Draft 2 for project "Global Value Chains in the Era of Industry 4.0: East Asia and Latin America" coordinated by the Economic Research Institute for ASEAN and East Asia (ERIA) and Georgetown Americas Institute (GAI)

Promoting East and Southeast Asian digital services' integration into regional and global value chains through Industry 4.0 technologies

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23 November 2025

1. Introduction

Digital services are the fastest-growing part of world trade as well as of East and Southeast Asian economies' exports. This transformation in the region's export basket has coincided with a digital transformation and the growing adoption of Industry 4.0 technologies – defined here as AI, cloud computing, blockchain, and internet of things (IoT) – by the region's businesses.

This study explores connections between these two trends, hypothesizing that Industry 4.0 adoption by East and Southeast Asian (here, Japanese, Korean, and Southeast Asian) digital services providers has helped boost their digital exports and participation in value chains. This inquiry is timely: global demand for digital services has been expanding in the past decade and is poised to grow further, as industries around the world demand specialized digital services to differentiate themselves from their competitors and promote their productivity.[1] This study also explores the challenges that the region's firms face in adopting and using Industry 4.0 for value creation and trade opportunities.

Digital services here are defined as insurance and pension, financial, telecommunications, computer and information, research and development, professional and management consulting, and technical, trade-related, and other business services.

The research aims to offer actionable policy recommendations for East and Southeast Asian governments to take advantage of the Industry 4.0 revolution to enable the region's digital service providers to grow their exports and supply chain relationships in domestic and regional markets.

The main findings are as follows:

- Digital services exports and value-added have expanded in East and Southeast Asian economies in the past two decades. In 2005-24, the region's digitally delivered services exports grew at an average annual average 11.5 percent, three times faster than merchandise and non-digital commercial services exports. Singapore, Korea, and Japan remain the top exporters of digital services, while Cambodia, Indonesia, Singapore, and Vietnam have the fastest growth rates. The region's digital services value-added in

regional and global value chains has grown in absolute terms especially for Cambodia, Myanmar and Vietnam in 2011-20, period for which data are available. Japan and Singapore have also grown the share of their digital services value-added of all digital services value-added in global value chains. However, their share has declined in Asian regional value chains, likely due to the rise of China. In addition, the use of digital services (both from domestic and international sources) to add value in the 12 examined economies' own manufacturing and services value chains was still relatively low in 2020 compared to OECD peers.

- Industry 4.0 adoption appears to have played a role in the region's remarkable digital services' export growth and participation in global value chains. A survey of 800 Southeast Asian firms prepared for this study suggests that the region's digital service providers have adopted Industry 4.0 technologies such as AI, Generative AI, blockchain, and IoT in the past three years in particular – and that digital service providers and industries that leverage Industry 4.0 technologies intensively are more export-driven, competitive, and faster-growing than their peers that do not use Industry 4.0 as intensively. The intensive Industry 4.0 users also appear to have more durable and steadier global value chain relationships.

- Investments in Industry 4.0 appear to be paying off also at the country-level. Preliminary econometric evidence suggests that economies with strong Industry 4.0 startup ecosystems, presence of foreign tech companies with Industry 4.0 capabilities, and promotion of national innovation capacity (as proxied by patent applications) are particularly well-positioned to promote digital services exports.

- The survey data suggest that East and Southeast Asian digital services firms face a number of challenges to adopting and using Industry 4.0 technologies, such as with access to staff with the right expertise to harness Industry 4.0, identifying appropriate technologies to use, and cybersecurity concerns. In response, the region's governments should expand their ongoing efforts to invest in digital skills, expand access to digital transformation grants and loan guarantees, deepen domestic Industry 4.0 ecosystems, including through partnerships with global tech firms, and develop focused programs to promote digital service providers' exports.

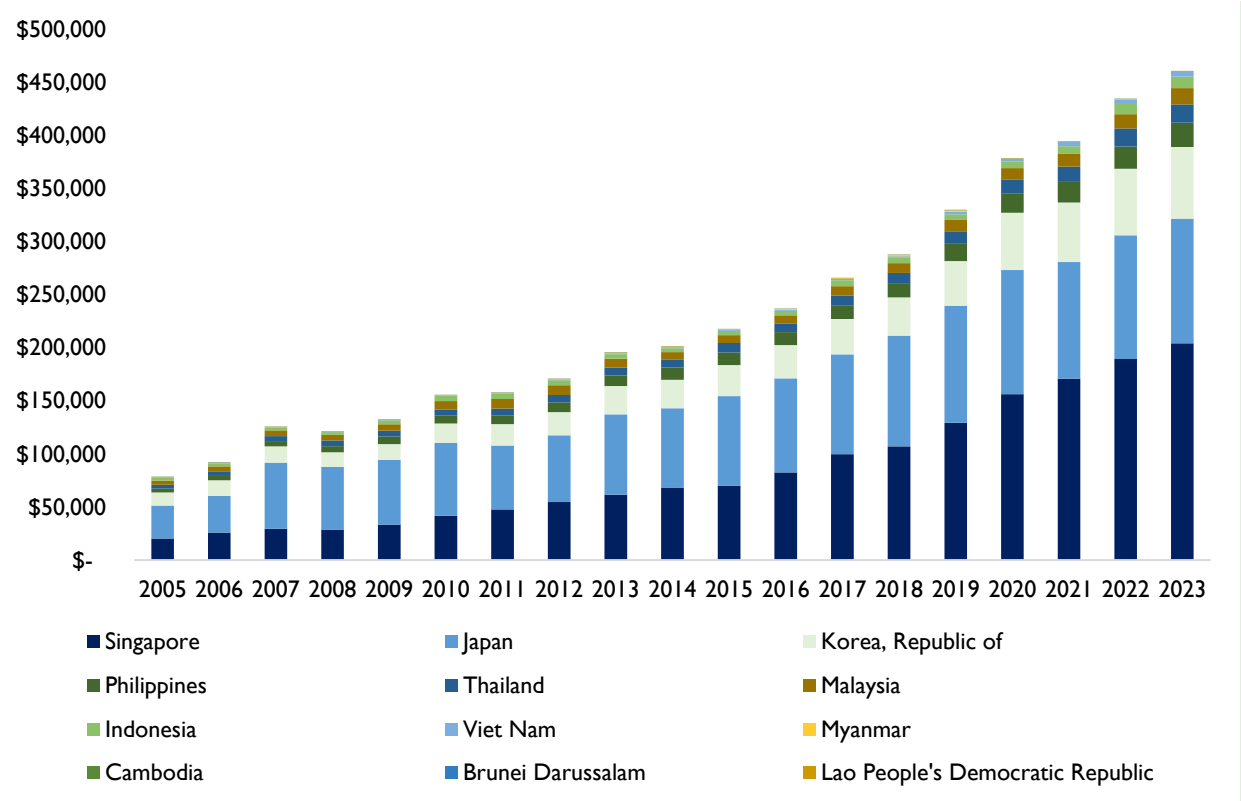
The following section reviews trends in East and Southeast Asian digital services exports and value chain participation. Section three reviews the survey data. Section four examines the relationship between Industry 4.0 adoption and digital services trade. Section five concludes with policy recommendations.

2. Value chain structure: East and Southeast Asia's digital services exports and integration into value chains

About a fifth of all firms in East and Southeast Asia offer digital services. How internationalized then are Southeast Asian, Korean, and Japanese digital service providers, and how integrated are they in global value chains? The first part of this section draws on World Trade Organization's (WTO) digitally delivered services dataset in 2005-24 and the OECD Balanced Trade in Services and Trade in Value Added (TiVA) databases to evaluate the growth of Southeast Asian, Korean, and Japanese digital services exports and integration into domestic, regional and global value chains. There are six main observations.

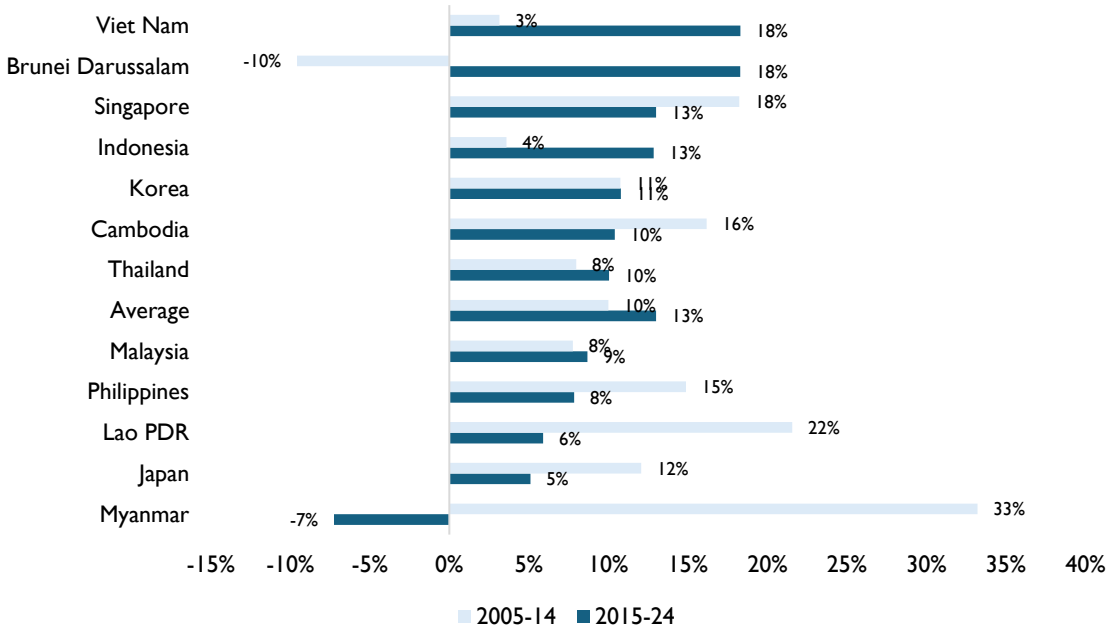
First, East and Southeast Asian digital services exports have grown at an annual average of 11.5 percent in the past 20 years, from $66 billion in 2005 to $461 billion in 2024 (figure 1). The region's digital services exports make up 10 percent of total global digital services exports. Singapore, Korea, and Japan are the top exporters of digital services, while Cambodia, Indonesia, Singapore, and Vietnam's digital services exports have grown fastest over the past decade (figure 2). All in all, the region's digital services export growth has grown three times faster than manufacturing and services exports, or by 596 percent in 2005-2024 (figure 3).

Figure 1 – Digitally deliverable services exports in East and Southeast Asian countries (millions USD), 2005-24



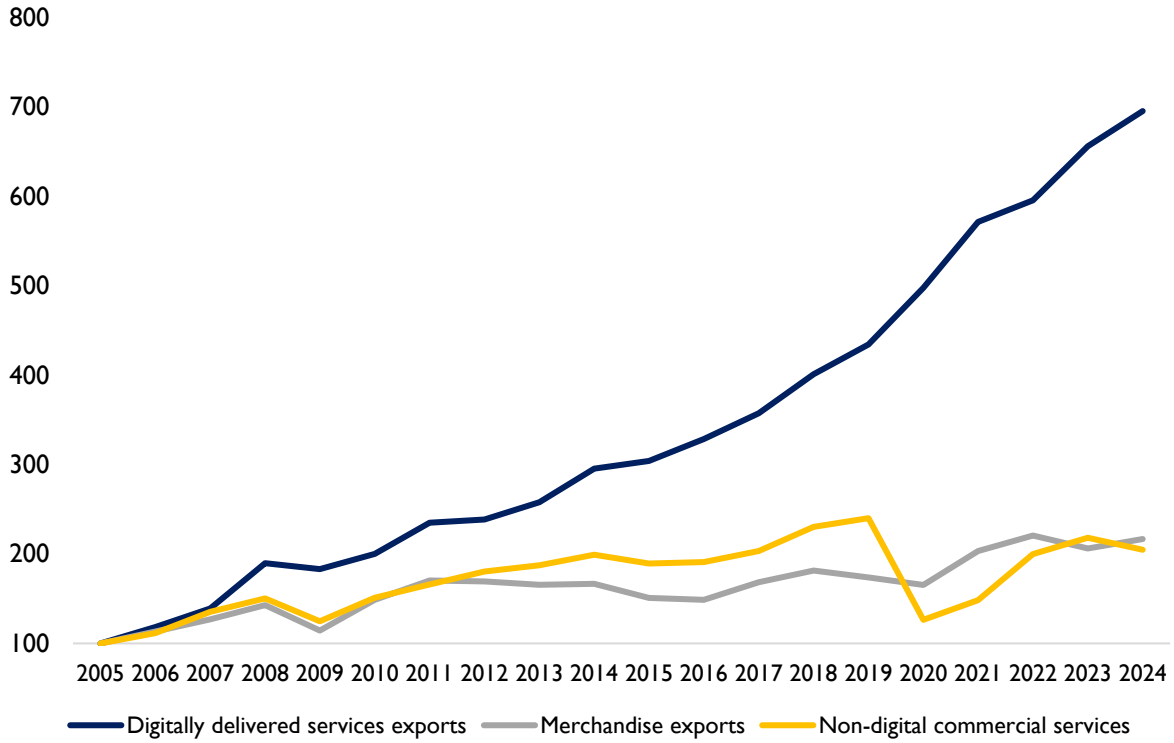
Source: World Trade Organization (WTO), Digitally delivered services trade dataset, https://www.wto.org/english/res_e/statis_e/gstdh_digital_services_e.htm

Figure 2 - Growth of East and Southeast Asian region's digital services exports in 2005-24



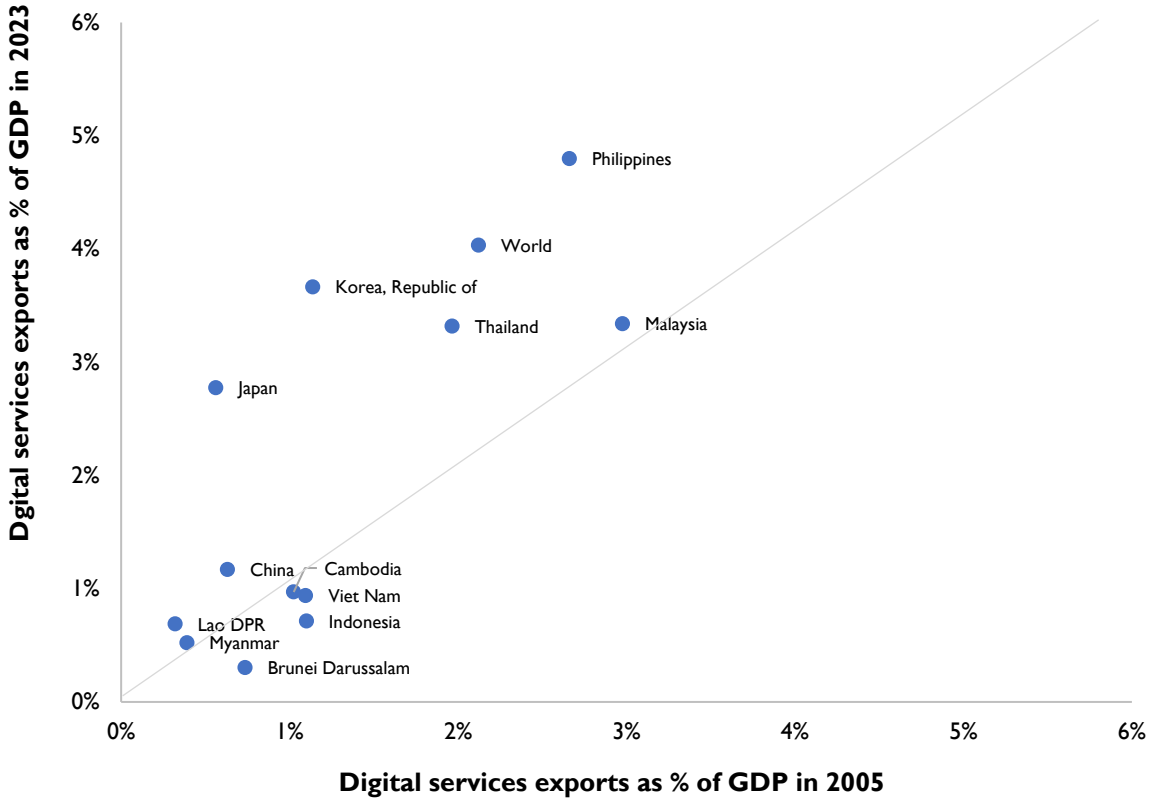
Source: World Trade Organization (WTO), Digitally delivered services trade dataset, https://www.wto.org/english/res_e/statis_e/gstdh_digital_services_e.htm

Figure 3 - Growth of East and Southeast Asian region's digital services, non-digital commercial services, and merchandise exports in 2005-24



Second, as a result of this rapid expansion, East and Southeast Asian digitally delivered services exports have expanded from 25 percent in 2005 as a share of commercial services exports to 51 percent in 2024. Digital services exports have also become more relevant in the region's economies, growing, for example, from some 2.3 percent of the Philippine GDP in 2005 to 5 percent in 2023, and from 1 percent of Korea's GDP to nearly 4 percent in 2023 (figure 4). Singapore is an outlier, with digital service exports equivalent to 38 percent of GDP in 2025.

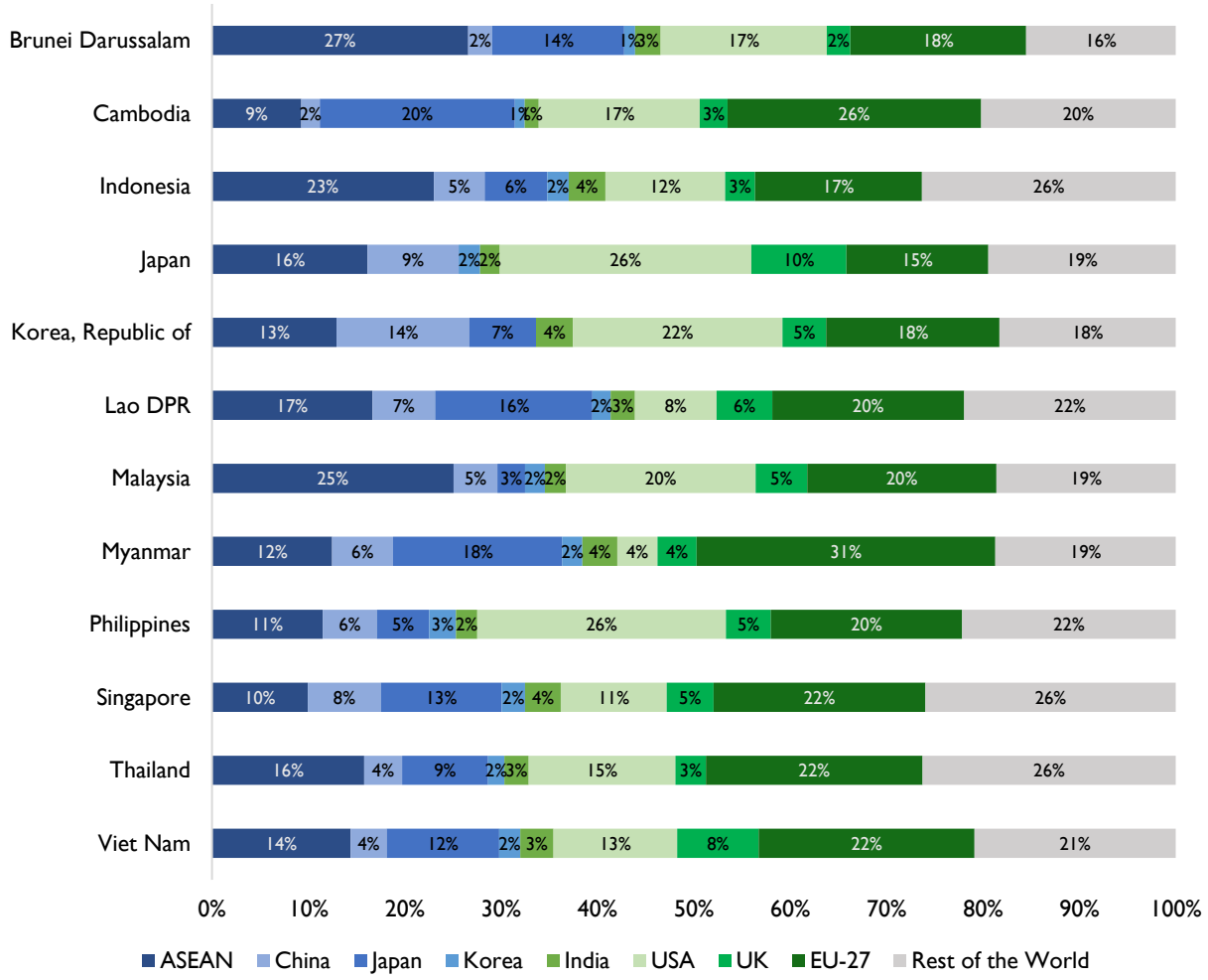
Figure 4 – Digital services exports as a percent of GDP, by East and Southeast Asian country in 2005 and 2023



Source: World Trade Organization (WTO), Digitally delivered services trade dataset, https://www.wto.org/english/res_e/statis_e/gstdh_digital_services_e.htm; for GDPs, World Bank, World Development Indicators.

Third, Europe and the United States were the leading destinations for the region's digital services exports in 2023, making up just over one-half of the total (figure 5). ASEAN itself is a major destination for Brunei, Indonesia, and Malaysian exporters, and the Asian market in general for ASEAN LDCs.

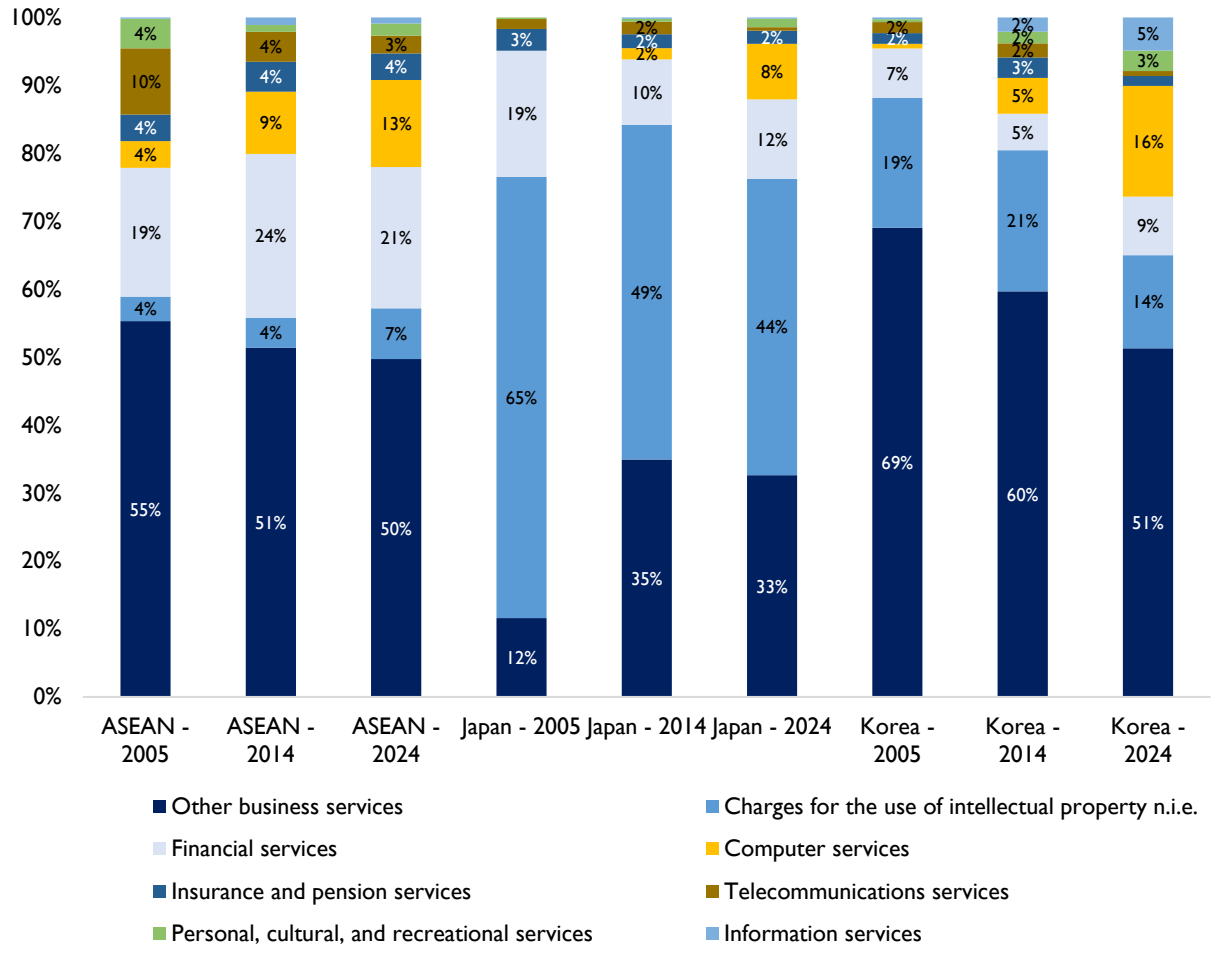
Figure 5 - Digital services export destinations of ASEAN economies, Korea, and Japan in 2023



Source: OECD-WTO Balanced Trade in Services (BaTIS) dataset; https://data-explorer.oecd.org/vis?lc=en&fs[0]=Topic%2C0%7CTrade%23TRD%23&pg=0&fc=Topic&bp=true&snb=80&df[ds]=dsDisseminateFinalDMZ&df[id]=DSD_BATIS%40DF_BATIS&df[ag]=OECD.SDD.TPS&df[vs]=1.0&isAvailabilityDisabled=false

Fourth, among digital services industries, computer services have grown especially rapidly in the region's export baskets, from only 4 percent to 13 percent of total digital services exports in 2005-20 in the ASEAN, 2 percent to 8 percent in Japan, and less than 1 percent to 16 percent in Korea (figure 6), reflecting global demand for knowledge- and technology-intensive services. Other business services also expanded and remained the largest subsector, accounting for nearly half of total digital service exports by 2024.

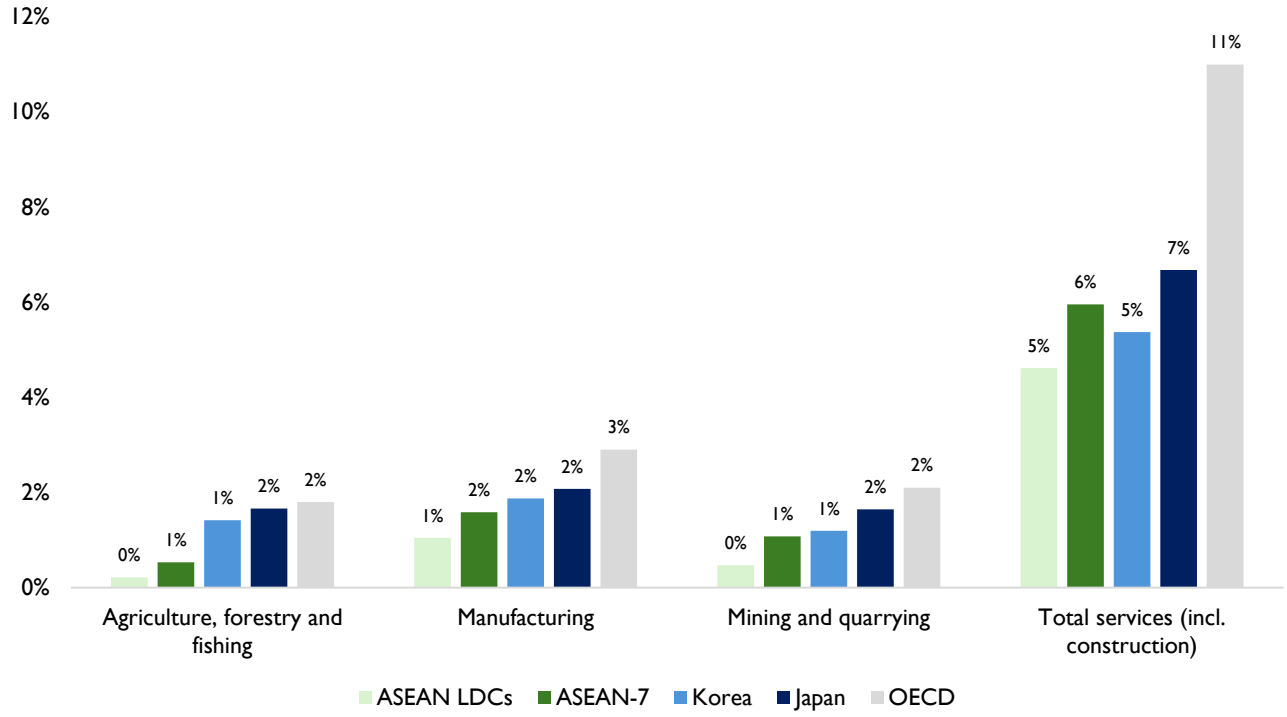
Figure 6 – Digitally deliverable services export sectors in East and Southeast Asian economies, 2005, 2014, and 2024



Source: World Trade Organization (WTO), Digitally delivered services trade dataset, https://www.wto.org/english/res_e/statis_e/gstdh_digital_services_e.htm..

Fifth, East and Southeast Asian manufacturing and services sectors are leveraging domestic and global digital services in their value chains – but still not at the levels of OECD peers. For example, the share of information and communication industry value-added (the closest proxy for digital services in the OECD TiVA database) in the gross manufacturing exports was 1.6 percent for ASEAN-7 and 1.9 percent in Korea and 2.1 percent for Japan, compared to 3 percent in OECD. Digital services value added was between 5 and 7 percent of the regional economies' respective gross services exports, below the OECD average of 11 percent (figure 7). Most of East and Southeast Asian digital services value added is domestic, expect for the ASEAN LDCs.

Figure 7 – Share of information and communication industry value-added in the gross exports of the East and Southeast Asian economies in 2020, by export sector



Sixth, at the regional level, Cambodia, Myanmar, and Vietnam have expanded their digital services value added in manufacturing gross exports (figure 8). The share of East and Southeast Asian digital services value added *of all digital services value added* used in Asian (ASEAN, Chinese, Japanese, and Korean) gross manufacturing exports grew slightly for Indonesia, Thailand, and Vietnam in 2011-20 (figures 9-11). However, the share of Japanese and Korean digital services value added in Asian value chains has declined (from 18 to 12 percent and from 12 percent to 10 percent, respectively), likely because of the growth of China in the regional value chains.

At the global level (excluding Asia), Cambodia, Myanmar, Philippines, and Singapore have been growing their value-added most (figure 12). The share of Japanese and Singaporean digital services of all digital services value added in global (U.S., EU-27, India, Latin America, Australia and New Zealand, and African) gross exports grew from 0.7 to 0.8 percent and 0.3 to 0.4 percent, respectively (figure 14). The trends are similar in both services and manufacturing gross exports (figure 14-15).

Figure 8 - Annual average growth of East and Southeast Asian digital services value added in Asian regional manufacturing and services value chains (of Asian economies' gross exports), 2011-20

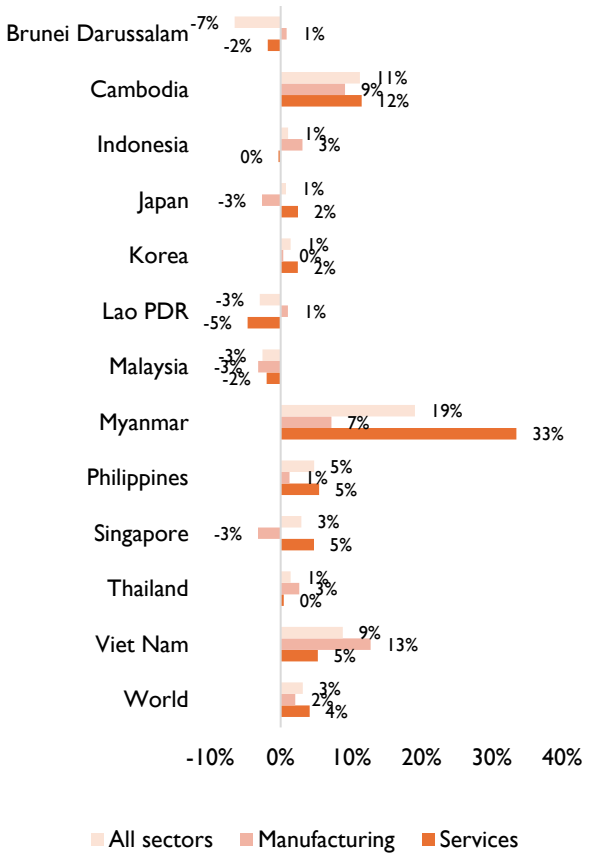


Figure 9 - East and Southeast Asian digital services value added as share of all digital services value added in Asian regional value chains (of Asian economies' gross exports), 2011-20

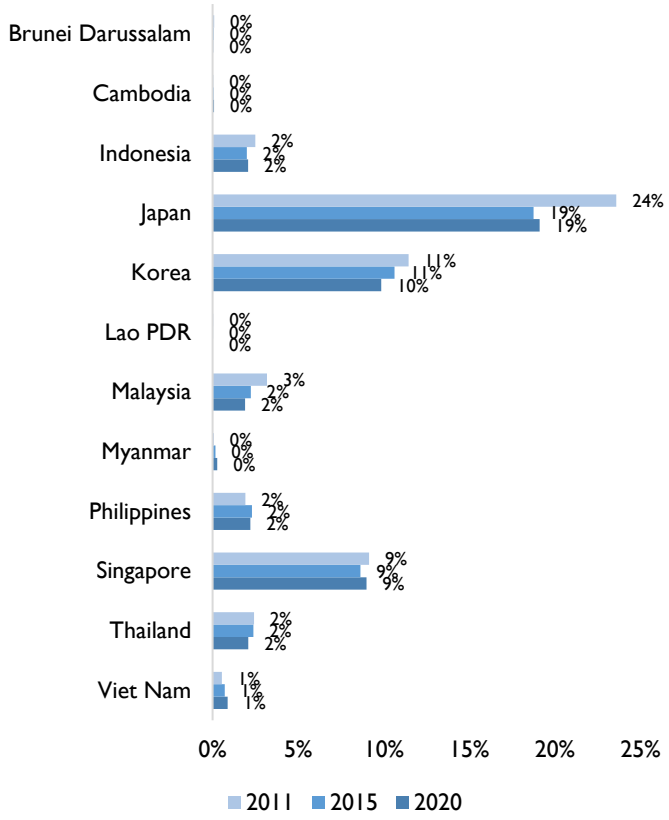


Figure 10 - East and Southeast Asian digital services value added as share of all digital services value added in Asian regional services value chains (of Asian economies' gross services exports), 2011-20

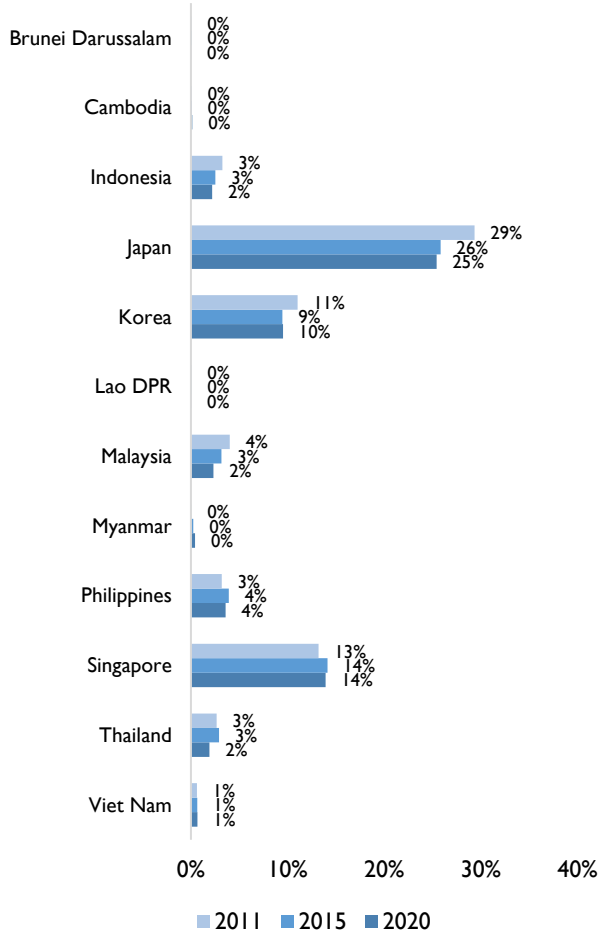


Figure 11 - East and Southeast Asian digital services value added as share of all digital services value added in Asian regional manufacturing value chains (of Asian economies' gross manufacturing exports), 2011-20

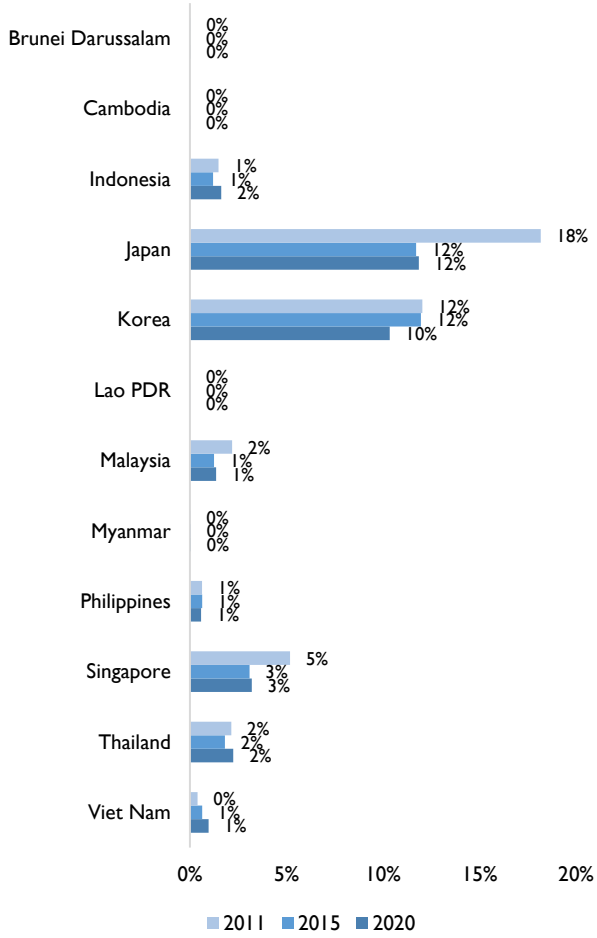


Figure 12 - Annual average growth of East and Southeast Asian digital services value added in global manufacturing and services value chains (in global gross manufacturing and services exports), 2011-20

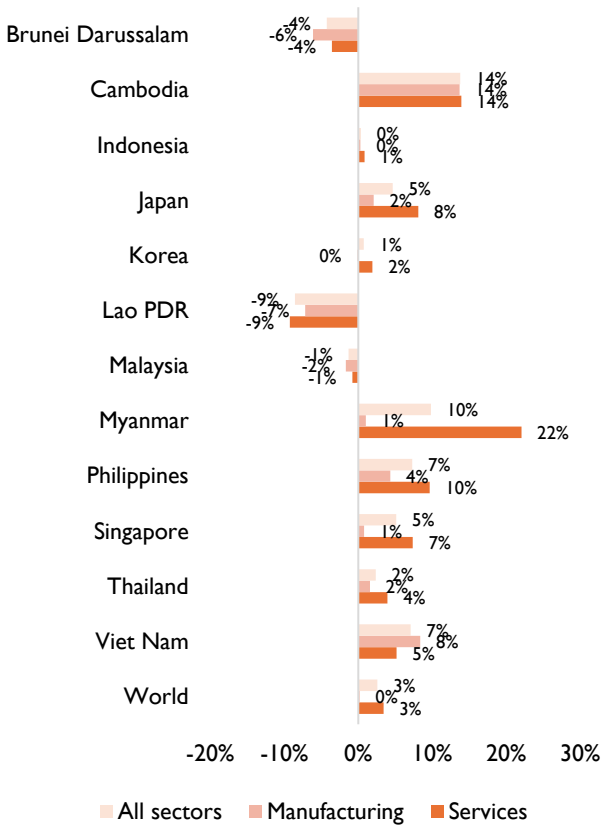


Figure 13 - East and Southeast Asian digital services value added as share of all digital services value added in global manufacturing and services value chains (of world gross exports), 2011-20

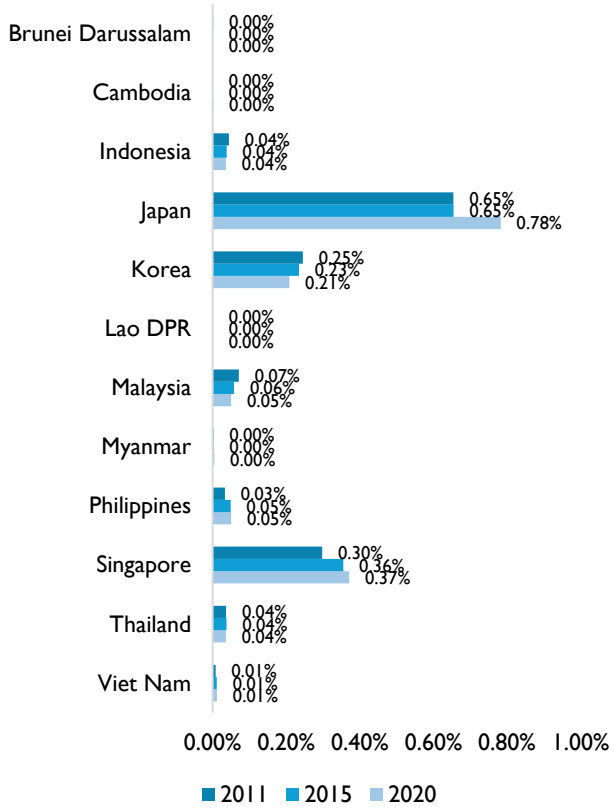


Figure 14 - East and Southeast Asian digital services value added as share of all digital services value added in global services value chains (of global gross services exports), 2011-20

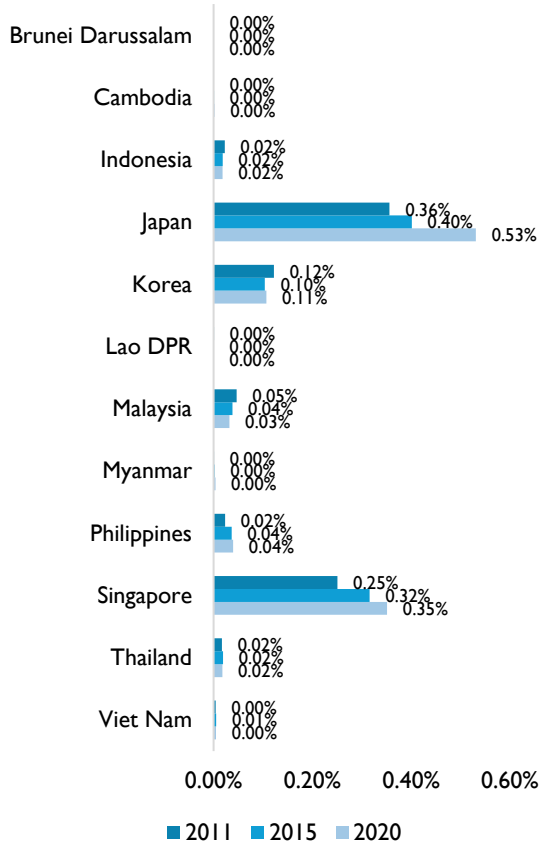
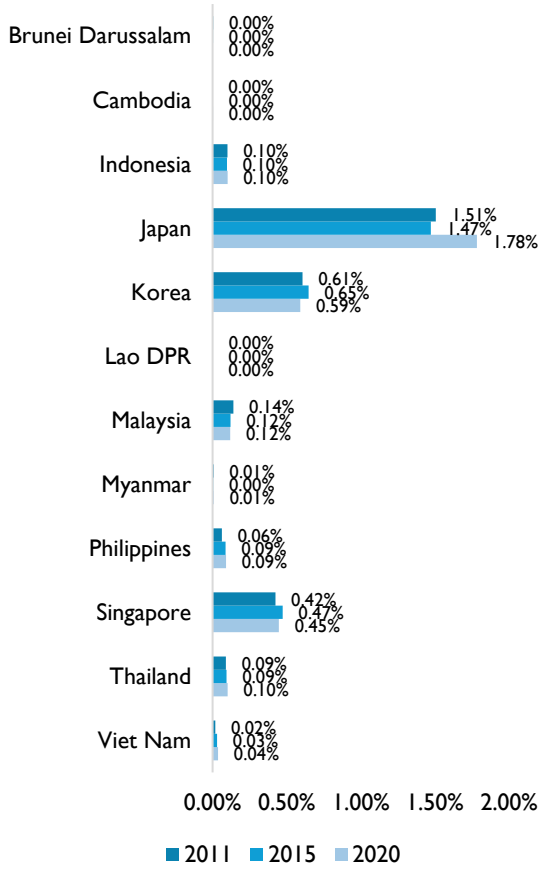


Figure 15 - East and Southeast Asian digital services value added as share of all digital services value added in global manufacturing value chains (of world gross manufacturing exports), 2011-20



This section has analyzed the growth of East and Southeast Asian digital services exports and value-added in regional and in global value chains. The section has found that:

- East and Southeast Asian digital services exports grew by 12 percent annually since 2005, outpacing the growth of goods and non-digital services exports.

- Singapore, Korea, and Japan lead in terms of export volumes; Vietnam, Brunei, Singapore, and Indonesia have had the strongest growth in digital service exports in the past decade.

- Digital services now make up more than one-half of the region's commercial services, up from a quarter in 2005, and represent a growing share of most regional economies' GDPs.

- The value added of regional digital services in regional and global value chains has been growing in absolute terms especially for such economies and Cambodia, Myanmar, Singapore, and Vietnam, but grown only slightly in relative terms in global value chains and declined in regional value chains. The data, however, concludes in 2020, thus limiting visibility into the region's performance in the past few years.

What, then, does Industry 4.0 have to do with these trends? Are the sectors and firms that use Industry 4.0 particularly export-driven and integrated into global value chains? The next section explores.

3. How Industry 4.0 supports digital service exports and value chain participation: insights from a firm-level survey

The rise of East and Southeast Asian digital services exports and value chain participation has coincided in the use of Industry 4.0 capabilities among digital services providers. This section reviews cases of Industry 4.0 use among the regional digital services firms and how Industry 4.0 has changed the way digital services are developed and delivered. This section then uses survey data with 800 Southeast Asian digital service providers to understand how Industry 4.0 use translates into digital service providers' exports and participation in regional and global value chains.

a. Industry 4.0-eables and -drive firms in East and Southeast Asia: examples

Digital service providers can be divided into three groups:

1. Firms that do not use Industry 4.0 technologies;
2. "Industry 4.0-enabled" that leverage digital services in their production (such as a law firm that leverages AI); and
3. "Industry 4.0-driven" digital service providers that themselves offer Industry 4.0 technologies as their main value proposition (like an AI company helping the law firm).

Some examples of the ***Industry 4.0-enabled*** firms in East and Southeast Asia include:

- Indonesia's ride-hailing company Gojek (recently merged with Tokopedia into the GOTO Group), for example, uses machine learning models to predict where surges of traffic will surge.[2]

- Kim & Chang, Korea's largest law firm, launched in 2024 an AI compliance application to assist firms in managing the risks associated with AI.[3] The tool aids in ensuring compliance with regulatory standards concerning AI usage.

- WorkVenture is a Thai work platform that applies machine learning to connect graduates and employers.[4] It uses predictive algorithms to assess job seeker profiles, match them with relevant job openings, and provide career recommendations. Targeting young professionals and university students, WorkVenture collaborates with educational institutions and corporations throughout Thailand.

These are just a handful of examples of the use of Industry 4.0 in digital services. Industry 4.0 technologies can be used in multiple places in digital services value chain, including:

- **Upstream inputs and R&D:** Digital services firms in financial services, actuarial modelling, and consulting can use AI, agentic AI, and cloud infrastructure for data collection, modelling, and algorithm development for accelerating and automating their services.

- **Midstream in service production and operations:** Professional and management consulting firms can use machine-learning tools for market intelligence, risk modelling, and scenario planning. Similarly, engineering, technical, and trade-related service providers can adopt AI-driven digital twins to optimize operations and deliver higher-quality services. Insurance and pension providers use AI for underwriting, fraud detection, customer segmentation, and real-time risk assessment.

- **Downstream in service delivery and client service:** AI-enabled chatbots, natural language processing, and automated advisory tools enhance customer service across digital services. AI agents can perform diverse tasks in customer service and sales staff. Cloud-based platforms enable digital service providers to offer technical and consulting services across borders. Use of blockchain can improve transparency, authentication, and traceability in trade-related and compliance-oriented professional services.

- **Development of new digital service products**: AI companies provide models, APIs, and agentic systems as exportable services to other sectors.

Over time, Industry 4.0 technologies have helped change industries and the way services are delivered. One good example is AI, which is now entering the agentic AI era.

The first wave, traditional AI, promoted digital services firms' capabilities in prediction, pattern recognition, and decision-making, enhancing core activities such as legal document review, actuarial modelling, fraud detection, risk scoring, and job-matching.

The second wave, generative AI, has more recently expanded automation into knowledge work, such as drafting legal memos and compliance briefs, summarizing large case files or regulatory proposals, generating consulting research syntheses, and enhancing customer service through natural language systems. GenAI overall has reduced the time required to produce high-quality analysis and shifted human work from creating to refining and validating contents and outouts created by machines.

The current wave, agentic AI, is now reshaping digital services by automating multi-step workflows using AI agents. Agentic systems can plan, retrieve information, use external tools, and execute sequential actions such as scanning new legislation, generating compliance assessments, modelling business impacts, and preparing full client-ready outputs. In digital services like law firms, consulting practices, and insurance providers, AI agents function as semi-autonomous digital analysts or associates, executing tasks and processes autonomously start to finish.

While Industry 4.0 technologies used by the East and Southeast Asian companies can be provided by global technology giants or other foreign firms, there has also been a surge of ***Industry 4.0-driven firms*** in the region – firms that monetize the Industry 4.0 technology first and foremost and support other firms, such as digital service providers. This ecosystem has grown rapidly in East and Southeast Asia. Crunchbase data of AI, blockchain, IoT, and cloud startups yields nearly 4,000 companies in 2025 that are Industry 4.0-driven (figure 16). The

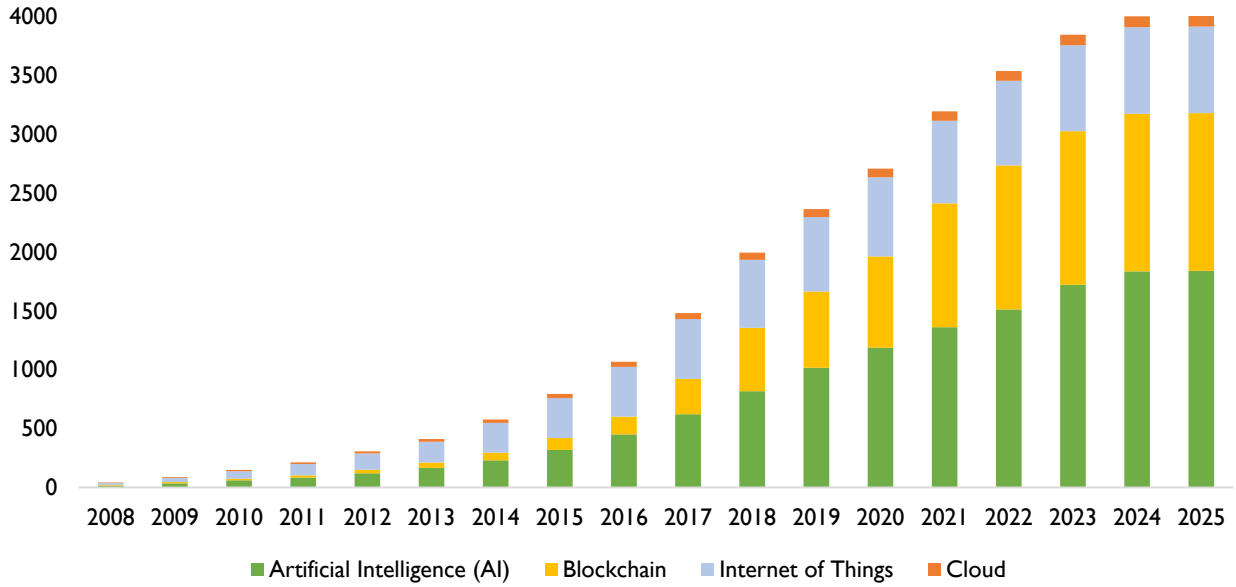
region's Industry 4.0-driven business ecosystem has grown by 35 percent annually from 2008 to 2024. Some examples of firms include:

- Lunit is a Seoul-based medical AI company specializing in cancer diagnostics through deep learning.[5] Its flagship products, Lunit Insight CXR and Lunit INSIGHT MMG, are used in hospitals and screening centers across more than 40 countries, including South Korea, Brazil, Italy, and Saudi Arabia.

- Prowriting is an Indonesian AI startup that provides usability analytics and user experience testing services for digital services.[6] It uses natural language processing and machine learning algorithms to evaluate user feedback, identify friction points, and optimize the design of websites and mobile applications.

- Vietnamese company AirCity offers IoT and IoT technologies to automate and streamline property management.[7] It provides a platform for landlords and real estate operators to manage tenant relations, billing, facility maintenance, and security in residential complexes.

Figure 16 - Cumulative number of Industry 4.0-driven firms in East and Southeast Asia, by year founded and industry



Source: Nextrade Group on the basis of Crunchbase, 2025.

To be sure, startups are not the only Industry 4.0-driven firms. Also, diverse traditional companies in the region have created Industry 4.0-driven digital services applications and exports. For example:

- Japan's Wenco International Mining Systems, a Hitachi Construction Machinery subsidiary, has created a suite of AI-driven smart mining tools that are widely used in

mines in Latin America.[8] As such, a part of Wenco's business consists of Industry 4.0-driven digital services that furthermore are exported.

- Telkom Indonesia has created a new line of business helping agricultural producers to use internet of things technologies to tap data with which to optimize yields and production methods.[9]

- Hyundai Robotics began as a robotics unit within Hyundai Heavy Industries in South Korea, initially supporting internal automation needs in heavy manufacturing.[10] Since becoming an independent company in 2020, it has transformed into a key Industry 4.0 player, developing AI-driven service robots. Its smart factory in Daegu, South Korea, manufactures up to 10,000 robots annually using advanced automation and data analytics.[11]

- Infineon Technologies Singapore originally focused on semiconductor backend manufacturing, but has become a global model for Industry 4.0 transformation with smart factory technologies, automated guided vehicles, robotics, and full digital integration across its manufacturing value chain.[12]

In addition, global Industry 4.0 players in such sectors and AI and cloud have invested in the region (table 1).

Table 1 - Major AI and cloud investments in Southeast Asia

Investor	Amount (USD)	Economy	Investment focus	Intended users
Amazon AWS[13]	$8.9 billion over 2024-28	Singapore	Cloud infrastructure, flagship AI program	Public sector, enterprises (Grab, MPA, Singlife), community AI skills
Microsoft[14]	$2.2 billion over 2024-28	Malaysia	Cloud + AI infrastructure, National Innovation Center, skilling 200,000	Developers, SMEs, government, security sector
Microsoft[15]	$1.7 billion over 2024-28	Indonesia	Cloud + AI infrastructure, skilling 840k, developer support	Workforce, development communities, government (Golden Indonesia 2045)
Oracle[16]	$6.5 billion announced Oct 2024	Malaysia	Public cloud region, AI & analytics capabilities	Government, financial services, airlines, hospitality
Google[17]	$2 billion over 2024-30	Malaysia	Data center + Google Cloud region; AI literacy & sovereign cloud services	SMEs, public sector, students, developers
Google[18]	$1 billion	Thailand	Data center + Cloud region in Chonburi/Bangkok	Enterprises, startups, government agencies, fintech
Amazon AWS[19]	$5 billion over 15 years	Thailand	New AWS Region, cloud infrastructure, reskilling	Developers, startups, public sector, students, SMEs

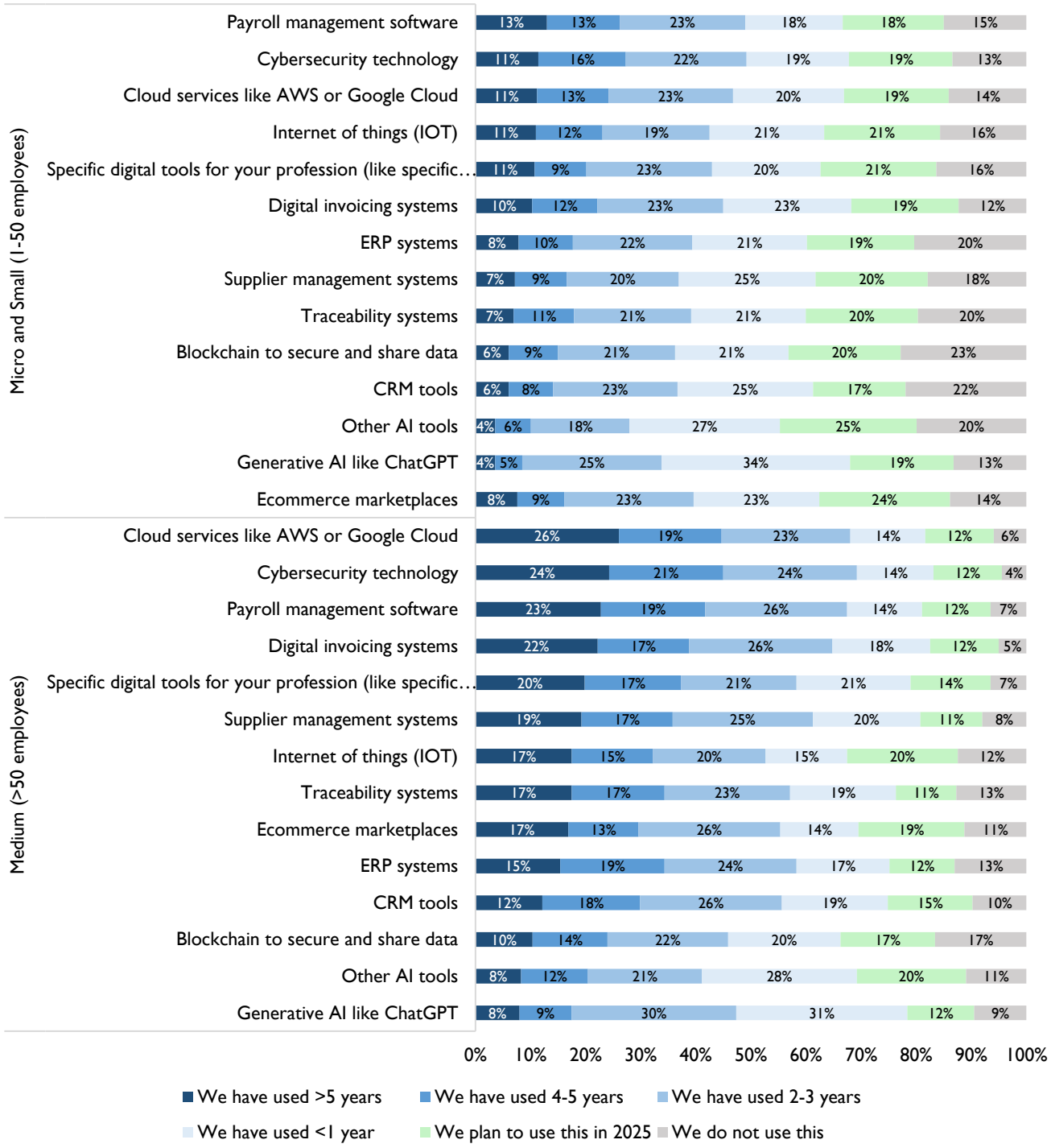
YTL Power + NVIDIA[20]	$4.3 billion	Malaysia	AI supercomputer + green data center park	Research institutes, enterprises, government

b. Survey data on Industry 4.0 use among 800 ASEAN firms

How, then, might Industry 4.0 technologies in East and Southeast Asia propelled the region's remarkable growth in digital services exports? Here, we use survey data with 800 digital service providers in Southeast Asia to provide preliminary answers. The survey was fielded on May 30, 2025-June 4, 2025, as a random sample and covered Indonesia, Malaysia, Thailand, and Vietnam (appendix 1). There are five main results:

First, East and Southeast Asian digital service providers have adopted Industry 4.0 technologies especially in the past three years. For example, 25 percent of micro and small firms have used Generative AI for three years and 9 percent have used it longer, while 30 percent of medium firms have used GenAI for up to 3 years and 17 percent have used it longer (figure 17). Cloud services have been used by 23 percent of micro and small firms for three years and by 24 percent even longer. Blockchain has also been employed by 57 percent of micro and small firms and 66 percent of medium firms. Firms with staff with strong IT backgrounds have been especially rapid adopters (appendix figure 2-1).

Figure 17 - Industry 4.0 and digital services adoption, by firm size and years used



Firms tend to use technologies in bundles – they start a digital journey, adopting some technologies, mature, and add new technologies (table 2). Industry 4.0 users are firms that are well on their way in digital journey, using numerous other digital technologies such as CRM and ERP systems.

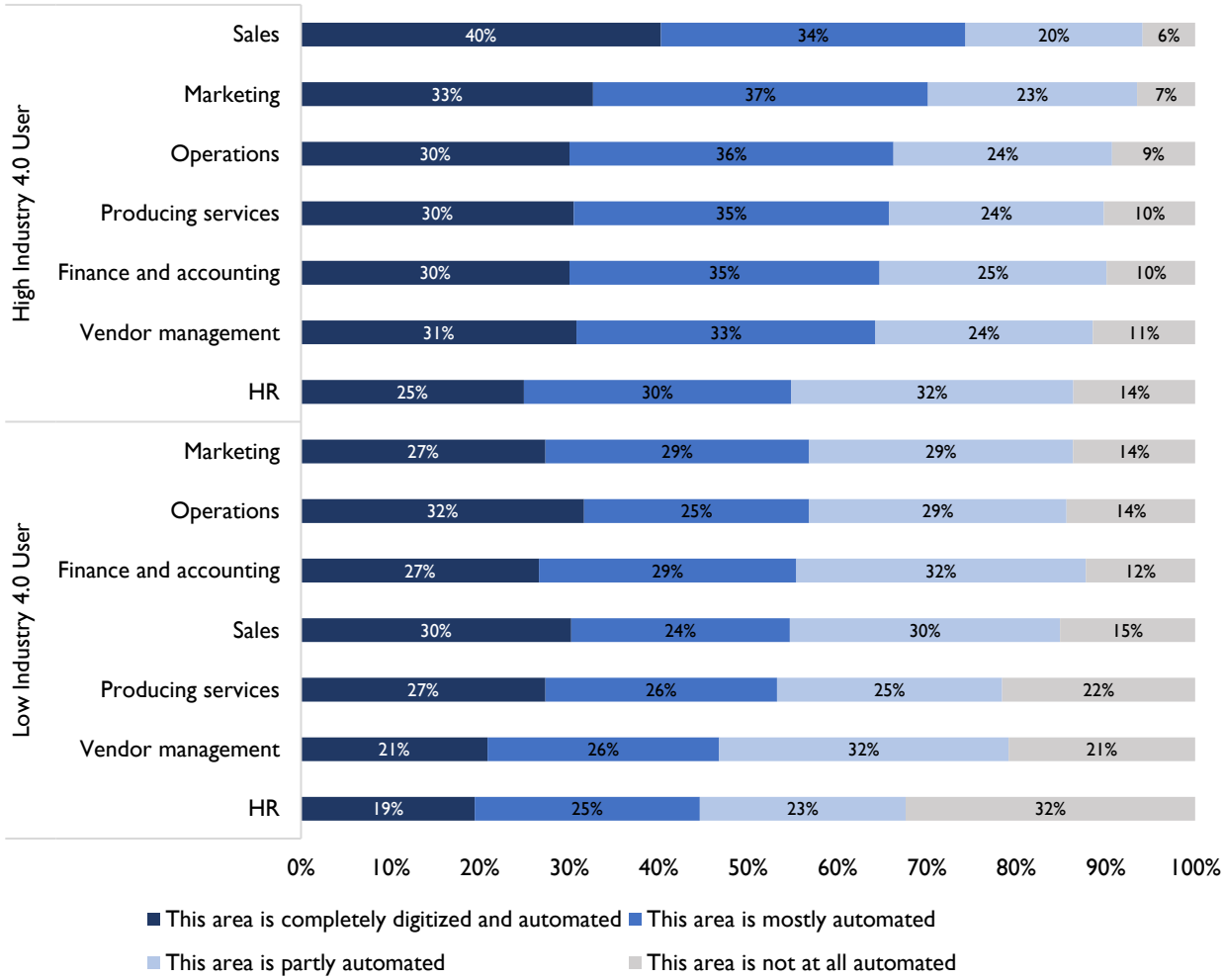
Table 2 – Pairwise correlations in firms' adoption digital services

	Ecommerce marketplaces	CRM tools	Supplier management systems	Payroll management software	Digital invoicing systems	ERP systems	Traceability systems	Cybersecurity technology	Cloud services like AWS or Google Cloud	Generative AI like ChatGPT	Other AI tools	Blockchain to secure and share data	Internet of things (IOT)
Ecommerce marketplaces													
CRM tools	0.38												
Supplier management systems	0.32	0.39											
Payroll management software	0.26	0.34	0.43										
Digital invoicing systems	0.34	0.38	0.44	0.49									
ERP systems	0.30	0.49	0.42	0.43	0.46								
Traceability systems	0.36	0.46	0.44	0.41	0.43	0.59							
Cybersecurity technology	0.31	0.33	0.39	0.40	0.48	0.38	0.48						
Cloud services like AWS or Google Cloud	0.28	0.31	0.33	0.34	0.41	0.32	0.35	0.49					
Generative AI like ChatGPT	0.26	0.26	0.30	0.27	0.29	0.31	0.31	0.34	0.40				
Other AI tools	0.32	0.41	0.34	0.29	0.32	0.42	0.43	0.31	0.35	0.48			
Blockchain to secure and share data	0.34	0.37	0.37	0.39	0.31	0.42	0.49	0.33	0.31	0.30	0.48		
Internet of things (IOT)	0.29	0.31	0.28	0.33	0.31	0.38	0.38	0.32	0.27	0.30	0.42	0.51	
Specific digital tools for your profession	0.22	0.34	0.28	0.33	0.32	0.33	0.33	0.43	0.40	0.29	0.35	0.38	0.44

Second, firms that use Industry 4.0 technologies intensively outperform their peers in automation and revenue growth. The survey includes some firms that have a long track record of using Industry 4.0 technologies; others that are recent adopters, and still others that have yet to adopt these technologies. This study divides the surveyed firms into two groups: low-intensity Industry 4.0 users that use one or no Industry 4.0 technologies; and high-intensity Industry 4.0 users that use two or more of these technologies.

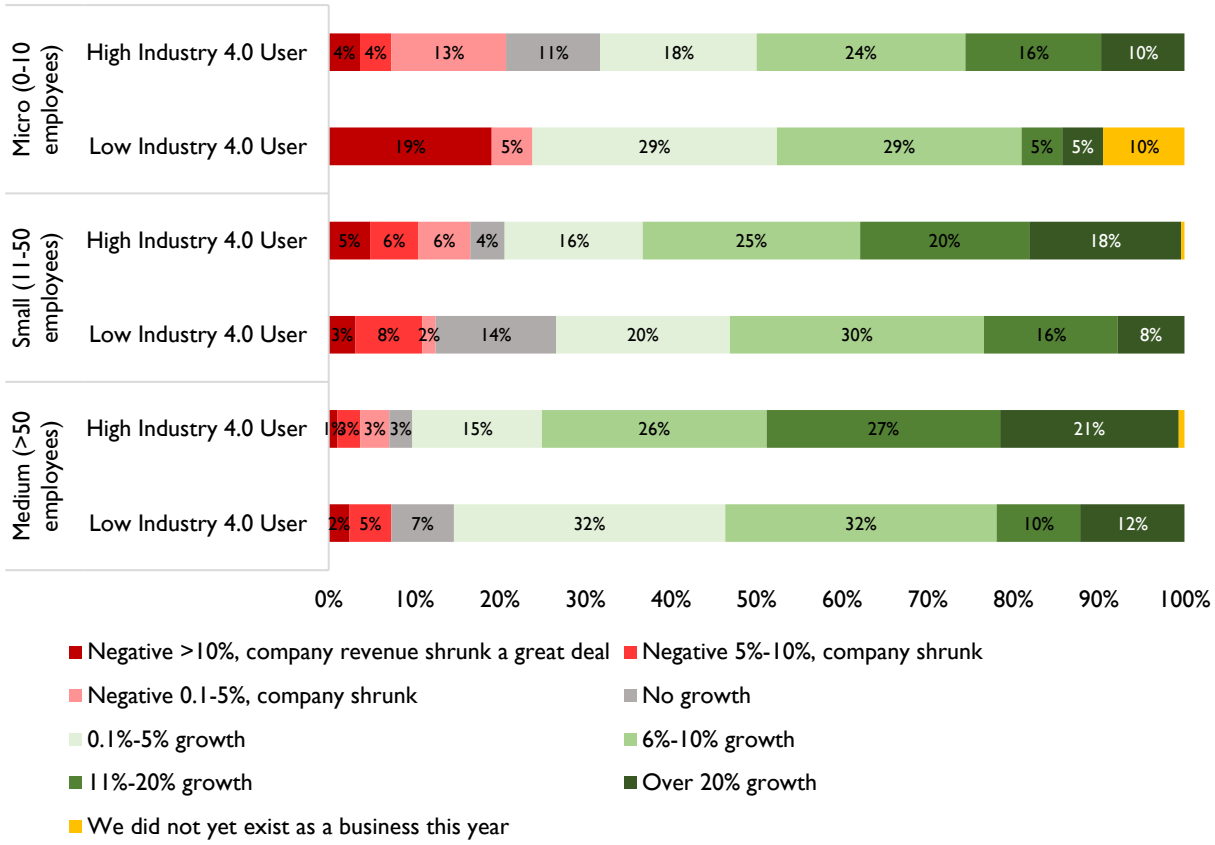
The data indicate that high-intensity Industry 4.0 users are farther along in automating their businesses. Some 74 percent have "completely" or "mostly" automated sales, 70 percent have done so in marketing, and 66 percent in operations (figure 18). Meanwhile, among low-intensity Industry 4.0 users, 57 percent of them have "completely" or "mostly" automated marketing, operations, and in finance and accounting. Two-thirds of high-intensity Industry 4.0 users have at least 50 percent of AI do the work in marketing, 65 percent in sales, and 58 percent in operations (appendix figure 2-2).

Figure 18 - Automation of business functions, by Industry 4.0 use



Across all firm sizes, firms that are intensive users of Industry 4.0 technologies experience faster revenue growth. For example, of micro enterprises that are high industry 4.0 users, 26 percent grew faster than 10 percent in 2024, compared to only 10 percent of low-intensity users (figure 19).

Figure 19 - Revenue growth in 2024, by firm size and Industry 4.0 use



Third, high-intensity Industry 4.0 users report greater export participation, intensity, and diversification. High-intensity Industry 4.0 users report greater gains than low-intensity users from the use of technologies. Of medium firms, 63 percent report cost savings, 63 percent attraction of new customers, and 45 percent new exports (figure 20). Of high-intensity micro firms, 78 percent export and 27 percent derive more than a quarter of their revenue from exports (figure 21). In contrast, only 43 percent of low-intensity micro users export, and only 14 percent of these derive a quarter or more of their revenue from exports. Industry 4.0 adoption also correlates with export diversification (figure 222).

The causality likely runs both ways – larger, more productive, digitized, and export-driven firms are likelier to adopt Industry 4.0 than their less productive peers, and digital service providers that start to use Industry 4.0 technologies will, as a result, expand their export intensities and form more diverse and lucrative value chain relationships.

Figure 20 – Firms' gains from digitization, by firm size and Industry 4.0 use

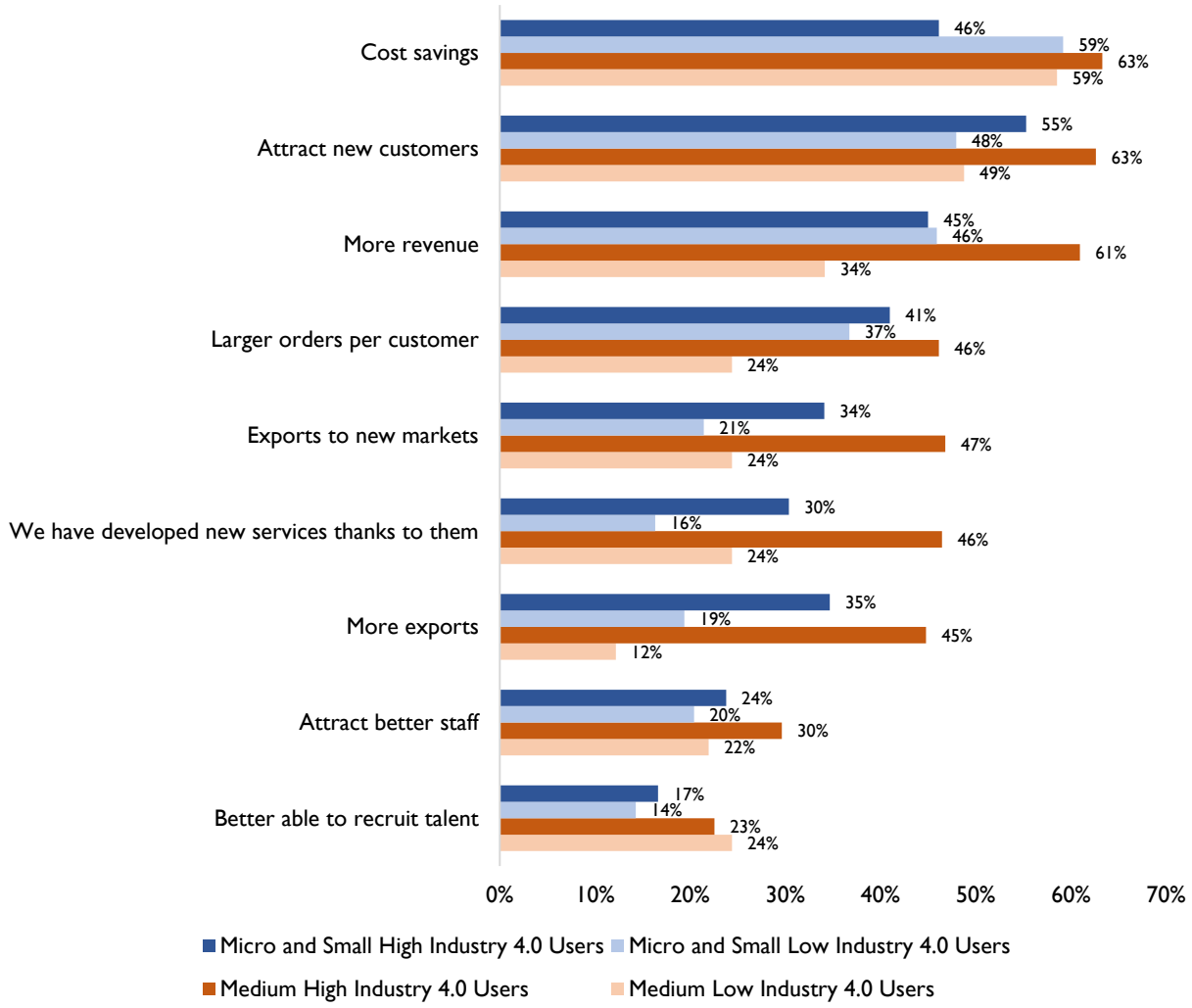


Figure 21 - Export participation and share of exports of total revenue, by firm size and Industry 4.0 use

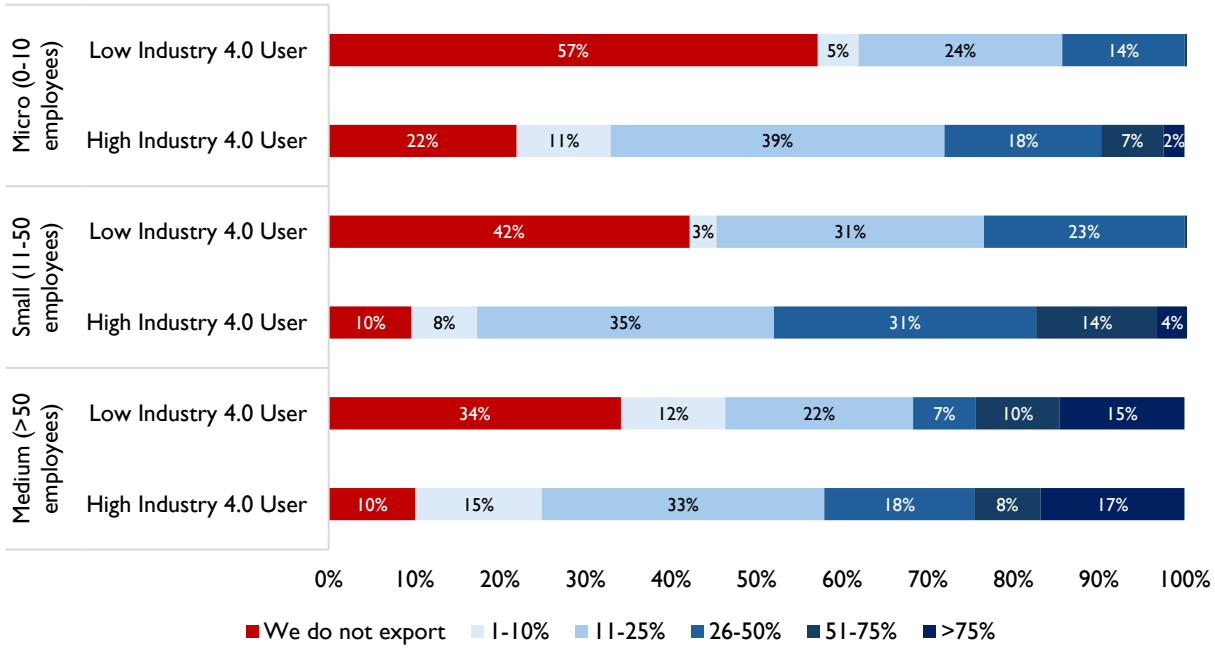
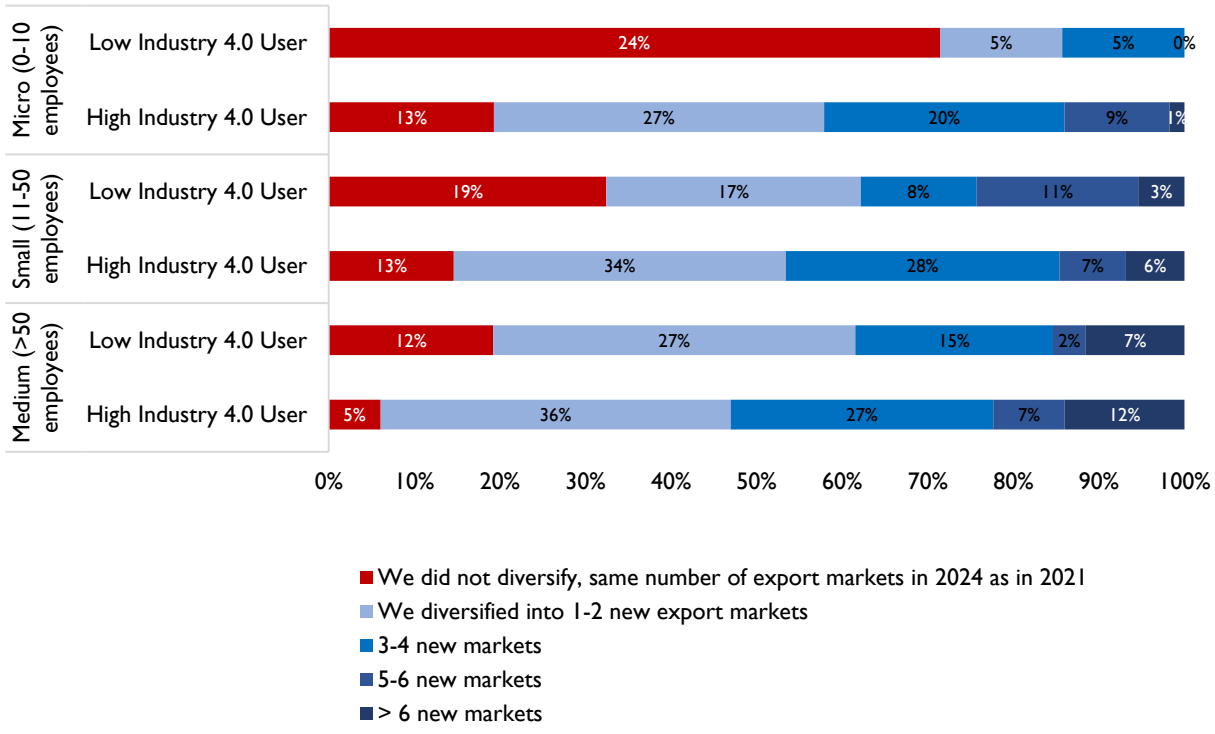
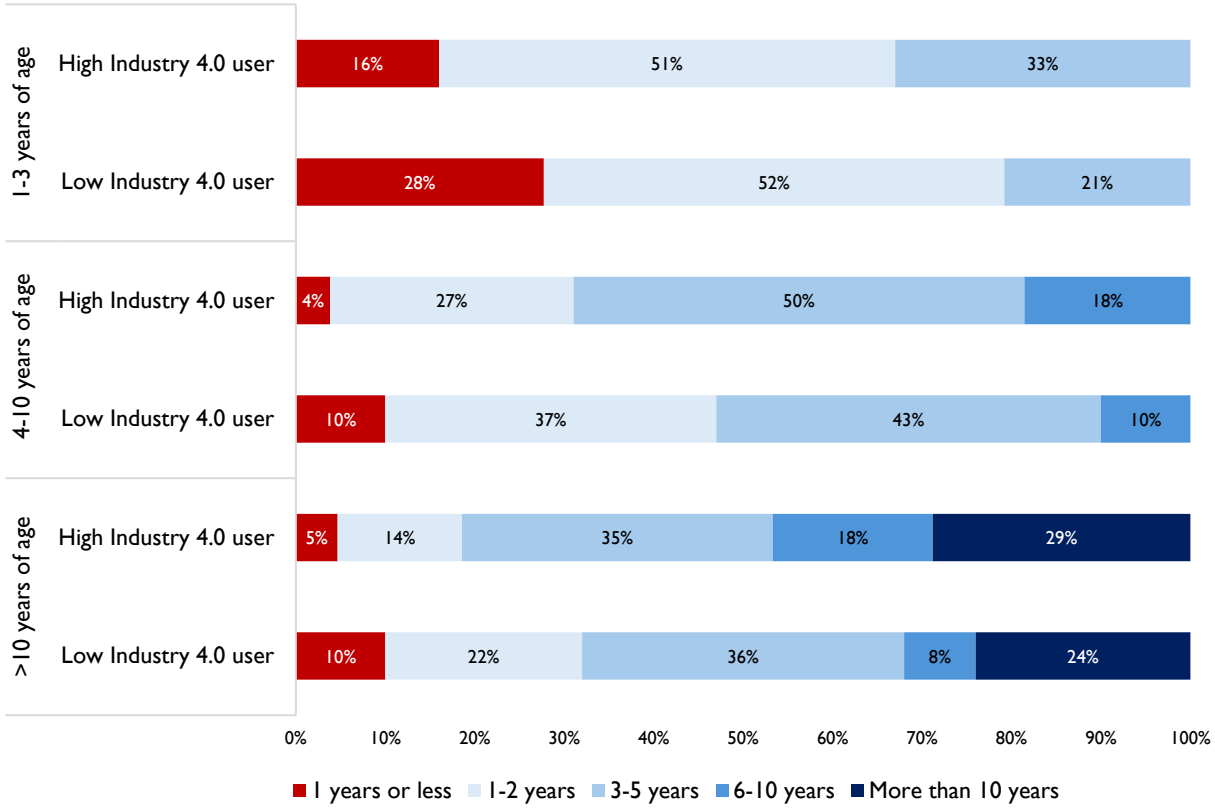


Figure 22 - Export diversification by firm size and Industry 4.0 use (exporters only)



Fourth, intensive Industry 4.0 users appear to have more lasting value chain relationships. Firms with high Industry 4.0 adoption tend to maintain longer client relationships compared to low adopters, especially as they mature – and have less churn and greater stability. Among firms aged over 10 years, 47 percent of high-intensity Industry 4.0 users have served their clients for more than six years, compared to only 32 percent of low-intensity users (figure 23). Among firms between ages 4 and 10 years, 68 percent of high-intensity Industry 4.0 users have serviced their clients three years or longer, compared to us 53 percent for low Industry 4.0 users.

Figure 23 - Average length of serving clients, firm age and Industry 4.0 use



Fifth, these econometric exercises suggest that both the adoption of Industry 4.0 capabilities and the intensity of spending on them matter. Industry 4.0 capabilities are associated with export participation, intensity, and diversification and length of customer relationships (table 3). The model is as follows:

$$Yfi=\beta0+\beta1FirmSizefi+\beta2Locationfi+\beta3Agefi+\beta4GenderCEOfi+\beta5AISpendSharefi+\beta6CloudYearsfi+\beta7EcommYearsfi+\beta8AIYearsfi+\mu c(i)+\mu ind(i)+\varepsilon fi$$

where

ExportsSharefi is exports as a % of sales
ExportMarketsfi is the number of export markets
CustRelLengthfi is the length of international customer relationships (years)
FirmSize is the number of employees
Location is 1 if main urban location, 0 if rural/other
Age is firm age in years
GenderCEO is 1=female, 2=male, 3=both
AISpendShare is AI spend as % of revenue
CloudYears is number of years using cloud computing
EcommYears is number of years using e-commerce
AIYears is the number of years using AI

In particular, length of using AI and cloud and investment in AI is strongly associated with higher export intensity, greater diversification of export markets, and more robust supply chain relationships (controlling for firm size, age, location, and gender of CEO, and using sector and year fixed effects). Meanwhile, ecommerce adoption is a strong predictor of whether firms export at all, though, as could be expected, it has less impact on whether they participate in global value chains.

Table 3 – Regression results with firm-level data

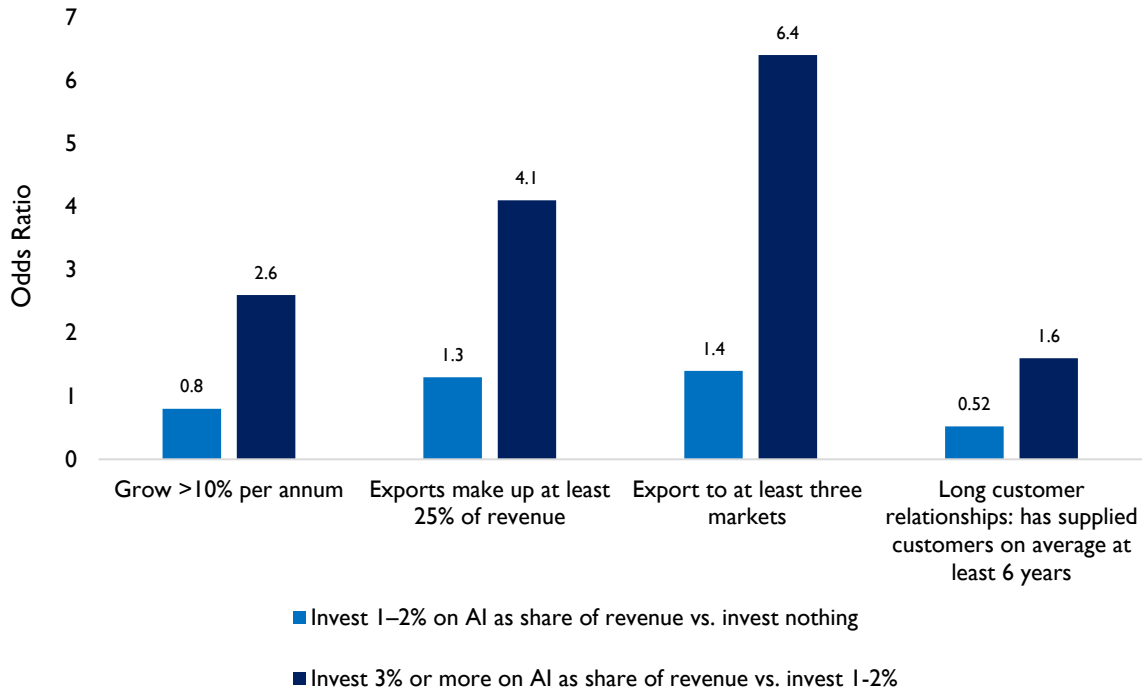
	Export	Exports as % of sales	Number of export markets	Length of customer relationships
Firm size (employees)	0.019* (0.010)	0.189*** (0.046)	0.086*** (0.031)	0.121*** (0.028)
Location (main urban = 1, rural=5)	–0.026** (0.010)	0.006 (0.047)	0.008 (0.031)	–0.030 (0.028)
Age	–0.005 (0.013)	0.189*** (0.060)	0.045 (0.040)	0.297*** (0.036)
Gender of CEO (1=female, 2=make, 3=both)	–0.032 (0.021)	–0.171* (0.094)	–0.072 (0.062)	–0.102* (0.056)
AI spend as % of revenue	0.080*** (0.013)	0.514*** (0.060)	0.281*** (0.039)	0.076** (0.036)
Cloud use in years	–0.019** (0.009)	–0.064 (0.043)	–0.055** (0.028)	0.077*** (0.025)
Ecommerce use in years	0.040*** (0.010)	0.284*** (0.044)	0.137*** (0.029)	0.021 (0.026)
AI use in years	0.042*** (0.011)	0.097** (0.049)	0.061* (0.032)	0.051* (0.029)
Constant	0.439*** (0.074)	–0.096 (0.333)	0.758*** (0.219)	0.828*** (0.198)
N	750	750	750	750
R^2	0.234	0.352	0.245	0.305
Adj. R^2	0.202	0.325	0.213	0.276
FE	Country + Industry	Country + Industry	Country + Industry	Country + Industry

*** significant at 1 percent level; ** significant at 5 percent level; * significant at 10 percent level. Standard errors in parentheses.

Further regressions using the survey data found that firms that invest 3-5 percent or more of their revenue are, compared to firms that invest 1-2 percent (figure 24):

- 2.6× more likely to grow at double digits (over 10%)
- 4.1x more likely to earn at least a quarter of all revenue from exports
- 6.4× more likely to sell to at least three foreign markets.
- 1.6× more likely to maintain long-term supplier relationships (of 6 years or longer on average)

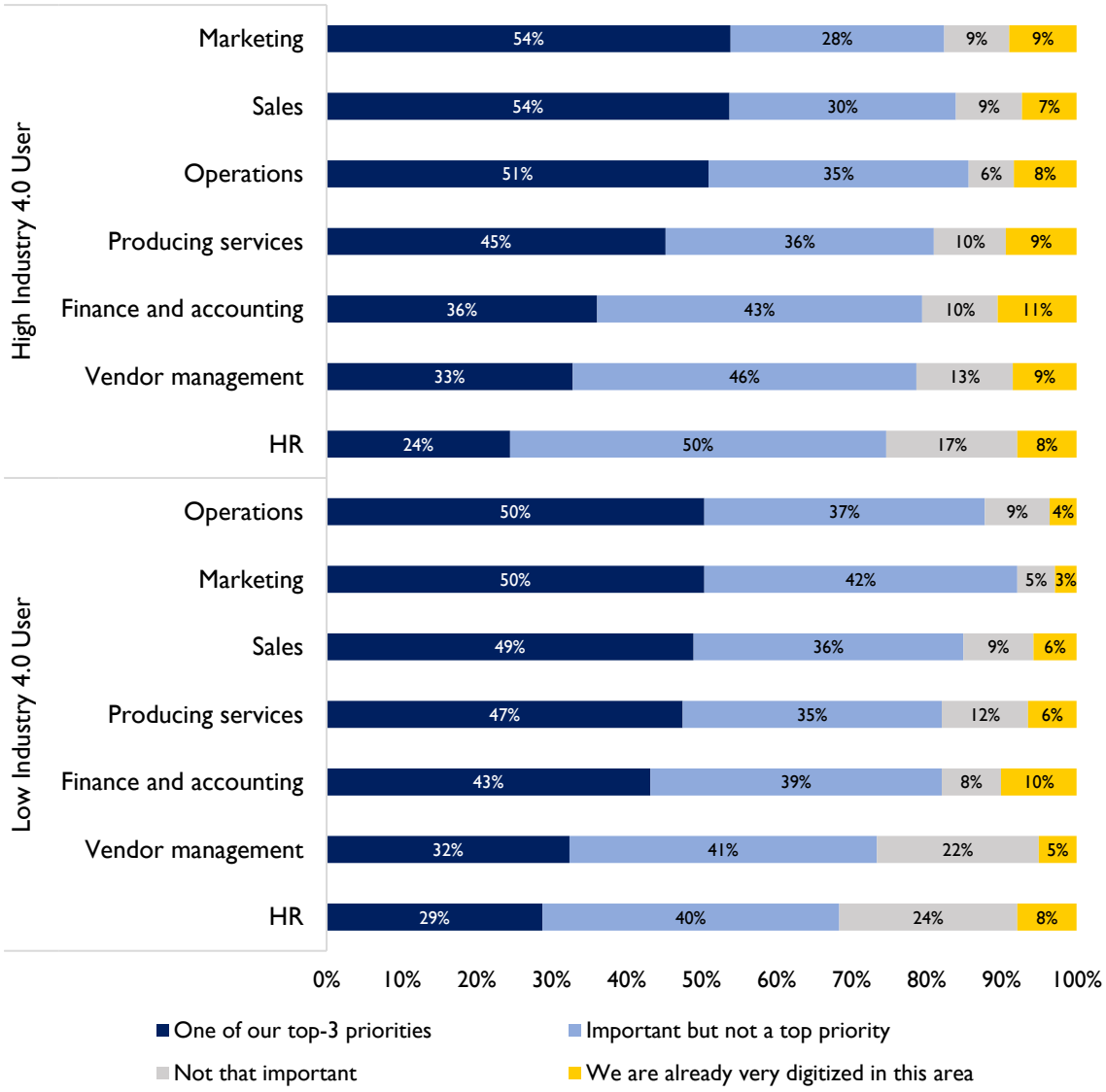
Figure 24 - Relative gains from AI investment, by firms' investment in AI



Sixth, while most surveyed firms want to digitize and leverage Industry 4.0 technologies, various knowledge, staff and cybersecurity challenges stand in the way. Firms that use Industry 4.0 intensively report especially strong prioritization of digital transformation in marketing, sales, and operations, with over half identifying each as one of their top-3 digital priorities. These firms also show notable progress on digitizing their back office operations, such as in finance, HR, and vendor management. Importantly, the data also reveal that low Industry 4.0 users are keen to digitize. Across nearly all business functions, a substantial proportion of

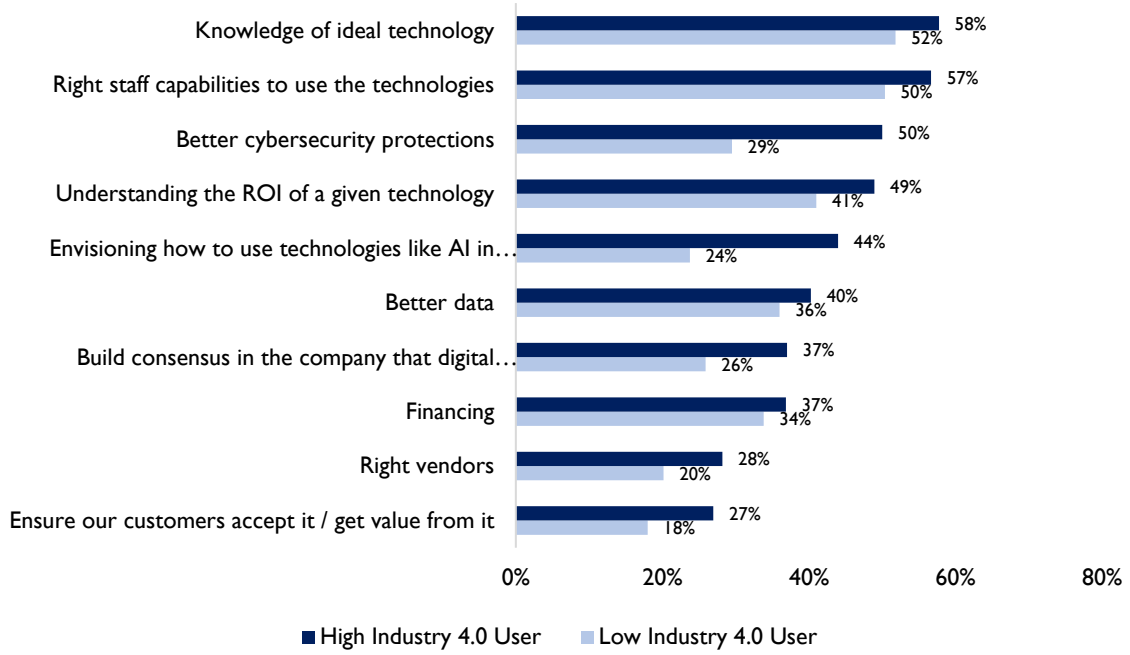
these firms rank digital transformation as a top or important priority, particularly in operations (50%), marketing (50%), and sales (49%) (figure 25).

Figure 25 – Importance of digital transformation for various business areas in 2025, by Industry 4.0 use



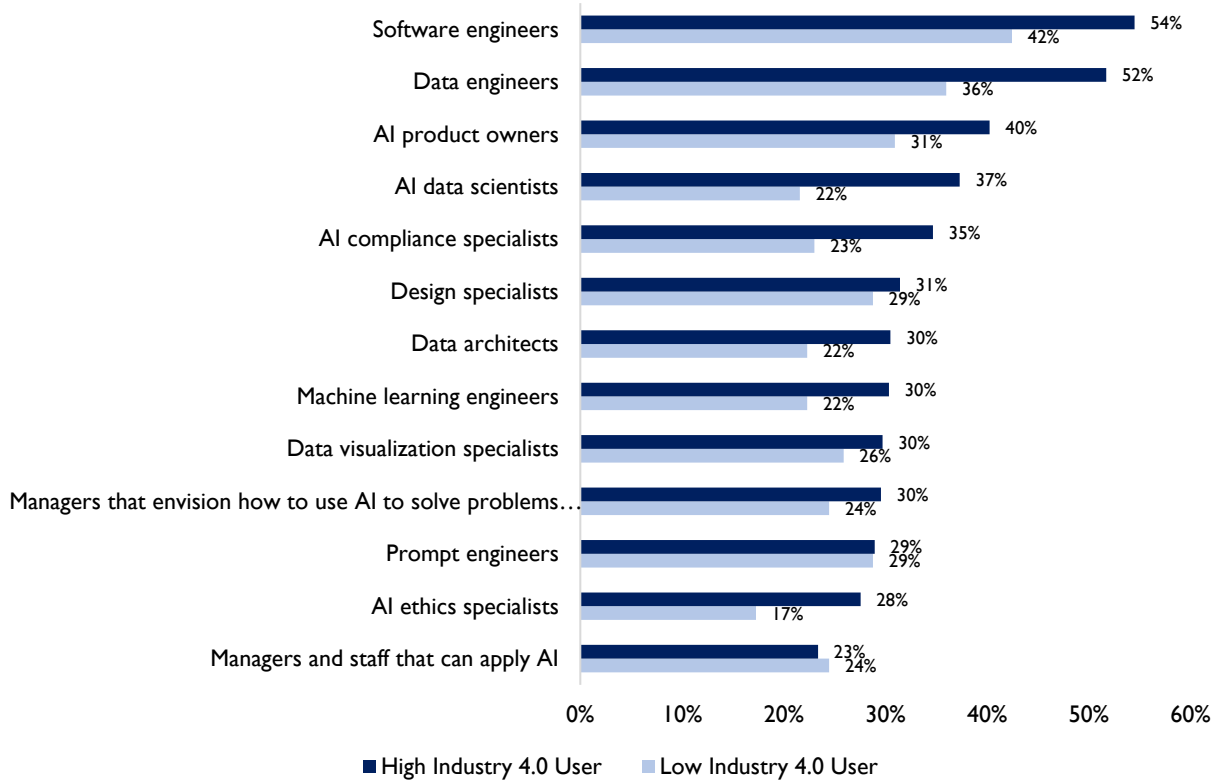
However, various policy challenges and constraints arrest regional digital service providers' use of Industry 4.0, including skills and financing gaps. Some 58 percent of intensive Industry 4.0 users need support identifying the ideal technology, 57 percent need staff with the right capabilities, and 50 percent need better cybersecurity protections (figure 26). The corresponding figures for firms with limited use of Industry 4.0 are 52 percent, 50 percent, and just 29 percent, respectively. In addition, 44 percent of intensive users require help envisioning how to apply technologies such as AI in different business contexts, compared to only 24 percent of low users.

Figure 26 - Firms' needs for digital transformation, by Industry 4.0 use



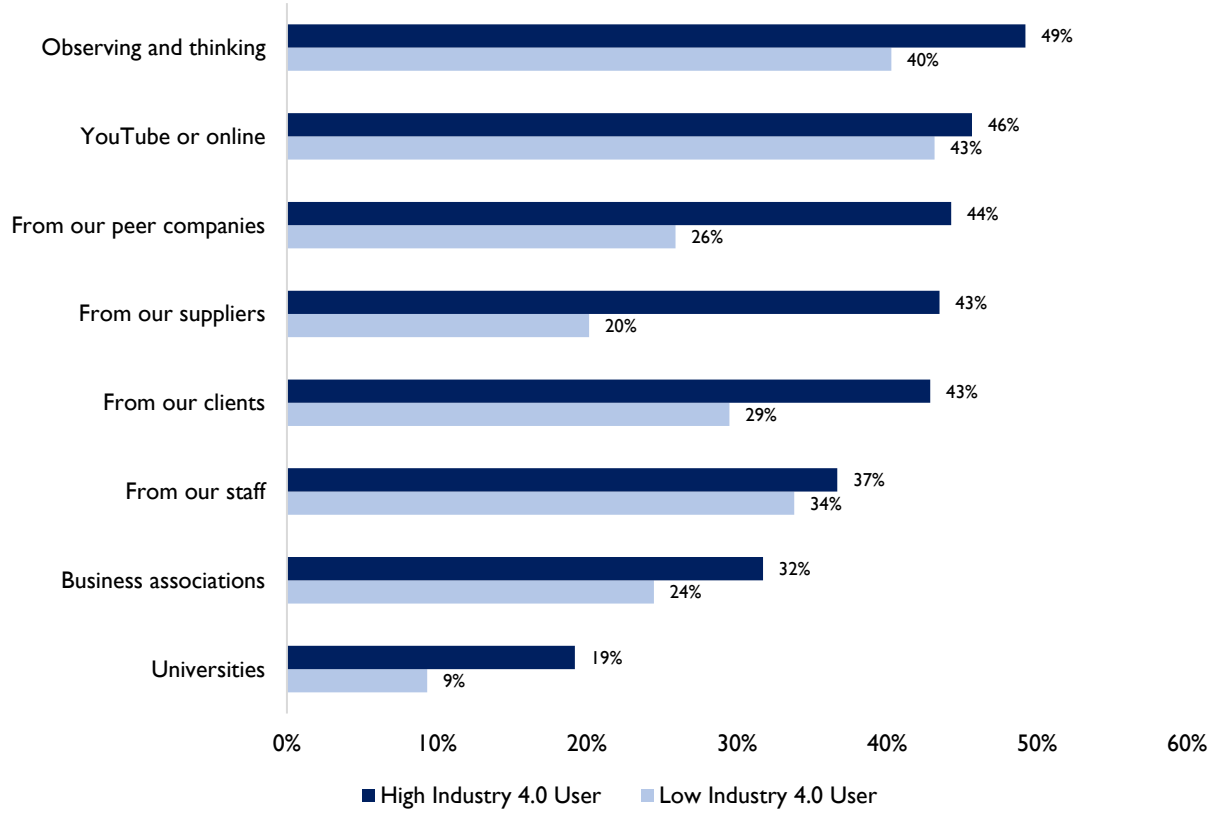
High-intensity Industry 4.0 users have higher needs for AI expertise, especially software and data engineers. 54 percent of high Industry 4.0 users need software engineers, while 42 percent of low Industry 4.0 users need them (figure 27).

Figure 27 - Firms' envisioned staff needs to use AI



Firms have so far sought to learn about Industry 4.0 by observing and thinking (49 percent of high Industry 4.0 users and 40 percent of low Industry 4.0 users), and learning from online (YouTube, their staff, peers, and clients and suppliers (figure 28).

Figure 28 - Firms' sources of learning about Industry 4.0, by current Industry 4.0 intensity,



In sum, the survey findings are as follows:

- The use of Industry 4.0 technologies has been growing across all firm sizes in East and Southeast Asia especially in the past three years.
- High-intensity users of Industry 4.0 outperform low-intensity users in terms of automation, revenue growth, and AI integration across business functions.
- High-intensity Industry 4.0 users are more export-oriented, with higher export intensity, market diversification, and value chain integration than their peers.
- High-intensity Industry 4.0 users also maintain longer-lasting client relationships, particularly as they mature, signaling stronger customer retention.
- Both high and low Industry 4.0 users prioritize digital transformation across business functions. High users face greater needs for AI talent, cybersecurity, and technology strategy, while low users are also eager to digitize but require support to overcome capacity and skills gaps.

The next section analyzes the potential relationship between Industry 4.0 and digital trade at the economy-level.

4. Does industry 4.0 capacity in an economy promote digital services exports and value chain participation? Initial econometric evidence

The survey data suggest that East and Southeast Asian economies have grown their digital trade at the time of proliferation of Industry 4.0 technologies and the rise of Industry 4.0-driven startups. The data also indicates that firms that use Industry 4.0 technologies are more export-driven and likelier to integrate in global value chains, and possibly have longer-standing international customer relationships.

To what extent are these relationships causal? How might Industry 4.0 technology adoption help boost digital services exports and participation in value chains?

Here, we go beyond correlations to exploring statistical relationships between Industry 4.0 intensity and digital exports. As there are no systematic measures of Industry 4.0 use in economies, this study uses as proxy for the intensity of Industry 4.0 in an economy the number of patents applied by residents, and as the proxy for the adoption of Industry 4.0 by industries the share of high-technology manufacturing exports of all manufacturing exports. The two variables that are rather widely available for all economics and years from the World Bank. Descriptive statistics are in appendix 2.

I also use net FDI inflow data to capture the presence of global technology companies (another Nextrade-built variable captures the presence of global tech companies in the region). In addition, the study preliminarily includes data on local industry 4.0 ecosystems, measuring the number of AI-driven startups in 25 economies in 2011-25.

The regressions use the gravity model, controlling for standard gravity variables such as size of the exporter and importer and distance between them. The hypothesis is that country pairs with strong Industry 4.0 capacity (proxied as the volume of patent applications) and strong capacity to transpose Industry 4.0 innovation into products and services (provided as the adoption of technologies in manufacturing industries) have greater digital services trade flows between them – and that the impact of the Industry 4.0 adoption is particularly notable in knowledge-intensive services industries where patents and Industry 4.0 capabilities offer a particularly strong value proposition. Foreign direct investment inflows and local Industry 4.0 ecosystems are expected to further promote local innovation and exports of digital services.

The model is as follows:

$$lnDSijt=\beta0+\beta1lnPatentsit+\beta2lnPatentsjt+\beta3HighTechShareit+\beta4HighTechSharejt+\beta5lnFDIit+\beta6AIecosystemit+\beta7lnInternetit+\beta8lnInternetjt+\beta9lnDistij+Zij\delta$$

where

DSijt denotes bilateral digital services exports from country i to country j in year t
Patents are the number of resident patent applications (proxy for Industry 4.0 capacity).
HighTechShare is the share of high-technology manufacturing exports in total manufacturing exports (proxy for Industry 4.0 adoption in industry).

FDI is net foreign direct investment inflows (control for presence of global tech companies).
Dist is bilateral distance in km.
Zijδ is a vector of standard gravity controls (common language, colonial history, contiguity).

In the baseline OLS model, the coefficients on patents for both the exporter and importer sides are highly positive and statistically significant (table 4). High-technology exports in manufacturing both the exporter and importer sides are also significant. FDI inflows also come out significant in column (3). Patents, high-tech exports, and FDI inflows are significant also with country and year fixed effects in column (3). For example, 10 percent increase in the number of patents in the exporting country raises exporter country's digital services exports by 0.4 percent, and a 10 percent increase in FDI inflows into the exporting country is associated with an increase in digital services exports of 3.74 percent. In experimental regressions, the size of the AI ecosystem also translates into more digital services exports.

The PPML model (preferred model for the gravity model) in column (4) can be interpreted as follows: a 10 percent increase in exporter's patent stock raises digital exports by 1.5 percent and a 10 percent increase in the importer's patent stock increases exports by 1 percent, indicating that technologically advanced importers demand more digital services. FDI is not significant in the PPML model perhaps simply because the variable is not specific to high-tech FDI or digital services. Nextrade FDI proxy for office locations of tech companies is significant but highly correlated with patents and fixed effects.

Table 4 – Regression results on digital services exports (in logs in OLS regressions, not in logs in PPML)

Independent variables	(1) OLS	(2) OLS	(3) Clustered HDFE OLS	(4) PPML
Internet connections in exporting country	1.206*** (0.014)	1.755*** (0.030)	0.051 (0.056)	0.285*** (0.068)
Internet connections in importing country	0.346*** (0.012)	0.651*** (0.023)	-0.144** (0.053)	-0.137** (0.042)
Number of patents in exporting country	0.578*** (0.002)	0.249*** (0.004)	0.043*** (0.021)	0.146*** (0.032)
Number of patents in importing country	0.528*** (0.002)	0.371*** (0.004)	0.056*** (0.025)	0.095** (0.031)
High tech as % of manufacturing exports in exporting country	0.019*** (0.0004)	0.200*** (0.005)	0.014*** (0.006)	-0.035 (0.001)
High tech as % of manufacturing exports in importing country	0.02*** (0.00037)	0.260*** (0.004)	0.013 (0.008)	0.017 (0.001)
Net FDI inflows		0.0547*** (0.006)	0.374*** (0.005)	0.06 (0.005)
Distance	-0.894*** (0.005)	-0874*** (0.007)	-0.864*** (0.024)	-0.493*** (0.005)
Contiguous	-0.0467 (0.025)	-0.196*** (0.036)	0.218** (0.143)	0.110 (0.134)
Common language	1.773*** (0.018)	1.418*** (0.248)	0.514*** (0.069)	0.369*** (0.115)
Colonial relationship	0.430*** (0.028)	0.532*** (0.039)	0.299*** (0.097)	-0.123 (0.117)
Fixed Effects	None	None	Exporter, Importer, Year	Exporter, Importer, Year
Clustering	None	None	Pair ID	Pair ID
Observations (N)	297,408	130,013	130,013	133,230
Overall R-sq	0.457	0.537	0.647	0.724

*** significant at 1 percent level; ** significant at 5 percent level; * significant at 10 percent level. Standard errors in parentheses.

To explore the heterogeneity in the responsiveness of digital services trade to Industry 4.0 innovation, I ran another regression interacting exporter patent intensity with a set of service subsector dummies. The results indicate that technical, trade-related, and other business services, consulting and management services exports are particularly strongly associated with patents, likely benefiting from proprietary tools and processes that are patent-protected or innovation-intensive. Computer services and financial services are also significant at 5% level. Insurance

and pension services and research and development services register relatively modest responsiveness to exporter patenting. These results suggest that exports of knowledge-intensive business services, such as technical, consulting, computer, and financial services, are particularly strong associated with innovation and Industry 4.0 intensity.

5. Policy implications

Over the past 20 years, the growth of digital services exports in East and Southeast Asia has outpaced the growth of merchandise and services exports. This transformation in the region's export basket has coincided with a striking digital transformation in regional businesses, including the adoption of Industry 4.0 capabilities. This study has sought to understand the connections between these two trends, hypothesizing that Industry 4.0 adoption by Asian digital services firms and economies is conducive to their digital exports and value chain participation.

The survey results as well as preliminary econometric evidence in this paper indicate that Industry 4.0 adoption and use is associated with digital services exports and value chain participation. Firms that are intensive users of Industry 4.0 technologies are more export-driven and have diversified their exports, and appear to have steadier, longer-term client relationships. At the country-level, innovation capabilities and use of high-tech services – two proxies here for Industry 4.0 intensity in economies – are associated with economies' trade in digital services.

However, the data also suggests that even if most regional firms are keen on digital transformation, their Industry 4.0 technology adoption is still a work in progress in East and Southeast Asia. In particular, businesses highlight challenges with access to expert staff, identifying appropriate technologies, and cybersecurity as key constraints to Industry 4.0 adoption. At the national levels, innovation capacity and firms' ability to leverage innovations into new value creation also needs to be enhanced.

To unlock the full potential of digital services in East and Southeast Asia's exports and regional and global value chains, regional policymakers and businesses should:

- **Build digital skills at scale for Industry 4.0 adoption.** Governments should expand national digital skilling initiatives through public-private academies focused on engineering, AI skilling, and data science. There are good examples in the region. The ASEAN-ROK TVET Mobility program is a US$5.8 million initiative launched by the ASEAN Secretariat and the Korean government to enhance Industry 4.0 readiness among technical and vocational educators across ASEAN.[21] It facilitates cross-border exchange, upskilling teachers in sectors like electronics and IT, and aligning curricula with evolving industry needs. The program emphasizes public-private collaboration, coordinated by the Korea Chamber of Commerce and Industry (KCCI). At the regional level, economies should prioritize mutual recognition of digital and AI-related certifications and create fellowship programs for mid-career professionals to gain hands-on Industry 4.0 experience.

- **Scale access to finance for Industry 4.0 adoption.** Governments can expand their innovation finance facilities tailored to digital services SMEs, including credit guarantees and matching grants. One good example is Malaysia's SME Automation and Digitalization Facility (ADF) supported by Credit Guarantee Corporation Malaysia (CGC) and Syarikat Jaminan Pembiayaan Perniagaan (SJPP) which provides 80 percent guarantees on bank loans for Malaysian SMEs, of up to US$725,000.[22] Multilateral development banks and

public development funds can play a catalytic role in de-risking early-stage investment into high-potential but capital-constrained digital firms.

- **Deepen domestic Industry 4.0 ecosystems, including with leading global cloud and AI companies.** Foreign investments can help catalyze Industry 4.0 innovation ecosystems and promote adoption. Governments could promote smart technology districts and clusters that promote co-creation among startups, traditional firms, and multinational technology providers. As an example, the Philippine Department of Trade and Industry has partnered with Bosch to launch an Industry 4.0 pilot factory, focused on advanced manufacturing technologies such as AI-driven automation, IoT, and data analytics.[23] The pilot site serves as a co-creation hub where Filipino startups, traditional manufacturers, and global tech firms jointly develop and test smart manufacturing solutions. Another example is Japan's AI Bridging Cloud Infrastructure (ABCI), operated by Japan's National Institute of Advanced Industrial Science and Technology since 2018.[24] The ABCI is a cloud-based supercomputer platform accessible to SMEs for AI applications in manufacturing and services. It deepens the domestic Industry 4.0 ecosystem by linking advanced cloud infrastructure with real-world industrial use.

- **Promote cybersecurity**. Businesses report that cybersecurity risks are a key barrier to adopting Industry 4.0 solutions. Both companies and policymakers should embed cybersecurity as a core pillar of Industry 4.0 strategies. This includes establishing or strengthening national cybersecurity frameworks aligned with global standards such as ISO/IEC 27001 and the NIST Cybersecurity Framework. Also public-private partnerships can accelerate adoption of secure-by-design technologies. For example, Singapore's Cybersecurity Labelling Scheme for consumer IoT devices encourages manufacturers to integrate security into product design and provides buyers with an easy-to-understand trust mark.

- **Regear export promotion to promote Industry 4.0-powered digital services exporters**. National export strategies should prioritize digital services exports and create targeted programs offering coaching, branding support, and matchmaking with international buyers in AI, cybersecurity, and cloud-based services. For example, the Japan External Trade Organization (JETRO) has reoriented its export promotion toward high-tech service sectors by launching programs like "AI Global Growth Program" and its Trade Tie-up Promotion Platform, which offer tailored coaching, branding support, and B2B matchmaking to Japanese firms in AI, digital health, and cloud services, connecting them with international buyers and investors in the U.S. and Europe.[25] The Korea Creative Content Agency (KOCCA) provides an export platform, one-on-one consulting, overseas business center matchmaking, and financing support to digital content and cybersecurity SMEs, enabling them to connect with buyers in Asia, North America, and Europe.[26] Governments should also use digital procurement platforms and B2B marketplaces to connect domestic service providers with foreign demand, especially from multinational firms operating in Asia-Pacific, Europe, and North America.

To incentivize Industry 4.0 adoption and use, governments could work in public-private partnerships with tech companies and Industry 4.0 leaders to promote 5G expansion and access to affordable cloud infrastructure in areas outside major urban hubs.

In addition, the region's digital policies should support interoperability, platform integration, and cross-border data flows that enable digital service firms to scale.

6. Conclusion

Digital services exports have become the leading driver of East and Southeast Asia's export growth and value chain integration. This study finds that this rise has unfolded in parallel with accelerating adoption of Industry 4.0 technologies by firms and economies. At the firm level, digital service providers that use AI, cloud, blockchain, and IoT intensively are more automated, grow faster, export more, serve more markets, and tend to enjoy more durable client relationships than peers with limited Industry 4.0 use.

At the country level, proxies for Industry 4.0 capacity and adoption – proxied here with patenting activity, high-tech manufacturing export shares, FDI linked to global tech firms, and the depth of AI and broader Industry 4.0 startup ecosystems – are positively associated with higher digital services exports, especially in knowledge-intensive business services.

At the same time, the region's Industry 4.0 transformation is far from complete. To fully unlock the potential of digital services in exports and value chains, East and Southeast Asian economies will need to pair continued investments in innovation, AI and digital skills, and Industry 4.0 ecosystems with targeted support for digital services exporters and enabling digital policies that foster interoperability and cross-border data flows. Doing so would help more firms transition from being simple users of digital tools to providers of high-value, Industry 4.0=driven services embedded in regional and global production networks.

Appendix 1 – Survey methodology and sample

This report draws on original firm-level data collected via a structured online survey administered by Nextrade Group between May 30 and June 4, 2025. The survey covered 800 digital services firms in Indonesia, Malaysia, Thailand, and Vietnam. The survey gathered detailed data on firms' adoption of Industry 4.0 technologies (such as AI, cloud, blockchain, IoT), usage duration, workforce composition, export activities, and performance metrics such as automation, revenue growth, and value chain participation.

The survey was conducted via the Pollfish platform, enabling respondents to complete the questionnaire on desktop or mobile. Pollfish's infrastructure provides high scalability, cost efficiency, and rapid fielding capabilities across diverse geographies. It was selected for its ability to precisely target respondents based on firm size, industry, digital services activity, and location. Nextrade Group has used this approach in multiple studies and validated its reliability through methodological comparisons with traditional CATI (Computer-Assisted Telephone Interviewing) surveys. These comparisons show highly consistent results between formats, with online surveys yielding attentive, high-quality responses while offering flexibility for respondents.

A rigorous multi-step quality control protocol was employed, including:

- Digital fingerprinting to prevent duplicate responses
- Device/IP controls to ensure single access per respondent
- Built-in attentiveness checks within the questionnaire

The sample consists largely of small and mediums firms with over 10 employees (figure 1-1). The firms surveyed are in a wide range of industries, led by accounting, IT, banking and finance, and advertising (figure 1-2). Most respondents are based in large cities with populations over one million, especially in Indonesia and Malaysia (figure 1-3).

Figure 1-1: Demographics of respondents by firm size and country

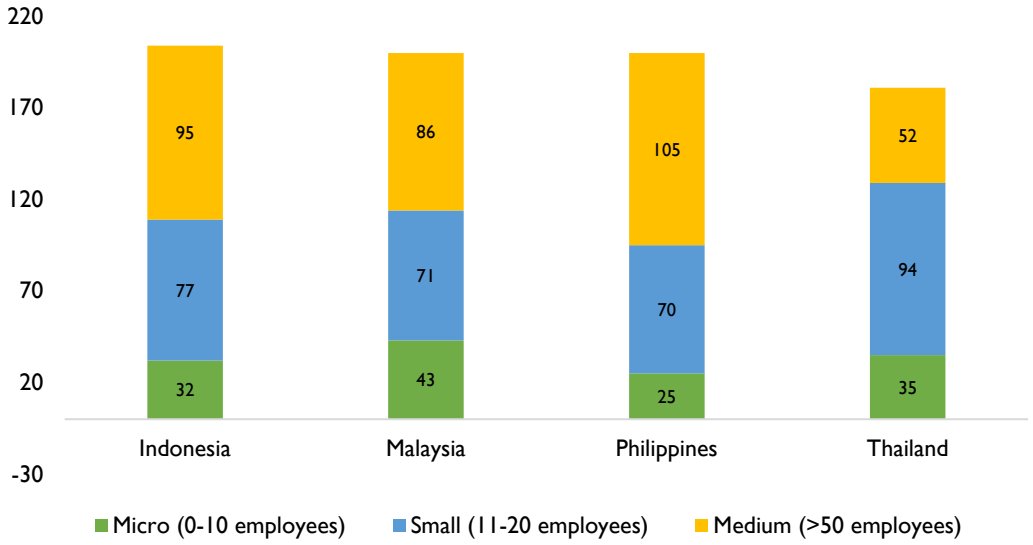


Figure 1-2: Survey respondents by industry and country

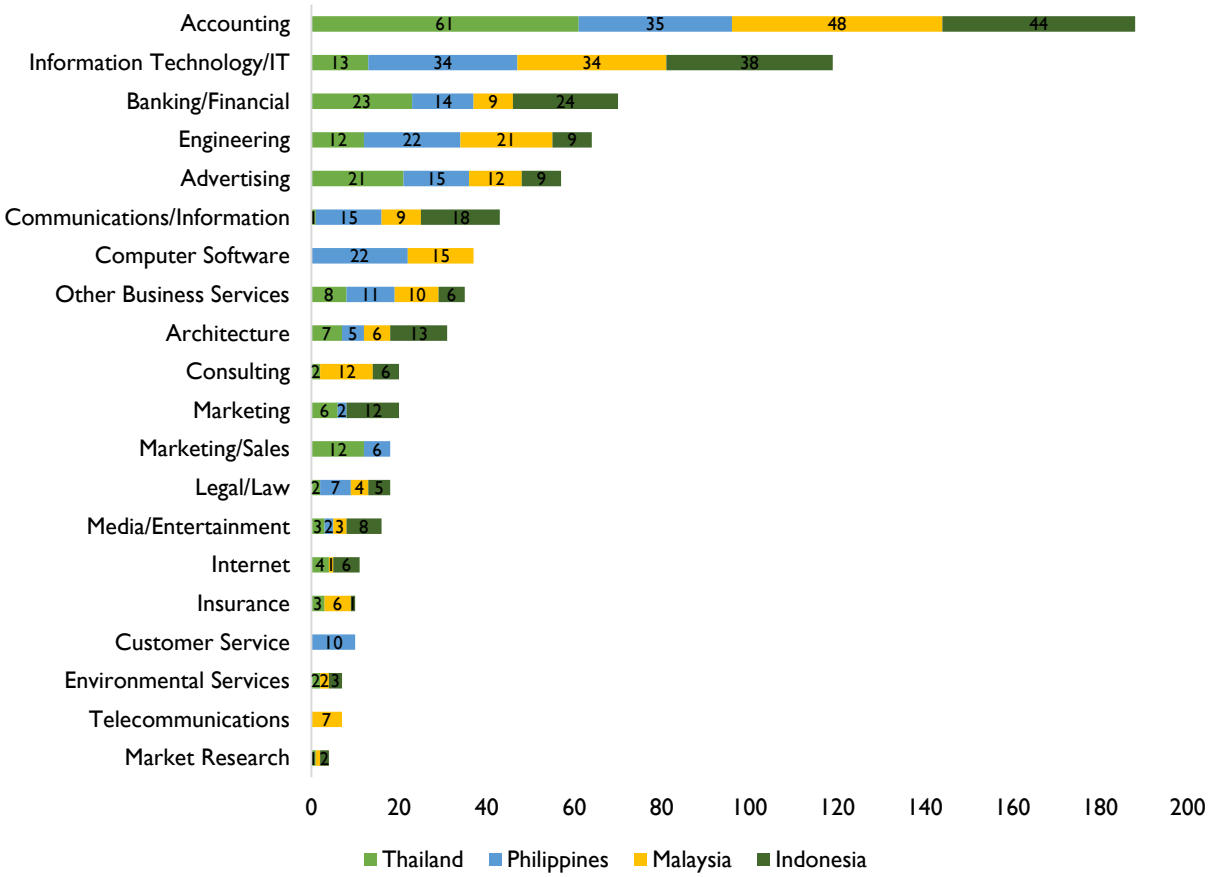
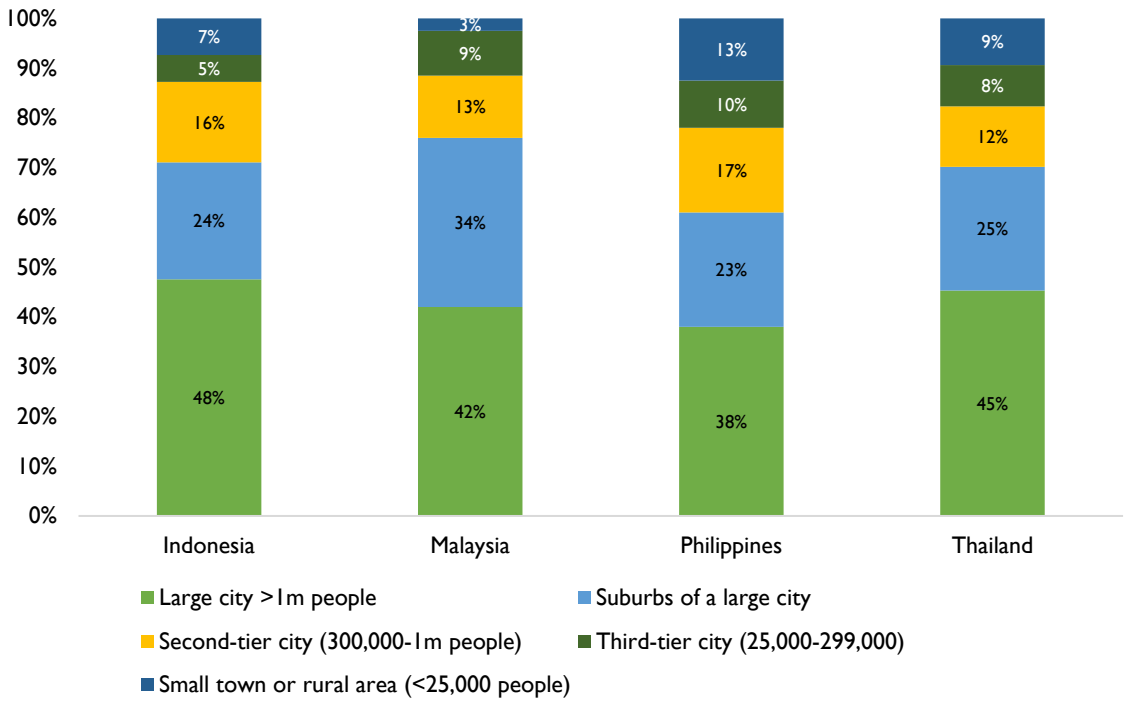


Figure 1-3: Survey respondents by location and country



Appendix 2

Figure 2-1: Industry 4.0 and digital services adoption, by firm managements' IT capabilities and years used

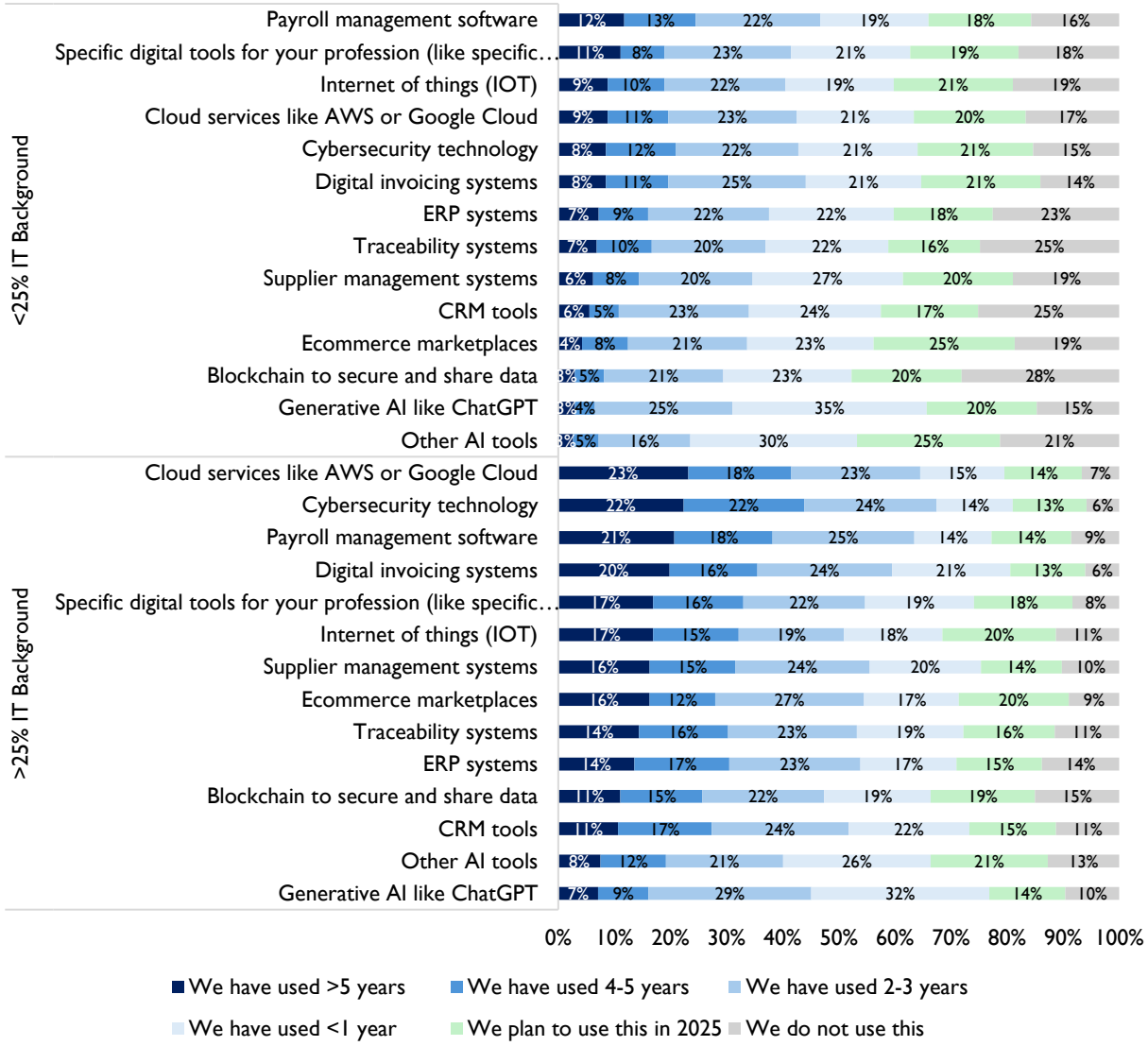


Figure 2-2: AI adoption in business functions, by Industry 4.0 use

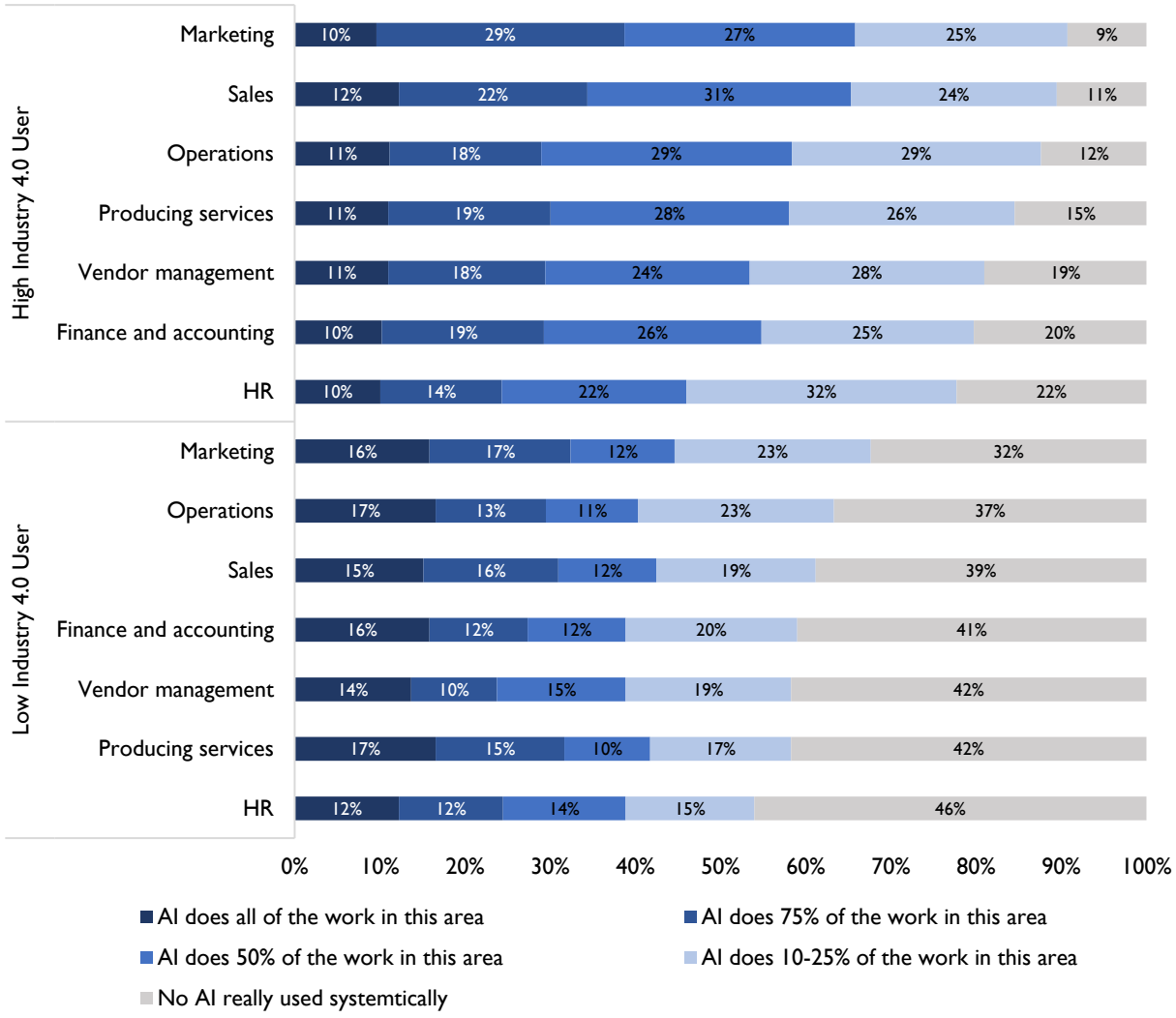


Table 2-1 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lntrade	438,989	0.52	3.56	-13.82	11.06
lngdp1	456,190	26.66	1.59	23.08	30.95
lngdp2	456,190	26.69	1.59	23.08	30.95
lnhightech	396,900	23.05	2.20	10.97	27.57
lninternet1	456,190	4.17	0.60	0.06	4.61
lninternet2	455,210	4.14	0.64	0.06	4.61
lnpatent1	385,140	7.19	2.35	0.69	14.17
lnpatent2	385,610	7.24	2.34	0.69	14.17
Hightech1	396,900	18.84	12.76	0.003	72.64
Hightech2	396,150	18.67	12.71	0.003	72.64
lnFDI	191,315	23.42	1.59	2.30	28.66
AI ecosystem size	136,309	634.5	2,129	1	56525
ln_dist	456,190	8.46	1.08	4.09	9.89
contig	456,190	0.04	0.20	0.00	1.00
comlang_off	456,190	0.07	0.26	0.00	1.00
colony	456,190	0.03	0.16	0.00	1.00

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