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CIRCULAR ECONOMY AND PRODUCTIVITY IN A LARGE DEVELOPING COUNTRY: EMPIRICAL EVIDENCE FROM INDONESIA

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CIRCULAR ECONOMY AND PRODUCTIVITY IN A LARGE DEVELOPING COUNTRY

EMPIRICAL EVIDENCE FROM INDONESIA

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A B S T R A C T

Circular economy aims to improve the used-resources efficiency and effectiveness holistically, thereby self-sustained and sustainable. Such concept promotes an all-inclusive productivity worldview. Yet, a question remains to what extent does the circular economy practices have impact on firms' productivity, particularly in developing economies where there are conditions that are not necessarily in line with textbook rules that are mostly based on the developed economies paradigm. As the concept of the circular economy is a relatively new focus of research, it makes this paper to be the first empirically investigating the impact of circular economy practices on firms productivity in Indonesia. The open paradigm of circular economy that is non-restrictive and adaptable to the social and ecological environment depending on the availability of resources (low-tech to high-tech) and markets (small to large), makes circular economy approach, theoretically, is effective to improve productivity sustainably with limited resources available as in developing economies such as Indonesia. The study also contributes by highlighting the challenge on limited data availability related to measuring the circular economy measurements. We find the evidence in support of circular economy practices positively affecting firms productivity. However, the effects differ across sectors. What also important is that the dynamics of other deteminant variables of productivity shows that there is unique treats of firms that implement circular economy practices which makes them different and more resilient compared to other general firms.

Keywords: Circular economy, productivity, Indonesia

JEL Classifications: C5, D2, Q5

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1. Introduction

While the concerns on sustainability can be traced back as far as to the year 1849 (Ruskin, 1849), up until now the general awareness of sustainability is still very limited. The idea of the earth has physical limits in the form of depletable natural resources and that the earth has a finite capacity to absorb emissions (Daly, 1972; Meadows, Randers, & Meadows, 2005) up until now is still rarely to be considered as first priority in business decisions.

Mathis Wackernagel et al. (2002) argued that human is currently overused the earth's resources by around 20 percent above the global carrying capacity. Responding to that notion, the circular economy concept arises as the opposing concept of linear economy, which is to transform products to create self-sustaining production systems and workable relationships between ecological systems and economic growth, by using cyclical materials flows, renewable energy sources and cascading-type energy flows (Geissdoerfer, Savaget, Bocken, & Hultink, 2017a; Korhonen, Honkasalo, & Seppälä, 2018; Prieto-Sandoval, Jaca, & Ormazabal, 2018a; Winans, Kendall, & Deng, 2017).

Circular economy paradigm has an open paradigm that is non-restrictive and adaptable to the social and ecological environment depending on the availability of resources (low-tech to high-tech) and markets (small to large). That also includes a wide range of firm styles and earnings models (Wageningen, 2018; Winans et al., 2017). Circular economy aims to improve the used-resources efficiency and effectiveness holistically, thereby self-sustained and sustainable. This makes circular economy approach, theoretically, is effective to improve productivity sustainably with limited resources available as in developing economies such as Indonesia. Thus, based on this construct, we are motivated to empirically examine the impact of circular economy practices on manufacturing firms' productivity.

Circular economy concept promotes an all-inclusive productivity worldview. Yet, very limited research has been done that focuses on the relationship between circular economy practices and firms productivity empirically. A question remains to what extent does the circular economy practices have impact on firms productivity, particularly in developing economies where there are conditions that are not necessarily in line with textbook rules that are mostly based on the developed economies paradigm. As the concept of the circular economy is a relatively new focus of research[1], it makes this paper to be the first empirically investigating the impact of circular economy practices on firms productivity in Indonesia. Should the circular economy paradigm provides pontential solutions to improve firms productivity, this marks the importance of this study as Paul Krugman highlights in The Age of Diminishing Expectations (1994) that "Productivity isn't everything, but in the long run it is almost everything".

The nature of empirical circular economy research that encounters challenges in data limitation, more so in developing countries due to poor administration and institution. This study confronts the similar problem. One of which is on capturing the flow of materials. As the database for material flows[2] in firm level is not yet available for most developing countries including Indonesia, we employ "the value of production of goods (in Indonesian Rupiah) produced by firms whose raw materials are from the waste of other firms" as the proxy of the amount of materials circulating/recycling within the economic sector. Therefore, this research focuses on capturing the flow of materials within sectors and exclude the inter-sectoral material flows due data limitation. However, we extend what previous research have done by adopting

[1] The term was introduced by policy makers of China in mid-2008 and European Union in 2015 (Geissdoerfer, Savaget, Bocken, & Hultink, 2017b; Mathews & Tan, 2011; Prieto-Sandoval, Jaca, & Ormazabal, 2018b)
[2] A global economy-wide material flow database (Haas et al., 2015, Schaffartzik et al., 2014).

circularity level variable (Haas, Krausmann, Wiedenhofer, & Heinz, 2015) instead of using the circular economy innovation dummy variable as in Horbach and Rammer's (2019), and other revenue as the circular economy measurements. The firm's circularity level is the value of production of goods (in Indonesian Rupiah) produced by firms whose raw materials are from the waste of other firms in one sector divided by the total value of production of goods (in Indonesian Rupiah) in that sector. The other circular economy measurement is firm's other revenue (profits from the sale of unprocessed goods, sales of waste/production waste).

We employ a unique large database of the Indonesian Survey of Large and Medium Manufacturing (SIBS)[3] that covers more than 20,000 manufacturing firms[4] in 34 provinces in Indonesia covering the period of 2000-2015 annually. The findings of this research suggest the evidence in support of circular economy practices positively affecting firms productivity. However, the effects differs in different sectors.

The rest of the paper is organized as follows. Section two reviews the literature on the relationships between social capital and economic development. Sections three discusses the data analyzed in this study. Section four elaborates the empirical method to analyze the data. Section five presents the results of the estimations. Section six provides a discussion of the findings. Section seven concludes.

2. Literature Review and Hypothesis Development

The circular economy concept is the opposing concept of linear economy concept. Linear economy concept is where we only concern on how to collect the raw materials, and then transformed into products that are used (take-make-use) until they are finally discarded as waste. While in circular economy, we assume that the planet is a closed circular system, where the amount of resources depleted in a period is equal to the amount of waste generated in the same period. Although limited by some basic physical laws, circular economy seeks continually sustain the circulation of resources and energy within a closed system thus reducing the need for new raw material inputs into production systems (Genovese, Acquaye, Figueroa, & Koh, 2017a). Circular economy presents as the structural fixes of the currently overused earth's resources to strengthen the sustainability revolution (Ansell & Cayzer, 2018; D'Amato et al., 2017; Meadows et al., 2005). In a circular economy ecosystem, the resource input and waste, are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through reuse, recycle, redesign / enduring design, maintenance, remanufacture, reduce, recover, refurbish (Geissdoerfer et al., 2017a; Winans et al., 2017).

By adopting the circular economic perspective, the notion of sustainability in supply-focused industries can broaden the role of the industries not only as the producers that are required to implement sustainable production, but also as consumers (of the producers) that are required to implement sustainable consumption (Genovese, Acquaye, Figueroa, & Koh, 2017b). The circular economy pushes the limits of environmental sustainability by inducing the idea of product transformation and partnership so that ecological systems can be sustained along with economic growth (Genovese et al., 2017a). Circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates." (Korhonen et al., 2018). In a circular economy ecosystem, the resource input and waste, are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through reuse, recycle, redesign / enduring

[3] https://www.bps.go.id/subject/9/industri-besar-dan-sedang.html
[4] which have a workforce of 20 or more people (medium and large sized industries)

design, maintenance, remanufacture, reduce, recover, refurbish (Geissdoerfer et al., 2017a; Winans et al., 2017).

Many literature focuses on the conceptual level such as the evolution of terms related to circular economy concept such as “Industrial Symbiosis” (Amato et al., 2018; Domenech, Bleischwitz, Doranova, Panayotopoulos, & Roman, 2019), “Cleaner Production” (Hens et al., 2018), “Finnish bio-economy” (Takala et al., 2019), and “EU’s transition efforts towards circular economy” (Brears, 2015). Other research such as Nasiri et al. (2018) reviews the concept of sustainability and existing approaches to find sustainable solutions for firms, while Wreford et al. (2019) proposes an assessment framework to analyse where New Zealand’s current position for bioeconomy-based wealth creation and solutions to enable New Zealand to transform into a fully functioning bioeconomy. Cooper et al. (2017) analysed the effect on the energy use of applying a wide range of circular economy approaches using Thermodynamic insights. Other research discussed ethical framework of circular economy (Dicks, 2017) and role of media to promote awareness of biogas as a potential renewable energy solution in Finland (Lyytimäki, Nygrén, Pulkka, & Rantala, 2018). Brears (2015) reviews EU's transition efforts history towards circular economy. Foschi and Bonoli (2019) shows how European Commission has worked to regulate production and consumption of plastic carrier bags and packaging including food packaging, while Swagemakers, Garcia and Wiskerke (2018) discussed experience in developing a biomass waste conversion that is challenged by questions of scale, administrative and regulatory barriers, conflicting land-use claims and financial cutbacks from public sector. Most literature in circular economy is focused on valorisation and waste management technologies, environmental benefits measurements.

The concept of circular economy translates the concept of systemic productivity beyond measuring the labor and capital inputs efficiency. It is by taking into account economic growth, ecological systems, cyclical materials flows, renewable energy sources and cascading-type energy flows. Measuring the impact of circular economy which also purports productivity improvements, some papers developed asessments on the circularity level of each research unit. Bala et al. (2014) presents food security modelling in Malaysia that models the circular causality between variables in the paddy and rice production system using computer model system dynamics methodology to improve food security, while Didenko et al. (2018) empirically presented the environmental impact of linear economy in comparison with circular economy from macro perspectives. Haas et al. (2015) assessed the circularity of global material flows with an interesting fact of Europe despite having a higher end of life recycling rate, yet low circularity level. Thus, very limited research has been done that focuses on the relationship between circular economy practices and firms productivity empirically. Learning from these articles, we developed a proxy of circularity measurement of a firm that is a percentage of reuse or recycle as input of total input and (if any) a percentage of circularity level of total waste.

To find the gap in the circular economy literature related to firm productivity, we did literature search in February 2020 using Scopus website with the keyword of “circular economy AND firm productivity” for all years available. The search is limited to final published articles to ensure the reliability of the literature search and to English literature. The literature search code was as follows:

TITLE-ABS-KEY (circular AND economy AND firm AND productivity) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

We obtained 6 literature from the literature search, and after removing duplication, applying inclusion and exclusion criteria to title, abstract, keywords and full papers, we only obtained 1 literature. It was a paper by Horbach and Rammer (2019). They questioned whether firms with circular economy innovations perform better or worse in terms of sales growth and employment using quantile regression (shrinking, stable, slowly growing, fast growing firms) with panel data of German community innovation survey wave 2014 and 2016. They found that circular economy innovations are positively linked to turnover and employment growth. While there is no statistically significant impact on labour productivity, at the same time, firms with CE innovations show a significantly better financial standing.Horbach and Rammer (2019) employ a circular economy variable as a dummy variable of the firms that introduced circular economy innovations during the period of year 2012-2014[5] with a significant impact on the environment and the firms that did not introduce any circular economy innovations during the period. They defined the circular economy innovation by firms as process-related circular economy innovation, reduced energy use per unit of output, recycled waste, water, or materials for own use or sale, reduced material use/use of water per unit of output, replaced fossil energy sources by renewable energy sources, replaced materials by less hazardous substitutes, product-related CE innovation, reduced energy use, extended product life through longer-lasting/more durable products, and improved recycling of product after use. This approach is the most feasible since the most challenging part of estimating the circular economy variable empirically in firm level, is the data availability.

Capturing the complete notion of circular economy in the literature, we conducted a second literature search using Scopus website using the keywords of "reuse OR recycle AND firm AND productivity" for all years available. The search is limited to final published articles to ensure the reliability of the literature search. The literature search code was as follows:

TITLE-ABS-KEY (reuse OR recycle AND firm AND productivity) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "ECON")) AND (LIMIT-TO (DOCTYPE , "ar"))

We obtained 8 literature from the literature search, and after removing duplication, applying inclusion and exclusion criteria to title, abstract, keywords and full papers, we only obtained 2 literature. Gupta S.K., Gupta S., Dhamija P. (2019) suggest that larger firms should reflect on resource conservation practices such as 3R (reduce, recycle and reuse) principles. Doran J., Ryan G. (2014) advocate that eco-innovation[6] activities increase firms' productive capacity complementarily and substitutionally depends on the combinations of eco-innovation. Reducing material use within the firm at the same time as improving the ability to recycle the product after use, is the example of complementary eco-innovations combinations. While reducing material use within the firm at the same time as recycling waste, water or materials within the firm, is the example of subsitutory eco-innovations combinations.

In this paper, we succeeded to extend the circular economy variable using the circularity level variable adopted from Haas et al. (Haas et al., 2015), instead of using the circular economy innovation dummy variable as in Horbach and Rammer's (2019). On top of it, we lengthen further by using the variable of firm's other revenue (profits from the sale of unprocessed goods, sales of waste / production waste) as the second circular economy variables.

We include various dimensions of firms' productivity measurements to mitigate any productivity misinterpretations of the analysis, with data limitation in mind. They are the value of output production, value of total revenue, value of value added, value added productivity (ratio of value added to total labor), and labor productivity (ratio of output production to total labor) adopting from Horbach et al. (2019). We also look at the circular economy impacts on

[5] German community innovation survey (CIS)
[6] Any form of product, process or organisational innovation that contributes towards sustainable development.

firms' productivity by controlling for foreign investment, the market concentration measure, size of the firms, used installed capacity, import share of inputs and export share of outputs, ratio of R&D expenditure, capital ratio, and non-production labor ratio as in Horbach et al. (2019). They are indicators that are perceived that may affect the productivity of a firm.

The hypothesis of our study is that *an increase in circular economy variables increase the firm's productivity indicators*. It is grounded on the theoretical and empirical works constructed by previous literature supporting the importance of circular economy approach on productivity (Bala et al., 2014; Didenko et al., 2018; Haas et al., 2015; Horbach & Rammer, 2019).

3. Data

The circular economy data was obtained from the Indonesian Survey of Large and Medium Manufacturing (SIBS) database from Statistics Indonesia (BPS).[7] The **SIBS** database provides a complete enumeration of all manufacturing industry firms in Indonesia which have a workforce of 20 or more people (medium and large sized industries). The SIBS database covers more than 20,000 manufacturing firms in 34 province in Indonesia covering the period of 2000-2015 annually. SIBS categorize each manufacturing industry firms into different sectors and sub-sectors based on the Indonesian Standard Industrial Classification (KBLI) that follows the International Standard Industrial Classification of All Economic Activities (ISIC). This paper is the first researching circular economy that employs the large dataset of SIBS. We chose manufacturing sector since it is the only sector in Indonesia with extensive data series available.

We established the model over three datasets to explore whether there are different effects of circular economy variables on firms' productivity in different sectors. The buildings of the datasets unevitably is constraint by limited data availability. We used purposive sampling in this research to capture the circularity level in a firm. The data selection is based on the sub-sector label names in SIBS database representing the circular economy activities attached to their operations[8] (Tabel 1). The circularity level data is the production of goods (in Indonesian Rupiah) produced by firms whose raw materials are from the waste of other firms in one sector devided by the total production of goods (in Indonesian Rupiah) in that sector. This research focuses on capturing the flow of materials within sectors and exclude the inter-sectoral material flows. The other circular economy variable in this study is the firm's other revenue (profits from the sale of unprocessed goods, sales of waste / production waste). The first dataset is the dataset of firms that apply circular economy (5 sub-sectors identified referring to their label names, as in Table 1). The second dataset is the dataset of firms that apply circular economy in agriculture sub-sectors as in Table 2, to observe whether there is different effects of circular economy variables on firms' productivity in different sectors. The third dataset is the full dataset of firms in the SIBS database for the robustness check.

[7] https://www.bps.go.id/subject/9/industri-besar-dan-sedang.html
[8] By referring to their label names mentioning that they use waste of other sub-sector as their inputs

Table 1 Industry sub-sectors with circular economy operations (Dataset 1)

Subsectors	Sector	KBLI Code 2009	Number of Company in year 2000-2015	
			Min	Max
Industry of Other Processing and Preservation for Fish	Fish Processing and Preserving Industry and Fish Products	10219	7	185
Industry of Organic Basic Chemical Sourced from Agricultural Products	Chemical Industry	20115	13	53
Industry of Natural/Non-Synthetic Fertilizer for Primary Macro Nutrients	Fertilizer and Nitrogen Compound Industry	20121	5	74
Industry of Used Lubricating Oil Refinery	Petroleum Refining Products Industry	19214	0	3
Recycling Industry	Water Management, Waste Water Management, and Waste Recylcing, and Remediation Activities	383	0	207

Source: SIBS – Indonesia Statistics

Table 2 Agriculture sub-sectors with circular economy operations (Dataset 2)

Subsectors	Sector	KBLI Code 2009	Number of Company in year 2000-2015	
			Min	Max
Industry of Other Processing and Preservation for Fish	Fish Processing and Preserving Industry and Fish Products	10219	7	185
Industry of Organic Basic Chemical Sourced from Agricultural Products	Chemical Industry	20115	13	53
Industry of Natural/Non-Synthetic Fertilizer for Primary Macro Nutrients	Fertilizer and Nitrogen Compound Industry	20121	5	74

Data treatments

In obtaining the data series for each firms, we recall the data using the Indonesian Standard Industrial Classification (KBLI) code and the firm identification (id) code embedded in the SIBS database. Throughout the period of 2000-2015, the SIBS database have two different firm id code references. They are KIPN[9] reference that consists of firm id for the period of 2001, 2002-2006, and PSID[10] reference that consists of firm id for the period of 2000, 2001, 2007-2015. Thus, for the year of 2001, we have both reference of KIPN and PSID for firm id. We then re-align the KIPN reference with the PSID reference using the 2001 data as the bridge. This method has successfully made the time series data aligned and consistent throughout the period. Even so, the data merging process with the year of 2001 as the base merging year may leave out some newly established firms data that emerged in 2002-2006. However, this risk is perceived quite inferior in order to get the time series data aligned and consistent.

The circular economy variables

We used the Circularity Level variable and the Other Revenue variable as the proxies of circular economy activities. Due to data limitation, we use "the value of production of goods

[9] Kode Identitas Perusahaan, 9-digit code
[10] Kode Identitas Perusahaan, 4-digit code

(in Indonesian Rupiah) produced by firms whose raw materials are from the waste of other firms" as the proxy of the amount of materials circulating / recycling within the economic sector. As mentioned above that we adopt a purpose sampling method to capture the circularity level in a firm.

The circularity level data is defined as the production of goods (in Indonesian Rupiah) produced by firms whose raw materials are from the waste of other firms in one sector devided by the total production of goods (in Indonesian Rupiah) in that sector. We calculated the Circularity Level as follows:

$$CL_{it} = \frac{Output\_Prod_{it}}{Total\_ProdSector_{mt}} \quad (1)$$

where CL_t is the circularity level of firm i in period t, $Output\_Prod_t$ is production output of firms i in period t, $Total\_ProdSector_t$ is the total production output of sector m in period t. The Other Revenue (profits from the sale of unprocessed goods, sales of waste / production waste). The first and second datasets are the datasets of firms that apply circular economy was available on the given data and we transformed it into a log form to ensure stationarity. For the robustness check in Dataset 3, we included all firms data available in SIBS database and adopt the same approach to measure circular economy variables. Therefore, we assume the firms that do not implement circular economy activities (firms with sub-sectors that are not mentioned in Table 1 and 2) have no circularity or the circularity level is zero[11].

The other variables

The dependent variables representing firm's productivity is measured by the value of output production, value of total revenue, value of value added, value added productivity (ratio of value added to total labor), and labor productivity (ratio of output production to total labor) adopting from Horbach et al. (2019). The data was in real value and was transformed into log forms in the model to ensure stationarity. The other variables explaining productivity, are foreign investment, the market concentration measure, size of the firms, used installed capacity, import share of inputs and export share of outputs, ratio of R&D expenditure, capital ratio, and non-production labor ratio as in Horbach et al. (2019). Foreign investment indicator is considered as firm that has foreign investment might have more access to new technology that will increase its productivity. The market concentration indicator used is the Herfindahl-Hirschman Index (HHI) which is a measure of the size of firms in relation to the industry. It is defined as the sum of the squares of the market shares of the firms within the industry. The result is proportional to the average market share, weighted by market share (IMF, 2004). Higher values indicate greater concentration, while a decrease in the HHI indicates an increase in competition in the industry or lower concentration. Herfindahl-Hirschman Index (HHI) is as follows:

$$HHI_t = \sum_{i=1}^{N} s_i^2$$

[11] We do not include circular economy dummy as one of the independent variables since it is not compatible in Dataset 1 and 2, and in Dataset 3 the zero values will take up more than 98% of the data (circular economy practicing companies are only 2% of all companies population in Dataset 3).

where s_i is the market share of firm i in the market, and N is the number of firms. The HHI ranges from 0 to one and represents the level of competitiveness in the industry:

1. HHI below 0.01 indicates a highly competitive industry
2. HHI below 0.15 indicates an unconcentrated industry
3. HHI between 0.15 to 0.25 indicates moderate concentration
4. HHI above 0.25 indicates high concentration

Size of the firms, used installed capacity, ratio of R&D expenditure, capital ratio, non-production labor ratio, import share of inputs and export share of outputs are perceived as indicators that may affect the productivity of a firm. Larger firms tend to be more productive and unused installed capacity hinders the productivity to improve. Firms wirh R&D may have more productivity due to better technology. A better technology may also represent in high capital ratio (ratio of machines price to total labor expenditure) (Wacker, Yang, & Sheu, 2006). Non-production labor ratio is defined as a ratio of non-production labor to total labor. Non-production labor includes engineers, product designer, quality inspectors, administrators and other non-production roles. In general, the more headcounts of non-production labor hinder the productivity improvement. Therefore, the more bureaucratic a firm is, the more possible it is as the bottleneck for productivity. However, non-production labor are required to control production through supervising workers (Balasubramanyam and Fu, 2003) reported the critical role of non-production and supervisory workers in Chinese manufacturing plants. Effective administration is critical to the productivity of many medium-sized enterprises. Engineering labor may play a significant role in these plants by implementing process improvements to improve output. No large-scale empirical studies have been conducted to verify the effect of non-production labor on a manufacturing plant's productivity since country differences in productivity generally can be attributed to difference in social, cultural, political, or economic differences (Wacker et al., 2006). Thus, the effect can be vary in each firm. A few researchers have confirmed the effect of national culture on manufacturing decisions (e.g., Pagell et al., 2005).

Import share of inputs may positively affect firm's productivity due to better quality of inputs and more cost-effective (Halpern, Koren, & Szeidl, 2005). Export share of outputs may positively affect firm's productivity related to participation in knowledge-intensive activities (Benkovskis, Masso, Tkacevs, Vahter, & Yashiro, 2017). Benkovskis et al. (2017) argue that the relationships are reciprocal, since exporting firms tend to be more productive, larger, pay higher wages and are more capital intensive than non-exporting firms. While this is partly because firms that are originally more productive and have better performances are more likely to enter export, those firms realize higher labour productivity level as the result of export entry.

The missing data of the export share of outputs data is assumed as zero, meaning that such firms do not have any export activities during the period of the missing data. We estimate the R&D data using the variable named as the "other of other expenditure" that contains R&D expenditure together with other expenses (such as management fee, promotion, telephone, prevention of environtment pollution, and human rescource development cost). We obtained the data from the SIBS database. For the detailed definition of each independent and control variables, refer to Table 3.

Table 3 Definition of Variables

Variable	Variable Definition
logoutput_prod	Value of production of goods of the company
logtotal_revnue	Total revenue from selling output and other goods
logvalue_added	The difference between total revenue and total expenditures
logvalueadd_productivity	Value added per labor
loglabor_productivity	Output production per labr
circularity_lvl	Production of good (IDR) produced by industries whose raw materials are from the waste of other industries in one sector per total productin of goods in that sector
logother_revnue	Profits from the sale of unprocessed goods, other non-industrial services, sales of waste/production waste
dpma	Dummy of foreign investment
hhi	Amount of competition measure (firm's concentration ratio)
firm_size	Dummy of size of companies
used_cap	Used installed-capacity
Import_share	Ratio of imported inputs to total inputs
Export_share	Ratio of exported outputs to total outputs
R&D_ratio	Ratio of R&D expenditure to total labor expenditure
capital_ratio	Ratio of machines price to total labor expenditure
nonprodlabor_ratio	Ratio of non-production labor to total labor

4. Empirical method

This study aims to establish the impact of circular economy activities on productivity in Indonesia within the period of 2000-2015 annually by using panel regression. Since there are three datasets that are analyzed with different sectoral base data of the SIBS database, we estimate three slightly different models:

$$Y_{it} = \alpha_0 + \alpha_1 CE1_i + \alpha_2 X_{it} + \varepsilon_{it}$$

$$Y_{it} = \alpha_0 + \alpha_1 CE2_i + \alpha_2 X_{it} + \varepsilon_{it}$$

$$Y_{it} = \alpha_0 + \alpha_1 CE3_i + \alpha_2 X_{it} + \varepsilon_{it}$$

where Y_{it} is productivity indicator of firm (output production, total revenue, value added, value-added productivity, and labor productivity) firm i at time t, $CE1_i$ is the circular economy activities (circularity level and other revenue) in 5-sub-sectors firm i at time t, $CE2_i$ is the circular economy activities (circularity level and other revenue) in agriculture-sub-sectors firm i from at time t, $CE3_i$ is the circular economy activities (circularity level and other revenue) in all-sectors firm i at time t, X_{it} is control variables of firm i at time t, and ε_{it} is the error term.

By using panel estimations, we aim to: (1) control individual heterogeneity; (2) get more infromative, variability, and efficient data, but less colinear; (3) study the dynamics adjustment better, especially in economic development outcome; (4) identify and measure effects better;

(5) construct and test more complicated behavioral model; (6) measure the micro data more accurately (Baltagi, 2005). First, we estimated the datasets using both FE and RE, then tested each model by using Hausman Test. The Hausman Test indicated that the models were consistent by using fixed effect model (FE) but the output for labor productivity model in dataset 2 we use random effect model (RE).

5. Estimation Results

The estimation results of the effects of circular economy practices on the productivity indicators are presented in Table 4. Table 4 shows the estimation results for circular economy effects on productivity of dataset 1, dataset 2 and dataset 3. Dataset 1 includes all firms of 5 subsectors implementing circular economy practices. Dataset 2 contains all firms from agriculture sectors implementing circular economy practices. Dataset 3 comprises all firms in the SIBS database. In the tables, the coefficient of a category of a circular economy component is the percentage change in the productivity indicator due to one percentage increase in circular economy variables or other determinants variable in the dataset. The remaining of this section discusses how each productivity indicator is affected by the circular economy practices and other determinants.

Table 4 Summary of estimation results for circular economy effects on productivity

Variables	Output Production (Log)	Total Revenue (Log)	Value Added (Log)	Value Added Productivity (Log)	Labor Productivity (Log)
Circularity Level					
Dataset 1	**9.7582***	**9.4636***	**10.0395***	**9.1852***	**8.5867***
	(3.0660)	(2.7325)	(3.2567)	(3.2427)	(3.0362)
Dataset 2	6.5316	6.1021	**12.1584***	**12.4886***	**9.3939***
	(3.9501)	(3.7048)	(4.3821)	(4.2828)	(2.8881)
Dataset 3	**3.9544***	**3.0269***	2.0788	**2.8956***	**4.4854***
	(1.2482)	(1.1262)	(1.2385)	(1.2095)	(1.2115)
Other Revenue (Log)					
Dataset 1	**0.1523***	**0.2169***	**0.2296***	**0.2100***	**0.1312***
	(0.0222)	(0.0189)	(0.0226)	(0.0225)	(0.0220)
Dataset 2	**0.1787***	**0.2686***	**0.2989***	**0.2798***	**0.1657***
	(0.0252)	(0.0237)	(0.0280)	(0.0274)	(0.0179)

Dataset 3	**0.2012***	**0.2429***	**0.2332***	**0.1966***	**0.1638***
	(0.0024)	(0.0021)	(0.0023)	(0.0023)	(0.0023)

Note: the effects of circular economy practices on the output for labor productivity in dataset 2 are estimated using random effect panel model

As we can see in Table 4, the result suggests that the circularity level positively affecting the five productivity indicators (output production, total revenue, value added, value added productivity and labor productivity) especially for firms of 5 subsectors implementing circular economy practices (dataset 1). As for firms from agriculture sectors implementing circular economy practices (dataset 2), the results also indicate that circularity level positively affecting the three out of five productivity indicators (value added, value added productivity and labor productivity). As for all set of firms included in the SIBS database (dataset 3), the result imply that circularity level positively affecting the four out of five productivity indicators (output production, total revenue, value added productivity and labor productivity). By observing the magnitude of the parameters, we can analyze that the effects of circularity level on productivity vary across sectors. Agriculture sectors implementing circular economy practices (dataset 2) shows the highest positive impact on productivity. While all firms in the SIBS database (dataset 3) shows lowest positive impact of circularity level on productivity. The firms implementing circular economy practices (dataset 1) shows medium positive impact of circularity level on productivity.

Refering to table 4, for other circular economy variables (other revenue or profits from the sale of unprocessed goods, other non-industrial services, sales of waste/production waste), its effect on productivity less feasible compared to that of circularity level's. Yet we can still observe the impact' difference on productivity across sectors. Similar with the phenomena of circularity level, the other revenue variable's impact on productivity for firms of agriculture sector implementing circular economy practices (dataset 2) is the highest, while the impact on productivity for firms implementing circular economy practices (dataset 1) is relatively the same with that of for all firms in the SIBS database (dataset 3).

For detail of the estimation results of firms implementing circular economy practices (dataset 1), the estimation results of firms of agriculture sector implementing circular economy practices (dataset 2), and the estimation results of all firms in the SIBS database (dataset 3), see the appendix 4-6.

Estimation results of Dataset 1 – Firms of 5 subsectors

Appendix 4 (Estimation results of dataset 1 that includes firms of 5 subsectors) shows the effect of the circular economy variables, as well as the other productivity determinants, on 5-sub-sectors firms' productivity indicator. Based on the estimation result, both circularity level and profits from sale of unprocessed goods and waste has positive significant effect on all productivity indicator. It means that an increase in circularity level and profits from sale of unprocessed goods and waste increases all productivity indicator.

An increase in circularity level, profits from sale of unprocessed goods and waste, and import share increases production output. A percentage point increase in the circularity level increases the production output by 9.76 percent and a percent increase in the profits from sale of unprocessed goods and waste increases the production output by 0.15 percent. Meanwhile, a percentage point increase in the import share increases the production output by 1.4 percent. However, an increase in capital per total labor cost decreases production output. A percentage point increase in the capital per total labor cost decreases production output by 0.053 percent. Other determinants do not have significant effect on the production output.

An increase in circularity level and profits from sale of unprocessed goods and waste increases the total revenue received by the firm. A percentage point increase in circularity level increases the total revenue received by the firm by 9.46 percent. Meanwhile, a percent increase in profits from sale of unprocessed goods and waste increases the total revenue received by the firm by 0.22 percent. The big manufactures also tend to have higher total revenue than medium manufactures, where big manufactures have 0.37 percent higher in total revenue than medium firm. Furthermore, an increase in other determinants do not have effect on the total revenue received by the firm.

An increase in circularity level, profits from sale of unprocessed goods and waste, the amount of competition measure (concentration ratio) in the industry, and capital per total labor cost increases the value-added produced the firm. A percentage point increase in circularity level and a percent increase in profits from sale of unprocessed goods and waste increases the value-added of the firm by 10.04 percent and 0.23 percent, respectively. Meanwhile, a percentage point increase in ratio capital per total labor cost increases the value–added of the firm by 0.027 percent. A point increase in the firms' concentration ratio (less competition) also increases the value-added of the firm. Big manufactures also tend to have higher value-added than medium manufactures, where big manufactures have value-added 0.34 percent higher than medium manufactures. Furthermore, an increase in other determinants do not have effect on the value-added produced by the firm.

An increase in circularity level, profits from sale of unprocessed goods and waste, the amount of competition measure (concentration ratio) (concentration ratio) in the industry, and capital per total labor cost increases the value-added productivity. A percentage point increase in circularity level and a percent increase in profits from sale of unprocessed goods and waste increases the value-added productivity by 9.185 percent and 0.21 percent, respectively. A percentage point increase in capital per total labor increases the value-added productivity by 0.027 percent. However, big manufactures tend to have lower value-added productivity than medium manufactures, where big manufactures have value-added productivity 0.44 percent lower than medium manufactures. Furthermore, the other determinants do not have significant effect on the value-added productivity.

An increase in circularity level and profits from sale of unprocessed goods and waste increases the labor productivity. A percentage point increase in circularity level increases the labor productivity by 8.59 percent. Meanwhile, a percent increase in profits from sale of unprocessed goods and waste by 0.13 percent. However, an increase in capital per total labor cost decreases the labor productivity, where a percentage point increase in capital per total labor cost decreases the labor productivity by 0.051 percent. Big manufactures tend to have labor productivity lower than medium manufactures, where big manufactures have 0.58 percent lower labor productivity than medium manufactures. Furthermore, an increase in other determinants do not have effect on labor productivity.

Estimation results of Dataset 2 – Firms of agriculture subsectors

Appendix 5 (Estimation results of dataset 2 that includes firms of 5 subsectors) shows the effect of the circular economy variables, as well as the other productivity determinants, on agriculture-subsectors firms' productivity indicator. Based on the estimation result, profits from sale of unprocessed goods and waste has positive significant effect on all productivity indicators while circularity level has positive significant effect on value-added, value-added productivity, and labor productivity which estimated using RE.

An increase in profit from sale of unprocessed goods and waste increases the production output of the firm. It means that a percent increase in profit from sale of unprocessed goods and waste increases the production output by 0.18 percent. Meanwhile, big manufactures tend to have higher production output than medium manufactures, where big manufactures have production output 0.56 percent higher than medium manufactures. However, an increase in capital per total labor cost decreases the output production, where a percentage point increase in capital per total labor cost decreases the production output by 0.053 percent. Furthermore, an increase in other determinants do not have effect on production output.

An increase in profit from sale of unprocessed goods and waste, export share, and R&D expenditure per total labor cost increases the total revenue of the firm. A percent increase in profit from sale of unprocessed goods and waste increases the total revenue by 0.269 percent. A percentage increase in export share and R&D expenditure per total labor cost increases the total revenue by 0.43 and 2 percent, respectively. Meanwhile, big manufactures tend to have higher total revenue than medium manufactures, where big manufactures have total revenue 0.42 percent higher than medium manufactures. However, an increase in capital per total labor cost decreases total revenue per labor. A percentage point increase in capital per total labor cost decreases the total revenue by 0.016 percent. Furthermore, other determinants do not have a significant effect on the total revenue of the firm.

An increase in circularity level, profit from sale of unprocessed goods and waste, the amount of competition measure (concentration ratio) in the industry, and capital per total labor cost increases the value-added produced by the firm. A percentage point increase in circularity level increases the value-added produced by the firm by 12.16 percent, while a percent increase in profit from sale of unprocessed goods and waste increases the value-added produced by the firm by 0.3 percent. A point increases in the concentration ratio (less competition) increases the value-added produced by the firm by 0.79 percent. Meanwhile, a percentage point in capital per total labor cost increases the value-added produced by the firm by 0.02 percent. Furthermore, other determinants do not have a significant effect on the value-added produced by the firm.

An increase in circularity level, profit from sale of unprocessed goods and waste, the amount of competition measure (concentration ratio) (concentration ratio) in the industry, export share, capital per total labor cost, and non-production labor per total labor increases the value-added productivity. A percentage point increase in circularity level increases value-added productivity by 12.49 percent, while a percent increase in profit from sale of unprocessed goods and waste increases the value-added productivity by 0.28 percent. A percentage increase in export share, capital per total labor cost increases the value-added productivity by 0.45 percent and 0.022 percent, respectively. Meanwhile, a percentage point increase in non-production labor per total labor increases the value-added productivity by 1.09 percent. A point increase in the concentration ratio (less competition) increases value-added productivity by 0.79 percent. However, big manufactures tend to have lower value-added productivity than medium manufactures, where big manufactures have value-added productivity 0.6 percent lower than medium manufactures. Furthermore, an increase in other determinants do not have effect on value-added productivity.

Meanwhile in labor productivity model, we used the RE as the model estimation. In RE model, we assume that the individual unobserved effect is random, means that there is zero correlation between observed explanatory and the unobserved effect[12]. An increase in

[12] While in FE, we assume that the individual unobserved effect is fixed, means that the estimator will omit the time-invariant unobserved effect.

circularity level, profit from sale of unprocessed goods and waste, import share, export share, non-production labor per total labor increases the labor productivity. A percentage point increase in circularity level increases the labor productivity by 9.4 percen, while a percent increase in profit from sale of unprocessed goods and waste increases the labor productivity by 0.17 percent. A percentage point increase in import and export share increases the labor productivity by 0.87 and 0.4 percent, respectively. A percentage point increase in non-production labor per total labor increases labor productivity by 0.77 percent. However, big manufactures tend to have lower output production labor productivity than medium manufactures, where big manufactures have labor productivity 0.3 percent lower than medium manufactures. An increase in capital per total labor cost also decrease labor productivity, where a percentage point increase in capital per total labor cost decrease labor productivity by 0.056 percent. Furthermore, an increase in other determinants do not have effects on labor productivity.

Estimation results of Dataset 3 – All firms of the SIBS database

Appendix 6 (Estimation results of dataset 3 that includes all firms of the SIBS database) shows the effect of the circular economy variables, as well as the other productivity determinants, on all-sector firms' productivity indicator. Based on the estimation result, profits from sale of unprocessed goods and waste has positive significant effect on all productivity indicator while circularity level has positive significant effect on almost all productivity indicator, except value-added.

An increase in circularity level, profit from sales of unprocessed goods and waste, foreign capital, size of firm, used installed-capacity, and import share increases the production output. A percentage point increase in circularity level increases the production output by 3.95 percent, while a percent increase in the profit from sales of unprocessed goods and waste increases the production output by 0.201 percent. Manufactures that have foreign capital have output production 0.26 percent higher than manufactures that do not have foreign capital. Big manufactures also have output production 0.97 percent higher than medium manufactures. Meanwhile, a percentage point increase in used installed-capacity and import share increases the production output by 0.12 and 0.33 percent, respectively. However, the amount of competition measure (concentration ratio) (concentration ratio) in the industry, capital per total labor cost, and non-production labor per total labor decreases the production output. A point increase in the concentration ratio in the industry (less competition) decreases the production output by 0.26 percent. Meanwhile, a percentage point increase in capital per total labor cost and non-production labor per total labor decreases the production output by 0.0004 and 0.006 percent, respectively. Furthermore, an increase in other determinants do not have effect on the production output.

An increase in circularity level, profit from sales of unprocessed goods and waste, foreign capital, size of firm, used installed-capacity, import share, and R&D expenditure per total labor cost increases the total revenue received by the firm. A percentage increase in circularity level increases the total revenue by 3.95 percent, while a percent increase in profit from sales of unprocessed goods and waste increases the total revenue by 0.24 percent. Manufactures that has foreign capital have total revenue 0.27 percent higher than manufactures who do not have foreign capital. Big manufactures also have total revenue higher 0.92 percent than medium manufactures. A percentage point increase in used installed-capacity and import share increases the total revenue by 0.095 percent and 0.29 percent, respectively. A percentage increase in R&D expenditure per total labor cost increases total revenue by 0.020 percent. However, an increase in the amount of competition measure (concentration ratio) (concentration ratio) in the industry decreases the total revenue received by the firm. A point increase in the concentration ratio in the industry (less competition) decreases the total revenue by 0.304 percent. Furthermore, an increase in other determinants do not have effect on the total revenue received by the firm.

An increase in profit from sales of unprocessed goods and waste, size of firm, used installed-capacity, import share, export share, and R&D expenditure per total labor cost increases the value-added produced by the firm. A percent increase in profit from sales of unprocessed goodds and waste increases the value-added by 0.23 percent. Manufactures which have foreign capital have value-added 0.19 percent higher than that of manufactures which do not have foreign capital. Big manufactures have value-added 0.92 percent higher than medium manufactures. A percentage increase in use installed-capacity and R&D expenditure per total labor cost also increases the value-added by 0.092 percent and 0.01 percent, respectively. Meanwhile, a percentage increases in import and export share increases value-added by 0.28 percent and 0.068 percent, respectively. However, an increase the the amount of competition measure (concentration ratio) (concentration ratio) in the industry and non-production labor per total labor decreases the value-added produced by the firm. A point increase in the concentration ratio in the industry (less competition) decreases the value-added by 0.29 percent. Meanwhile, a percentage increase in non-production labor per total labor also decreases the value-added by 0.11 percent. Furthermore, an increase in other determinants do not have effects on value-added produced by the firm.

An increase in circularity level, profit from sales of unprocessed goods and waste, foreign capital, used installed-capacity, import share, export share, R&D expenditure per total labor cost increase the value-added productivity. A percentage increase in circularity level increases the value-added productivity by 2.9 percent, while a percent increase in profit from sales of unprocessed goods and waste increases the value-added by 0.2 percent. Manufactures that have foreign capital have value-added productivity 0.067 percent higher than manufactures that do not have foreign capital. A percentage increase in used installed-capacity and R&D expenditure per total labor cost increases the value-added productivity by 0.075 percent and 0.011 percent, respectively. Meanwhile, a percentage increase in import and export share increases the value-added productivity by 0.17 and 0.094 percent, respectively. However, an increase in the amount of competition measure (concentration ratio) (concentration ratio) in the industry, size of firm, and non-production labor per total labor decreases the value-added productivity. A point increase in the concentration ratio in the industry (less competition) decreases the value-added productivity by 0.34 percent. Meanwhile, a percentage point increase in non-production labor per total labor decreases the value-added productivity by 0.4 percent. Big manufactures also have value-added productivity 0.44 percent higher than medium manufactures. Furthermore, an increase in other determinants do not have effect in value-added productivity.

An increase in circularity level, profit from sales of unprocessed goods and waste, foreign capital, used installed-capacity, import share, and export share increases the labor productivity. A percentage point increase in circularity level increases the labor productivity by 4.49 percent, while a percent increase in profit from sales of unprocessed goods and waste increases the labor productivity by 0.16 percent. Manufactures that have foreign capital have labor productivity 0.15 percent higher than manufactures that do not have foreign capital. A percentage point increase in used installed-capacity increases the labor productivity by 0.098 percent. Meanwhile, a percentage point in import and export share increases the labor productivity by 0.22 percent and 0.06 percent, respectively. However, the amount of competition measure (concentration ratio) (concentration ratio) in the industry, size of firm, capital per total labor cost, and non-production labor per total labor decreases the labor productivity. A point increase in the concentration ratio in the industry (less competition) decrease the labor productivity by

0.32 percent. Big manufactures also have labor productivity 0.39 percent lower than medium manufactures. A percentage increase in capital per total labor cost and non-production labor per total labor decreases the labor productivity by 0.0004 percent and 0.347 percent, respectively. Furthermore, an increase in other determinants do not have effects on labor productivity.

6. Discussion

Figure 1 to Figure 5 summarize the estimation results on the effects of circularity level and other determinants on firms' productivity. From the figures we can see that the effects of circularity level on productivity vary across sectors. Agriculture sectors implementing circular economy practices (dataset 2) shows the highest positive impact on productivity. While all firms in the SIBS database (dataset 3) shows the lowest positive impact of circularity level on productivity. The firms implementing circular economy practices (dataset 1) shows medium positive impact of circularity level on productivity. While the impact of other circular economy variables (other revenue) on productivity is less tangible.

For other determinant variables, the degree of competition measure (concentration ratio) in the industry has negative impact on productivity indicators for all firms in the SIBS database (dataset 3), meaning a decrease in HHI or less concentration (more competition) in the industry increases the productivity indicators. However, the estimation result suggests the opposite findings specifically for the firms implementing circular economy practices (dataset 1) and for the firms in agriculture sectors implementing circular economy practices (dataset 2). It may be related with the uniqueness of circular economy ecosystem that encourages the producers to have a coordinated capacity to be able to make a circular business flow. This reflects the relationship between innovation and incentive to innovate (Schiffbauer & Ospina, 2010), where innovation enables a firm to break away from intense competition for a certain period of time. Circular economy paradigm and practices are assumed as the improving-productivity-innovation. Thus, the less market competition or the more market concentration, the easier for firms to establish the circular ecosystem and gain more value added productivity measurements as an increase in market competition between intermediate producers will reduce expected future profits from innovations. This is also inline with the arguments of Wacker et al. (2006) that productivity generally can be attributed to differences in social, cultural, political, or economic differences based on international study.

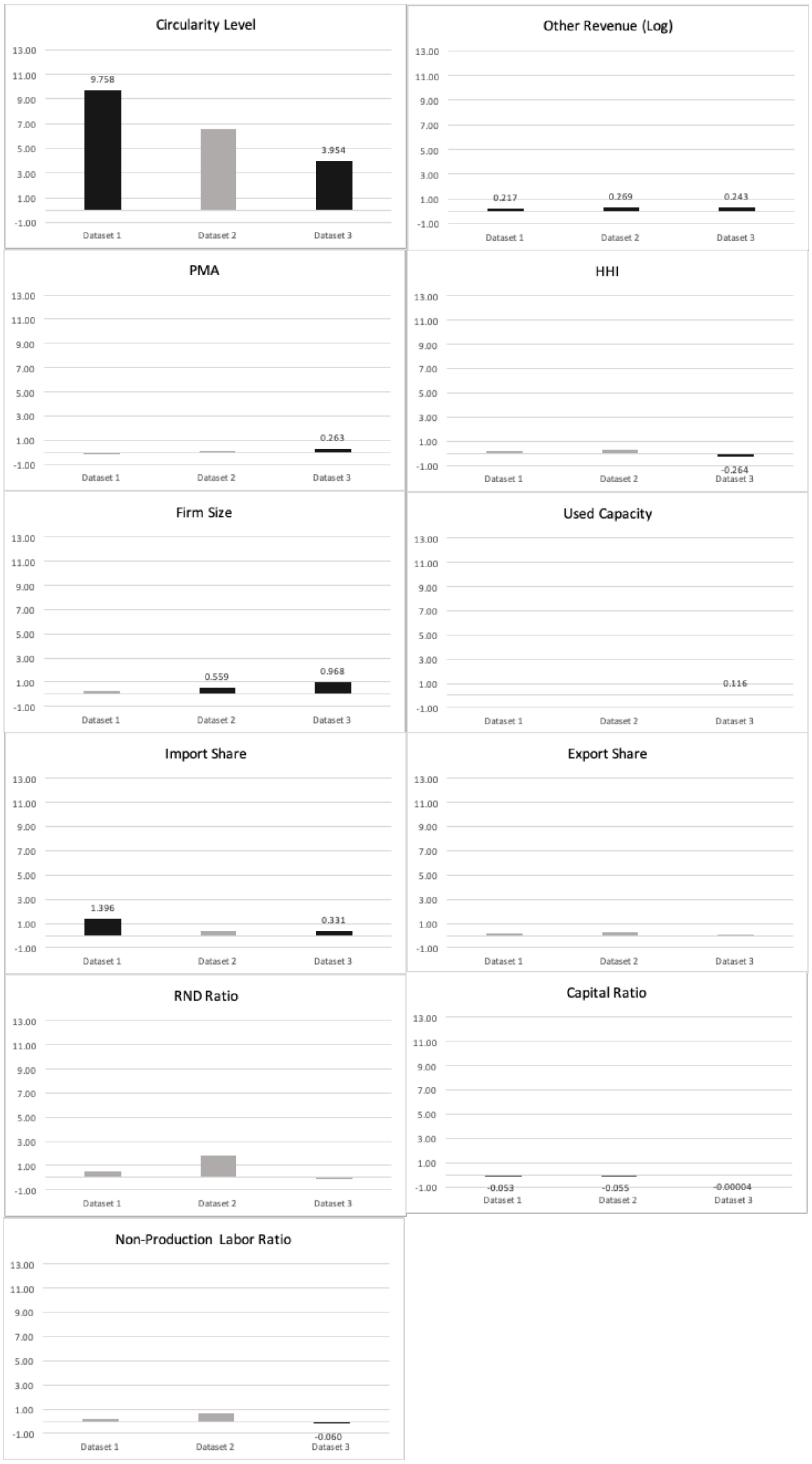
For import share, export share, and R&D ratio, they all have positive impacts on productivity for all datasets. For firm size, the effects are positive on productivity measurements of total output, total revenue, value added for all datasets, while the effects are negative on productivity measurements of value added productivity (value added per labor) and labor productivity (output per labor). This may be due to the larger the firm, the larger its total output, total revenue, value added. However, when we look at the increment per labor, the effects become negative, as the more headcounts work in the firm, the less marginal productivity per labor and more costs.

The capital ratio (ratio of machines price to total labor expenditure) has negative effects on productivity measurements of total output and labor productivity (output per labor) for all datasets, while it has positive effects on productivity measurements of total revenue, value added and value added productivity for all datasets. This may be due to high capital ratio means that the firm is capital intensive which invites value added and revenue, and capital intensive firm with high capital ratio invites better economies of scale gained by the firm during the production process. Thus, the firm can produce goods with less costs (less value or price for total output and output per labor).

Non-production labor ratio has positive effects on productivity measurements of value added and value added productivity for firms in agriculture sectors implementing circular economy practices (dataset 2), while it has negative effects on productivity measurements of output production, value added, value added productivity and labor productivity for all firms in the SIBS database (dataset 3). For the firms implementing circular economy practices (dataset 1), it has no significant effects. This may be due to there is a difference between non-production labor's role importance specifically in firms in agriculture sectors implementing circular economy practices (dataset 2) with that of all general firms in the SIBS database (dataset 3). For agriculture sectors, administration skills is important to obtain certificates (for instance, organic certificate) which will increase the productivity, while in all sectors, generally an increase in non-production labor means more costs to bear for the firm.

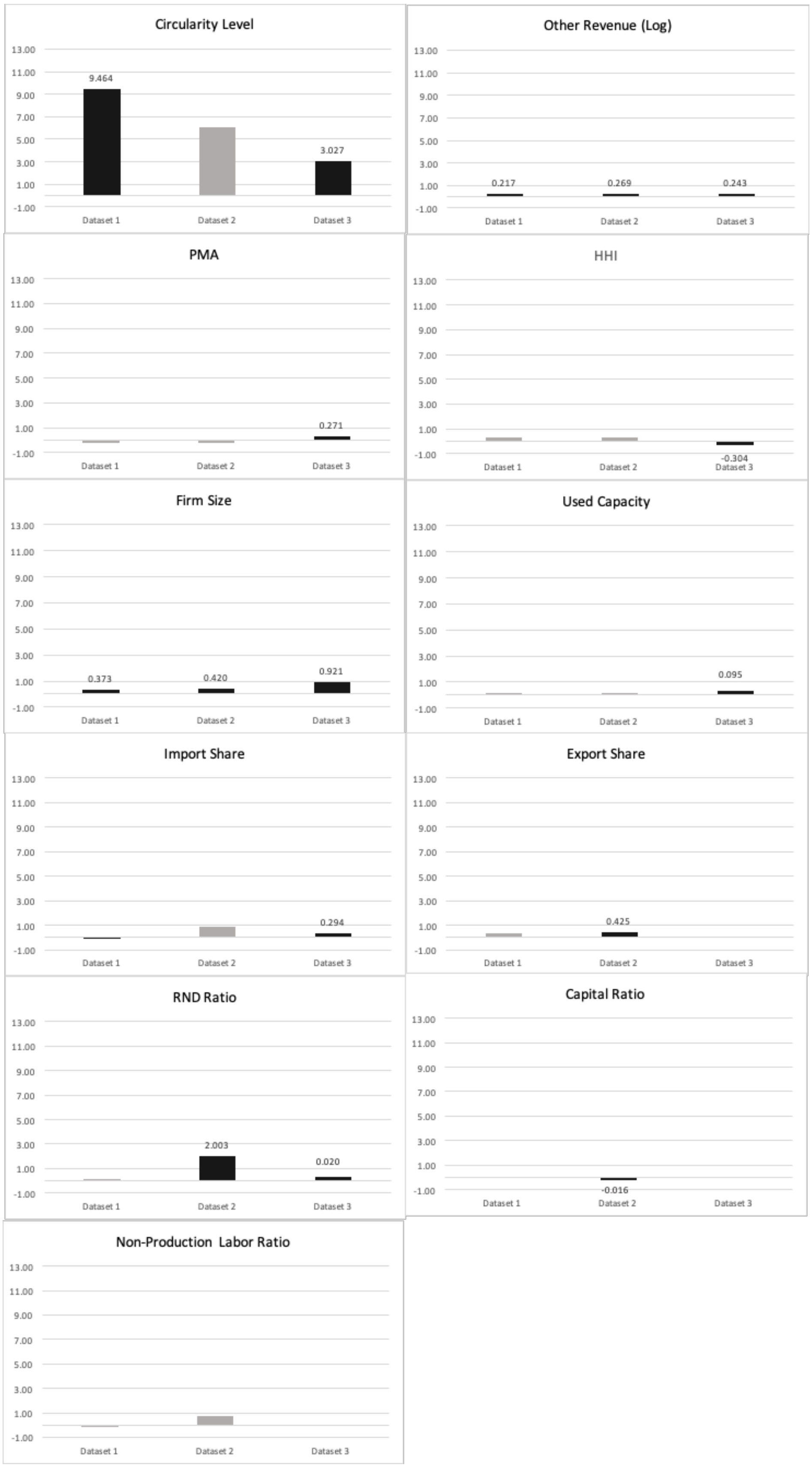
Surprisingly, foreign ownership does not play a significant role in increasing productivity for firms implementing circular economy practices (dataset 1 and 2), while it has significant positive impact on productivity for all general firms in the SIBS database (dataset 3). Similar case with that of used capacity variable. This may be due to circular economy ecosystem encourages producers to go local, to empower local, to shorten the supply chain, produce with coordinated capacity with other producers to build the circular business flows. Thus, foreign ownership and used capacity do not contribute to the increase in productivity. This makes firms implementing circular economy practices (dataset 1 and 2) more resilient to global shocks.

Figure 1. The effect of circular economy and other determinants on log production output



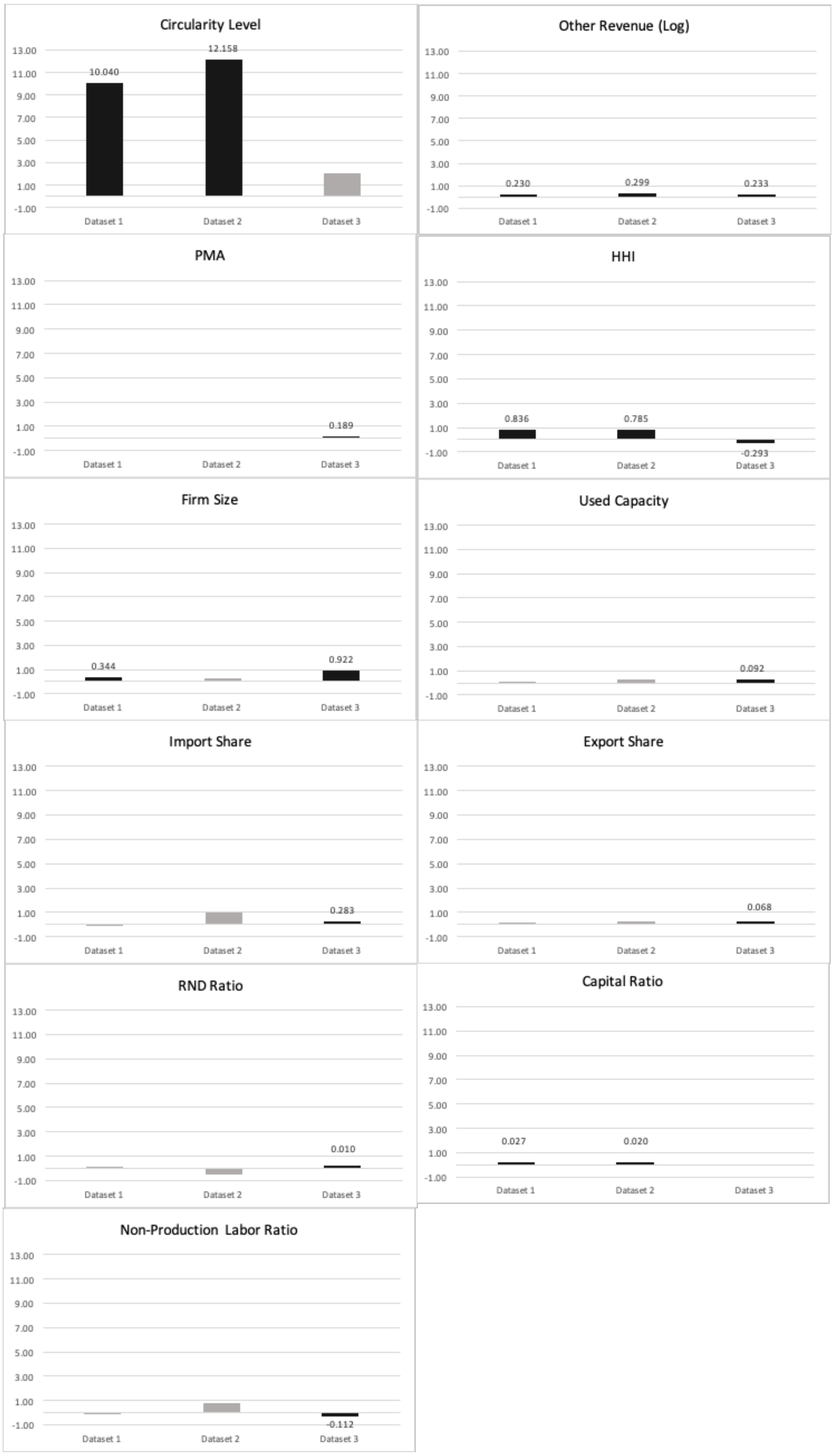
Note: ▬ = statistically significant; ▬ = statistically insignificant

Figure 2. The effect of circular economy and other determinants on log total revenue



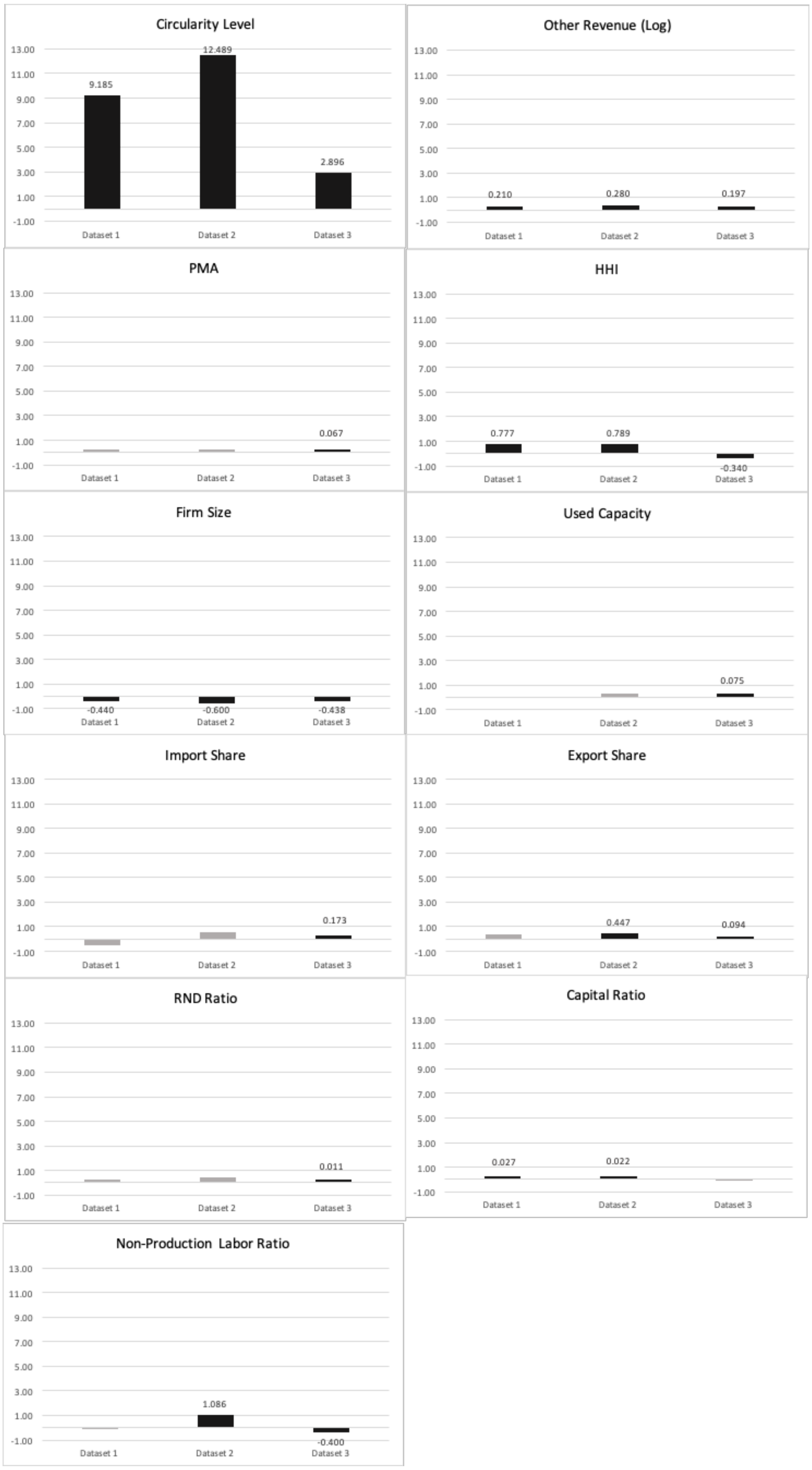
Note: ■ = statistically significant; ■ = statistically insignificant

Figure 3. The effect of circular economi and other determinants on log value-added



Note: ▬ = statistically significant; ▬ = statistically insignificant

Figure 4. The effect of circular economy and other determinants on log value-added productivity



Note: ■ = statistically significant; ■ = statistically insignificant

Figure 5. The effect of various circular economy and other determinants on log labor productivity

Note: ■ = statistically significant; ■ = statistically insignificant

Table 5 Summary of estimation results for other explaining variables effects on productivity

Variables	Output Production (Log)	Total Revenue (Log)	Value Added (Log)	Value Added Productivity (Log)	Labor Productivity (Log)
PMA					
Dataset 1	-0.2171	-0.2422	0.0926	0.0570	-0.2058
	(0.4267)	(0.3964)	(0.4724)	(0.4704)	(0.4225)
Dataset 2	0.0508	-0.1846	0.0457	0.0250	-0.0635
	(0.4245)	(0.3981)	(0.4709)	(0.4603)	(0.2214)
Dataset 3	**0.2630***	**0.2714***	**0.1890***	**0.0674***	**0.1463***
	(0.0335)	(0.0302)	(0.0332)	(0.0325)	(0.0326)
HHI					
Dataset 1	0.1716	0.3405	**0.8361***	**0.7773***	0.1325
	(0.2784)	(0.2585)	(0.3081)	(0.3068)	(0.2756)
Dataset 2	0.2416	0.2795	**0.7846***	**0.7890***	0.2816
	(0.2678)	(0.2512)	(0.2971)	(0.2904)	(0.2236)
Dataset 3	**-0.2643***	**-0.3042***	**-0.2926***	**-0.3398***	**-0.3148***
	(0.0292)	(0.0258)	(0.0284)	(0.0277)	(0.0284)
Firm size					
Dataset 1	0.2877	**0.3731***	**0.3437***	**-0.4398***	**-0.5834***
	(0.1857)	(0.1435)	(0.1711)	(0.1703)	(0.1839)
Dataset 2	**0.5588***	**0.4200***	0.2986	**-0.5995***	**-0.2973***
	(0.2183)	(0.2048)	(0.2422)	(0.2367)	(0.1228)
Dataset 3	**0.9683***	**0.9214***	**0.9218***	**-0.4381***	**-0.3943***
	(0.0170)	(0.0153)	(0.0168)	(0.0164)	(0.0165)
Used capacity					
Dataset 1	0.0808	0.1181	0.0896	0.0528	0.0206
	(0.1519)	(0.1252)	(0.1492)	(0.1486)	(0.1504)
Dataset 2	0.1046	0.1810	0.2616	0.2151	0.0418
	(0.1679)	(0.1575)	(0.1863)	(0.1821)	(0.1250)
Dataset 3	**0.1156***	**0.0952***	**0.0923***	**0.0754***	**0.0984***
	(0.0180)	(0.0161)	(0.0176)	(0.0172)	(0.0175)
Import share					
Dataset 1	**1.3958***	-0.0078	-0.1207	-0.5533	0.9442
	(0.5358)	(0.4554)	(0.5428)	(0.5404)	(0.5306)

Dataset 2	0.3494	0.8828	1.0102	0.5828	**0.8690***
	(0.9796)	(0.9188)	(1.0868)	(1.0621)	(0.3790)
Dataset 3	**0.3305***	**0.2936***	**0.2826***	**0.1729***	**0.2224***
	(0.0348)	(0.0309)	(0.0340)	(0.0332)	(0.0338)
Export share					
Dataset 1	0.2133	0.3064	0.1563	0.4184	0.3952
	(0.2160)	(0.1971)	(0.2349)	(0.2339)	(0.2139)
Dataset 2	0.2965	**0.4253***	0.2486	**0.4473***	**0.4012***
	(0.2065)	(0.1937)	(0.2291)	(0.2239)	(0.1374)
Dataset 3	0.0322	0.0472	**0.0676***	**0.0936***	**0.0575***
	(0.0279)	(0.0252)	(0.0277)	(0.0271)	(0.0271)
R&D ratio					
Dataset 1	0.5102	0.1446	0.0305	0.0346	0.9216
	(0.5206)	(0.1077)	(0.1283)	(0.1278)	(0.5155)
Dataset 2	1.8527	**2.0027***	-0.5126	0.2072	0.4055
	(0.9582)	(0.8986)	(1.0629)	(1.0389)	(0.2907)
Dataset 3	-0.0525	**0.0197***	**0.0096***	**0.0112***	-0.0404
	(0.0373)	(0.0036)	(0.0040)	(0.0039)	(0.0362)
Capital ratio					
Dataset 1	**-0.0525***	-0.0119	**0.0269***	**0.0274***	**-0.0508***
	(0.0090)	(0.0082)	(0.0098)	(0.0097)	(0.0089)
Dataset 2	**-0.0548***	**-0.0160***	**0.0203***	**0.0219***	**-0.0563***
	(0.0087)	(0.0081)	(0.0096)	(0.0094)	(0.0080)
Dataset 3	**-0.0004***	-0.000013	-0.000001	-0.000041	**-0.0004***
	(0.00009)	(0.00002)	(0.00002)	(0.00002)	(0.00009)
Non-production labor ratio					
Dataset 1	0.1500	-0.1667	-0.1422	-0.1036	0.0009
	(0.3374)	(0.2734)	(0.3259)	(0.3245)	(0.3341)
Dataset 2	0.6082	0.7760	0.8272	**1.0856***	**0.7662***
	(0.4399)	(0.4126)	(0.4880)	(0.4770)	(0.2646)
Dataset 3	**-0.0603***	-0.0336	**-0.1124***	**-0.4001***	**-0.3471***
	(0.0256)	(0.0231)	(0.0254)	(0.0248)	(0.0249)

7. Conclusion

The circular economy arises as the opposing concept of linear economy based on the awareness of sustainability. Since the concept of the circular economy is a relatively new focus of research, very limited research has been done that focuses on the relationship between circular economy practices and firm productivity empirically. This paper is the first empirically assessing the relationships between circular economy practices and firm productivity in Indonesia. Circular economy paradigm has an open paradigm that is non-restrictive and adaptable to the social and ecological environment depending on the availability of resources (low-tech to high-tech) and markets (small to large). This makes circular economy approach, theoretically, is effective to improve productivity sustainably with limited resources available as in developing economies such as Indonesia.

This study contributes to circular economy and productivity literature by examining the dynamics and the importance of circular economy variables (circularity level and profit from the sale of byproducts and waste) on firm's productivity using large datasets from Indonesia. The context of developing economies provides new perspectives and is not necessarily in line with textbook rules that are mostly based on the developed economies paradigm. The study also contributes by highlighting the challenge on limited data availability related to measuring the circular economy measurements.

The study finds that the circularity level positively affects the productivity indicators but with different magnitude of effects across sectors. Agriculture sectors implementing circular economy practices (dataset 2) shows the highest positive impact on productivity. While all firms in the SIBS database (dataset 3) shows lowest positive impact of circularity level on productivity. The firms implementing circular economy practices (dataset 1) shows medium positive impact of circularity level on productivity. For other circular economy variables (other revenue or profits from the sale of by-products and waste), its effect on productivity less tangible compared to that of circularity level's. Yet we can still observe the impact' difference on productivity across sectors.

What also important is that the dynamics of other deteminant variables of productivity shows that there is unique treats of firms that implement circular economy practices which makes them different and more resilient compared with other general firms. It is the higher role of non-production labor for productivity, the different effects of market concentration and that as the circular economy ecosystem encourages producers to go local, to empower local, to shorten the supply chain, produce with coordinated capacity with other producers to build the circular business flows. This makes firms implementing circular economy practices are more resilient to global shocks.

For further research, the authors suggest developing the database of the flow of materials, within and the inter-sectoral material flows since it will certainly add vital information and provide deeper and more accurate research opportunity in improving the all-inclusive productivity.

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Appendix

Appendix 1. Summary of Dataset 1

Variables	Mean	Std. Dev.	Min.	Max.
Circularity Level	0.003	0.014	0	0.277
Other Revenue (Log)	7.377	2.463	4.174	15.925
PMA	0.064	0.244	0	1
HHI	0.147	0.158	0	1
Firm Size	0.176	0.381	0	1
Used Capacity	0.645	0.331	0	1
Import Share	0.047	0.170	0	1
Export Share	0.109	0.287	0	1
R&D Ratio	0.040	0.090	0	0.749
Capital Ratio	0.732	21.090	0	1.125.451
Non-Production Labor Ratio	0.178	0.184	0	1.267

Appendix 2. Summary of Dataset 2

Variables	Mean	Std. Dev.	Min.	Max.
Circularity Level	0.003	0.013	0	0.277
Other Revenue (Log)	7.124	2.209	1.512	15.925
PMA	0.059	0.236	0	1
HHI	0.155	0.175	0	0.779
Firm Size	0.156	0.363	0	1
Used Capacity	0.684	0.306	0	1
Import Share	0.025	0.114	0	0.997
Export Share	0.138	0.317	0	1
R&D Ratio	0.031	0.064	0	0.719
Capital Ratio	0.789	24.471	0	1.125.451
Non-Production Labor Ratio	0.156	0.178	0	1.2

Appendix 3. Summary of Dataset 3

Variables	Mean	Std. Dev.	Min.	Max.
Circularity Level	0.0001	0.0036	0.0000	0.9184
Other Revenue (Log)	6.3442	2.7599	2.7394	18.8218
PMA	0.0899	0.2861	0	1
HHI	0.1164	0.1592	0	1
Firm Size	0.3059	0.4608	0	1
Used Capacity	0.6532	0.3141	0	1
Import Share	0.0941	0.2426	0	1
Export Share	0.1121	0.2836	0	1
R&D Ratio	0.1691	10.1663	0	0.7495
Capital Ratio	5.3811	1.969.76	0	1.011.204
Non-Production Labor Ratio	0.1682	0.1966	0	16.1818

Appendix 4 Estimation results of Dataset 1 – Companies of 5 subsectors

Variables	Output Production (Log)	Total Revenue (Log)	Value Added (Log)	Value Added Productivity (Log)	Labor Productivity (Log)
Circularity Level	**9.7582***	**9.4636***	**10.0395***	**9.1852***	**8.5867***
	(3.0660)	(2.7325)	(3.2567)	(3.2427)	(3.0362)
Other Revenue (Log)	**0.1523***	**0.2169***	**0.2296***	**0.2100***	**0.1312***
	(0.0222)	(0.0189)	(0.0226)	(0.0225)	(0.0220)
PMA	-0.2171	-0.2422	0.0926	0.0570	-0.2058
	(0.4267)	(0.3964)	(0.4724)	(0.4704)	(0.4225)
HHI	0.1716	0.3405	**0.8361***	**0.7773***	0.1325
	(0.2784)	(0.2585)	(0.3081)	(0.3068)	(0.2756)
Firm Size	0.2877	**0.3731***	**0.3437***	**-0.4398***	**-0.5834***
	(0.1857)	(0.1435)	(0.1711)	(0.1703)	(0.1839)
Used Capacity	0.0808	0.1181	0.0896	0.0528	0.0206
	(0.1519)	(0.1252)	(0.1492)	(0.1486)	(0.1504)
Import Share	**1.3958***	-0.0078	-0.1207	-0.5533	0.9442
	(0.5358)	(0.4554)	(0.5428)	(0.5404)	(0.5306)
Export Share	0.2133	0.3064	0.1563	0.4184	0.3952
	(0.2160)	(0.1971)	(0.2349)	(0.2339)	(0.2139)
R&D Ratio	0.5102	0.1446	0.0305	0.0346	0.9216
	(0.5206)	(0.1077)	(0.1283)	(0.1278)	(0.5155)
Capital Ratio	**-0.0525***	-0.0119	**0.0269***	**0.0274***	**-0.0508***
	(0.0090)	(0.0082)	(0.0098)	(0.0097)	(0.0089)
Non-Production Labor Ratio	0.1500	-0.1667	-0.1422	-0.1036	0.0009
	(0.3374)	(0.2734)	(0.3259)	(0.3245)	(0.3341)
Cons	9.5361	9.3085	7.9965	4.3113	5.9192
	(0.2042)	(0.1754)	(0.2091)	(0.2082)	(0.2022)
F-Stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
R-Sq	**0.488**	**0.526**	**0.474**	**0.217**	**0.219**
Obs	**951**	**1,012**	**1,012**	**1,012**	**951**
Hausman Test	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0113**

*Signicifant at 5%, ( ) standard error

Appendix 5 Estimation results of Dataset 2 – Companies of agriculture subsectors

Variables	Output Production (Log)	Total Revenue (Log)	Value Added (Log)	Value Added Productivity (Log)	Labor Productivity (Log) (RE)
Circularity Level	6.5316	6.1021	**12.1584**	**12.4886***	**9.3939***
	(3.9501)	(3.7048)	(4.3821)	(4.2828)	(2.8881)
Other Revenue (Log)	**0.1787***	**0.2686***	**0.2989***	**0.2798***	**0.1657***
	(0.0252)	(0.0237)	(0.0280)	(0.0274)	(0.0179)
PMA	0.0508	-0.1846	0.0457	0.0250	-0.0635
	(0.4245)	(0.3981)	(0.4709)	(0.4603)	(0.2214)
HHI	0.2416	0.2795	**0.7846***	**0.7890***	0.2816
	(0.2678)	(0.2512)	(0.2971)	(0.2904)	(0.2236)
Firm Size	**0.5588***	**0.4200***	0.2986	**-0.5995***	**-0.2973***
	(0.2183)	(0.2048)	(0.2422)	(0.2367)	(0.1228)
Used Capacity	0.1046	0.1810	0.2616	0.2151	0.0418
	(0.1679)	(0.1575)	(0.1863)	(0.1821)	(0.1250)
Import Share	0.3494	0.8828	1.0102	0.5828	**0.8690***
	(0.9796)	(0.9188)	(1.0868)	(1.0621)	(0.3790)
Export Share	0.2965	**0.4253***	0.2486	**0.4473***	**0.4012***
	(0.2065)	(0.1937)	(0.2291)	(0.2239)	(0.1374)
R&D Ratio	1.8527	**2.0027***	-0.5126	0.2072	0.4055
	(0.9582)	(0.8986)	(1.0629)	(1.0389)	(0.2907)
Capital Ratio	**-0.0548***	**-0.0160***	**0.0203***	**0.0219***	**-0.0563***
	(0.0087)	(0.0081)	(0.0096)	(0.0094)	(0.0080)
Non-Production Labor Ratio	0.6082	0.7760	0.8272	**1.0856***	**0.7662***
	(0.4399)	(0.4126)	(0.4880)	(0.4770)	(0.2646)
Cons	9.2074	8.6062	7.0096	3.3468	5.5029
	(0.2221)	(0.2085)	(0.2466)	(0.2410)	(0.1647)
F-Stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
R-Sq	**0.439**	**0.462**	**0.478**	**0.268**	**0.245**
Obs	**691**	**693**	**693**	**693**	**691**
Hausman Test	**0.0000**	**0.0000**	**0.0000**	**0.0032**	**0.3306**

*Signicifant at 5%, ( ) standard error

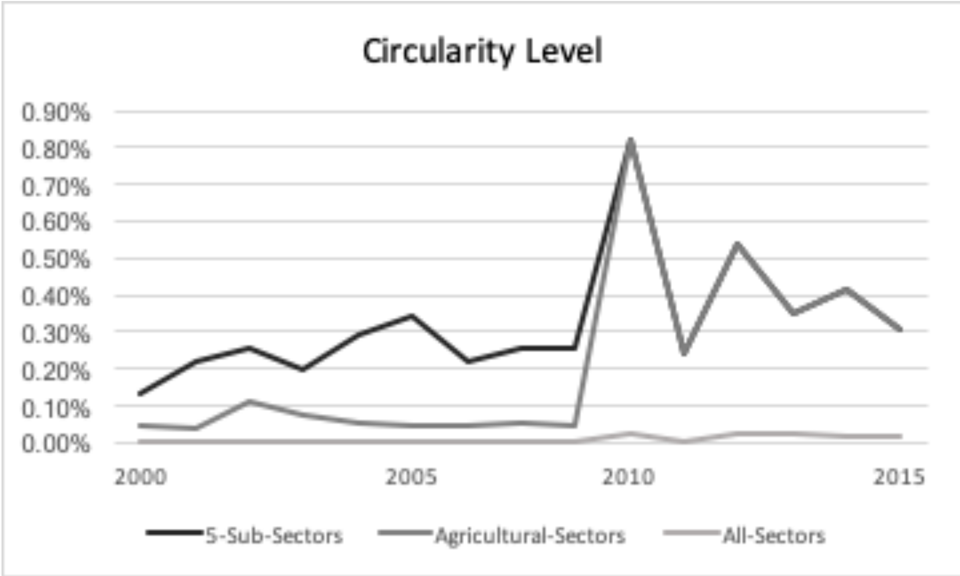
Appendix 6 Estimation results of Dataset 3 – full set of companies in SIBS database

Variables	Output Production (Log)	Total Revenue (Log)	Value Added (Log)	Value Added Productivity (Log)	Labor Productivity (Log) (FE)
Circularity Level	**3.9544***	**3.0269***	2.0788	**2.8956***	**4.4854***

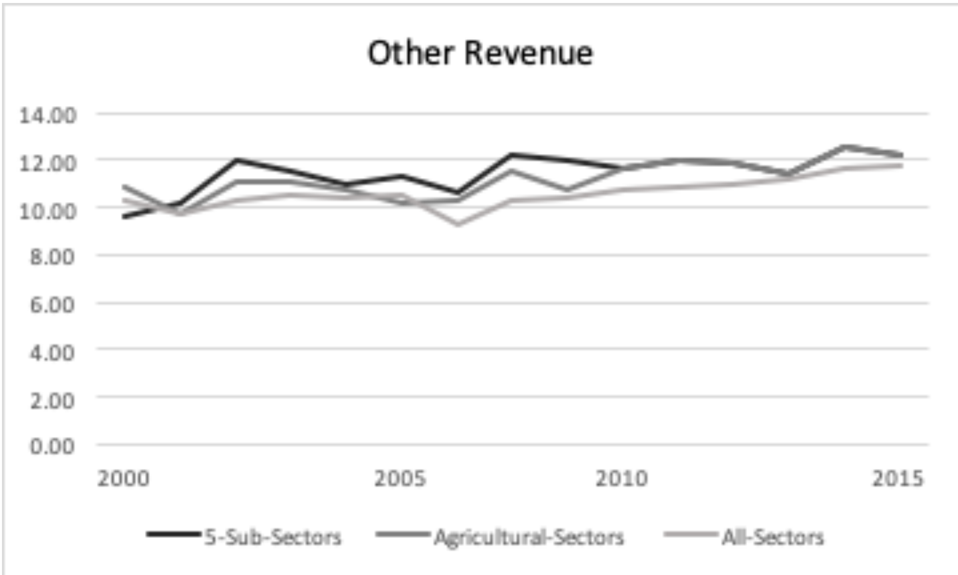
	(1.2482)	(1.1262)	(1.2385)	(1.2095)	(1.2115)
Other Revenue (Log)	**0.2012***	**0.2429***	**0.2332***	**0.1966***	**0.1638***
	(0.0024)	(0.0021)	(0.0023)	(0.0023)	(0.0023)
PMA	**0.2630***	**0.2714***	**0.1890***	**0.0674***	**0.1463***
	(0.0335)	(0.0302)	(0.0332)	(0.0325)	(0.0326)
HHI	**-0.2643***	**-0.3042***	**-0.2926***	**-0.3398***	**-0.3148***
	(0.0292)	(0.0258)	(0.0284)	(0.0277)	(0.0284)
Firm Size	**0.9683***	**0.9214***	**0.9218***	**-0.4381***	**-0.3943***
	(0.0170)	(0.0153)	(0.0168)	(0.0164)	(0.0165)
Used Capacity	**0.1156***	**0.0952***	**0.0923***	**0.0754***	**0.0984***
	(0.0180)	(0.0161)	(0.0176)	(0.0172)	(0.0175)
Import Share	**0.3305***	**0.2936***	**0.2826***	**0.1729***	**0.2224***
	(0.0348)	(0.0309)	(0.0340)	(0.0332)	(0.0338)
Export Share	0.0322	0.0472	**0.0676***	**0.0936***	**0.0575***
	(0.0279)	(0.0252)	(0.0277)	(0.0271)	(0.0271)
R&D Ratio	-0.0525	**0.0197***	**0.0096***	**0.0112***	-0.0404
	(0.0373)	(0.0036)	(0.0040)	(0.0039)	(0.0362)
Capital Ratio	**-0.0004***	-0.00001	-0.000001	-0.00004	**-0.0004***
	(0.00009)	(0.00002)	(0.00002)	(0.00002)	(0.00009)
Non-Production Labor Ratio	**-0.0603***	-0.0336	**-0.1124***	**-0.4001***	**-0.3471***
	(0.0256)	(0.0231)	(0.0254)	(0.0248)	(0.0249)
Cons	9.4116	9.2866	8.3467	4.8302	5.8946
	(0.0207)	(0.0184)	(0.0203)	(0.0198)	(0.0201)
F-Stat	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
R-Sq	**0.581**	**0.635**	**0.631**	**0.235**	**0.165**
Obs	**22,166**	**22,827**	**22,827**	**22,827**	**22,166**
Hausman Test	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

*Signicifant at 5%, ( ) standard error

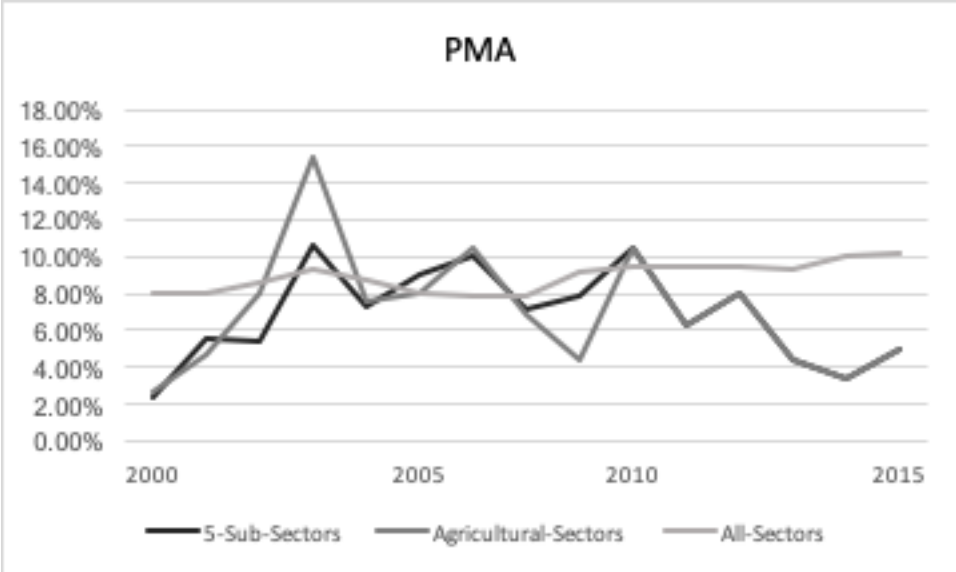
Appendix 7. Mean of Circularity Level



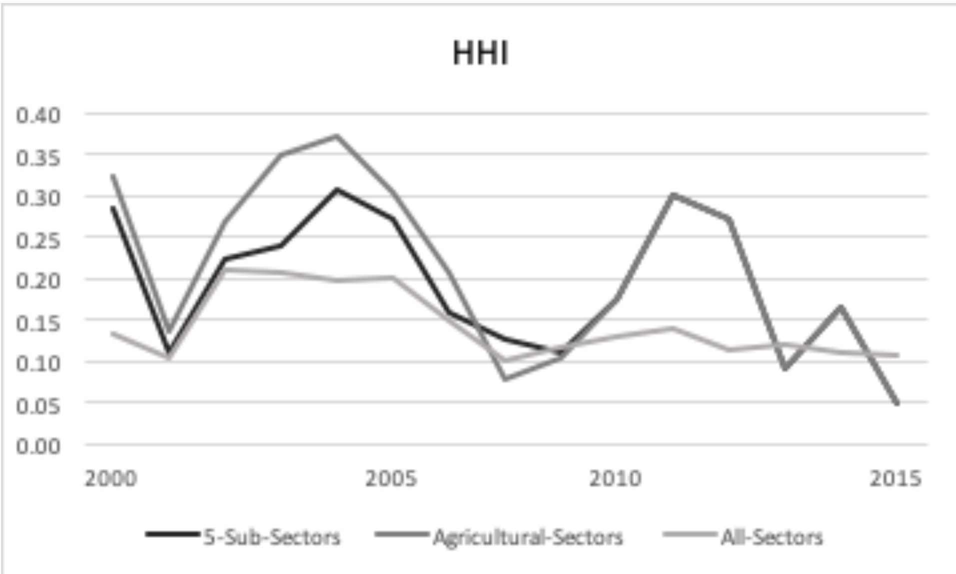
Appendix 8. Mean of Log Other Revenue



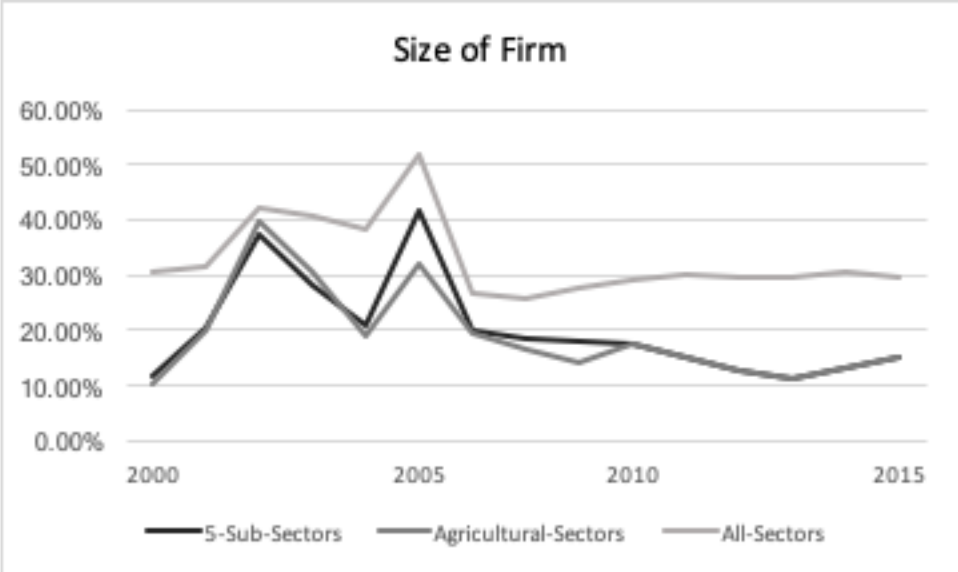
Appendix 9. Mean of Proportion of Companies with Foreign Capital



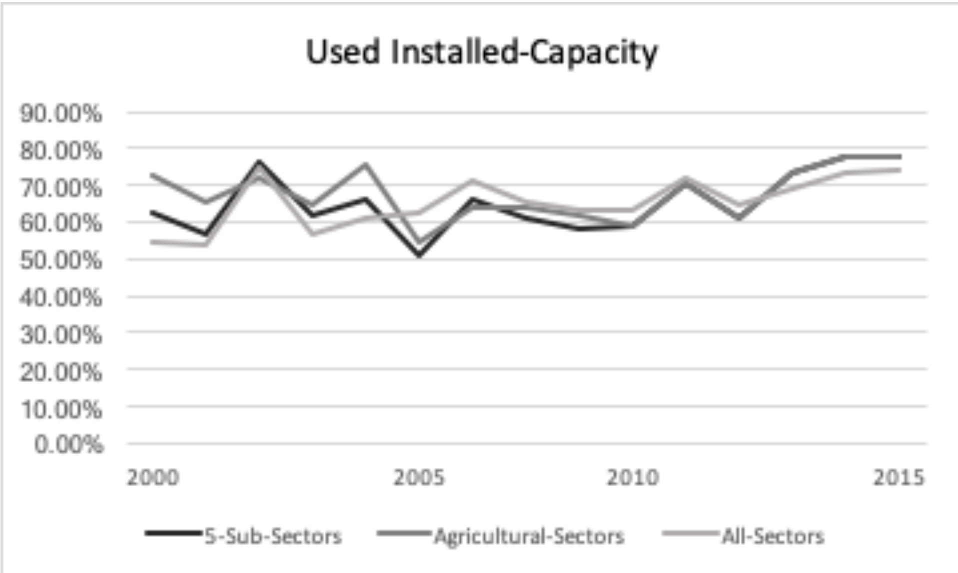
Appendix 10. Mean of HHI



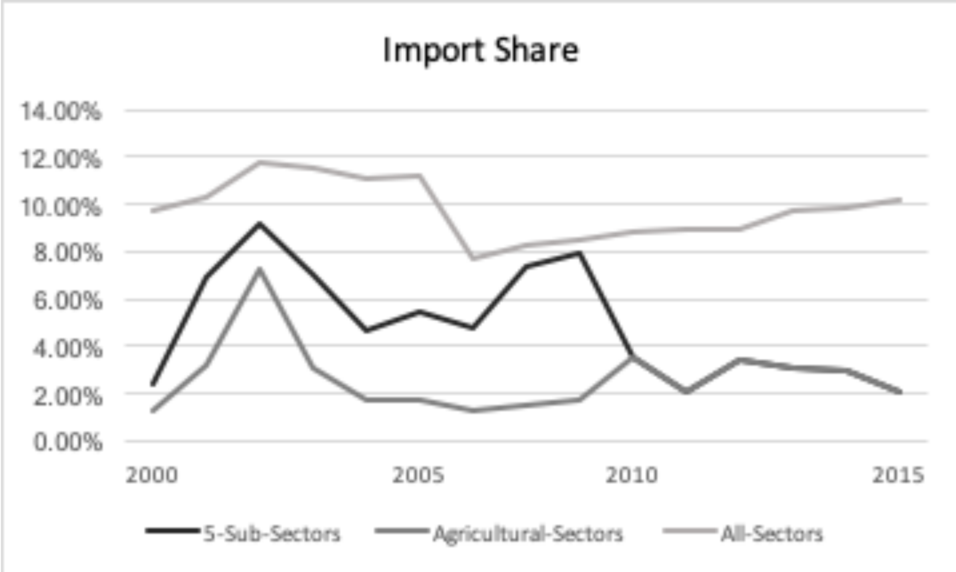
Appendix 11. Mean of Proportion of Big Firm



Appendix 12. Mean of Used Installed-Capacity

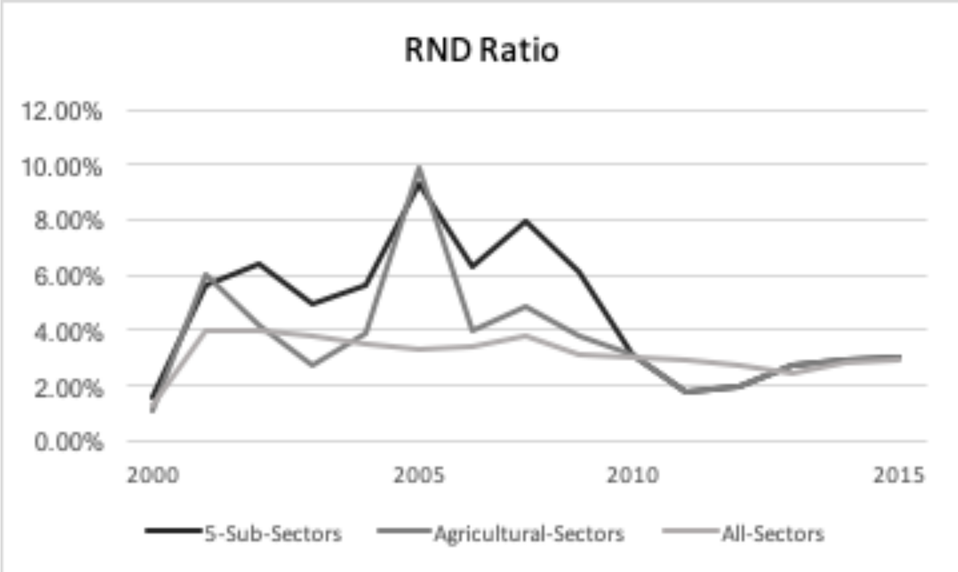


Appendix 13. Mean of Import Share

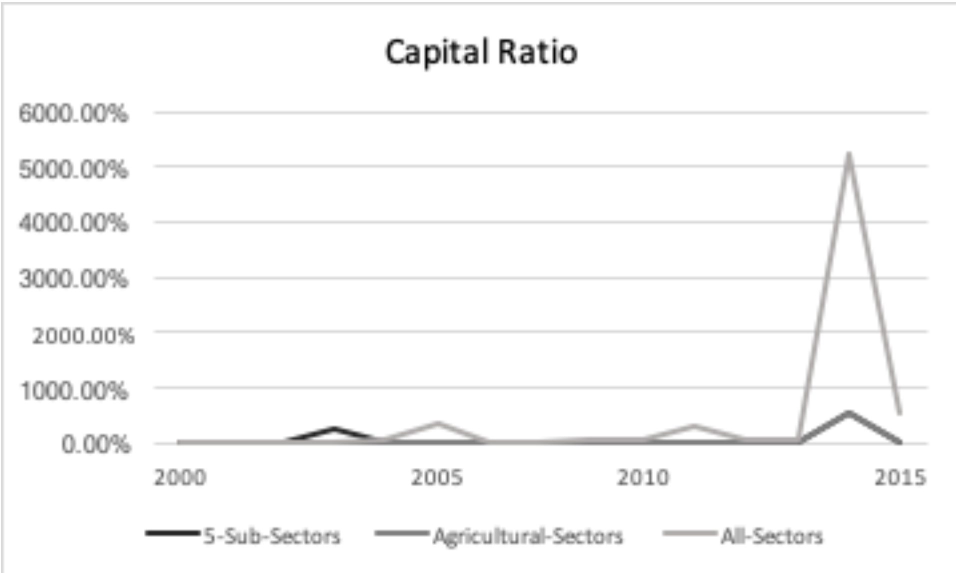


Appendix 14. Mean of Export Share

Appendix 15. Mean of Ratio of RND to Total Labor



Appendix 16. Mean of Ratio of Capital to Total Labor



Appendix 17. Mean of Ratio of Non-Production Labor to Total Labor