CSIS Working Paper Series

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Centre for Strategic and International Studies

EMERGING TECHNOLOGY IN INDONESIA'S MANUFACTURING SECTOR

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CENTRE FOR STRATEGIC AND INTERNATIONAL STUDIES

A Working Paper by
CSIS Indonesia

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Suggested Citation

Aswicahyono, Haryo, and Dandy Rafitrandi. 2020. "Emerging Technology in Indonesia's Manufacturing Sector". CSIS Working Paper. Jakarta: CSIS Indonesia.

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ACKNOWLEDGEMENT

This working paper is part of the Supporting Technological Transformation in Indonesia project, funded by the Asian Development Bank.

The study is a collaboration between an interdisciplinary research team from the University of Cambridge and the Centre for Strategic and International Studies in Indonesia, with valuable guidance and support from the Fiscal Policy Agency of Indonesia's Ministry of Finance. The main output of the study, "Innovate Indonesia: Unlocking Growth through Technological Transformation" is available for download at www.adb.org.

CENTRE FOR STRATEGIC AND INTERNATIONAL STUDIES

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ABSTRACT

This study explores Indonesia's opportunity in the Industry 4.0 era to revitalize its manufacturing sector performance using two approaches. Industry 4.0 is the term given to the fourth phase of the industrial revolution, characterized by technologies such as digitization and artificial intelligence (AI). First, we use input data from *Statistik Industri* to explore the relation between high-tech inputs and production. Our estimates found that high-tech inputs have a significant but small effect on productivity due to low technological adoption in Indonesia. Sectors such as rubber, motor vehicles and other manufacturing use a large share of high-tech inputs and receive substantial gains in terms of productivity. Second, using a firm-level survey, this approach aims to observe the level of adoption, especially considering Industry 4.0, of technologies such as AI, robotics and automation, 3D printing, cloud computing, and big data. From our survey, automation and robots are the Industry 4.0 technologies that see the highest awareness and utilization. Interestingly, there is a strong correlation between research and development (R&D) and Industry 4.0 adoption. Small- and medium-sized firms have a relatively lower probability of adopting more advanced technology due to their financial capacity. Lastly, we found low awareness of the government's Making Indonesia 4.0 masterplan.

Keywords: manufacturing, technology adoption, industry 4.0

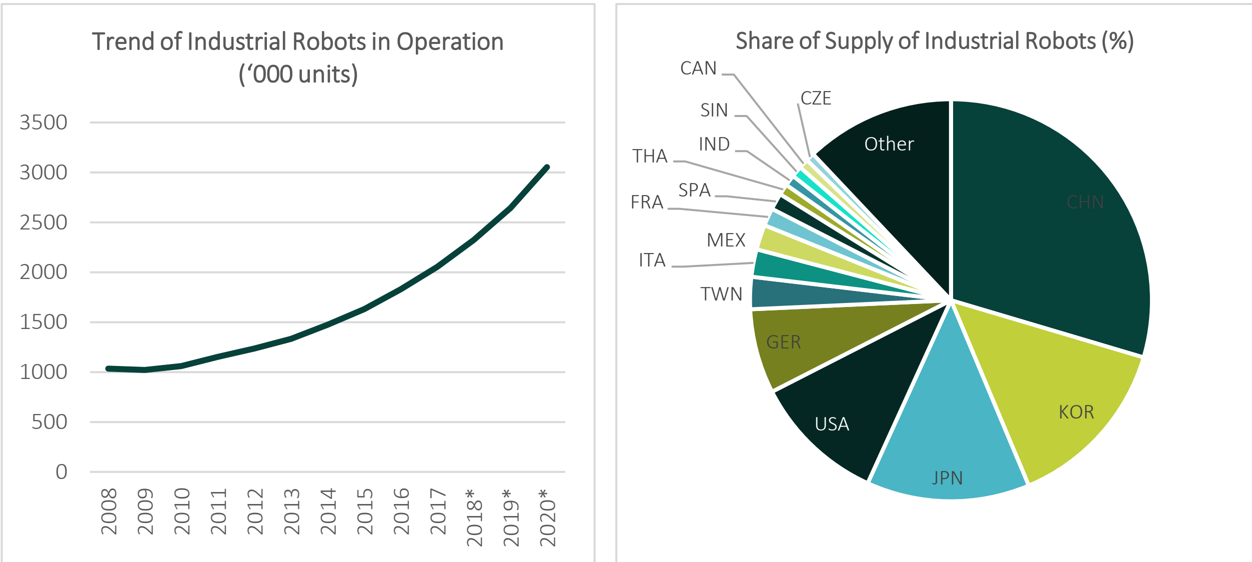
JEL codes: O14, O33

I. INTRODUCTION

Technology has transformed the economy with unprecedented speed and pervasiveness. The new wave of technology in the manufacturing sector usually refers to Industry 4.0, offering machine-to-machine communication through the Internet of Things (IoT), entire lifecycle improvement in product monitoring, as well as global value chain and logistics network optimization by the real-time exchange of information (Roca, 2019). Technologies such as AI, automation/robots and 3D printing will have a massive impact on business models and even the nature of work. For example, in the footwear industry, automated 3D printing can potentially increase production precision, minimize product variation and allow for customization. These technologies should result in higher productivity for firms and can remove humans from monotonous, repetitive, and hazardous jobs.

Will robots take over all jobs in the future? At least in the case of industrial robots, which are used heavily in the manufacturing sector, they are predicted to become more prevalent with around 3 million industrial robots in operation by 2020 (International Federation of Robotics, 2017). In Figure 1, the growth of industrial robots in operation increased almost threefold in the last decade. Five countries—China, Korea, Japan, the United States, and Germany—accounted for almost 75% of the total supply of industrial robots in 2016, with Asian countries the main driver.

Figure 1: Trend of Industrial Robots in Operation ('000 units) (a) and Share of Supply of Industrial Robots (%) (b)

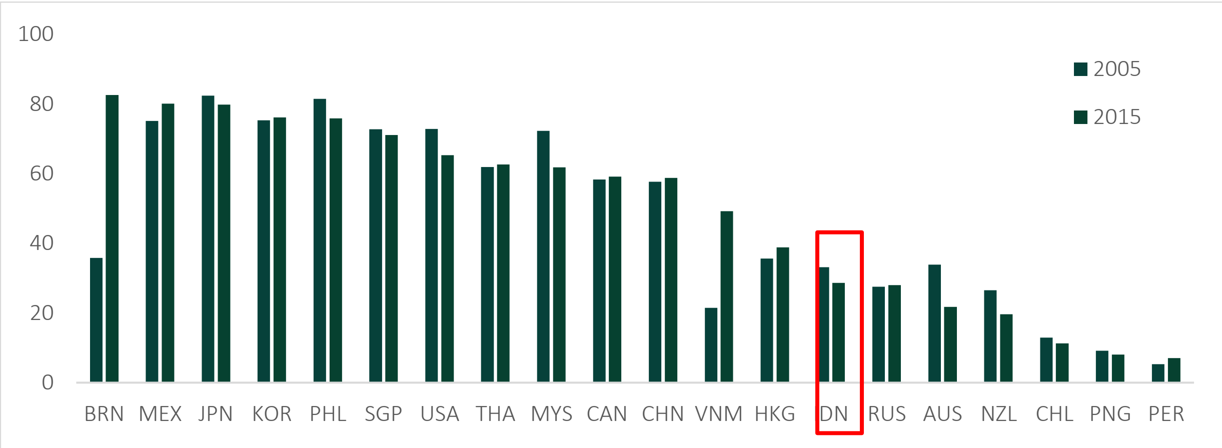


Source: International Federation of Robotics (accessed 20 May 2019).

In Indonesia, the manufacturing sector has been a significant contributor to the country's economic development. However, the share of manufacturing in Indonesia's GDP has declined since the 1998 Asian financial crisis. In 2002, the sector accounted for 31.9% of GDP, which continuously declined to 20.1% in 2017. Furthermore, from 1990-1996, the manufacturing sector saw double-digit growth on average compared with post-crisis, when the sector saw growth at half that rate. Plausible explanations are the manufacturing sector losing its competitiveness in recent decades due to poor infrastructure and high logistic costs, as well as a commodity boom that saw a significant increase in labor costs (Aswicahyono & Rafitrandi, 2018).

The consequence of the problems mentioned above is firms' inability to produce more sophisticated products, reflected by the low share of high-tech products in Indonesia's exports. Figure 2 shows that Indonesia's manufacturing exports have become less sophisticated.[1] Also, compared to other countries, Indonesia's medium- and high-tech exports are among the lowest, which means that most of Indonesia's manufactured exports have low value. For many years, Indonesia's top export products have been commodities such as palm oil and coal. Thus, there is a call for reformation in this sector.

Figure 2 Medium and High-Tech Exports (% manufactured exports)



Source: World Bank. WDI. http://data.worldbank.org/data-catalog/world-development-indicators (accessed 20 May 2019).

The Indonesian Industry Ministry inaugurated its "Making Indonesia 4.0" plan in 2018, aiming to revitalize the country's manufacturing industry and prepare it for opportunities and challenges in the Industry 4.0 wave. It comprises priority sectors, targets, potential benefits and challenges, which translate into 10 key national strategies to fulfill Indonesia's aspiration to become one of the world's top 10 economies by 2030. This is a worldwide trend, as there is growing interest from the United Kingdom, France, Japan and Korea in the "industrial policy 4.0" as a response to concern about the manufacturing sector's growth, share and jobs (Warwick, 2013). Through Making Indonesia 4.0, the government is committed to developing

[1] The data from UN COMTRADE is downloaded in SITC Revision 3, 3-digit, by reporting country, year, partner code, commodity and flow (export and re-export). SITC medium technology: 266, 267, 512, 513, 533, 553, 554, 562, 571, 572, 573, 574, 575, 579, 581, 582, 583, 591, 593, 597, 598, 653, 671, 672, 678, 711, 712,713, 714, 721, 722, 723, 724, 725, 726, 727, 728, 731, 733, 735, 737, 741, 742, 743, 744, 745, 746, 747, 748, 749, 761, 762, 763, 772, 773, 775, 778, 781, 782, 783, 784, 785, 786, 791, 793, 811, 812, 813, 872, 873, 882, 884, 885; SITC high technology: 525, 541, 542, 716, 718, 751, 752, 759, 764, 771, 774, 776, 792, 871, 874, 881, 891.

firms' capacity to adopt Industry 4.0 technology and increase productivity in Indonesia's manufacturing sector.

The objective of this study is to fill a gap in the literature on observing the state of technological adoption in Indonesia's manufacturing sector, especially amid recent developments in digitalization and technological disruption. The study can be used to assess the level of readiness, evaluate current challenges and recommend policy responses related to recent technological transformations.

We use four approaches in this study. First, the study will discuss typical technological adoption indicators at a macro level, such as trends in structural change, international trade, Foreign Direct Investment (FDI), Total Factor Productivity (TFP) and information and communication technology (ICT) contributions. Second, this study utilizes two datasets, the World Bank Enterprise Survey (WBES) and International Federation of Robotics (IFR), related to technological adoption among manufacturing firms. Third, the study explores the connection between technology and firms' productivity using input data. All firms' input products are classified based on United Nations Industrial Development Organization (UNIDO) research and development intensity, i.e. high-tech and low-tech input. Last, we also conduct a firm-level survey in four provinces to complement the analysis more specifically on the utilization of Industry 4.0 in Indonesia.

The introduction provides details about the background of this research, relevancy in terms of the manufacturing sector's current challenges and an overview of some common arguments from the subsequent chapters. A review of the literature on disruptive technology and Industry 4.0, as well as Indonesia's readiness and manufacturing sector trends from various perspectives, focusing on the 2000s, will be discussed later. The next three chapters deal with methodology and data, empirical econometrics model and survey analysis. The final part will discuss policy implications and recommendations.

II. INDUSTRY 4.0 AND MAKING INDONESIA 4.0

This chapter provides a brief explanation of the nature and recent trends of disruptive technology, as well as global experiences in the manufacturing sector. We also look closely into how the definition of disruptive technology differs across the literature. This chapter includes factors and measurements to illustrate this concept. Furthermore, we will also discuss the likely impact on firms' performance, such as productivity and labor. The last part covers preliminary findings on Indonesia's response and readiness to face Industry 4.0. Table 1 below illustrates several examples that particular organizations have used.

Table 1 Key Characteristics/Technologies in Industry 4.0

Boston Consulting Group	Institute for Manufacturing (IfM)	UNIDO
• Internet of Things (IoT) • Horizontal and vertical integration • Big data and analytics • Cloud computing • Additive manufacturing • Augmented reality • Cybersecurity • Simulation • Autonomous robots	• Cyberphysical systems • Cloud computing • Big data • Artificial intelligence (AI) • Machine learning • IoT	• Smart communities: factories, cities, and societies • Big data • Cloud computing • AI • Blockchain • Cyberphysical systems • Additive manufacturing • Simulation and visualization models

UNIDO = United Nations Industrial Development Organization.

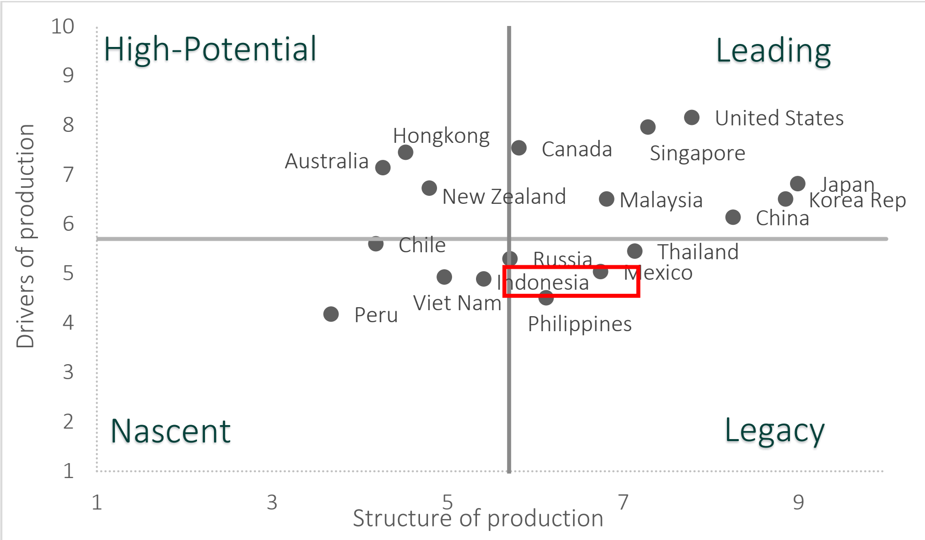
Source: Author's compilation

The literature is limited as this topic is quite new, especially in the manufacturing sector. Most studies focus on developed countries such as the US and European Union member states. Topics that have received a decent amount of attention include robotics, automation, AI, and its impact on the economy, especially on employment. For example, a study by Frey and Osborne (2017) projects that almost 47% of total employment in the US that could be automated in the near future. On the impact of robots and how they relate to labor productivity and wages, Graetz and Michaels (2017) found that robots raised the annual growth of labor productivity by about 0.37 percentage points between 1993 and 2007. Also, the use of robots per hour worked appears to boost total factor productivity and average wages.

Furthermore, an additional robot could replace six workers, and one robot per thousand workers can reduce wages by 0.5% (Acemoglu and Restrepo, 2017). Based on European Manufacturing Survey (EMS) data, the most comprehensive firm-level data to date, firms utilizing robotics have higher labor productivity but there was unclear evidence on labor displacement (European Commission Report on Robotics and Employment, 2016). Using automation patent data from 1976 to 2014 in the US, Mann and Puttmann (2017) find that automation causes employment in manufacturing to fall, but increases employment in services with an overall positive effect. This is consistent with Dauth et al. (2018) which studies German data from 1994 to 2014.

Indonesia is still at a nascent stage in terms of Industry 4.0 and digitalization, according to the Readiness for the Future of Production Report 2018 (Figure 3). Compared with other countries in the region, Indonesia lags not only behind "the leaders" such as Singapore, Malaysia, and China, but also behind its peers such as the Philippines (in structure) and Thailand (both in terms of structure and as a driver of production). Indonesia is at almost the same level as Vietnam. However, Vietnam has a more favorable investment and trade regime compared with Indonesia. It has proven it can effectively attract a large amount of FDI, and gives the government room to ratify trade agreements aggressively.

Figure 3 Readiness for the Future of Production Report 2018[2]



Source: World Economic Forum Insight Report, 2018 (accessed 20 May 2019).

One of the factors causing Indonesia to lag behind other countries is a lack of innovation. Damuri et al (2018) show that most R&D expenditure is from government and public universities (around 80%). In manufacturing, only a limited number of large private companies have an awareness of innovation. Low foreign investment and labor restrictiveness, a lack of incentives, the substantial cost of investment, as well as a lack of basic science and technology and an innovation environment are several reasons why Indonesia has a relatively weak innovation culture compared with other countries. As a result, many multinational enterprises (MNEs) have R&D facilities outside Indonesia, such as in Malaysia, Thailand and Vietnam.

Aiming to accelerate the manufacturing sector's adoption of Industry 4.0, the Making Indonesia 4.0 masterplan has several ambitious targets for 2030: a 10% net export-to-total GDP ratio; a twofold increase in productivity-to-cost; and a 2% R&D spending share of GDP in 2030. For comparison, Indonesia's R&D spending share in 2013 was only 0.08% of the total GDP. Assuming full utilization of Industry 4.0, it estimated that GDP growth would increase by

[2] Drivers of production consist of technology and innovation, human capital, global trade and investment, institutional frameworks, sustainable resources, and a demand environment, while key variables for structure production are complexity and scale.

1%-2% per year from 2018 to 2030, with an additional 10 million jobs, and manufacturing sector expansion to more than 20% of total GDP. There are five top sectors, based on economic impact, attractiveness and feasibility in each sector: food and beverages, textiles and apparel, automotive, electronics, and chemical. Finally, the masterplan is also equipped with 10 key national priorities, as depicted in the figure below.

Figure 4 Making Indonesia 4.0 National Priorities

Source: Ministry of Industry (2018)

Box. 1: Making Indonesia 4.0: Missing Links

The government's commitment to set up a masterplan should be appreciated. However, there are several important factors not yet discussed in the masterplan, such as an urge to de-bottleneck classic problems such as the global value chain (GVC) approach; improving the services sector; and the need for data related to Industry 4.0. New plans and initiatives are good but the impact of solving some traditional problems might bring greater benefits and help the growth of Industry 4.0 in Indonesia as well.

By using the supply-chain approach, the government could identify bottlenecks and the sources of low competitiveness in Indonesia exports. For example, one of the priority sectors is food and beverages, which is closely related to small and medium enterprises (SMEs) and food policy and regulations. In recent years, the government has placed heavy regulations and restrictions on the imported food products of salt, sugar and beef. Given the unequal supply and demand in the domestic market, these policies are one of the reasons for high volatility in food prices in Indonesia. Furthermore, an auction for these commodities will only lengthen the supply chain, increase corruption and close SMEs' access to affordable inputs.

Second, the importance of service sector reform should also be addressed. As the global value chain has managed to become an important platform in international trade, especially exports, service sector efficiency has become a crucial determinant for firms to decide on the locations of production hubs. So, what is the role of the services sector in the global value chain? The sector enables services that provide "glue" for other sectors. Some examples are transportation, telecommunications and information technology services. This means that the value added which is created by these sectors is embodied in the output of production. The other role of the sector is services that stand as pure outputs, for instance banking and insurance services. Given this unique feature, the value added from the services sector is often underreported because it is simply hard to calculate. Note that around 40% of the total value is created in the United States, while the rest of it has been offshored. Particularly, service sectors such as research and development, design, advertising and marketing, data processing, and transportation and insurance are provided by foreign companies.

Last, it is necessary to have more comprehensive data about the progress of this masterplan. The Central Statistics Agency (BPS) should cooperate with the private sector, e.g. associations, universities, research institutes and thinktanks to gather Industry 4.0 related data so that the policies derived from the masterplan can be supported by comprehensive firm-level data, for example the European Manufacturing Survey (EMS). BPS surveys e.g. *Statistik Industri* and *Survei Tenaga Kerja Nasional* are not sufficient for policymakers as they still do not capture recent developments in technology and jobs.

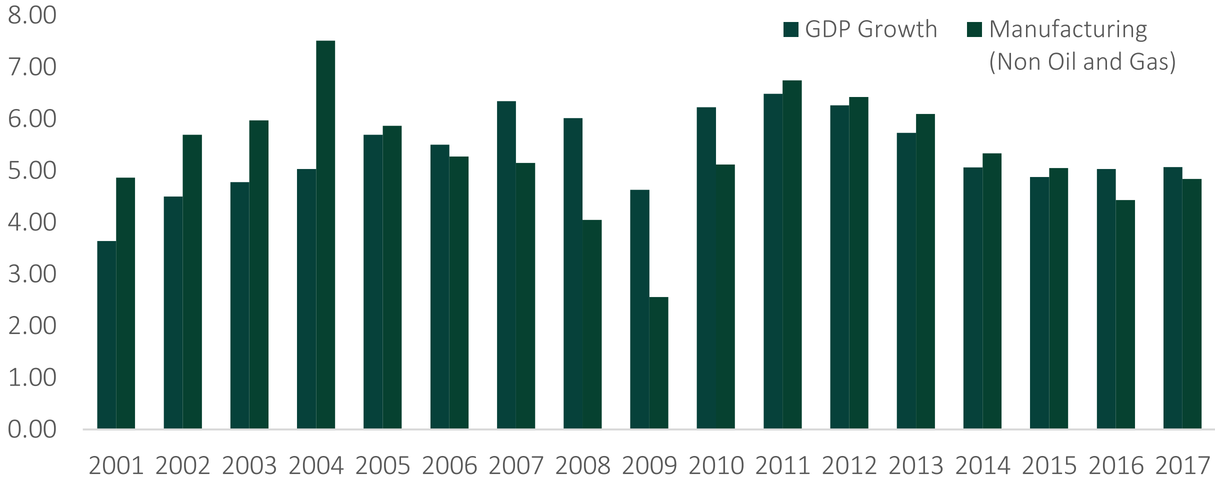
III. POTRAIT AND TECHNOLOGICAL ADOPTION IN INDONESIA'S MANUFACTURING SECTOR

Thee (2005) argues that international trade (especially imported capital goods) and FDI are important channels for technological adoption. Therefore, higher exports and imports, especially in ICT products and FDI inflow in high-technology intensity sectors, should reflect a catalyst to prevail in this "disruptive" period. Beyond that, this paper also discusses total factor productivity (TFP) as one of the proxies to measure technological progress, knowledge accumulation, resource allocation, and human capital. These indicators will be discussed further in the next section.

Indonesia's Manufacturing Sector and Technology: A Snapshot

This section captures a snapshot of the performance of the manufacturing sector. In the last 15 years, Indonesia's economic growth improved by 5.52% on average per year, while manufacturing saw 5.36% growth. Figure 5 shows that manufacturing growth was more volatile than economic growth. Note that from 2005 until 2009, there was a dramatic declining trend in manufacturing growth due to the global financial crisis, which resulted in weak demand from the global market. Manufacturing growth started to pick up in 2010, until declining again in 2016.

Figure 5 GDP and Manufacturing Growth 2001-2017 (%)

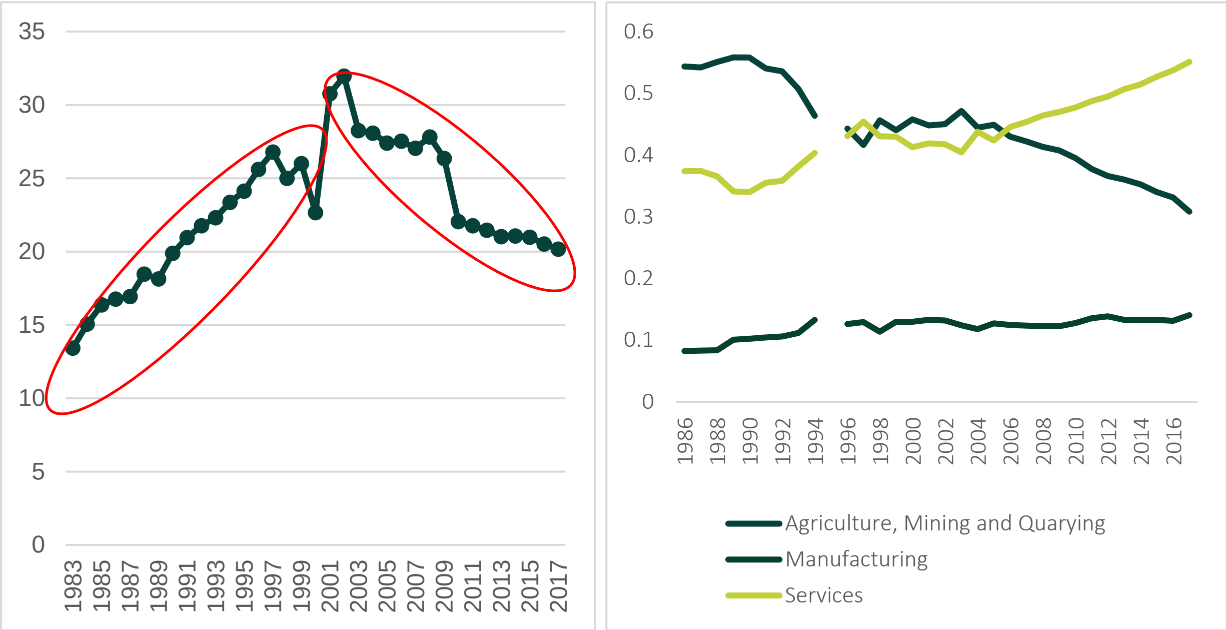


GDP = gross domestic product

Source: Central Statistics Agency (BPS)

Figure 6 illustrates the trend of the share of the manufacturing sector in GDP and employment from the 1980s until now. The share of the manufacturing sector in GDP has been falling over the last 15 years. It is a different story compared with the precrisis period, when there was an increasing trend. Furthermore, the share of manufacturing workers is relatively stagnant. Both the agriculture and services sectors drastically changed the structure of employment in the economy, as services surpassed agriculture as the largest sector in terms of employment in 2005.

Figure 6 Share of Manufacturing Sector in GDP (a) and Total Employment (b)



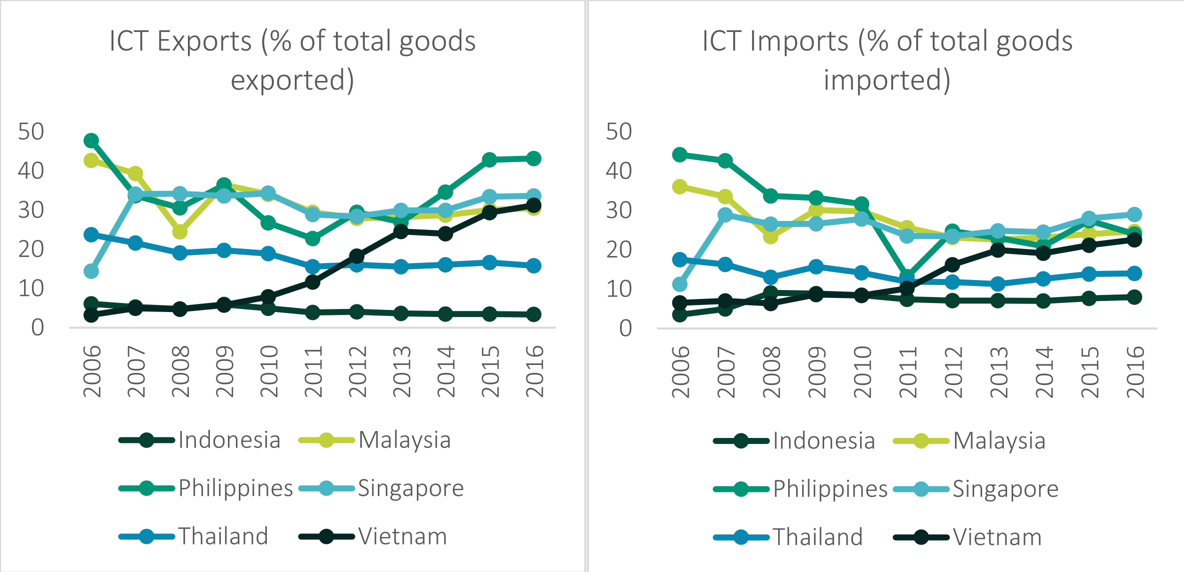
GDP = gross domestic product

Source: Central Statistics Agency (BPS) (accessed 20 May 2019)

In this part, we take a closer look at technological adoption indicators using trade data, i.e. exports and imports in the manufacturing sector. According to UN-COMTRADE data, Indonesia's ICT[3] exports and imports are the lowest among Association of Southeast Asian Nations (ASEAN) countries. For exports, the trend declined from 6.1% in 2006 to 3.4% in 2017, while there was an increase in ICT imports from 3.5% in 2006 to 8% in 2017 (Figure 8). Vietnam is the only country in ASEAN that has had a consistent increase over the last 10 years, surpassing Thailand and Indonesia. Some literature argues that this trend is because of the substantial FDI in Vietnam. To verify this, we will discuss the trend of Indonesia's FDI in the manufacturing sector.

[3] ICT exports are defined as computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous).

Figure 7 ICT Exports and Imports 2006-2016



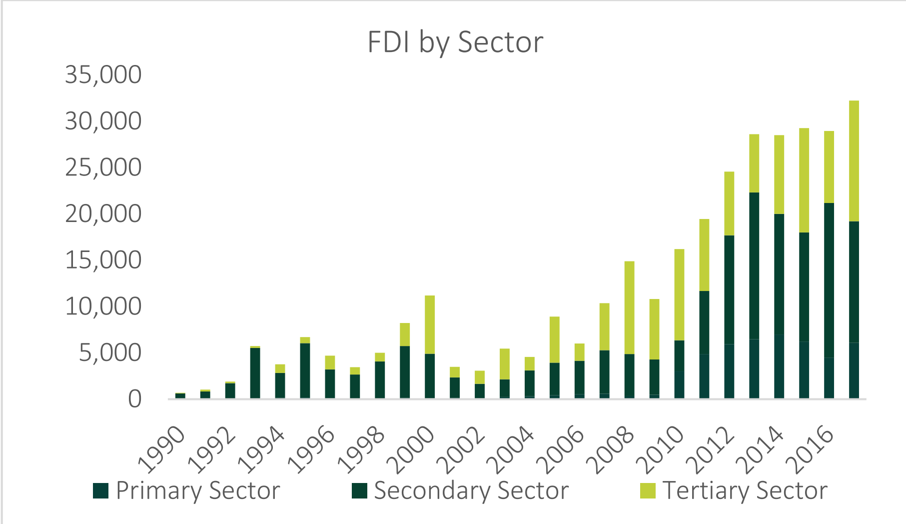
ICT = information and communications technology

Source: UN-COMTRADE

As mentioned, FDI has had an important role for innovation and diffusion in the past. Therefore, the government needs to improve the current investment climate to attract more FDI to the country, especially in high-tech and Global Value Chain (GVC)-oriented sectors. In the last two decades, FDI realization in Indonesia was at its highest level in 2017 at $32 billion, after a relatively stagnant period from 2013-2016. Investors are still predominantly attracted to Indonesia's manufacturing sector compared with the agriculture and services sectors. There was a shift in FDI in 2010, when FDI growth in the primary sector started to multiply, which might have a connection with booms in commodities such as palm oil and coal. The services sector also grew consistently, especially over the last five years.

Proportionately, the manufacturing sector's FDI is relatively stagnant. Capital intensive sectors such as the metal, machinery and electronics, and chemical and pharmaceutical industries are the top FDI recipients. One reason for this is that the sectors are the most liberal sectors for FDI. However, the agriculture and services sectors have been gradually catching up with the higher growth rate in recent years. In other words, FDI is still flowing to Indonesia's high-tech sectors, but the connection between FDI and innovation seems to have weakened.

Figure 8 FDI Realization Trend 1990-2017

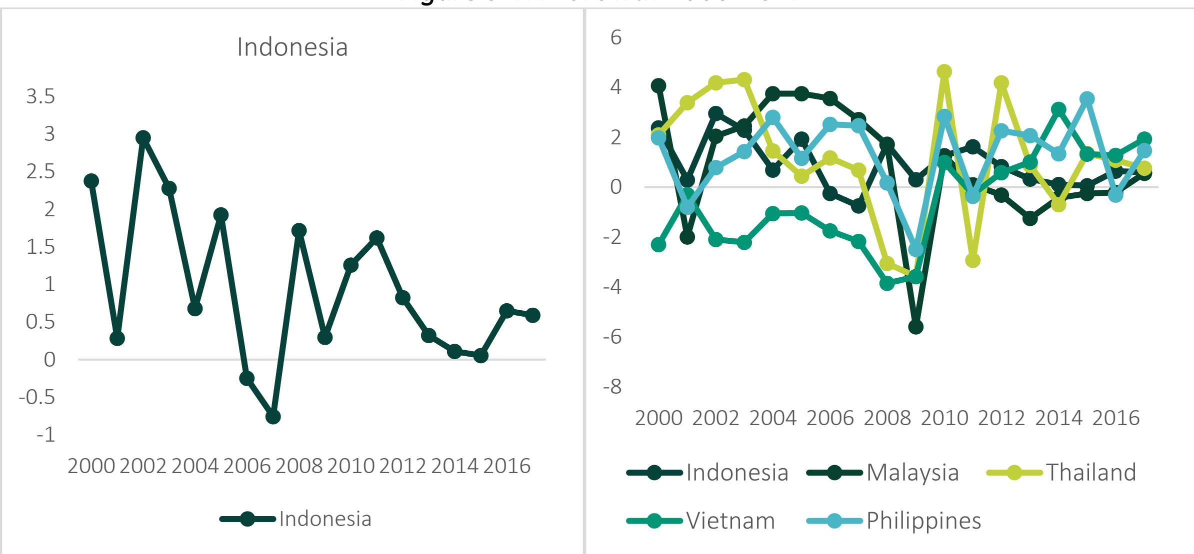


FDI = foreign direct investment

Source: Investment Coordinating Board (BKPM)

To estimate the country's productivity, TFP is one proxy that shows technological adoption. Figure 10 shows that Indonesia's TFP growth is still positive, but has been on a declining trend since 2011. This means that although the Indonesian economy has moved toward a better productivity level, the change in knowledge accumulation, human capital improvement and technological progress has slowed since then. As a comparison in Figure 10, Indonesia saw stable positive TFP, albeit slower growth, compared with Vietnam and the Philippines after 2011.

Figure 9 TFP Growth 2000-2017

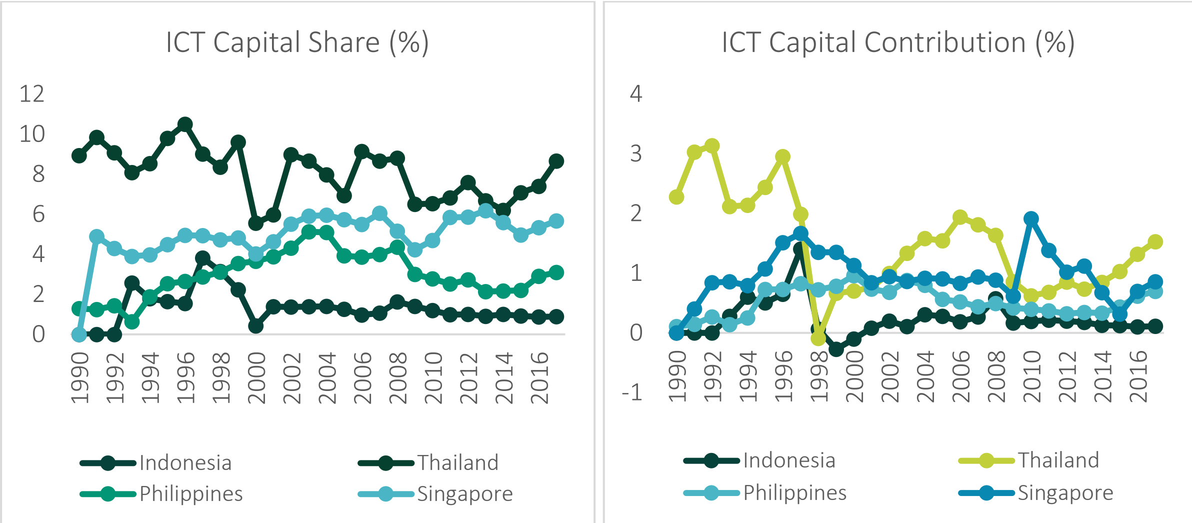


TFP = total factor productivity

Source: Conference Board (accessed 20 May 2019)

To complete the picture regarding technology and productivity, one important indicator is to compare capital share in the economy. Higher capital share means that a country uses capital more intensively than other inputs such as labor. Specifically, capital can be divided into two groups—ICT and non-ICT capital share.[4] A greater ICT share means more technology is involved in the production process. Figure 11 shows that the ICT share was stagnant from 2000 to 2017, at around 1%. The highest ICT sector share was 3.8% in 1997. The same applies to ICT capital's contribution to economic growth.[5] A study by Motobashi (2005) found that ICT capital significantly improved firms' productivity, especially for foreign-owned firms. De Bondt & Polder (2015) also reached the same conclusion by classifying ICT into four groups—hardware, networks, purchased software, and own-account software.

Figure 10 ICT Capital Share and Contribution 1990-2016



ICT = information and communications technology

Source: Conference Board (accessed 20 May 2019)

In summary, the manufacturing sector has been stagnated in terms of growth and employment since the Asian financial crisis. Indonesia is still struggling to improve its competitiveness and is trapped in low value-added export and import products, especially in ICT. Its failure to enhance FDI and improve the investment climate has caused Indonesia to fall behind its peers. Although capital intensive industries such as chemicals and machinery are still attractive to investors, a declining trend in TFP growth suggests that Indonesia relies heavily on investment in physical (non-ICT) capital, rather than ICT capital, to achieve economic growth. A small contribution of ICT capital to growth and declining TFP growth over time might also reflect long-term declining competitiveness. The government should consider a comprehensive plan to improve its trade and investment regime and give incentives for firms to increase their ICT capital spending.

Firms' Technological Adoption in Indonesia

This section provides a more micro and sectoral analysis to complement the picture of technological adoption in the manufacturing sector. We will discuss two relevant databases as valuable datasets—the World Bank Enterprises Survey (WBES) and the International Federation of Robotics

[4] ICT capital share is the share of ICT capital compensation in GDP.

[5] ICT capital contribution is the contribution of capital services provided by ICT assets to GDP growth.

(IFR). Both databases contribute to a great extent to our sectoral analysis and as the basis of our firm-level survey.

The WBES has a comprehensive questionnaire with good-quality size and sectoral coverage. It also has a dedicated chapter on technology and innovation, which is very useful for our survey as a starting point. However, the survey has not yet captured two important sectors, automotive and electronics, and has no questions regarding Industry 4.0. technology. On the other hand, the IFR data focuses on stock and the flow of robotics across sectors and countries. Therefore, the data provides a good approximation in terms of sectoral utilization and cross-country comparison. However, Indonesia does not have a secondary data provider like Japan and Korea to verify the primary data from suppliers. Also, many robots are classified under the "unspecified" sector, due to difficulties in defining the area of application.

From the WBES in 2015, there are some interesting findings regarding innovation and technology. First, rubber and plastic products and textiles have the highest usage of foreign companies' technology licenses. Chemicals and chemical products have the highest online presence from having websites and using email extensively. On product and process innovation, the food sector and rubber and plastics are the leaders. Last, chemicals and chemical products are heavily invested in R&D, while textiles and garments are the lowest spenders on R&D.

Table 2 Sectoral Technological Adoption (2015)

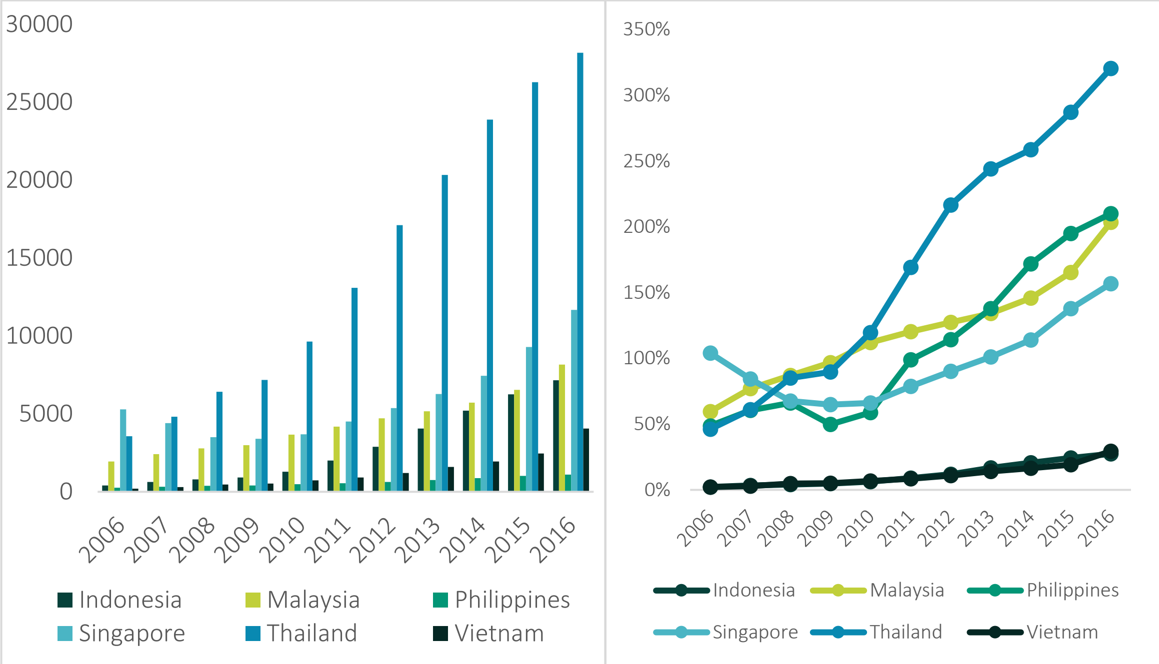
	Percent of firms using technology licensed from foreign companies	Percent of firms with a website	Percent of firms using email to interact with clients/suppliers	Percent of firms that introduced new products/services	Percent of firms that introduced a process innovation	Percent of firms that spend on R&D
Food	7.5	15.4	13.9	**31.9**	28.6	0.9
Textiles	25.6	21.9	35.3	14.6	19.1	0.3
Garments	16.3	19.1	23	19	19	0.4
Chemicals and chemical products	24	41.2	**53.7**	9.2	15	**13.9**
Rubber and plastic products	**39.8**	6.8	12.7	3.3	**40.1**	0.8
Non-metallic mineral products	4.7	6.3	42.4	6.2	6.6	0.8
Other manufacturing	30.9	22.7	31.7	5.3	7.4	3

R&D = research and development

Source: World Bank Enterprise Survey

To see the utilization of robotics in industry, the IFR releases yearly statistics on industrial robots. It comprises data on stocks and imported robots for all countries and sectors. The IFR definition of an industrial robot refers to ISO 8373:2012, which is "an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications". Based on IFR's operational stock of robot data, there are around 7,155 robots operating in Indonesia. This number is low compared to neighboring countries such as Thailand, Singapore, and Malaysia. Vietnam has been rapidly catching up in the past few years. If the operational stock of robots is divided by the number of total workers in manufacturing sectors, Indonesia is still below the Philippines and is almost at the same level as Vietnam (Figure 12).

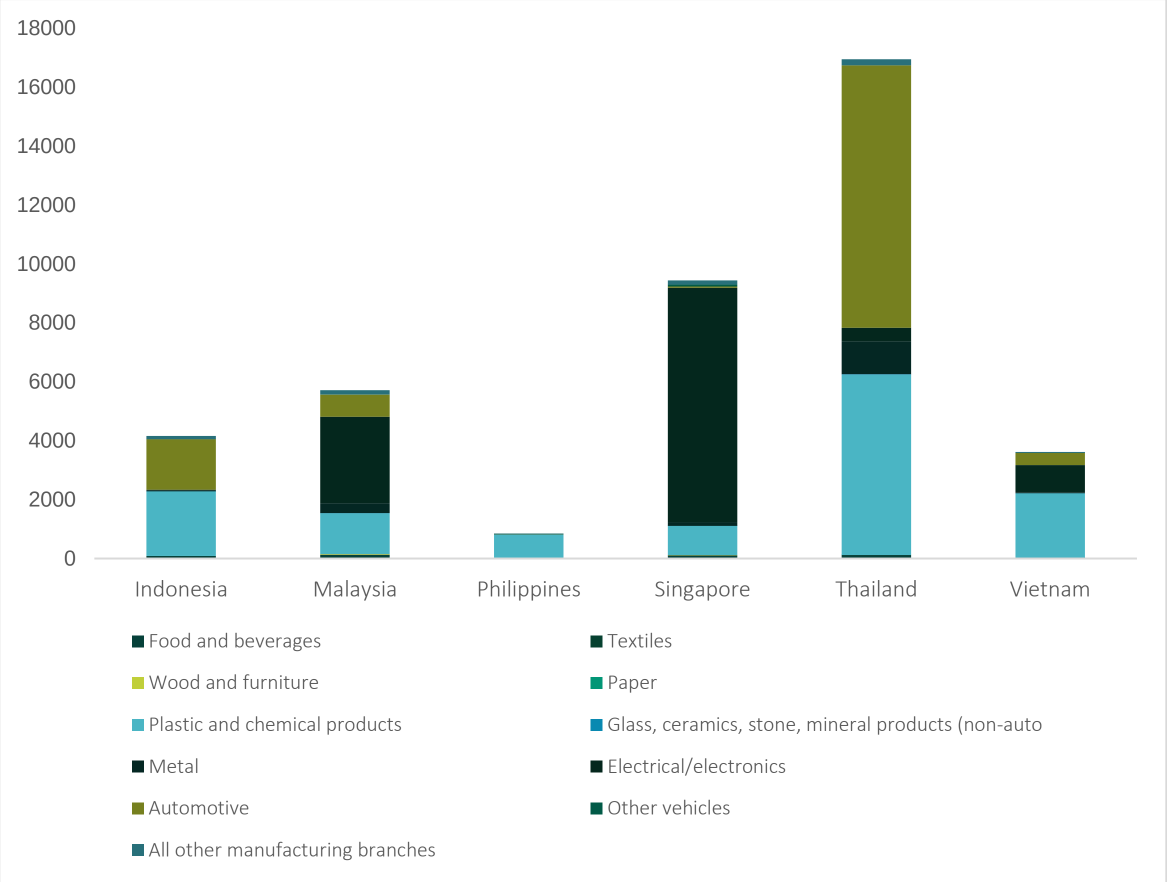
Figure 11 Operational Stock of Robots and Proportion of Operational Stock of Robots per 1,000 Workers in Manufacturing Sector



Source: International Federation of Robotics (IFR)

Interestingly, according to Figure 13, industrial robots in Indonesia are used heavily by two subsectors—rubber and chemicals (31%), and automotive (24%). Therefore, these two sectors should be the most advanced in terms of Industry 4.0 utilization. We expect that the electronics sector would have a large proportion of the stock of robots, but there was only a small number indicated in the data. Moreover, robots can be found across almost all sectors in Singapore and Malaysia, although they are mostly utilized in the electronics sector. The composition in Thailand and Vietnam is almost the same as Indonesia, although there is more variety in the distribution of the operational stock of robots in the electronics and metal industries.

Figure 12 Proportion of Operational Stock of Robots by Subsector



Source: International Federation of Robotics (IFR)

IV. FIRM-LEVEL ANALYSIS: EMPIRICAL RESULT

This chapter uses secondary data from the *Statistik Industri* (SI) dataset and analyzes the link between technology and firm productivity. Ideally, a firm's level of technological adoption is assessed by its technological usage and investment. However, because of data limitation, we use input data to approach firms' technological intensity, and then find out whether a firm with high-tech input has higher productivity, and vice versa. This approach is reasonable in the sense that intermediate inputs are one of the essential channels of technology diffusion across countries (Romer, 1990, Grossman & Helpman, 1991, and Aghion & Howitt, 1992). Therefore, we assume that a high proportion of high-tech input should positively correlate with high technological adoption.

Technology, as mentioned, is not necessarily disruptive. This study uses a 2006 to 2015 sample period to capture the most recent developments of technology in manufacturing. We approach this by using UNIDO's technology classification[6] to define high-tech and low-tech input (Appendix 1). Therefore, we can obtain the value and the proportion of high-tech input used by a firm, i.e. technological input intensity. The hypothesis is that a firm that uses more high-tech inputs should have higher productivity. To check the validity of this measurement, we compared the UNIDO classification with the estimated value of machinery and equipment and found that it positively correlated. This means a firm that uses high-tech inputs more extensively also has a higher value of machinery (Appendix 4).

The study utilizes information from three datasets to explore the impact of technology on a firm's performance. SI comprises annual data on Indonesian medium- and large-size manufacturing firms with at least 20 employees. It includes industry codes, a unique plant code, the number of employees, value added, imports, and export values. Industry codes are defined up to the five-digit International Standard Industrial Classification (ISIC) level. Second, SI's unpublished Input Dataset provides firm-level information on the inputs used by each plant.[7] Finally, the Wholesale Price Index (WPI) deflates the nominal value added using a four-digit level WPI published by BPS. For the input data, we use a two-digit level WPI.

To examine the effect of high-tech input on productivity, we start by estimating a standard Cobb-Douglas production function with two inputs—capital and labor.

$$Y = A\, K_{it}^{\beta_1} L_{it}^{\beta_2} \qquad (1)$$

Where Y is the output of firm *i* in year *y, L* is labor and K is capital stock. We define *A* as follows:

[6] This definition also used in recent literature for example in ADB and Bappenas (2019). The technology classification is based on R&D expenditure incurred in the production of manufactured goods. Manufacturing industries with a higher R&D intensity are considered high-technology industries. R&D intensity refers to the ratio of R&D expenditure to an output measure, usually gross value added (Galindo-Rueda and Verger, 2016).

[7] We are grateful to be able to use the dataset from Narjoko, Anas & Herdiyanto (2018).

$$A = f(ownership,\ market\ orientation,\ technological\ input\ intensity) \quad (2)$$

Finally, we estimate the labor productivity equation below:

$$lnVA/L_{it} = \beta_1 + \beta_2 lnK/L_{it} + \beta_3 \ln TII_{it} + \beta_4 FDI + \beta_5 export + u_{it} \quad (3)$$

Using a fixed effects (FE) model, we explore the connection between high-tech input and labor productivity $(value\ added/L)$ in equation (3). A graph showing the link between high-tech input and productivity across sectors can be found in the appendix. In Table 3, column 1 uses an FE model while column 2 uses FE with first difference. Although technological input intensity contributes significantly, it only has a small impact on firms' productivity. Possible reasons for this are the low adoption of technology and the nascent stage of Industry 4.0 in Indonesia's manufacturing sector.

The estimation shows that a 10% increase in high-tech input is associated with 0.15% of productivity. This elasticity is lower than K/L (capital/labor) elasticity, which means increasing K/L will give a higher productivity effect to the firm compared to input. Export and FDI variables are also significant individually although the interaction term shows they affect productivity negatively in column 1.

Table 3 Proportion of Operational Stock of Robots by Subsector

	Productivity (VA/L)	
lninputtech	0.0150***	
	7.84	
d.lninputtech		0.0176***
		9.71
K/L	0.0602***	0.0449***
	20.77	11.74
export	0.284***	0.0782***
	42.29	8.89
fdi	0.174***	0.0945*
	5.36	2.20
export & fdi	-0.253***	-0.0685
	-9.43	-1.93
Observations	125322	117720
R-squared	0.027	0.006

*Notes: All estimations use sector dummy variable. t statistics in parentheses, * p<0.05, **p<0.01, *** p<0.001*

From the sectoral data, the significant and positive impact of high-tech inputs on productivity is found in high-tech sectors such as rubber and plastics, motor vehicles and other manufacturing. In other words, more high-tech inputs generate higher productivity for firms in these sectors. Additionally, the positive and significant impacts also appear in the low-tech sectors of tobacco, leather, fabricated metal, furniture, food and apparel. Finally, high-tech input in nonmetallic minerals and the electrical equipment sector has a negative and significant effect. The relation between technological input intensity and labor productivity can be found in Appendix 3.

V. SURVEY ANALYSIS

This section will discuss the results of our firm-level survey. The motivation of this survey is to provide evidence from the firms' perspective regarding technology, especially Industry 4.0 technologies such as AI, automation/robotics, 3D printing, cloud computing and big data. Moreover, this survey can complement previous datasets and analysis as some of the secondary data that have been discussed previously have limitations in answering the objective of this study.

Our dataset consists of a firm-level survey of 502 firms located in four provinces—DKI Jakarta, Banten, Jawa Barat, and Jawa Timur. The survey was conducted in all locations between December 2018 and February 2019 through a series of face-to-face interviews. The questionnaire was divided into five parts: company characteristics (ownership, exports, imports); research and development activity (budget, activities); technological adoption (benefits and constraints, ICT adoption); Industry 4.0 technology (awareness, utilization, impact); and employment (structure, wages). This study expects a large variation of technological adoption across sectors as it has been observed in various developing countries (World Bank, 2005, Pohjola, 2003).

Six sectors—food and beverages, garments, footwear, electronics, automotive, and rubber and plastics—were selected based on employment and output proportion in the economy as well as the Making Indonesia 4.0 masterplan focus sector. The survey uses sector, region and size (number of workers) for a stratification strategy using 2015 SI as the sampling frame. Last, we follow most of the surveys related to disruptive technology to collect responses from senior executives, who sometimes hold responsibility for IT/technology (Hogarth, 2017).

Firm Characteristics

In summary, the largest sectors in the survey are food and beverages (33.7%), garments (26.9%), and footwear (20.9%). Almost 64% of firms are domestic-oriented (non-exporter and non-importer). There are 105 (20.9%) exporter companies and 135 (26.9%) importer companies. Only 58 companies (11.6%) are both an exporter and importer. Most exporters and importers are found in the electronics sector, and only 9.2% of firms are foreign and joint-venture companies. Table 5 illustrates firms' basic information such as size, ownership, and export/import activity.

Table 4 Firms' Characteristics

	Garments		Footwear		Electronics		Automotive		Food and Beverages		Rubber and Plastics	
	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean
Total Labor	115	590.9	79	399.4	33	1539.1	53	2036.1	169	626.4	53	670.5
% Large Firm	115	28.7	79	19.0	33	60.6	53	69.8	169	30.0	53	23.5
% Foreign	115	6.1	79	8.9	33	18.2	53	20.8	169	2.4	53	1.9
% Exporter	115	19.1	79	12.7	33	48.5	53	41.5	169	13.0	53	24.5
% Importer	115	15.7	79	27.8	33	57.6	53	39.6	169	23.7	53	28.3

n = number of firms

Research and Development

This section discusses firms' R&D efforts to innovate and adopt new technology. Using aggregate data of 16 OECD countries, a study found that R&D has become an essential channel to increase productivity growth especially by domestic businesses (Guellec and Van Pottelsberghe de la Potterie, 2001). In total, 37% of firms have an R&D department. Firm size also matters, as almost 62% of large firms have a dedicated R&D department, while small and medium firms were at only 17% and 27%, respectively. Electronics and the automotive sector had the strongest R&D department presence.

Among all firms that have R&D departments, most firms spend 1-5% of their total sales on their R&D budget. Moreover, 7% of both medium and large firms have R&D budgets of more than 20% of their total sales. In terms of sector, 37% of companies in the garment sector have less than 1% budgeted for R&D, the least among other sectors, while 10.3% of footwear companies have more than 20% for their R&D budget, which is the highest among other sectors.

The last part of this section explores intellectual property right (IPR) ownership such as patents, trademarks, industrial design, and copyright, as a proxy of a firm's innovation efforts. Table 2 shows that 51% of firms own trademarks, while copyright is the IPR least owned by firms (23%). This finding is consistent with previous research by the World Intellectual Property Organization (WIPO) (2018) that shows trademarks have the biggest share of residents' registrations. Once again, a larger firm is significantly more likely to own an IPR. The electronics sector is the most advanced sector in terms of IPR ownership of all types, while garments is the weakest. Note that the question did not ask about IPR validity.

Table 5 Firms' R&D Profiles

		Size (%)			Sector (%)						
		Small	Medium	Large	Garments	Footwear	Electro-nics	Auto-motive	Food and Beverages	Rubber and Plastics	n
Has R&D Division		16.8	26.6	61.9	26.1	36.7	72.7	62.3	30.8	35.8	187
R&D Budget	<1%	22.2	33.3	11.6	36.7	17.2	8.7	15.2	19.2	15.0	36
	1-5%	44.4	36.8	38.4	30.0	37.9	39.1	33.3	40.4	55.0	72
	5-10%	11.1	17.5	24.1	20.0	20.7	26.1	21.2	23.1	10.0	39
	10-20%	11.1	3.5	6.3	6.7	6.9	8.7	3.0	5.8	5.0	11
	>20%	0.0	7.0	7.1	3.3	10.3	8.7	6.1	7.7	0.0	12
	Don't know	11.1	1.8	12.5	3.3	6.9	8.7	21.2	3.8	15.0	17
Has IPR	Patent	9.3	18.2	53.6	15.7	25.3	60.6	34.0	33.1	26.4	146
	Trademark	30.8	48.1	66.9	33.9	50.6	75.8	41.5	60.4	54.7	257
	Industrial Design	11.2	17.3	52.5	19.1	20.3	57.6	35.8	27.2	41.5	144
	Copyright	7.5	10.7	45.9	9.6	15.2	54.5	34.0	25.4	22.6	114

R&D = research and development, IPR = intellectual property rights, n = number of firms

Firms' Technological Adoption

The third part of the questionnaire asked about firms' technological adoption in general. Interestingly, a large proportion of firms (34%) agreed that changing the production process was their main strategy to maintain competitiveness. Cutting their profit margin (24%) and reducing workers (19%) were the second and third options. According to the firms' own assessments, only 30 companies were at an advanced level[8] (mostly large firms and in the automotive sector). Scale also matters when it comes to technological adoption, as 86% of small firms are at a basic level. Last, in line with the previous finding, the largest proportion of firms in the garment sector still uses basic technology (75.7%).

Internet presence is also used to observe the level of technology in a firm, such as through social media and a website. Social media is used quite extensively for small and medium firms (39% and 42%), compared with large firms (37%), although not very substantially. However, large firms have the highest utilization of company websites, especially in the electronics sector (85%). One of the possible reasons is that social media is a low-cost marketing tool, reflecting the limited internet utilization to achieve higher productivity in SMEs.

The last part of this section asked about firms' innovation efforts over the last three years, such as products, production process, organizational practices, and marketing. Almost 56% of firms showed innovation in their products, the highest among other types of innovation. Large firms also had more extensive innovation efforts. Last, the electronics sector was the most innovative in all fields of innovation, except in marketing/sales, as footwear firms were the leader in this field.

[8] The definitions are as follows.
a) Basic: performing many activities without the use of digital tools/with basic tools such as spreadsheets and email.
b) Intermediate: using some advanced technologies in specific operations such as ERP and CRM systems, computer-aided manufacturing (CAM), and collaborative supply chain management (e.g. SAP, Oracle).
c) Advanced: using technologies across various operations, which might be fully integrated, including virtual modelling, machine to machine (M2M) systems, big data analytics, IoT.

Table 6 Firms' Technological Adoption

		Size (%)			Sector (%)						
		Small	Medium	Large	Garments	Footwear	Electro-nics	Auto-motive	Food and Beverages	Rubber and Plastics	n
Level of technological adoption	Advanced	0.0	1.4	14.9	2.6	0.0	6.1	18.9	6.5	7.5	30
	Intermediate	14.0	22.4	48.6	21.7	25.3	66.7	41.5	25.4	35.8	151
	Basic	86.0	76.2	36.5	75.7	74.7	27.3	39.6	68.0	56.6	321
Uses social media		39.3	42.1	37.6	48.7	39.2	42.4	22.6	42.6	28.3	200
Has website		21.5	32.2	65.7	40.9	34.2	84.8	54.7	33.1	45.3	211
Firm's innovation in last three years	Product	47.7	52.8	65.7	53.9	68.4	78.8	67.9	44.4	56.6	283
	Production system/process	32.7	31.8	63.5	33.0	38.0	69.7	62.3	41.4	45.3	218
	Organizational practices	24.3	31.3	55.2	31.3	29.1	63.6	54.7	39.1	34.0	193
	Marketing/sales	41.1	40.2	53.0	44.3	49.4	39.4	47.2	45.0	41.5	226

n= number of firms

Table 9 shows the top five benefits and constraints for firms as a response to the rapid development of technology and digitalization. Most firms benefited from greater factory productivity and, interestingly, more efficient energy and resource use. The financial constraint is a heavy burden for small firms in adapting to technology. This factor is also considered the top concern across sectors. A lack of skilled human resources and skill gaps are other constraints that need to be addressed, according to firms.

Table 7 Top 5 Benefits and Constraints in Technological Adoption

		Size (%)			Sector (%)						
		Small	Medium	Large	Garments	Footwear	Electro-nics	Auto-motive	Food & Beverages	Rubber and Plastics	n
Benefits	Improved planning and budgeting	61.7	62.1	77.3	70.4	69.6	66.7	73.6	68.6	49.1	339
	Improved factory productivity	71.0	70.1	81.8	77.4	78.5	72.7	71.7	75.1	64.2	374
	Improved product quality and reduced production variability	56.1	63.1	70.7	60.9	65.8	78.8	69.8	66.9	47.2	323
	Reduced energy and resource use	57.9	62.6	80.1	63.5	57.0	87.9	71.7	71.6	66.0	341
	Improved knowledge of customer needs and more direct interfaces with customers	62.6	58.9	75.1	69.6	64.6	75.8	77.4	63.3	47.2	329
Constraints	Cultural resistance to change; current organisational/managerial culture	47.7	31.8	35.4	40.0	43.0	45.5	47.2	28.4	28.3	183
	High financial investment requirements	69.2	51.9	47.5	62.6	54.4	36.4	54.7	50.3	56.6	271
	Qualification of employees and lack of skilled personnel	57.0	41.6	38.7	49.6	41.8	36.4	47.2	41.4	43.4	220
	Skills gap in board and management teams	48.6	35.5	34.3	41.7	35.4	30.3	49.1	37.9	26.4	190
	Technical uncertainties and lack of access to specialized expertise	46.7	38.8	31.5	42.6	38.0	36.4	35.8	36.7	34.0	190

n = number of firms

Industry 4.0: Awareness and Utilization

Unsurprisingly, large firms and the electronics sector have the highest awareness related to the five technologies in Industry 4.0. More specifically, most firms are familiar with automation/robotics (68%) while AI had the lowest awareness compared with other technologies, at only 35%. Firms mostly obtain information about Industry 4.0 in-house (60%), from peers (32%), and at seminars (24%). As most firms develop their knowledge on Industry 4.0 internally, skilled workers and the company's environment are critical factors in responding to technological change. The parent company is a vital source of information, specifically for large firms.

In line with our findings, firms have the highest utilization rates for automation/robotics at about 27%, with AI the lowest at 7%. Large firms are more prone to using Industry 4.0 technology. Firms in the automotive sector use more AI and big data, while robotics, 3D printing, and cloud computing are used more in the electronics sector. In line with our findings, the automotive sector has been acknowledged as an advanced sector, with car manufacturing carried out by robots (Wicaksono and Manning, 2018). We note that there is a difference between the survey's finding and IFR data, as the electronics sector did not appear as the top user in robotics technology. Last, FDI and exports are also important, as 83% of FDI companies and 78% of exporters use Industry 4.0 technology (mostly AI and robots).

Table 8 Awareness, Information, and Utilization of Industry 4.0

		Size (%)			Sector (%)						
		Small	Medium	Large	Garments	Footwear	Electronics	Auto-motive	Food and Beverages	Rubber and Plastics	n
Awareness	AI	15.9	30.4	52.5	25.2	25.3	63.6	52.8	34.3	39.6	177
	Automation/robotics	49.5	61.2	87.3	62.6	63.3	97.0	84.9	59.8	79.2	342
	3D printing	42.1	51.4	72.4	55.7	59.5	81.8	67.9	43.8	71.7	286
	Cloud	24.3	36.4	65.2	40.0	34.2	75.8	60.4	37.3	54.7	222
	Big data	21.5	29.0	59.1	33.9	22.8	69.7	49.1	36.7	45.3	192
Source of Information	Peer	34.4	34.0	46.1	40.2	22.8	53.1	50.0	40.5	34.1	150
	Parent company	4.7	5.2	40.0	6.5	7.0	34.4	43.5	26.1	15.9	77
	In-house	84.4	86.3	76.4	80.4	86.0	75.0	80.4	84.7	77.3	312
	Consultant	7.8	5.2	21.8	9.8	3.5	15.6	28.3	14.4	9.1	49
	Supplier	20.3	20.3	38.2	25.0	12.3	46.9	45.7	25.2	29.5	107
	Buyer	12.5	15.0	29.7	18.5	8.8	37.5	41.3	18.0	15.9	80
	Seminar	29.7	21.6	40.6	22.8	14.0	53.1	43.5	37.8	25.0	119
	Government	14.1	7.8	20.0	12.0	7.0	15.6	17.4	16.2	18.2	54
Utilization	AI	0.9	1.4	17.1	3.5	2.5	12.1	17.0	7.1	7.5	35
	Automation/robotics	15.9	8.4	55.2	13.9	21.5	51.5	47.2	24.3	35.8	135
	3D printing	1.9	2.3	19.3	6.1	6.3	21.2	17.0	4.7	11.3	42
	Cloud	5.6	7.9	30.4	12.2	10.1	33.3	28.3	11.2	20.8	78
	Big data	5.6	4.7	29.3	10.4	5.1	27.3	28.3	13.0	13.2	69

AI = artificial intelligence, n = number of firms

In addition to utilization, the survey also asked about the investment costs for firms that use Industry 4.0 technology. In total, most firms spent less than Rp 100 million. However, 23 firms using automation/robotics spent more than Rp 10 billion. For 3D printing, most firms spent Rp 100 million–Rp 499 million. Cloud and big data are arguably cheaper than other Industry 4.0 technologies, with most companies that use them spending less than Rp 100 million.

Industry 4.0: Impact and Functionality

Of firms that use Industry 4.0 technology, almost 98% of companies that use robotics agree that they increase production efficiency, and almost 91% say that they improve product quality. However, a weaker correlation was found between technology and production cost. Less than 50% of cloud and big data users agreed that the technologies had a significant impact on lowering production costs. Moreover, 15% of firms using AI stated that AI increased the cost of production. Agrawal, Gans, and Goldfarb (2018) argue that recent developments of AI should reduce the costs of providing a particular set of tasks, i.e. prediction tasks. Therefore, it is likely to be substituted for the human skill of prediction, but to complement other skills such as human judgment.

Most firms agreed that cloud technology has improved information system management. It makes sense that firms can rent "virtual machines" anytime they want and can also make this more accessible and integrated with other company data. Finally, big data utilization leads to less human error.

According to function, the questionnaire is divided into seven categories—production/assembly, logistics/inventory, procurement, finance, human resources, marketing/sales, and R&D. As expected, most Industry 4.0 technology production/assembly is especially for robotics, AI and 3D printing. Firms have utilized big data quite extensively in all functions, although finance and marketing/sales are most prevalent. A significant number of firms use AI. However, we cannot observe the level of complexity in those firms.

Table 9 Industry 4.0: Impact and Functionality

		%				
		AI	Robotics	3D Printing	Cloud	Big Data
Production Efficiency	More efficient	94.1	97.7	88.6	73.4	67.1
	More inefficient	5.9	0.8	2.3	0.0	0.0
	No impact	0.0	1.5	4.5	19.0	24.3
Production Cost	Cheaper	60.6	67.7	62.8	49.4	46.4
	More expensive	15.2	12.8	7.0	6.3	10.1
	No impact	18.2	18.8	23.3	35.4	36.2
Product Quality	Better	90.9	91.0	81.4	51.9	58.0
	Worse	6.1	1.5	2.3	0.0	0.0
	No impact	0.0	6.0	9.3	41.8	36.2
Information System Management	Better	69.7	68.4	72.1	93.7	75.4
	Worse	3.0	0.8	0.0	0.0	0.0
	No impact	21.2	27.8	20.9	2.5	15.9
Human Error	Less	75.8	85.7	72.1	65.8	94.3
	More	6.1	0.8	0.0	0.0	1.4
	No impact	12.1	11.3	18.6	26.6	0.0

Function	Production and assembly	71.4	91.9	61.9	21.8	23.2
	Logistics and inventory	25.7	16.3	11.9	34.6	34.8
	Procurement	25.7	20.7	16.7	23.1	27.5
	Financial	8.6	5.2	9.5	50.0	59.4
	Human resources	37.1	11.9	9.5	30.8	30.4
	Marketing and sales	28.6	7.4	23.8	44.9	58.0
	Research and development	28.6	9.6	28.6	42.3	44.9

AI = artificial intelligence, n = number of firms

Box 2: Why there is a lag for technology adoption in Indonesia?

Firm A is the supplier of a global footwear brand, located in Banten. As a local partner, there is a specific digital manufacturing road map and program developed by the brand which require all suppliers to meet standards. There is a dedicated team responsible for company's digital transformation.

The firm has high awareness about the recent developments of Industry 4.0. In fact, it already uses robotics/automation for production and assembly. The firm also uses 3D printing at the prototype level. According to the interview, the firm agrees that technology provides higher efficiency, lower production costs, higher product quality, better information system management and lower human error.

The firm explains that Indonesian firms are relatively slow in adopting new technologies because labor costs are still low. For example, firms can relocate their plants to new places that have a lower minimum wage to maintain their competitiveness. Furthermore, the supply of labor is abundant, especially unskilled labor. Second, technology has not been a feasible option for firms since it entails a high investment cost. At the current level, the return on investment is rather unclear. However, the firm agrees that economic scale of adopting technology will happen in the future.

There is also concern about companies that use additive manufacturing in Germany entering the market. This is understandable as it potentially creates new entrances and increases price competition (Weller, Kleer and Piller, 2015). The firm realizes that it should adopt technology more aggressively to maintain its competitiveness. It already has a blueprint for automating more lines of production and is considering other Industry 4.0 technology such as AI, cloud and big data.

Industry 4.0: Policy Related

Primarily, firms are reluctant to adopt such technologies because they are not yet important to them. This view is applied to all technologies. The second reason is the high investment cost. However, for cloud and big data technology, firms' capacity appears to be a more serious obstacle than investment cost. Firms' plans are also rather unclear. Only a small portion of firms are already in a trial stage of using automation/robotics, cloud, and big data technology. Most firms do not have plans to use these technologies anytime soon. The fact that firms do not observe technology as a matter of urgency might harm the prospects of Indonesia's manufacturing sector.

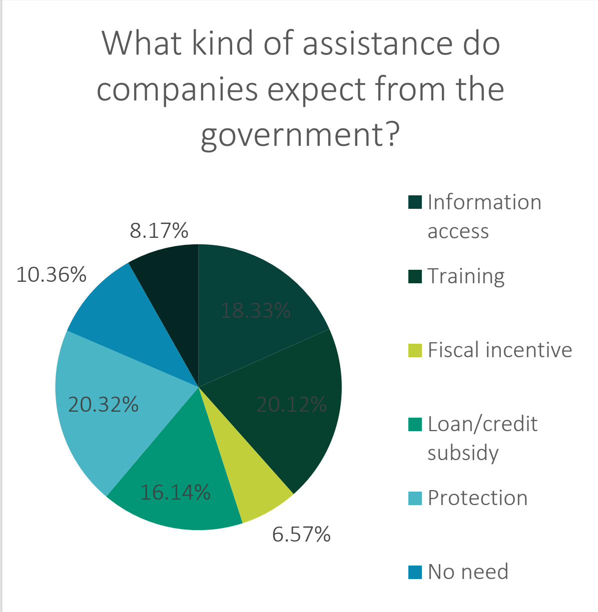
Table 10 Reasons for Not Using, and Future Plans for, Industry 4.0 Technologies

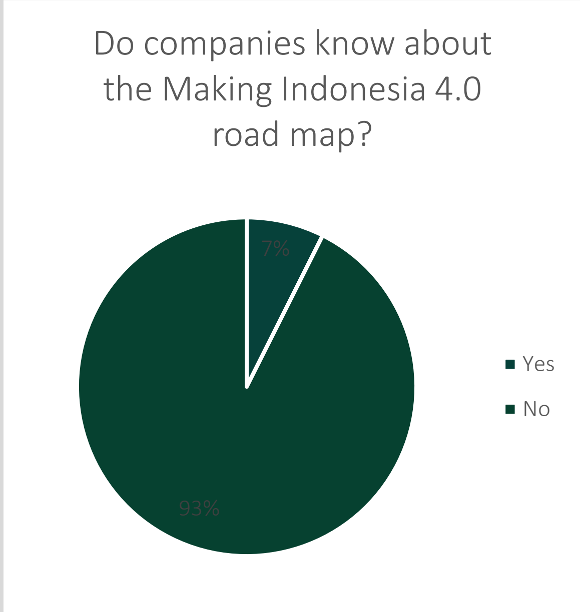
		%				
		AI	Robotics	3D Printing	Cloud	Big Data
Reason for not using	Expensive	18.2	29.4	18.7	12.9	12.2
	Not important/necessary	37.5	36.5	47.2	36.5	36.6
	No demand from market	12.6	13.1	12.6	10.4	9.9
	No capacity	17.8	21.8	17.4	16.5	14.0
Plans in the future	Trial stage	3.8	14.4	4.3	8.9	8.9
	In the company's blueprint	0.8	0.6	0.2	0.2	0.4
	There is already a strategic decision	1.0	2.6	1.0	2.2	1.4
	Considering	5.6	10.6	6.3	10.5	7.1
	No plan at all	88.8	71.7	88.3	78.2	82.2

Interestingly, among other assistance options, 20% of firms chose protection from the government. Training and more information access came second and third. One of the possible reasons is that given the high investment cost and low financial feasibility, firms need more time to compete with other firms that will have to adopt more productive technologies in the future. Second, protection is needed in the sense that the manufacturing sector in Indonesia is still labor intensive, with a high proportion of unskilled labor. Therefore, it takes time for firms to adjust and adopt new technologies that require less unskilled labor. Protection from the government might help to delay serious implications of this adjustment.

Most firms are also not aware of Making Indonesia 4.0 and how the road map will be implemented. The government should disseminate more information to industries and, more importantly, should make sure that firms are aware they must actively participate in and give input to the road map implementation.

Figure 13 Government Assistance Expectations and Awareness of Making Indonesia 4.0





VI. CONCLUSION AND POLICY RECOMMENDATION

This study confirmed our hypothesis that Indonesia is still in a nascent stage of Industry 4.0 development and is lagging behind its peers. As expected, the study also found that there is a different level of maturity across sectors. For example, electronics and automotive are leaders in advanced technology adoption, while garments and footwear are at an early stage. Both sectors are more labor intensive, which may contribute to the pace of technological adoption in such firms. Using input data, this study found that high-tech inputs contribute to the level of output and value added, although there is a small effect on productivity.

From our survey and secondary data, a firm's size plays a vital role in its level of technology. This study also emphasizes the investment cost as a significant burden, especially for SMEs, in technological adoption. Furthermore, a firm with an R&D department is more likely to adopt more advanced technology. Therefore, it is crucial for the government to push firms to put more effort into R&D, such as budget or a dedicated department as policy incentives. Firms' awareness and utilization of Industry 4.0 have a positive correlation. Moreover, automation/robotics have the highest levels of awareness and utilization compared to other technologies. This calls for government intervention to provide more access to information related to Industry 4.0. Furthermore, firms depend on in-house resources to acquire knowledge on Industry 4.0. Therefore, skilled workers are critical for firms to increase technological adoption. Finally, the government should evaluate the low awareness of the Making Indonesia 4.0 road map.

Several policy recommendations could be derived from the study, as follows.

1. *Provide effective incentives*

Technological adoption creates information and knowledge externalities for other firms. Therefore, it is reasonable for the government to provide incentives. The relatively small portion of firms' efforts in R&D reflects the lack of incentives. As our survey suggests, firms that have dedicated R&D departments are more innovative and more likely to adopt Industry 4.0 technology. The incentives should also help firms to upgrade their R&D capacity, for example, from product to production system/process innovation.

2. *Narrow the skill gap*

New technology transforms jobs and eventually changes the skills required for jobs. The survey highlights that there is concern about the shortage of skilled workers in the future. In the long term, the government should focus on human capital and a skill formation system. The growing population is a two-edged sword. It provides a massive potential market but people also need to be trained carefully to support the development of Industry 4.0 with the right skillsets. Additionally, one of the options for a short-term policy could be more flexibility for high-skilled foreign workers to fill the skills gap. Especially in Industry 4.0 related technology, experts are mostly foreigners, as Indonesia is still a technology-importing country.

3. *Improve innovation environment and encourage competition*

The government should improve innovation culture through IPR and competition policy. Our survey found that IPR are highly related to technological adoption. More efficient IPR procedures and a sound protection policy would give innovative firms the confidence to do R&D more extensively. Firms could also consider changing their business processes to be more competitive. This means that firms are aware that innovation is key to surviving against market competition. Interestingly, our survey also found that most firms ask for protection as the best form of assistance to face Industry 4.0. However, the government should be careful about the type of protection and avoid a policy of cherry-picking winners.

4. *Ensure infrastructure quality and facilitate Industry 4.0 policy*

Internet access and electricity are the central enablers for Industry 4.0. Without them, the potential benefits of this technological transformation will not be attainable. This issue is a prevalent problem in developing countries, including Indonesia. For example, good coverage and high-quality internet should not only be centralized in certain areas. This will increase the risk of a digital divide in Indonesia. Our survey highlights the importance of the internet and digitalization (websites, e-commerce and social media). The adoption of a flexible, clear, and adaptive policy to new technologies is as important as building good, hard infrastructure. In this borderless world, Indonesia should also consider international frameworks and actively contribute to global governance in digitalization and technology.

5. *Better data for better policy-making*

The study found difficulties in gathering relevant data on Industry 4.0 related technology. Given the size of the impact, the government should keep up with recent innovation and technology trends. Good quality and comprehensive data on Industry 4.0 technology and firms' innovation efforts is an inevitable requirement for the government in moving toward more sound policies. This is also important to track progress and bottlenecks in the implementation of the Making Indonesia 4.0 masterplan. The government could consider surveys such as the EMS in the EU and *Encuesta Sobre Estrategias Empresariales* (ESEE) in Spain as benchmarks.

REFERENCES

Acemoglu. D., & Restrepo, P. (2017). Robots and Jobs: Evidence from US Labor Markets. 2017. *NBER Working Paper No. 23285* March 2017 JEL No. J23, J24

Agrawal, A., Joshua, G. and Avi, G. (2018). Prediction Machines: The Simple Economics of Artificial Intelligence. *Harvard Business Review Press*, Boston MA.

Aswicahyono, H. and Rafitrandi, D. (2018). A Review of Indonesia's Economic Competitiveness. WPSECO 01/2018. Centre for Strategic and International Studies, Jakarta

Bappenas & ADB. (2019). Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.

Baptist S and Hepburn C. (2013). Intermediate inputs and economic productivity. Phil Trans R Soc A 371: 20110565. http://dx.doi.org/10.1098/rsta.2011.0565

Commander, S., Harrison, R., & Menezes-Filho, N. (2011). ICT and Productivity in Developing Countries: New Firm-Level Evidence from Brazil and India. Review of Economics and Statistics, 93(2), 528–541. doi:10.1162/rest_a_00080

Damuri (2018)

Dauth, W, S Findeisen, J Suedekum and N Woessner (2018), "Adjusting to robots: Worker-level evidence", Opportunity and Inclusive Growth Institute Working Paper 13, Federal Reserve Bank of Minneapolis.

De Bondt, H., & Polder, M. (2015). Types of ICT and Firm-Level Productivity. In Statistics Netherlands, ICT and Economic Growth, pp. 51-66. The Hague: Statistics Netherlands

European Commission Report on Robotics and Employment (2016)

Ergin Bayrak & John P. Conley & Simon Wilkie, 2011. "The Economics of Cloud Computing," Korean Economic Review, Korean Economic Association, vol. 27, pages 203-230.

Galindo-Rueda, F. and F. Verger (2016), "OECD Taxonomy of Economic Activities Based on R&D Intensity", OECD Science,Technology and Industry Working Papers, 2016/04, OECD Publishing, Paris.http://dx.doi.org/10.1787/5jlv73sqqp8r-en

Graetz & Michaels (2018). Robots at Work. *Review of Economics and Statistics*. Volume 100/5 p.753-768

Guellec, D. & van Pottelsberghe de la Potterie, B. (2001). R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries. *OECD Economic Studies 33, 2001/II,* pp.103-126

International Federation of Robotics (2017)

Levinsohn, J., & Petrin, A. (2003). Estimating Production Functions Using Inputs to Control for Unobservable. *The Review of Economic Studies, 70(2)*, 317-341

Mann, K. and L. Puttmann (2017): "Benign Effects of Automation: New Evidence from Patent Texts," SSRN Electronic Journal.

Ministry of Industry, Republic of Indonesia. (2018). Roadmap Making Indonesia 4.0

Motohashi, K. (2005). IT, Enterprise Reform and Productivity in Chinese Manufacturing Firms. University of Tokyo

Pohjola, M. (2003). The Adoption and Diffusion of ICT Across Countries: Patterns and Determinants". *The New Economy Handbook*, Orlando

Roca, B. J. (2019). The Digital Transformation of Manufacturing. ADB Briefs series. Forthcoming.

Thee Kian Wie (2005) The Major Channels of International Technology Transfer to Indonesia: An Assessment, Journal of the Asia Pacific Economy, 10:2, 214-236, DOI:10.1080/13547860500071493

Terence Hogarth, T. (2017). Automation, Artificial Intelligence, On-demand Labour and Other Flexible Forms of Labour in the New IDB Employer Survey "Skills at Work in LAC". Inter-American Development Bank

Warwick, K. (2013). Beyond Industrial Policy: Emerging Issues and New trends, *OECD Science, technology and Industrial Policy Papers, No.2.* OECD Publishing, Paris

Weller, C., Kleer, R. & Piller, F. T. (2015). Economic Implication of 3D Printing: Market Structure Models in Light of Additive Manufacturing Revisited. *International Journal Production Economics.* 164. Pp.43-56

Wicaksono, T. Y., & Manning, C. (2018). Globalisation and labour: the Indonesian experience. Indonesia *in the New World: Globalisation, Nationalism and Sovereignty, 201.*

WIPO (2018). Understanding the Use of Industrial Design in ASEAN Countries: National Report for Indonesia. Development Studies Series. Geneva: World Intellectual Property Organization. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_ds_2018_01.pdf

WDI

World Bank. (2005). World Development Indicators. Washington, DC

World Economic Forum Readiness Report (2018). The Readiness for the Future of Production Report 2018.

APPENDIX

A. Manufacturing industries at the 2-digit level of ISIC Rev 4 by technological intensity

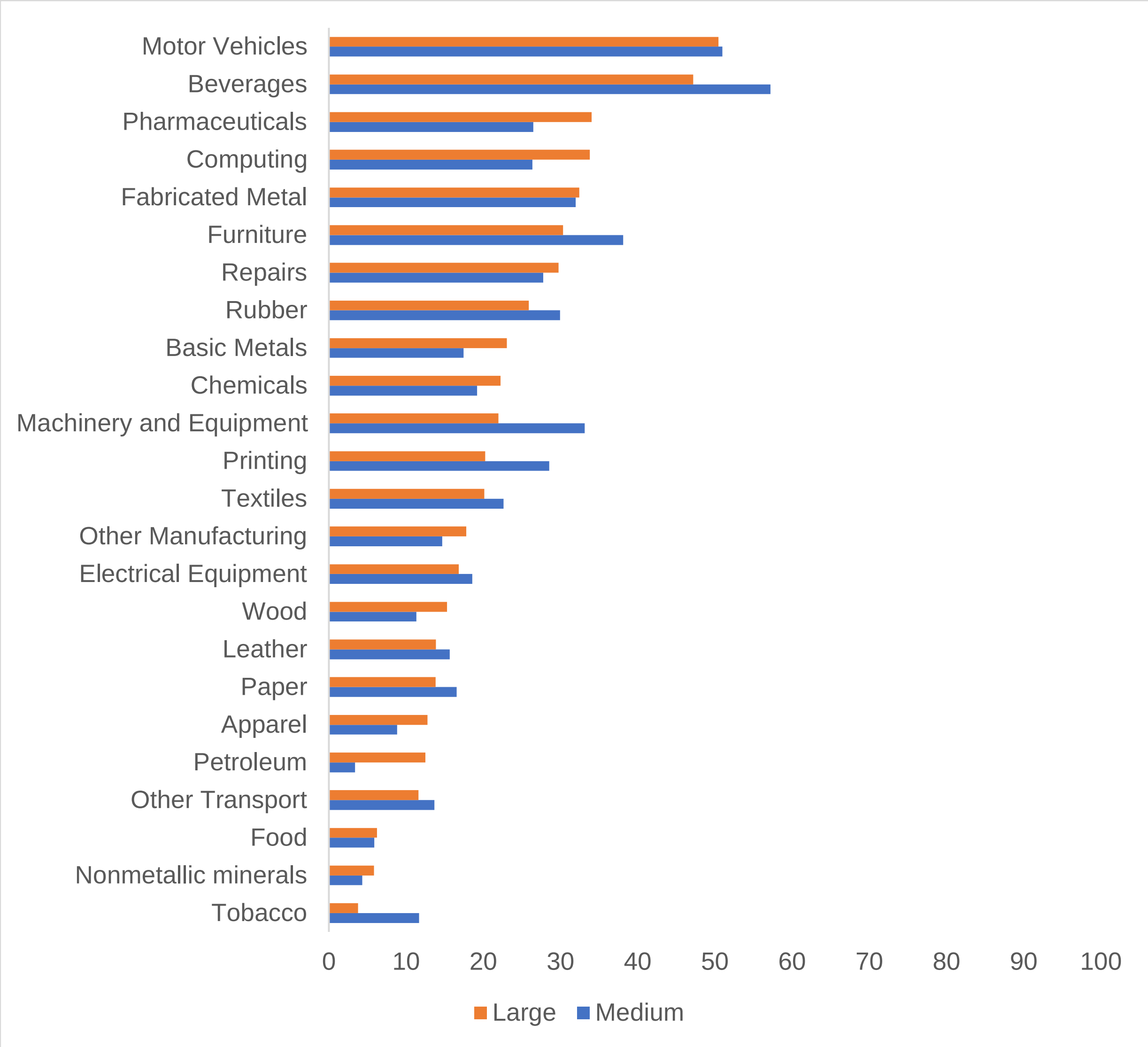
Medium-high and high technology *(high-tech)*

Division 20	Chemicals and chemical products
Division 21	Pharmaceuticals
Division 26	Computer, electronic and optical products
Division 27	Electrical equipment
Division 28	Machinery and equipment n.e.c.
Division 29	Motor vehicles, trailers and semi-trailers
Division 30	Other transport equipment except ships and boats
Division 22	Rubber and plastics products
Division 23	Other non-metallic mineral products
Division 24	Basic metals
Division 32	Other manufacturing except medical and dental instruments
Division 33	Repair and installation of machinery and equipment

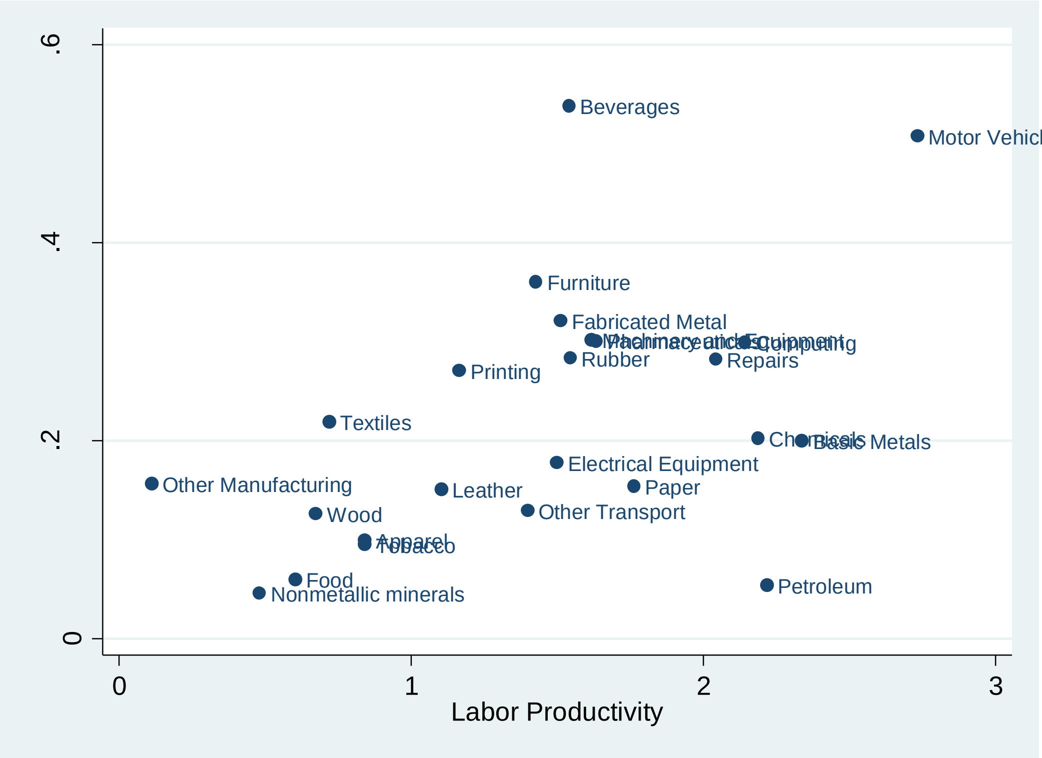
Low technology *(low-tech)*

Division 10	Food products
Division 11	Beverages
Division 12	Tobacco products
Division 13	Textiles
Division 14	Wearing apparel
Division 15	Leather and related products
Division 16	Wood and products of wood and cork
Division 17	Paper and paper products
Division 18	Printing and reproduction of recorded media
Division 19	Coke and refined petroleum products
Division 25	Fabricated metal products except weapons and ammunition
Division 31	Furniture

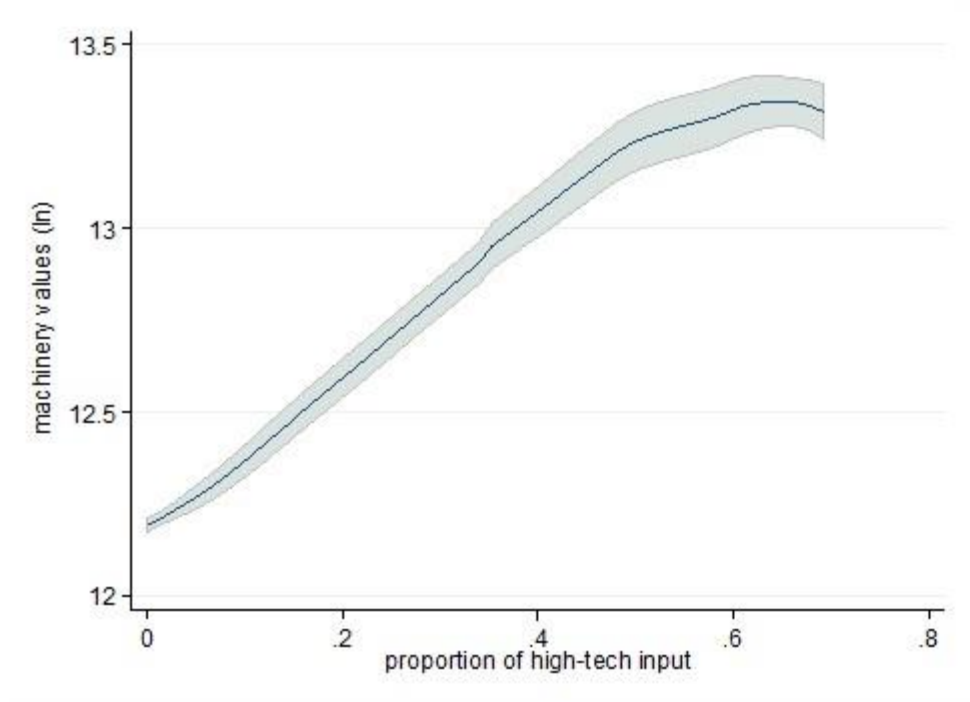
B. Share of High-Tech Input Across Sectors



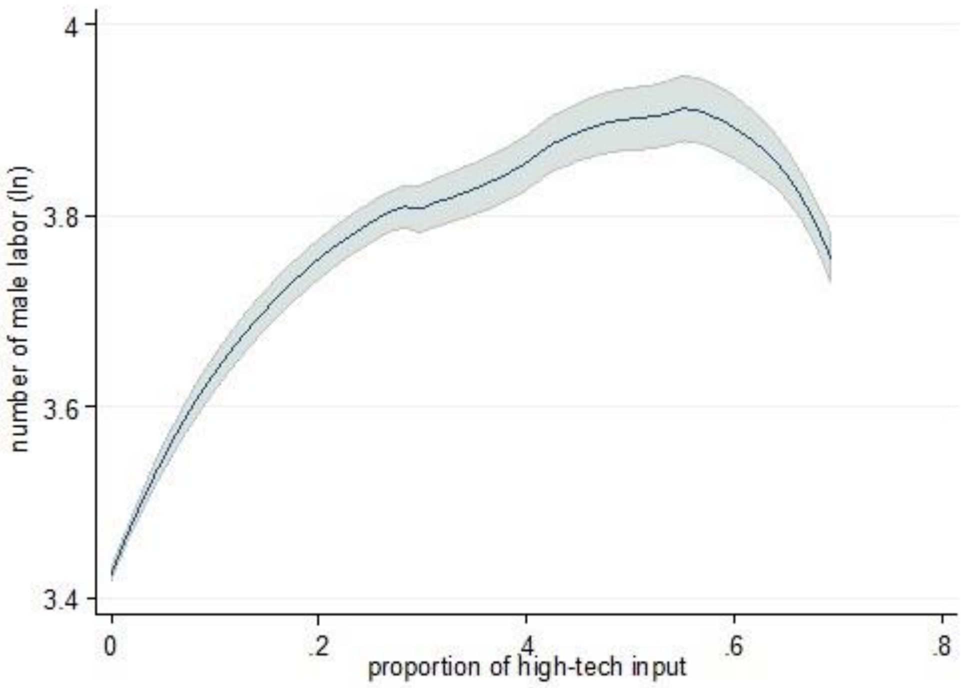
C. Labor Productivity and High-Tech Input Share

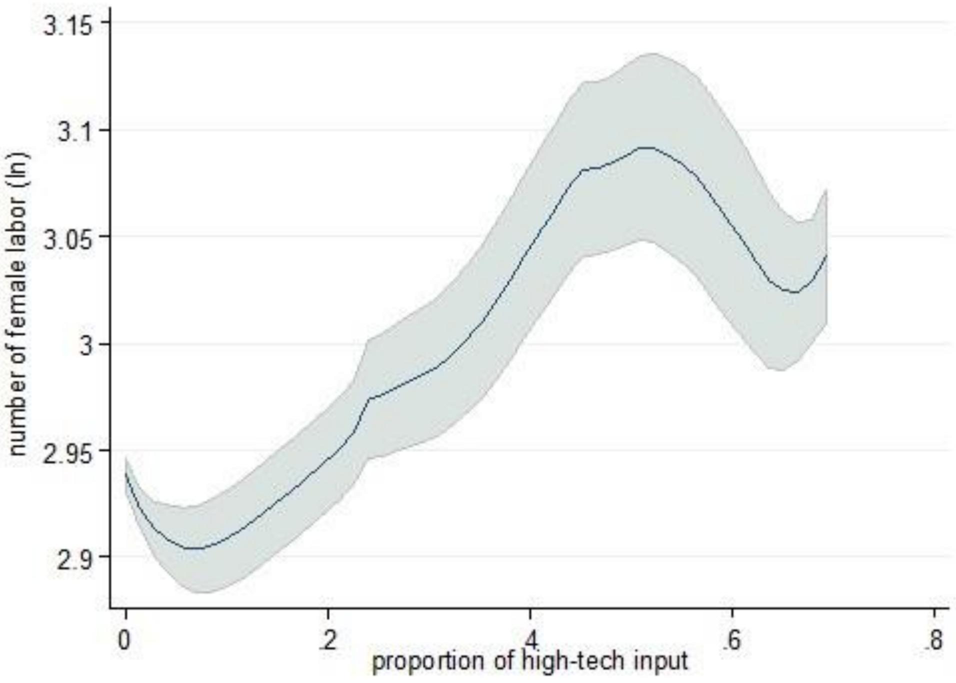


D. High-tech input share and number of estimated value of machineries



E. High-tech input share and male & female Labor





F. Robustness Check

	Lagged High-tech Input		Levinsohn & Petrin (2003)	
	lnoutput	lnva	lnoutput	lnva
	(4a)	(4b)	(5a)	(5b)
lnmhightech	0.119***	0.0661***	0.119***	0.0655***
	(76.53)	(33.22)	(77.36)	(33.28)
Observations	126071	121917	121917	126071
R-squared	0.517	0.477	0.485	0.291

*All estimation uses sector dummy variable. t statistics in parentheses, * p<0.05, **p<0.01, *** p<0.001*

G. Sectoral Estimation using Equation 6

Sector	Elasticity
Tobacco	0.154***
Leather	0.044***
Fabricated Metal	0.041***
Rubber	0.033***
Furniture	0.031***
Motor Vehicles	0.03***
Food	0.029***
Other Manufacturing	0.029***
Apparel	0.025***
Nonmetallic minerals	-0.03***
Electrical Equipment	-0.043***
Basic Metals	0.025
Machinery and Equipment	0.021
Other Transport	0.019
Paper	0.008
Chemicals	0.001
Beverages	0.001
Wood	0.001
Computing	-0.001
Pharmaceuticals	-0.007

Textiles	-0.009
Printing	-0.01
Repairs	-0.024
Petroleum	-0.048

*All estimation uses sector dummy variable. t statistics in parentheses, * p<0.05, **p<0.01, *** p<0.001*

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