years, and more than 21 years. The estimates come from a generalized ordered logit model (controlling for size, age, and sector).

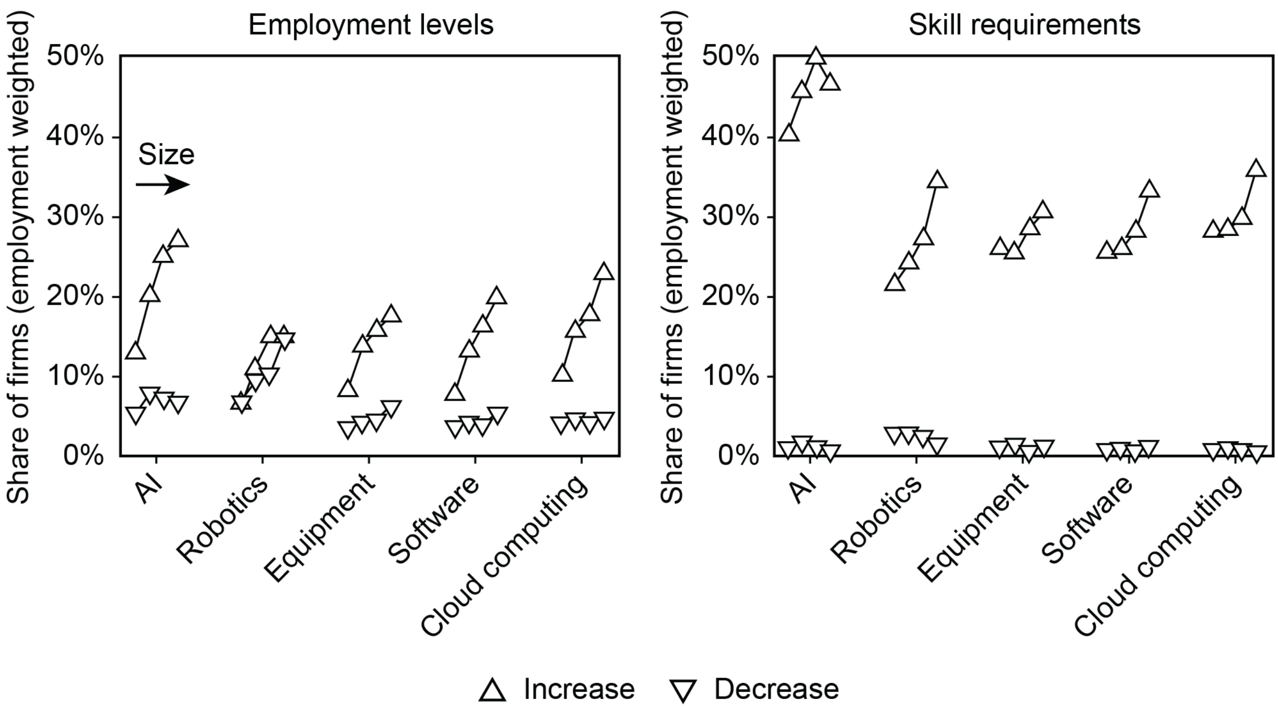

Figure A-1: Reported changes in employment levels and skill demand by firms adopting advanced technologies, employment-weighted shares by size from 2019 ABS. The markers provide the employment-weighted responses for firms with 0–9 workers, 10–49 workers, 50–249 workers, and more than 250 workers. The estimates come from a generalized ordered logit model (controlling for size, age, and sector).

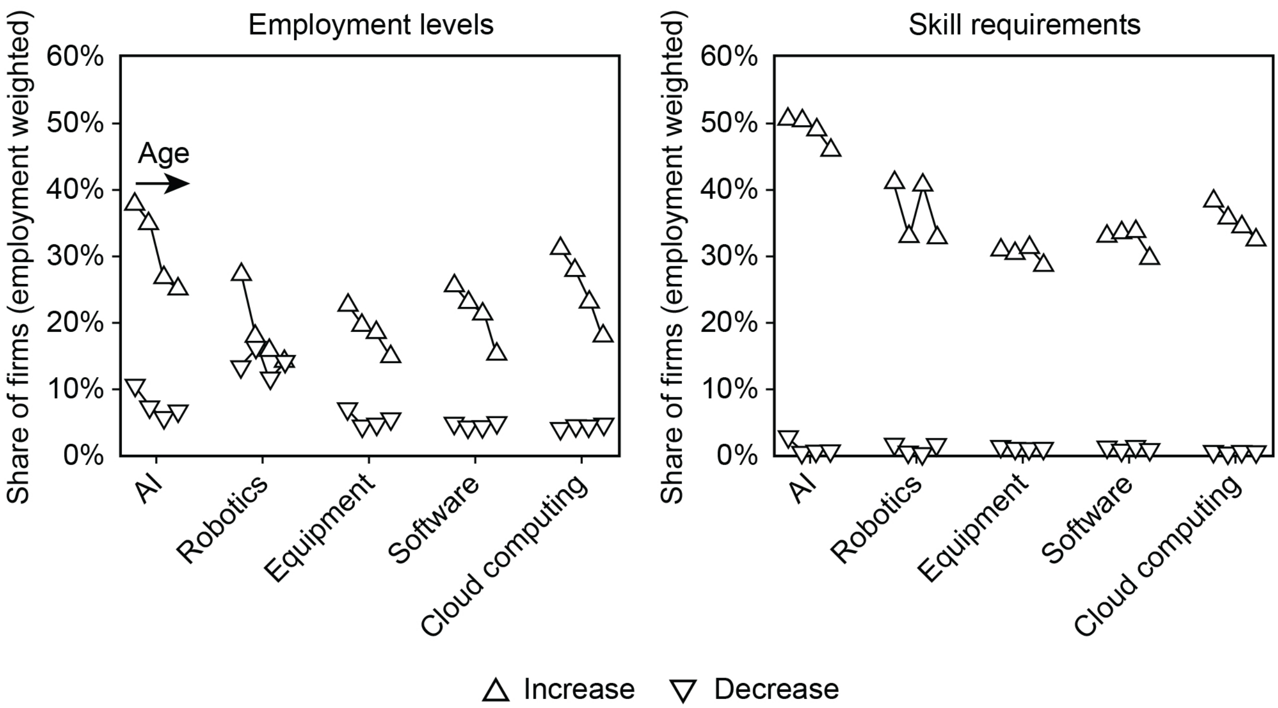

Figure A-2: Reported changes in employment levels and skill demand by firms adopting advanced technologies, employment-weighted shares by age from 2019 ABS. The markers provide the employment-weighted responses for firms of 0–5 years, 6–10 years, 11–20 years, and more than 21 years. The estimates come from a generalized ordered logit model (controlling for size, age, and sector).