Measuring sustainability: an elaboration and application of the system of environmental-economic accounting for Indonesia

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Chapter 5

Economic and environmental impact of electric vehicle production in Indonesia

Abstract

The use of fossil fuel-based vehicles may gradually be replaced by electric vehicles in the future. The trend indicates that the number of users of electric vehicles, especially electric cars, continues to increase. Indonesia is well-positioned to take advantage of this opportunity as it has the world's largest nickel reserves, an essential raw material for making electric vehicle batteries (EVB). The study examines the economic and environmental implications if Indonesia were to successfully set up electric vehicle (EV) production rather than exporting such raw materials overseas. We use an input-output model to estimate the economic and environmental impacts of electric vehicle production in Indonesia. This study assumes that nickel, which is usually exported, is absorbed by domestic economic activities, including being used in manufacturing batteries and electric vehicles in Indonesia. Our estimates include direct and indirect output, value-added, and employment changes. The same model is also used to estimate changes in emissions' environmental costs. It is evident from the results that batteries and EV production are economically beneficial. Additional value-added is Rp. 100.57 trillion, 1.5% of GDP in 2010. At the same time, 538,658 additional jobs were created, which is about a 0.5% increase. Lastly, EV production will have extra environmental costs of emissions, around Rp. 2.23 trillion, or an increase of about 0.6%. Based on these findings, it is concluded that electric vehicle production increases productivity, gross added value, and job creation with a relatively small impact on the environment. A limitation of this study is that we assumed EVs were produced for export only, and we did not assume a reduction in economic activities in the supply chain of conventional vehicles.

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5.1 Introduction

A transition from fossil fuel vehicles to electric-based vehicles in the last decade clearly gained momentum. This transition is essential to make the road transport system carbon-neutral. Several countries worldwide have experienced a rapid increase in sales of electric vehicles over the last decade, especially in North America, Europe, and Asia. One of the determining factors for the success of electric vehicles in penetrating the market is the existence of policy support from the government (Yang et al., 2016).

Electric batteries are a critical component of an electric vehicle. They are the sources of energy to run the engine. This energy source is what distinguishes electric vehicles from conventional petrol-based vehicles. Electric vehicles do not generate direct air emissions and, if charged with electricity from renewable sources, also have no indirect air emissions. There are two types of electric batteries that are widely used today, namely Lithium-ion (Li-ion) and Nickel Metal Hydride (NiMH). Li-ion batteries use the metal elements lithium and cobalt as electrodes, while NiMH uses nickel. A global shift from petrol-based vehicles to electric vehicles will require a massive growth in the use of these metals. The EU released a detailed study (by Roskill, in Fraser et al. 2021) which projected that EVs would be the most significant driver of nickel demand over the next two decades, and the amount of nickel used in EV batteries will rise exponentially. In numerical terms, nickel demand for EVs is projected to rise from 92kt in 2020 to 2.6 Mt in 2040 globally. Karabelli et al. (2020) show that global e-mobility demand will boost battery production by 2030 to around 1725 GWh, with Ni being the dominant raw material in lithium-ion batteries. Currently, nickel use in batteries' represents 4% of the annual global production. Karabelli et al. (2020) expect nickel demand for batteries would rise to 34% of current mining production in 2030.

Table 5.1 presents ten countries with the world's largest nickel resources and reserves. According to CIM (2014), mineral resources are the concentration or presence of economically valuable solid materials in or on the earth's crust in such form, grade, quantity, and quality that there are reasonable prospects for eventual economic extraction. Meanwhile, mineral reserves are economically mineable portions of indicated or measured mineral resources shown by at least a preliminary feasibility study, including diluent and allowance for losses that may occur when the material is mined. The table shows that the ten countries have 77 percent of the global nickel resources and 90 percent of the world's nickel reserves. It also shows that Indonesia has an important position as having the world's second-largest resource and the country with the largest reserves in the world. Indonesia's nickel reserves are around 24% of the world's total, of which 70% are in the form of nickel limonite.[4] Indonesia is rich in these raw materials, an essential raw material in the EVs supply chain.[5] This condition indicates that Indonesia has the potential to be superior in the global EV supply chain, especially in providing raw materials for the production of EV batteries.

Table 5.1. World Nickel Resources and Reserves (in million tons)

Global Resources			**Global Reserves**		
Country	Value	Percentage	Country	Value	Percentage
Australia	43,4	15%	Indonesia	21,0	24%
Indonesia	33,3	11%	Australia	19,0	21%
South Africa	33,2	11%	Brazil	11,0	12%
Rusia	24,4	8%	Rusia	7,6	9%
Canada	21,9	7%	Cuba	5,5	6%
Philipines	18,0	6%	Philipines	4,8	5%
Brazil	16,4	6%	South Africa	3,7	4%
Cuba	16,2	5%	China	2,8	3%
New Caledonia	15,0	5%	Canada	2,7	3%
China	6,0	2%	Guatemala	1,8	2%
Rest of the World	68,4	23%	Rest of the World	8,9	10%
Total	296,2	100%	Total	88,8	100%

Source: Nickel Institute, 2019 in Revindo and Alta, 2020

To support its electric vehicle (EV) ambition and encourage the production of value-added products, including processing minerals such as nickel ore, the government has issued a policy through Presidential Decree No. 55/2019 regarding the acceleration of the program for battery electric vehicles for road transportation. This Presidential Decree was followed by the Ministry of Energy and Resources Regulation No. 11/2019 concerning the nickel ore export ban with the content below 1.7% Ni, which, combined with a ban on exports of high grade nickel in 2014, brought all exports of nickel ore to a halt

[4] There are two types of nickel ore, nickel sulfide and nickel oxide (commonly called nickel laterite). Nickel sulfide is generally found in the subtropical hemisphere, while nickel laterite is located at the equator. Nickel laterite is divided into two types, saprolite and limonite. Various products such as ferronickel, Ni- matte, and nickel pig iron (NPI) are the saprolite processed products. Those kinds are intended for the export market as well as used for local stainless steel production. Meanwhile, nickel limonite is one of the essential raw materials in manufacturing batteries for electric vehicles.

[5] Indonesia has not been able to downstream nickel, which causes this type of nickel to have not been processed and appropriately utilized. This condition is unfortunate, considering that each tonne of nickel-based processed products on the world market can reach more than 200 times the price of nickel which is still in the form of ore (Revindo & Alta, 2020).

by Indonesia. These documents show that Indonesia is ambitious to become Asia's production hub for electric vehicles.

With this background in mind, it is important to analyze the impact of this EV production in the Indonesian context. Therefore, we conducted a study to analyze the economic and environmental impacts of EV production. This study simulates that all nickel ore produced is absorbed for further processing in domestic economic activities consisting of battery and EV production while assuming all produced EVs are destined for export.

This chapters's structure is organized as follows—section 2 first reviews earlier studies on the environmental and economic impacts of EV production. Section 3 explains that we used an input-output approach in this paper and describes the construction of the required database. Finally, section 4 presents the results of this study, and section 5 ends with a discussion and conclusions.

5.2 Literature review

The scientific literature gives various earlier studies on electric vehicle production's economic and environmental impact. Winebrake and Green (2009) tried to estimate the macroeconomic impact of reducing petrol use induced by plug-in electric vehicles in the US. The study found that plug-in electric vehicles on a large scale would reduce gasoline demand by more than 41 billion gallons per year, reduce the household gasoline spending by approximately $118 billion, and save household fuel costs by $86 billion overall. This effect would increase the US economic output by $23 to $94 billion and create around 162 to 863 thousand jobs. A more recent study by Winebrake et al. (2017) focused on adopting plug-in vehicles' economic and employment impacts, concluding that the transition from gasoline to electric vehicles brings positive economic and job creation effects.

Mase (2020) evaluated the impacts of producing electric vehicles on Japan's industrial output using the Leontief input-output production model. The study indicates that the positive and negative impacts of producing electric vehicles rather than internal combustion engine (ICE) vehicles on Japanese industrial output mainly depend on whether the suppliers of electrical machinery with electric vehicles are sourced domestically or overseas. The total impact on Japanese industrial output increased by 1.1 trillion yen in the case of producing the component electrical machinery in Japan; on the other hand, the impact decreased by 4.9 trillion yen when electrical component items were produced overseas. A study from Ribeiro (2020) for the case of the European Union shows that in the long term, investing in electric vehicles is beneficial, both economically and environmentally. Such a shift will reduce dependence on fossil fuels, increase GDP, and improve air quality. Generally, the literature finds that the economic and environmental impacts of electric vehicle production and adoption are positive (Hawkins et al., 2012; Melaina et al. 2016; ERIA, 2020; Kim & Mishra, 2021, Chen et al., 2021).

However, the adoption of electric vehicles will not necessarily reduce emissions when the whole life cycle is considered. Several studies conclude that the environmental impact of electric vehicle development will depend on the power generation mix and its carbon intensity (Karplus et al., 2020). Hawkins et al. (2013) conclude that electric vehicles powered by coal-based electricity may reduce emissions like PM2.5 but enhance CO_2 emissions. Doucette and McCulloch (2011) found that countries like India and China will not benefit from electric vehicle penetration unless they decarbonize their power generations. Meanwhile, ERIA (2020) found that deploying electric vehicles in Thailand, Malaysia, and Vietnam significantly reduces emissions. But not in the case of Indonesia. Investing in electric vehicles will reduce fuel import bills. However, this will not significantly reduce overall carbon emission as the current, carbon-intensive electricity mix is used.

5.3 Methodology and data

5.3.1 Rationale for choosing an input-output approach

This study uses an input-output model to evaluate the economic and environmental impacts of the production of electric vehicles in the Indonesian context. Currently, there are at least three main approaches used to estimate the broad or general socio-economic impact of economic change: the input-output (I-O) model, the Social Accounting Matrix (SAM) model, and the Computable General Equilibrium (CGE) model. The IO approach is the most commonly used of these models and the least expensive but suffers from the constraints of fixed prices, fixed coefficients for inputs, outputs, and extensions which can only be assumed in short-term time frames. SAM is an extension of the IO model but relates, amongst others, income paid to employees at different skill levels to final consumption, which allows assessing distributional impacts. The use of CGE models allows for overcoming many of the constraints of the IO model. Such models allow for assessing multi-directional sectoral impacts and can capture dynamic effects by taking into account a.o. Price and substitution elasticities (White & Patriquin, 2003). Using a CGE model would give a complete insight into economic change. CGEs have more extensive data requirements, such as price and substitution elasticities for the new battery and EV production sectors. Such data are difficult to obtain, and our more straightforward IO approach, which is much easier to implement, still gives a good, static first-order analysis of the implications for the Indonesian economy.

5.3.2 Principles of the input-output approach

In input-output analysis, a fundamental assumption is that the inter-industry flows from sector i to sector j in a specific period (usually a year) depends entirely on the total output of sector j for that same period. (Miller and Blair, 2009; Heinuki, 2017). With the set of fixed technical coefficients, the balanced equation for the input-output model is expressed as;

$$z = Az + y \tag{5.1}$$

where z is the gross output vector, A is the input coefficients matrix, and y is the final demand vector. The input coefficients aij are obtained as $a_{ij} = d_{ij}/z_j$, where d_{ij} denotes the domestic intermediate supply of intermediate inputs i (in million rupiahs) to industry j.

Equation (5.1) can be rewritten to be (I – A) X = y, where I denotes the identity matrix. Expressing the gross outputs in terms of final demands yields $X = (I - A)^{-1} y$ as the solution of the input-output model. Where $(I - A)^{-1}$ is the Leontief inverse (L). Since the model is linear, we can rewrite it as $\Delta X = (I - A)^{-1}\Delta y = L\Delta y$ giving the extra gross outputs corresponding to an arbitrary vector Δy of extra final demand (e.g., electric vehicles).

Value-Added (VA) is the primary input in which part of the overall input. Following the basic assumptions used in preparing the I-O table, the relationship between VA and output is linear. It implies that an increase or decrease in output will be followed proportionally by an increase and decrease in VA. The relationship can be described in the following equation:

$$V = \hat{V}X \tag{5.2}$$

Where V is value-added, and $\hat{V}$ is the diagonal matrix of value-added.

To see the impact of Δy on employment creation, the employment coefficient vector (e) is constructed as e_j/x_j, where e_j denotes the employment opportunity provided by the sector j, and we get the change in employment due to the change in domestic final demand as follows;

$$\Delta e = e\ L\ \Delta y \tag{5.3}$$

Similarly, the impact on pollution and related external costs can be calculated. If emissions per unit output of a sector and the external costs of each emission are known and combined to a pollution coefficient (p), the changes in external cost from such emissions can be calculated as follows;

$$\Delta p = p\ L\ \Delta y \tag{5.4}$$

5.3.3 Construction of the basic Indonesian extended Input-Output Table

In estimating the economic and environmental impact of electric vehicle production, we used the Indonesian Input-Output Table (IIOT) of 2010 from the Indonesian Central Bureau of Statistics (BPS). Since the IIOT has no environmental extensions, we used emission information on Indonesia from EXIOBASE, a comprehensive Global Multi-regional Environmentally Extended Input-Output (GMRIO) database developed by a European research consortium[6]. We mapped this emission data on the common, aggregated version of IIOT and EXIOBASE of 86 sectors and aggregated the highly detailed emission set from EXIOBASE to emissions of 34 individual substances. We further calculated the external costs related to the emissions of each sector and will in this study further express environmental impacts as externalities. This procedure has been described in detail in Pirmana et al. (2021), and we refer further to this reference.

5.3.4 Addition of a battery and EV production sector to the Indonesian Input-Output Table

We want to analyze the economy-wide impact of a diversion of raw materials exported to the production of car batteries and EVs in Indonesia. However, the IIOT (nor EXIOBASE) contains specific production sectors. We, therefore, constructed two new sectors in the 86 sector IIOT. The input and output coefficients of these sectors were estimated as follows. Details are provided in Appendix. We concentrate here on the coefficients of monetary inputs, including value-added creation, labor input, and environmental extensions of

[6] Institute of Environmental Sciences (CML), Netherlands Organization for Applied Scientific Research (TNO), the Norwegian University of Science and Technology (NTNU) and other partners.

battery and EV production, assuming these sectors will have only batteries and EVs as output.

Input coefficients

1. The initial input structures for the electric vehicle sector and the battery for electric vehicles are taken from the conventional vehicle sector and conventional battery industries from the original IIOT.
2. Next, modifications were made to the input structure by utilizing information from the results of studies/publications related to the input structure of the two new sectors.
3. For the motor vehicle industry, modification of the input structure of conventional vehicles is carried out by utilizing information on the cost structure of electric vehicle production from a study conducted by ERIA (2020) (see figure 5.2). Based on ERIA (2020) information, we estimate the electric vehicle industry's input structure by mapping the sector classification related to the cost structure of the electric vehicle industry in the 86 IIOT classification and put the input structure values into the related sectors.
4. The modification of the input coefficient from the conventional battery industry to the input structure of the electric vehicle battery is carried out by utilizing some information from various relevant sources (e.g., Sakti, 2015; Qnovo, 2016; Tsiropoulos et al., 2018; Campbell, 2019).
5. According to Tsiropoulos et al. (2018), the breakdown of the total cost of EV batteries consists of material costs, operating surplus, capital, and labor cost. The material costs consist of raw materials and other materials costs. To obtain an estimate of the input coefficient for each raw material, we multiply the share of each input by the proportion of the total raw material cost for producing the EV battery, using information from Campbell (2019) with assumptions for the raw material cost per 64 kWh EV battery. As for the proportions of other materials, the distribution of the input coefficients is based on the classification of sectors related to the production of EV batteries from the study of Sanfelix et al. (2016). The study contains a detailed list of inventory components to the industrial sector in the manufacture of cells, battery control units, and modules (see appendix for details).
6. As for the output row, the final demand is only accounted for, assuming there is no intermediate demand for electric vehicles and batteries for electric vehicles by each industry.
7. The input coefficients include imports. To accurately determine the inducement of domestic production, we deducted the inducement of

imports by subtracting the input structure in the total transaction table from the inputs originating from imports.

8. The electric vehicle body is assumed to be the same as a conventional vehicle

Labor input

Since the IIOT does not contain employment tables, we created an employment table for each sector based on the National Labor Force Survey (Sakernas) from the Indonesian Central Bureau of Statistics. However, the statistics on the number of employees are categorized into only 63 industries. Therefore, to split into 88 industries in the input-output tables in this study, generally, we estimate them with the following procedure (see the detailed procedure in appendix).

1. The total labor income in the input-output table is divided by the number of employees of the Sakernas database statistics to calculate income per employee.
2. We estimate the income per employee in the Sakernas and the input-output category based on the Indonesia employment table with the more detailed industry category. By multiplying the income per capita in the Sakernas category by the income ratio amongst industries in Indonesia, we get the income by sector, reflecting wage differences amongst industries.
3. Next, we divide the labor income by the income per employee to calculate the number of employees in the input-output category.
4. Lastly, we treated them by multiplying the adjustment factor so that the total number of employees in the input-output category matches the number in the Sakernas category. Then, the employment intensities are calculated based on the estimated employment table. Furthermore, the changes in employment induced by final demand are measured by multiplying those of production by employment intensities.
5. The employment intensities for the new sectors are assumed to be the same as the employment intensities of conventional vehicles and the conventional battery sector.

Environmental extensions

Besides input and employment coefficients, to estimate the environmental impact of battery and EV production, the study also needs the coefficient of the external cost from emissions. As mentioned above, the procedure to estimate the external cost value has been described in Pirmana et al. (2021), and we refer further to this reference. The value of the coefficient of external costs of emissions for the two new sectors is assumed to be the same as the coefficient of the conventional vehicle and the conventional battery industry.

5.3.5 Scenario assumptions

With an Input-Output table now available for Indonesia that includes a battery and EV production sectors, the economic and environmental impacts of the production of electric vehicles are carried out using the following assumptions:

- In line with the government's policy prohibiting nickel ore export, this study assumes that this nickel ore is 100% absorbed by domestic economic activities.
- The electric vehicle batteries produced are assumed to be of the NCA type (the type of battery with the highest nickel content)
- In this study, the production of electric vehicles is assumed only to be exported and not to substitute the use of conventional vehicles in the country, so there is no reduction in the production of conventional vehicles and petrol use.
- The analysis is limited to the production phase. The modeling in this study does not involve an impact analysis on the use phase of the produced EVs since it is assumed that all EVs are exported, and we focus on impacts in Indonesia.

5.4 Results

The general results of the economic and environmental impact of EV production are summarized in figure 2. To absorb the nickel output into domestic activities, i.e., all exported nickel is used for EVs, the final demand for EVs that the economy must create is around Rp. 135.35 trillion. Moreover, assuming the electric vehicle to be produced is a Tesla Model 3 with a unit cost of $23,300 or Rp. 212 million (converted using the exchange rate of $/Rp for 2010), the number of electric vehicles that can be produced is around 639.672 units per year[7].

[7] Kosak (2018) mentioned that the unit cost of producing a Tesla Model 3 is currently estimated at $23,300.

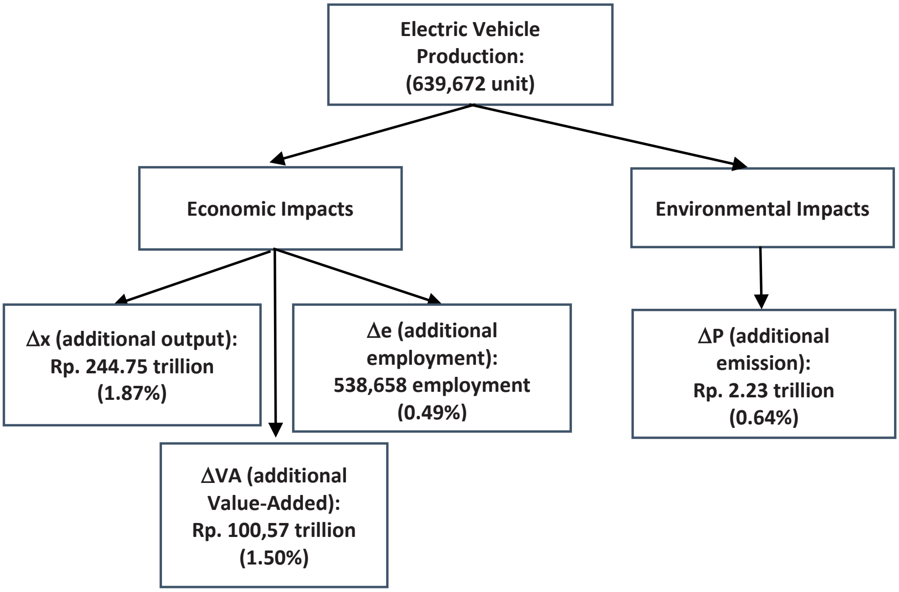

Figure 5.1. Economic and environmental impact of electric vehicle production
Source: Authors calculation.

Based on the calculation results, using nickels in new economic activities in Indonesia; in our case, battery and EV production has a positive economic impact on the Indonesian economy. Since our modeling essentially assumed that Indonesia would expand its economic activities, this is a logical outcome.

The following sectors would benefit the most from using nickel for battery and EV production: The manufacturing sector of motor vehicles, trailers, and semi-trailers.[8]; Mining of aluminum ores and concentrates; and the mining of chemical and fertilizer minerals, production of salt, and other mining and quarrying sectors. The Manufacturing sector of motor vehicles, trailers, and semi-trailers will see a growth in outputs of 22 %. Meanwhile, the mining of aluminum ores and concentrates is about 19.6%; and the mining of chemical and fertilizer minerals sector is around 4.2%.

8 The growth of this sector might occur because one of the inputs in electric vehicle production, the vehicle body, comes from this sector.

Table 5.2. The ten sectors that benefit the most from electric vehicle production

No	Description	Sector growth
1	Manufacture of motor vehicles, trailers and semi-trailers	22.05
2	Mining of aluminium ores and concentrates	19.56
3	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	4.24
4	Manufacture of rubber and plastic products	2.74
5	Insurance and pension funding, except compulsory social security	2.36
6	Computer and related activities	2.16
7	Plastics, basic	2.09
8	Renting of machinery and equipment without operator and of personal and household goods	2.02
9	Activities auxiliary to financial intermediation	1.89
10	Manufacture of gas; distribution of gaseous fuels through mains	1.84

Source: Author's calculation

The additional output created in the economy due to the final demand of the electric vehicle sector is Rp. 244.75 trillion (1.88%). The highest additional output in the economy from the final demand for the electric vehicle sector is the electric vehicle sector itself and the sectors directly related to the EV production chain (table 5.3).

The ten sectors with the highest additional output account for about 86% of the total additional output in the economy. More than half of the additional output came from the EV sector, contributing 135.35 trillion or almost 55% of the total additional output. Electric Vehicle Battery is the second largest sector, with an additional output of 10% of the total additional output, followed by the manufacture of motor vehicles, trailers, and semi-trailers sector of 9.2%; manufacture of rubber and plastic products of 2.8%; and mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c., about 2.3%.

Table 5.3. Top ten sectors creating additional output due to electric vehicle production

No	Sector activities	Additional output (trillion rp)	Percentage
1	Electric Vehicles	135.35	55.30
2	Electric Vehicle Battery	24.77	10.12
3	Manufacture of motor vehicles, trailers and semi-trailers	22.45	9.17
4	Manufacture of rubber and plastic products	6.73	2.75
5	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	5.59	2.28
6	Wholesale trade, except of motor vehicles and motorcycles	4.65	1.90
7	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessories [a)]	3.84	1.57
8	Other land transport	2.68	1.09
9	Electricity	2.13	0.87
10	Renting of machinery and equipment without operator and of personal and household goods	2.09	0.85
	Others	34.50	14.10
	Total	244.75	100

Source: Author's calculation

Notes: [a)] Including sale of car and motorcycle along with vehicles and motorcycles parts and accessories

In terms of added value, driven by the final demand for the EV sector, the additional value-added in the Indonesian economy was Rp. 100.57 trillion, or approximately 1.5%. Looking at the changes in value-added by sectors in table 5.4, it can be seen that over 88 sectors, almost 75% of the additional value-added come from the top ten sectors. The electric vehicle sector contributes about 47% of the additional value-added created in the economy, followed by the manufacture of motor vehicles, trailers, and semi-trailers sector at 11%; electric vehicle battery about 9%; Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c. of 4.5%. Other sectors in the top ten contribute a small percentage between 1-3%.

Table 5.4. Top ten sectors creating additional value-added due to electric vehicle production

No	Sector activities	Additional value-added (trillion rp)	Percentage
1	Electric Vehicles	47.37	47.1
2	Manufacture of motor vehicles, trailers and	10.99	10.93
3	Electric Vehicle Battery	9.04	8.99
4	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	4.56	4.53
5	Wholesale trade, except of motor vehicles and motorcycles	3.15	3.13
6	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessories[a)]	2.61	2.59
7	Manufacture of rubber and plastic products	1.78	1.77
8	Cultivation of plant-based fibers & crop nec	1.41	1.4
9	Other land transport	1.31	1.31
10	Renting of machinery and equipment without operator and of personal and household goods	1.29	1.28
	Others	17.06	16.96
	Total	100.57	100

Source: Author's calculation

Notes: [a)] Including sale of car and motorcycle along with vehicles and motorcycles parts and accessories

Another economic impact of EV production is employment creation. EV production drives additional jobs in the economy by 538,658 employment or an increase of about 0.5%. Approximately 85% of the additional employment comes from the ten sectors with the highest additional employment (table 5.5). The electric vehicle battery and the electric vehicle sector contributed to additional employment in the economy by 8% and about 6%, respectively.

Table 5.5. Top ten sectors creating additional employment due to electric vehicle production

No	Sector activities	Additional employment (thousand person)	Percentage
1	Cultivation of plant-based fibers & crop	100.64	18.68
2	Renting of machinery and equipment without operator and of personal and	80.49	14.94
3	Wholesale trade, except of motor vehicles and motorcycles	73.14	13.58
4	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and	71.24	13.23
5	Electric vehicle Battery	43.93	8.15
6	Electric vehicles	31.32	5.82
7	Mining of chemical and fertilizer minerals, production of salt, other	23.13	4.29
8	Transport via railways	12.74	2.37
9	Manufacture of rubber and plastic	12.04	2.24
10	Tanning and dressing of leather; manufacture of luggage, handbags,	10.17	1.89
	Others	79.81	14.82
	Total	538.66	100

Source: Author’s calculation

Notes: [a] Including sale of car and motorcycle along with vehicles and motorcycles parts and accessories

Sectors such as the sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycles parts and accessories, and the wholesale trade, except for the motor vehicles and motorcycles sector, are in the top ten sectors with additional output, added value, and labor, as a result of the production of electric vehicles in Indonesia. However, if we look at the percentage of the total effect, it is only small on the overall impact. Moreover, in this study, the production of electric vehicles is intended only for export purposes and not intended to replace the use of conventional domestic vehicles. So the addition of the electric battery and electric car industries does not significantly change the economic structure, especially when viewed from the technical coefficient of the Indonesian economy, as indicated by the distribution of technical coefficients before the addition of the two sectors. The existence of a new sector does not significantly impact other sectors. In addition, the magnitude of the export of electric vehicles is still relatively small compared to the entire economy.

The main motivation for developing electric vehicles in Indonesia is to reduce emissions and the number of fuel imports, as outlined in the release of the 2019 Presidential Decree (ERIA, 2020). However, this study only estimates the environmental impacts of emissions in the production phase expressed as external costs in relation to the assumption that all EVs are exported. The final demand for the EV sector turned out to cause additional external costs from emissions with a monetary value of Rp. 2.2 trillion or about 0.6%. The top ten sectors with additional external costs from emissions account for about 89% of the total additional external costs due to the final demand for the EV sector (table 5.6). Of the ten highest sectors, the top three consecutively are rubber and plastic products, the manufacturing of basic iron and steel and ferro-alloys and first products thereof, and the electricity sector contributes to almost 75% of the total additional external costs. The six sectors in the top ten additional external costs from emissions in table 6 are also in the ten sectors with the highest external costs in the economy due to final demand before the electric vehicle and electric vehicle battery sectors existed (see Pirmana et al. 2021). Meanwhile, the activities of the two new sectors also generated external costs from emissions, from the electric vehicle sector of 78.60 billion (3.5%) and the electric vehicle battery industry of 7.76 billion (0.4%).

Table 5.6. Top ten sectors creating additional emissions (expressed as external costs) due to electric vehicle production

No	Sector activities	Additional external cost (billion rp)	Percentage
1	Manufacture of rubber and plastic products	670.55	30.04
2	Manufacture of basic iron and steel and of ferro-alloys and first products thereof	637.64	28.56
3	Electricity	357.92	16.03
4	Electric Vehicles	78.60	3.52
5	Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	74.12	3.32
6	Sea and coastal water transport	39.56	1.77
7	Fertilizer	39.34	1.76
8	Paper & pulp	36.48	1.63
9	Other land transport	28.75	1.29
10	Chemicals nec	26.03	1.17
	Others	243.51	10.91
	Total	2,232.50	100

Source: Author's calculation

If we break down this additional emission based on the type of pollutant, SOx, CO2, and NOx are the primary sources of additional emissions due to the final demand in the EV sector (table 5.7). The additional emissions from these three sectors accounted for 58% of the total additional emissions, with SOx contributing around 26%, CO2 at 18%, and NOx at 14%.

Table 5.7. Top ten externalities due to additional external cost from emissions due to electric vehicle production by emission type

No	Emission types	Changes in external costs (billion Rp)	Percentage
1	SOx	569.87	25.53
2	CO_2	402.26	18.02
3	NOx	320.10	14.34
4	Pb	311.61	13.96
5	TSP	226.97	10.17
6	PM10	134.01	6.00
7	PM2.5	104.73	4.69
8	NMVOC	43.37	1.94
9	Hg	29.51	1.32
10	CH_4	26.95	1.21
	Others	62.66	2.81
	Total	2,232.04	100

Source: Author's calculation

5.5 Discussion and conclusions

This study is an initial attempt to analyze the economic and environmental impacts of electric vehicle production in Indonesia. In conclusion, we found that electric vehicle production positively boosts output, value-added growth, and job creation. Based on the calculation results, additional output, value-added, and labor due to the final demand for the electric vehicle sector, respectively, amounted to 1.87%, 1.5%, and 0.5%. Note, however, that we did the simulation with an input-output model for 2010. The Indonesian economy's current outputs and value-added generated is about 2.25 times higher than in 2010. Stimulating EV production in Indonesia would still make a significant contribution to economic growth, given that it comes just from one sector. The ambition of the Indonesian government to use its large Nickel reserves to stimulate fast-growing upstream user industries, like battery and EV production, to locate themselves in Indonesia hence makes sense.

On the negative side, this study finds that additional battery and EV production leads to additional external costs from emissions, albeit in insignificant amounts. This is related to our assumption that all produced EVs will be exported. Using EVs domestically, may lead to lower production of traditional vehicles and lower the gains in jobs and value-added. EVs have no direct emissions, which, if they replace traditional vehicles domestically, can potentially lead to the reduction of external costs, depending on the carbon intensity of electricity used. Such wider use of EVs is foreseen in Indonesia's electric vehicle roadmap. More detailed studies are needed that estimate the economic and environmental impacts of EV production both from the production phase and the usage phase.

Acknowledgments

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5.6 Appendix

This appendix contains the supporting information for this case study and includes details on the modelled processes, supporting calculations.

5.6.1 Information to adjust input coefficient of electric vehicle sector

The following are the steps in calculating the electric vehicle input coefficient (See detail in Supplementary Information):

1. The new coefficients for the electric vehicle sector are derived from existing input coefficients of the conventional motor vehicle manufacturing sector from the Indonesian input-output table for 86 sectors.
2. The domestic share is taken from the ratio of the domestic inputs to total inputs from the cost structure of the conventional vehicle industry, where the input is divided into inputs from domestic sources and imports.
3. Adjustment of the input coefficients column is carried out by utilizing information on input structure for electric vehicles from ERIA (2020) in figure 5.2 below or see SI in worksheet EV Cost structures cell A8.

Based on ERIA (2020), the electric vehicle sector's input structure consists of about 65% intermediate inputs, and primary input (VA) is about 35%. Figure 5.2 shows the breakdown of these EV input structures.

4. Next, an adjustment is made from the total intermediate input of the conventional vehicle industry to the intermediate input of the electric vehicle industry by changing the share of the total intermediate input of the conventional vehicle industry to the total intermediate input of the electric vehicle industry. The same is also done for the intermediate input component originating from imports. The consequence is that there is a change in the share of the intermediate input component of conventional vehicles, which is the basis for the cost structure of the Indonesian electric vehicle industry.

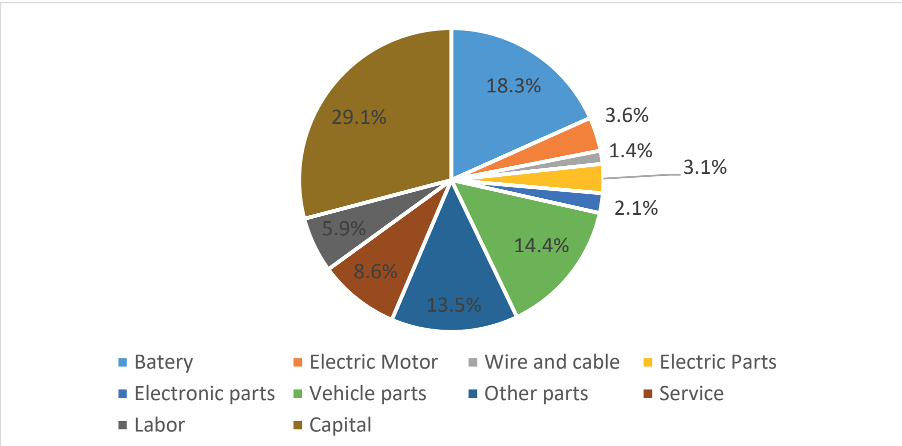

Figure 5.2. Input structures for electric vehicle sectors
Source: Adopted from ERIA, 2020

5.6.2 Information to adjust input coefficient of electric vehicle battery sector

The following are the steps for calculating the input EVB structure in this study:

1. Domestic share is taken from the ratio of domestic inputs to total inputs from the cost structure of the conventional battery industry in table IIOT 86.

2. Information to structure the EVB input is obtained from several sources. Initial information is taken from the study of Tsiropoulos et al. (2018). Based on their study, the breakdown of the total cost of the battery for intermediate inputs (materials) is 64%, and for primary inputs is 36% (see figure 5.3). However, in Tsiropoulos et al. (2018) study, the intermediate inputs from raw materials and other materials are not separated. In this study, we utilize the information from studies conducted by Lowe et al. (2010), Roland Berger (2012), Sakti et al. (2015), and Pilot (2015, which state that the proportion of raw materials is 50-52% of the total cost of producing an EV battery. Meanwhile, detailed information regarding the composition of raw materials for producing EV batteries is taken from Campbell (2019), as shown in Table 5.8.
3. After we know the share of each raw material cost to the total costs structure, adjustments are made from the total intermediate input of the conventional battery to the intermediate input of the electric vehicle battery industry. The adjustment is made by changing the share of the total intermediate input of the conventional battery industry to the total intermediate input of the electric vehicle battery industry. The same steps are also performed for the intermediate input components from imports. Consequently, there is a change in the share of the intermediate input components of a conventional battery. This result is the basis for the cost structure of the electric vehicle battery industry in Indonesia.

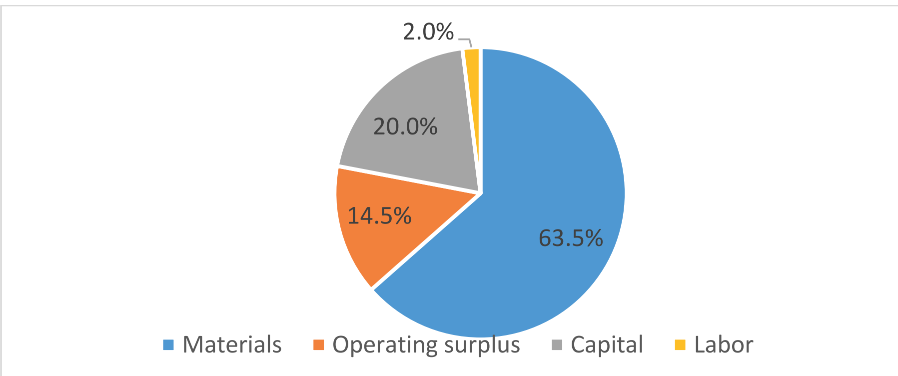

Figure 5.3. Breakdown of the total cost of battery in key components
Source: Adopted from Tsiropoulos et al (2018)

Table 5.8. Raw material costs per 64kWh EV Battery

Materials	Approx Cost per 64kWh EV Battery	Share to total raw material cost	Share of raw material cost to total costs structure
Copper	$320	0.080	0.041
Aluminum	$340	0.085	0.044
Nickel	$1,650	0.411	0.214
Cobalt	$700	0.175	0.091
Lithium	$1,000	0.249	0.130
Total	$4,010	1.000	

Source: Modified from Campbell (2019)

5.6.3 Creating an employment table

Employment tables (the number of employees in each industry sector) should be prepared to analyze the ripple effect on employment. We create an employment table for each sector based on the International Labour Organization's (ILO) ILOSTAT database since IIOT does not contain employment tables. However, the number of employees is categorized into only 63 industries. Therefore, to split into 88 industries in the input-output tables in this study, we estimate them with the following procedure. First, for each industry (i) in the ILO category, the total labor income (Yij) in the input-output table is divided by the number of employees (Li) of the ILO statistics to calculate income per employee (wi).

$$W_i = \sum(Y_{ij})/L_i \quad (5.5)$$

Next, we estimate the income per employee in the ILO category (w_i^J) and the input-output category (w_{ij}^J) based on the Indonesia employment table with the more detailed industry category. By multiplying the income per capita in the ILO category by the ratio of income amongst industries in Indonesia, we get the income (wij), reflecting wage differences amongst industries.

$$W_{ij} = W_i * W_{ij}^J / W_i^J \quad (5.6)$$

Then, we divide the labor income by the income per employee to calculate the number of employees (Lij) in the input-output category.

$$L_{ij} = Y_{ij}/W_{ij} \tag{5.7}$$

Finally, we treated them by multiplying the adjustment factor (ai) so that the total number of employees in the input-output category matches the number in the ILO category. In this study, we use Leij as the number of employees in the ILO category.

$$L_{ij}^{e}{=}L_{ij} * a_{ij}, \sum\left(L_{ij} * a_{i}\right) = L_{i} \tag{5.8}$$

Then, the employment intensities are calculated based on the estimated employment table. The changes in employment induced by final demand are measured by multiplying those of production by employment intensities.