THE DIGITAL ECONOMY: A POTENTIAL NEW ENGINE FOR PRODUCTIVITY GROWTH[1]

Globally, the COVID-19 pandemic and associated safe distancing measures have accelerated the digital revolution. A similar dynamic is taking place in Singapore, a country at the forefront of digital usage, including through unprecedented growth of e-commerce. An empirical analysis of sector-level labor productivity growth in advanced economies, including Singapore, suggests that digitalization and innovation, captured through e-commerce, robotization, and research and development, are associated with higher labor productivity growth. Singapore has scope for a sizeable expansion of e-commerce (despite recent rapid growth) and of research and development. This would help the country further reap the benefits of the digital economy, notably through higher productivity growth, and accelerate economic transformation.

A. The Digital Economy Landscape in Singapore

1. A generally agreed-upon definition of the digital economy is yet to emerge. A narrow definition of the digital economy refers to the information and communication technology (ICT) sector, including telecommunications, the Internet, ICT services, hardware and software. A broad definition of the digital economy includes both the ICT sector and parts of traditional sectors that have been integrated with digital technology (IMF, 2018). Considering the diversity of digital innovations, the lack of a generally agreed-upon definition of the digital economy, and the sparsity of data, this annex focuses on two specific areas related to the use of digitalization: the digitalization of production (robotics) and the digitalization of consumption (e-commerce), as well as broader innovation that tends to support the supply of digitalization.[2]

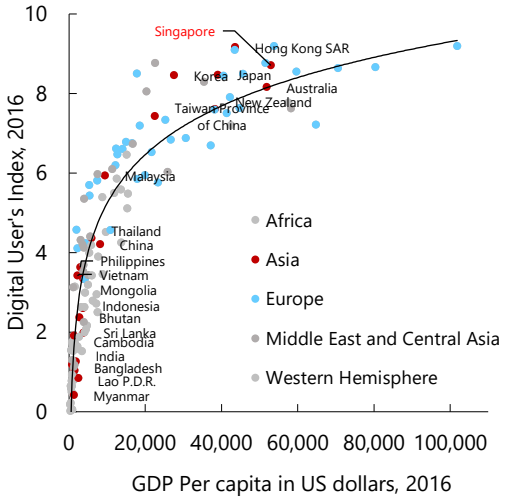
2. Singapore is at the forefront of digital usage. The digital user's index, which captures various aspects of mobile and internet usage, highlights Singapore's relatively high digital usage compared to countries in Asia, the region with the highest dispersion in digital technologies adoption across countries (Figure 1).[3] Singapore also stands out as one of the countries with the largest digital usage among peers. Singapore is at a mature stage of the digital momentum, characterized by relatively smaller increases in the digital usage index (Figure 2).

[1] Prepared by Tidiane Kinda (APD), with research assistance from Kaustubh Chahande (APD).

[2] Chapter 4 on *E-Payments During the COVID-19 Pandemic and Beyond* focuses on the digitalization of finance, another growing aspect of the digital economy.

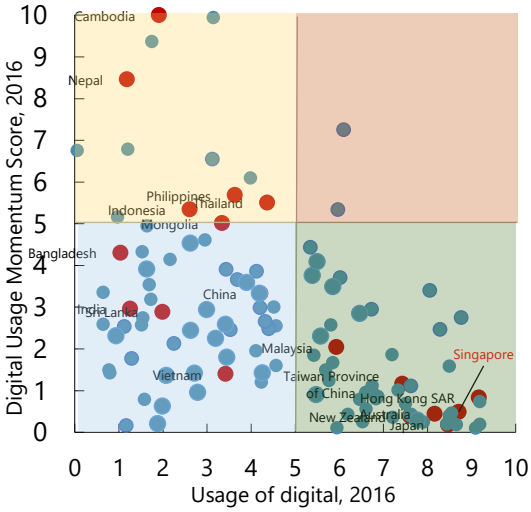
[3] The digital user's index is a composite index averaging six indicators: mobile phone subscriptions in terms of subscriptions per 100 population; percentage of individuals using the Internet; percentage of households with a personal computer; percentage of households with Internet access; fixed broadband Internet access in terms of subscriptions per 100 population; and mobile-broadband subscriptions in terms of subscriptions per 100 population.

Figure 1. GDP per Capita and Digital Usage
(Index 0–10)



Sources: IMF, World Economic Outlook; World Economic Forum; and IMF staff calculations.

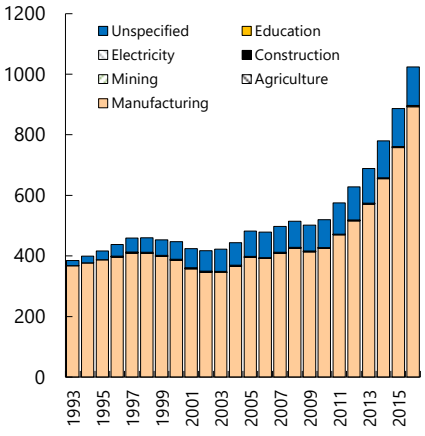
Figure 2. Digital Usage: Level and Momentum
(Index 0–10; Momentum change 2012–16)



Sources: IMF,World Economic Outlook; World Economic Forum; and IMF staff calculations.

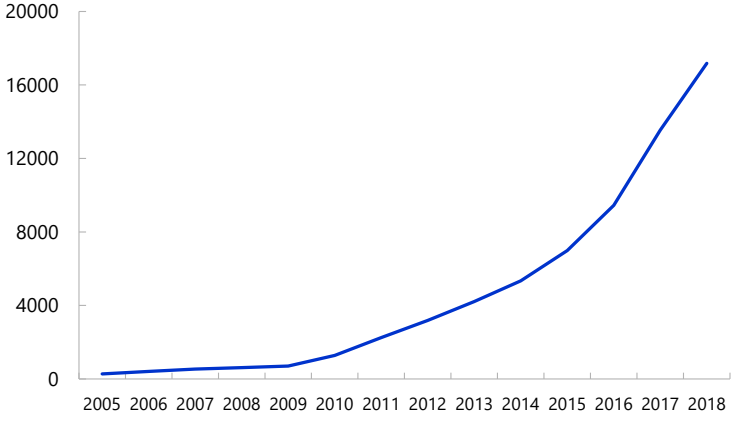
3. Singapore has made significant strides in the digitalization of production through industrial robots. Industrial robots are higher-end digitalization products predominantly used for automation in the manufacturing sector (Figure 3). Singapore's stock of operational robots in the manufacturing sector has rapidly increased during the past decade, from about 600 robots in 2008 to above 17,000 robots in 2018 (Figure 4). This rapid increase has translated into a rise in robot density from about 1 operating robot per 1,000 employees in 2008 to 45 operating robots per 1,000 employees in 2018, making Singapore one of the top users of industrial robots in the world (Figure 5). Most of the industrial robots in Singapore are used in the semiconductor sub-sector, which accounted for 70 percent of all industrial robots in 2018 (Figure 6).

Figure 3. Asia: Industrial Robots by Industry
(Thousands of robots)



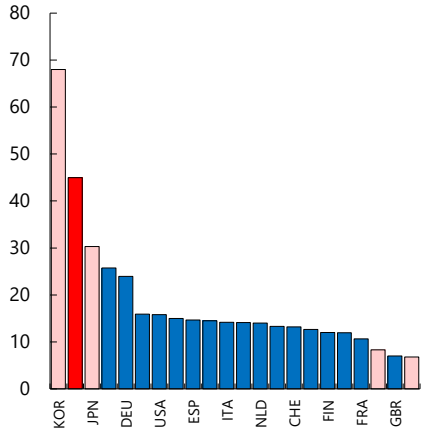
Source: International Federation of Robotics (2017).

Figure 4. Singapore: Operational Stock of Robots in Manufacturing
(Units)



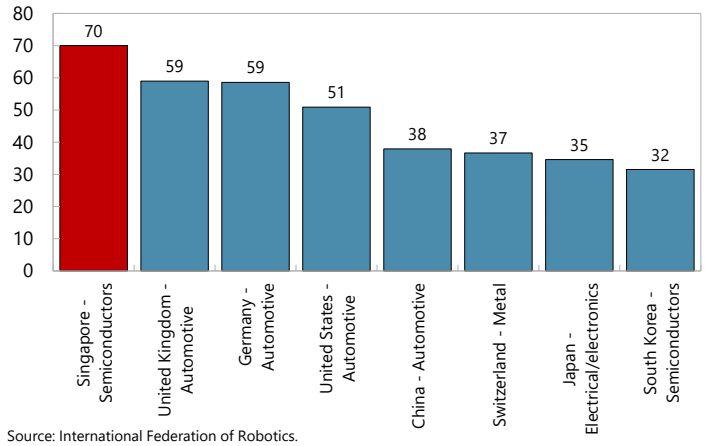
Source: International Federation of Robotics.

Figure 5. Robot Density in Manufacturing, 2018 or latest
(Number of industrial robot stock, per 1,000 employees)



Source: International Federation of Robotics.

Figure 6. Singapore: Concentration of Industrial Robots, 2018
(Top destination (sub-sector) of industrial robots as a share of total, Percent)



Source: International Federation of Robotics.

4. E-commerce has been thriving in recent years in Singapore, including in response to the COVID-19 pandemic, a trend that may continue post-pandemic. From about 0.3 percent of GDP in 2017, business-to-consumer e-commerce sales as a share of Singapore's GDP more than doubled to about 0.7 percent of GDP in 2020 (Figure 7). In 2020, e-sales grew by 32 percent in Singapore, one of the fastest growth rates among peers in Asia and advanced economies (Figure 8).[4] The acceleration in e-sales observed in 2020, including in response to the COVID-19 pandemic, may last longer, supported by a conducive digital environment. A survey conducted by Rakuten Insight found that close to 80 percent of respondents in Singapore stated that they would continue to buy products online even when businesses are open and social distancing measures are lifted (Figure 9).

5. Singapore still has sizeable scope to expand e-commerce, supported by a conducive e-environment. Despite the rapid growth in recent years, e-commerce in Singapore remains under 1 percent of GDP in 2020, well-below the level in most peer Asian and advanced economies (Figure 10). Yet, Singapore ranks among the countries with the highest readiness to e-commerce, measured by indicators that capture the use of secure internet services, the reliability of postal services for last mile delivery, and access to a financial account for payments (Figure 11). E-payment adoption among firms has also increased substantially in recent years, with more than 80 percent of firms having adopted e-payments by 2019 (Figure 12).

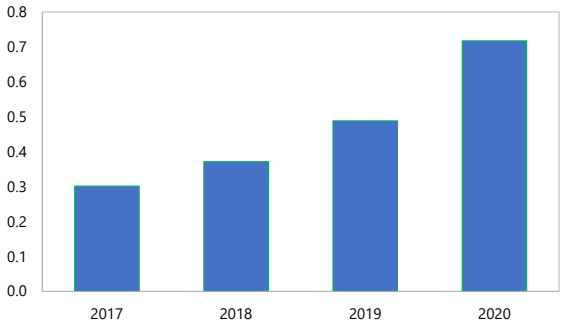
6. Singapore has scope for larger research and development (R&D) to support broader innovation. While the digital component of the economy, proxied narrowly by the share of the ICT sector, is relatively large in Singapore (Figure 13), innovation in the country is tilted towards ICT.[5] Patents in ICT, which may ultimately develop into digitalization products, represent close to 40

[4] The data on e-commerce sales in this paper are specifically collected from Statista's Digital Market Outlook. E-commerce sales refer to business-to-consumer digital commerce and do not include digitally distributed services, digital media downloads or streaming services, online booking, business-to-business digital commerce, and consumer-to-consumer digital commerce.

[5] The GDP contribution of the ICT sector is approximated by the sum of GDP from two subsectors: (1) information and communication and (2) computers, electronics, and optical products.

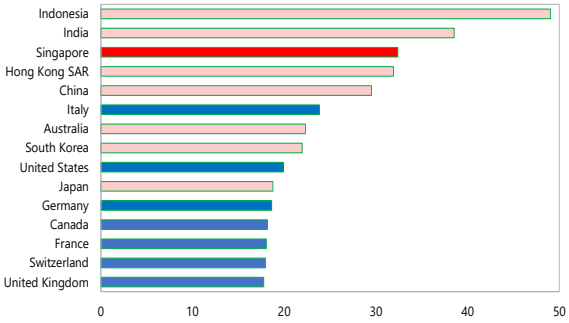
percent of total patents (Figure 14). Singapore's share of "triadic" patent families, that is all patent applications filed in Japan, Europe, and the United States, is relatively low compared to peer Asian economies and advanced economies (Figure 15). Consistent with low patent filling, Singapore's R&D expenditure has been relatively low and broadly constant in recent decades. This contrasts with the rapid growth and higher spending levels in R&D observed in many economies such as Korea, Switzerland, and Taiwan Province of China between 2000 and 2018 (Figure 16). Indeed, while Singapore ranked first in the World Economic Forum's Global Competitiveness Overall Index in 2019, the country ranked 21st in research and development with relatively lower score (rank of 23rd) in scientific publications.

Figure 7. Singapore: E-commerce Sales
(In percent of GDP)



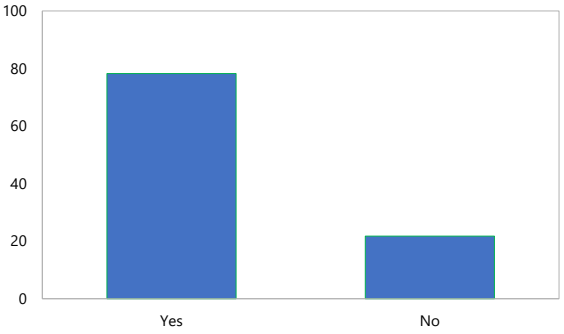
Sources: Statista; and staff estimates.

Figure 8. E-sales Growth Across Economies, 2020
(Percentage change, Y/Y)



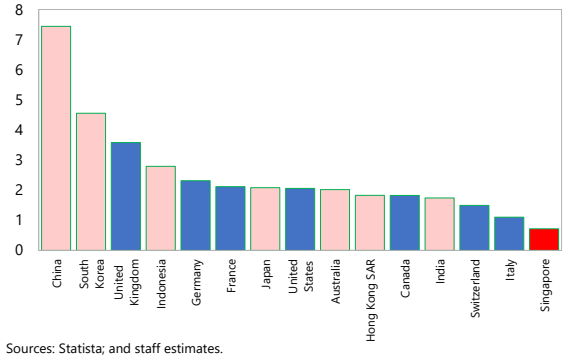
Sources: Statista; and staff estimates.

Figure 9. Singapore: Consumers to Continue Online Shopping Post-pandemic
(In percent)



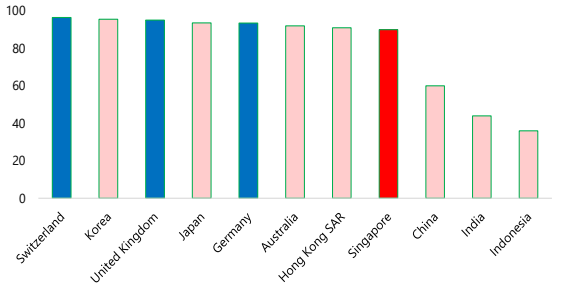
Sources: Rakuten Insight survey of May 2020; and staff estimates.

Figure 10. E-sales Across Selected Economies, 2020
(In percent of GDP)



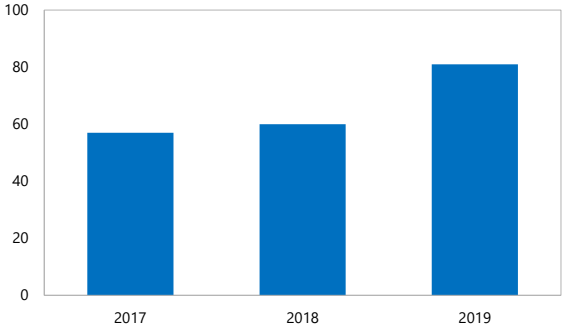
Sources: Statista; and staff estimates.

Figure 11. E-commerce Readiness Index 1/



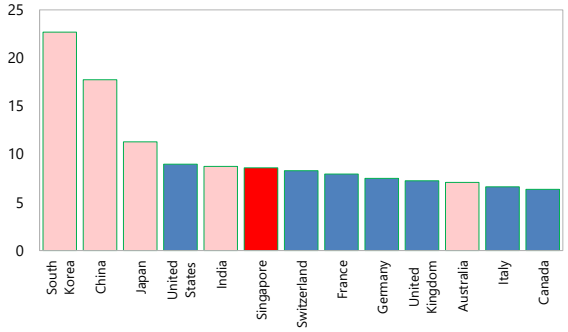
Source: United Nations Conference on Trade and Development B2C E-commerce Index.
1/ The B2C E-commerce Index is the simple average of four indicators: (1) the percentage share of individuals in the total population using the Internet; (2) the postal reliability score scaled between 0 and 100; (3) the percentage share of individuals in the total population with a financial account; and (4) an indicator of secure Internet server availability scaled between 0 and 100.

Figure 12. Singapore: Share of Enterprises that Adopted E-payments
(In percent)



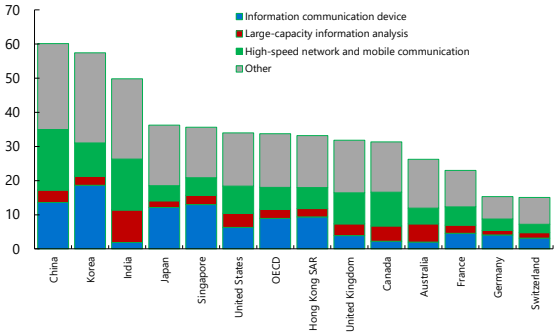
Sources: 2019 IMDA Annual survey on infocomm usage by enterprises.

Figure 13: ICT Sector as a Share of GDP, 2017 or latest
(In percent of GDP)



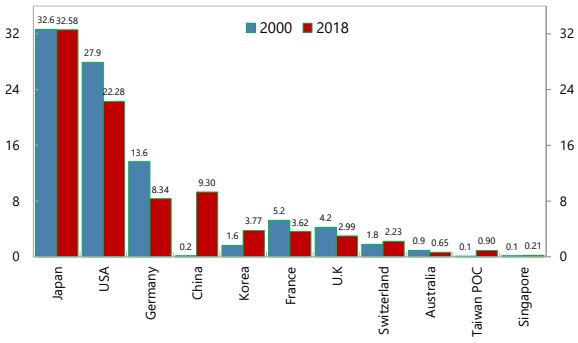
Sources: European Commission; and staff estimates.

Figure 14. Specialization in ICT-related Patents, 2012-15
(Patents in ICT as a percentage of total IP5 patent families)



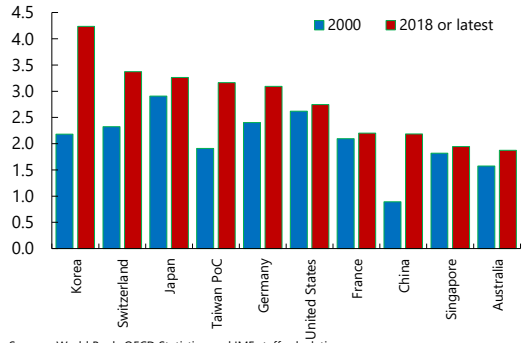
Sources: Organization for Economic Cooperation and Development Science Technology, and Innovation Micro-data Lab: Intellectual Property; and IMF staff calculations.

Figure 15. Share of Economies in Triadic Patent Families
(Percent)



Source: Organization for Economic Cooperation and Development Statistics.

Figure 16. R&D Expenditure
(Percent of GDP)



Sources: World Bank; OECD Statistics; and IMF staff calculations.

B. Digitalization, Innovation, and Productivity Growth

7. This section explores how digitalization and innovation may influence productivity growth, building on the existing limited literature. The emerging empirical evidence highlights the positive role of digitalization on productivity. For instance, Falk and Hagsten (2015) show that an increase in e-sales by 1 percentage point raises firm-level labor productivity growth by 0.3 percentage points on average in 14 European economies, with a larger effect for small firms and for firms in the services sector. Yang, Shi, and Yan (2017) show that e-commerce participation has the potential to positively impact firm productivity in China. World Bank (2016) shows that firms using e-commerce in Vietnam had on average 3.6 percentage points higher total factor productivity growth than firms not using e-commerce. Kinda (2019) shows that Asian firms engaged in e-commerce have on average 30 percent higher total factor productivity than other firms. Using robot shipment data at the industry and year levels across 17 countries, Graetz and Michaels (2015) find that robots may have increased productivity growth by more than 15 percent and account for about one-tenth of the increases in GDP between 1993 and 2007 (Seamans and Raj, 2018).

8. The analysis draws on sector-level cross-country labor productivity data. Data on value added per worker by industry, our proxy to define labor productivity growth, is from the OECD database and matched with data on Singapore from the Singapore Department of Statistics.

Because of limited data availability, our sample covers 22 advanced economies during the period 2000-2019.[6]

9. Labor productivity growth has recently stagnated in most service-oriented sectors in Singapore. While labor productivity has experienced a robust growth in the manufacturing sector since 2015, most service sectors, with the exception of financial services as well as information and communications, have experienced limited to no growth in labor productivity during the same period (Figure 17). More robust cross-country conditional correlations confirm that most service activities have had lower labor productivity growth compared to the manufacturing sector, including in Singapore (Table 1).

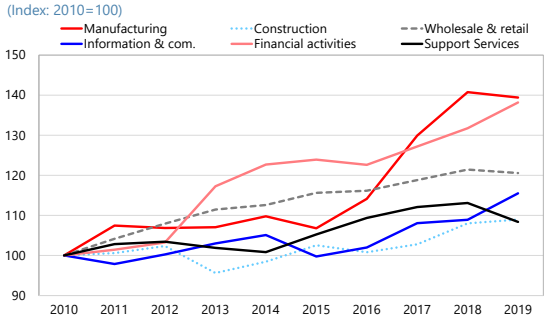


Figure 17. Singapore: Labor Productivity by Sector
(Index: 2010=100)
Note: Support Services includes Professional Services, Administrative & Support Services, and Other Services Industries.
Sources: Singapore, Dept. of Statistics & Ministry Of Manpower; and IMF staff calculations.

10. The empirical strategy investigates the potential role of digitalization and innovation on labor productivity growth, through the following equation:

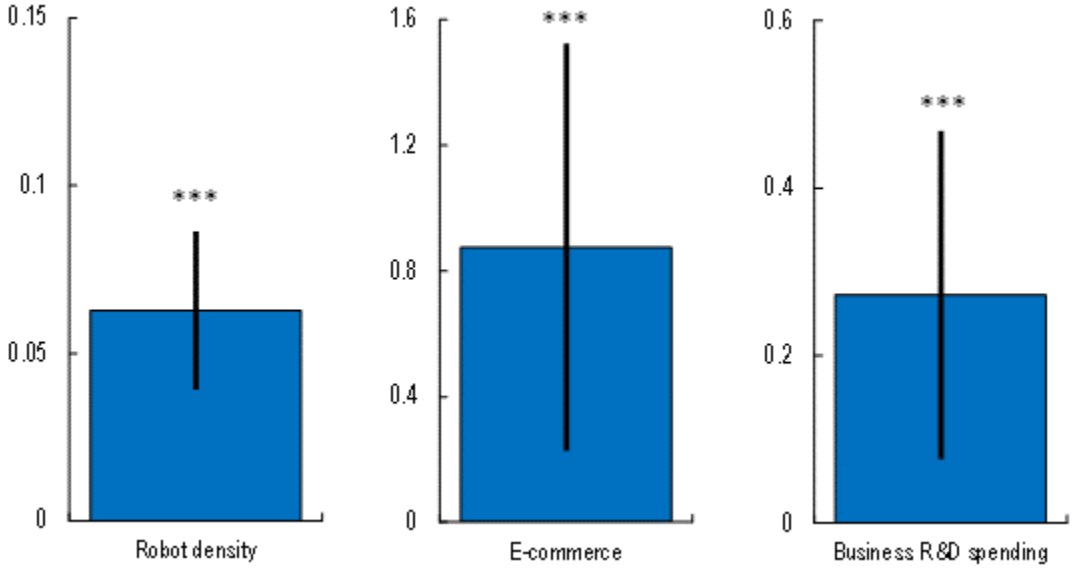
$$\Delta LP_{ijt} = \alpha + \gamma \boldsymbol{Dig}_{ijt} + \delta X_{ijt} + \varphi b_i + \eta I_j + \theta t_t + \epsilon_{it}$$

Where ΔLP_{ijt} captures the annual labor productivity growth rate of country i in sector j at time t. Dig_{ijt} represents the digitalization or innovation proxy either at the country level (e-commerce, robot density) or country-sector level (business R&D expenditure). X_{it-1} includes control variables such as sectoral inward FDI as a share of GDP to gauge the extent of inbound know-how transfer; and the trade to GDP ratio to capture openness to international trade. b_i, I_j, and t_t represent respectively country, sector, and time fixed effects. Beyond unobservable fixed factors, controlling for country and industry fixed effects allows us to account for time-invariant characteristics such as being a financial center. By controlling for common shocks across all countries and industries in a given year, for instance the global financial crisis, time fixed effects allow us to focus on the time varying structural aspects of digitalization and innovation that are deemed important for productivity growth. ϵ_{it} is the error term.

11. The results highlight that digitalization and innovation are associated with higher labor productivity growth (Figure 18 and Table 2). The baseline results show that overall, a larger share of e-commerce to GDP or a higher robot density are associated with higher labor productivity growth. Higher business R&D spending is also associated with higher labor productivity growth.

[6] The sector-level categorization comprises 6 sub-sectors: manufacturing; construction; wholesale and retail trade; information and communication; finance and insurance; and business services. Countries in the largest sample are Austria, Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Portugal, Singapore, South Korea, Spain, Sweden, Switzerland, United Kingdom, and United States.

Figure 18. Estimation Results: Digitalization, Innovation, and Labor Productivity Growth 1/



Source: Author's estimates.
1/ These figures illustrate coefficients and confidence intervals from three sector-level cross-country estimations of the potential effect of digitalization and innovation on labor productivity growth controlling for sectoral inward FDI, openness to trade, and cross country-industry and time fixed effects. The error bars refer to the 95 percent confidence intervals around the estimated coefficients. ** p<0.05; *** p<0.01.

12. The main results are robust to a variety of tests. As the digital revolution is still unfolding, its impact on productivity may increase over time. We do not find evidence that the digitalization of production or consumption has been associated with larger productivity growth in more recent years (Table 3).

13. While difficult to estimate due to data limitations, productivity spillovers from highly digitalized sectors to other sectors may support economy-wide productivity. For instance, Javorcik (2004) finds evidence of positive productivity spillovers from highly productive foreign firms to their local suppliers in upstream sectors in Lithuania. Kinda (2012) also shows that local firms, particularly small-local firms, that supply the most efficient firms have higher productivity, illustrating the existence of vertical spillovers through backward linkages.

C. Implications of the Results for Singapore: Fostering a Smarter Economic Recovery Post-Pandemic

14. The results suggest that boosting e-commerce and R&D would support productivity growth, the nascent recovery, and the transformation towards a smarter economy. The analysis highlighted that Singapore has room for a significant expansion of e-commerce and larger R&D, two elements that are associated with higher labor productivity growth. As such, further digitalization has the potential to boost aggregate productivity growth and presents an opportunity to lift medium-term growth prospects.

15. Singapore has introduced many initiatives to support digitalization. For instance, the Infocomm Media Development Authority's (IMDA) *SMEs Go Digital* program supports SMEs' adoption and use of digital technologies through various channels, including foundational digital solutions for new SMEs (*Start Digital Pack*); guidance on digital solutions and training required for each development stage of a firm (*Industry Digital Plan*); provision of business-to-business and business-to-consumer e-commerce platforms to help firms reach global markets (*Grow Digital*); consultancy services to support firms' use of digital technologies (*SME Digital Tech Hub*); pre-approved and proven SME-friendly solutions that can be adopted with the support of government grants such as the Productivity Solutions Grant (*PSG*). IMDA has also launched programs to accelerate the scale and speed of digital innovation (*Open Innovation Platform*); and adopted a multi-prong approach to facilitate the development of 5G in Singapore (*5GSG*), including by facilitating applications in selected industries, supporting a sound and forward-looking regulatory framework, and grooming talent.

16. In addition to boosting productivity growth, advancing the digitalization of the economy can increase tax revenues. While the digital tax base is still modest in most countries, including Singapore, the ongoing digital revolution and associated rapid growth of the sector present an opportunity to raise additional revenues in the medium to long-term, provided that a tax system commensurate to the digital economy is in place.

17. While this annex focuses on opportunities for productivity growth that may be associated with the digital economy, the latter also brings about some challenges. Policies to accelerate the digital transformation and reap its benefits should also give due consideration to challenges associated with digitalization, including labor displacements and possible rise in inequality (Saadi Sedik and Yoo, 2021). This calls for complementary labor market policies, such as skills upgrades and training to address and possibly catalyze on the distributional challenges associated with the digital revolution. Fortunately, Singapore is already at the forefront in designing such policies.

Table 1. Singapore: Labor Productivity Growth Across Activities

	Dependent Variable: Labor Productivity Growth (5-year moving average)		Dependent Variable: Labor Productivity Growth (3-year moving average)	
	All Countries	Singapore	All Countries	Singapore
	(1)	(2)	(3)	(4)
Sector (manufacturing is the benchmark)				
Construction	-2.637***	-0.907	-2.559***	-1.431
	(0.199)	(0.815)	(0.232)	(0.997)
Wholesale, retail, trade, accommodation, etc.	-1.884***	-1.929**	-1.820***	-2.349**
	(0.199)	(0.815)	(0.232)	(0.997)
Information and communication	0.389*	0.0428	0.309	-0.760
	(0.199)	(0.815)	(0.232)	(0.997)
Financial and insurance activities	-0.673***	-0.0341	-0.633***	-0.624
	(0.199)	(0.815)	(0.232)	(0.997)
Professional, scientific and support services, etc.	-2.727***	-2.410***	-2.627***	-2.911***
	(0.199)	(0.815)	(0.232)	(0.997)
Time Fixed-Effects	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes		Yes	
Observations	2,388	114	2,388	114
R-squared	0.271	0.291	0.216	0.318

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Singapore: Baseline Regressions

	Dependent Variable: Labor Productivity Growth (5-year moving average)		
	(1)	(2)	(3)
Robot Density	0.0626***		
	(0.0120)		
E-commerce sales		0.876***	
		(0.329)	
R&D spending			0.272***
			(0.0999)
Inward FDI	0.0502***	0.0202*	0.0377***
	(0.00746)	(0.0113)	(0.0100)
Trade Openness	0.00297	0.00142	0.00124
	(0.00214)	(0.00306)	(0.00292)
Constant	4.119***	0.621	0.963
	(1.312)	(0.953)	(2.676)
Time Fixed-Effects	Yes	Yes	Yes
Country*Sector Fixed Effects	Yes	Yes	Yes
Observations	1,445	324	912
R-squared	0.442	0.851	0.472

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3. Singapore: Robustness Check: Possible Structural Change in Digitalization

	Dependent Variable: Labor Productivity Growth (5-year moving average)					
	All Years	Post-2015	All Years	Post-2017	All Years	Post-2015
	(1)	(2)	(3)	(4)	(5)	(6)
Robot Density	0.0626***	0.0254**				
	(0.0120)	(0.0107)				
E-commerce sales			0.876***	0.706*		
			(0.329)	(0.390)		
R&D spending					0.272***	0.327**
					(0.0999)	(0.140)
Inward FDI	0.0502***	0.0180**	0.0202*	0.0254*	0.0377***	0.00457
	(0.00746)	(0.00883)	(0.0113)	(0.0147)	(0.0100)	(0.0124)
Trade Openness	0.00297	-0.00239	0.00142	0.000827	0.00124	0.00380
	(0.00214)	(0.00262)	(0.00306)	(0.00381)	(0.00292)	(0.00481)
Constant	4.119***	1.493**	0.621	1.021	0.963	0.965
	(1.312)	(0.740)	(0.953)	(1.136)	(2.676)	(1.274)
Time Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country*Sector Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,445	348	324	207	912	179
R-squared	0.442	0.866	0.851	0.899	0.472	0.890

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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