Chapter 4

Impacts on Industry by xEV Penetration

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Chapter 4

Impacts on Industry by xEV Penetration

1 Brief Introduction of Input–Output analysis

Input-output analysis is an economic model that estimates the effect of changes in one or several activity sectors, or the effect of consumption changes on the rest of the economy.

Input-output tables describe and synthesise all goods and services operations in the form of commodities and activity sectors and give coherent representations of national or regional production. Input-output tables were invented by French physician and economist François Quesnay in his *Tableau Économique* in 1758 and can be considered the first attempt of economists to visually represent the circulation of welfare, i.e. revenues, spending, and goods in a particular state (Phillips, 1955). Input-output model and technique development is attributed to the American-Soviet economist, Wassily Leontief (Isard and Kaniss, 1973).

Berman and Plemmons (1987) pointed out that Leontief's input–output analysis deals with one particular question: *what level of output should each of n industries in a particular economic situation produce, in order that it will just be sufficient to satisfy the total demand of the economy for that product?* Departing from this question, we provide a brief but simple explanation of input–output analysis in this sub-section.

In input–output analysis, production activities of a national or regional economy are grouped into *n* sectors of industries with the input–output table providing transactions of commodities amongst the sectors. The flows of transactions move as follows: to produce one unit of commodity *j*, sector *j* needs t_{ij} units of the *i* good as inputs for $i=1,\ldots,n$, and producing λ units of output of the *j* commodity requires λt_{ij} units of the *i* commodity. These coefficients, t_{ij}, are usually called input or technical coefficients and are usually assumed to be constant.

These coefficients of the production of each sector indicate how many units of output of *i* sector are needed to produce one unit of the output of *j* sector. Shown under any sector column of the table, they represent the relative importance of the output of the sector indicated by each sector row. This output is the equivalent amount of the input absorbed by each sector.

Defining X_i as the output of the *i* commodity per fixed unit of time, then part of this gross output is consumed as the input needed for production activities of the *n* sectors. If $\sum_{j=1}^{n} t_{ij}X_j$ represents the unit of the *i* commodity consumed in production activities, then *d*, that is, the final use or final demand or the net output, can be defined as:

(**equation 1**) $$d_i = X_i - \sum_{j=1}^{n} t_{ij}X_j$$

We can consider d_i as the contribution of the open sector of the economy such as investment, consumption or consumer purchase and export, etc.

Letting *X* and *d* be the *n*-vectors with components X_i and d_i, respectively, we can obtain the system of linear equation:

(**equation 2**) $(I - T)X = d$

The coefficient matrix:

(**equation 3**) $A = (I - T)$

is a matrix of size *(n x n)* that can be solved for the gross output non-negative vector:

(**equation 4**) $X = A^{-1}d$

The constants t_{ij} and d_i and the solutions X_i in **equation (1)** should satisfy the non-negativity constraint where gross output equals the sum of intermediate demand and final demand, as shown:

(**equation 5**) $X_i = \sum_{j=1}^{n} t_{ij}X_j + d_i$

Where the final demand is composed by consumption (C_i), investment (I_i) and export (E_i) of the *i* sector, we can also state,

(equation 6) $\boldsymbol{X_i = \sum_{j=1}^{n} t_{ij}X_j + (C_i + I_i + E_i)}$

Knowing the matrix of technical coefficients (T), we can calculate the matrix A by using **equation (3)**; consequently, we can find X_i by solving **equation (4)**. We can calculate then the output needed from each sector (X_i) when we know the demand or consumption, i.e. d of each of them. The change in consumption of the sector *1*, namely d_1, shall change the total output of each sector X_1, X_2, X_3, etc. since to produce more of commodity 1, there is a need also to increase commodities 1, 2, and so on, as they are needed in the production of the commodity 1.

At the same time, gross input (purchase) is the sum of intermediate inputs and primary inputs. Primary inputs can be represented by various elements such as wage or employees' compensation, consumption of fixed capital, operating surplus, net taxes, value added, imports, etc., in sector *j*. In **equation (7)** below, we assume only one of them, i.e. value added (V_j), and also that $t_{ij}X_i$ has included already imported products.

(equation 7) $\boldsymbol{X_j} = \sum_{i=1}^{n} \boldsymbol{t_{ij}} X_i + \boldsymbol{V_j}$

In Table 4-1, rows represent input and columns represent output. Each sector is therefore both a user of inputs and a producer of outputs. The necessary condition of the input–output table is the total output must be equal to total input.

(**equation 8**) $X_i = X_j$

Since $\sum_{i=1}^{n} t_{ij}X_j = \sum_{j=1}^{n} t_{ij}X_j$

(**equation 9**) $V = C + I + E$

The sum of the total income generated by a production system is equal to the total value of finished goods and services purchased by the final sectors for consumption, investment, and net exports.

Table 4-1 shows a hypothetical input–output transaction table.

Table 4-1. A Hypothetical Open Input–Output Table

	Intermediate use (columns)								Using sectors (inputs) – Final use			Total Output
Producing sector (rows)	1	2	.	.	j	.	.	n	Consumption	Investment	Export	
1	$t_{11}X_1$	t_{12} X_2	.	.	$t_{1j}\,X_j$	.	.	t_{1n} X_n	C_1	I_1	E_1	X_1
2	t_{21} X_1	t_{22} X_2	.	.	$t_{2j}\,X_j$	.	.	t_{2n} X_n	C_2	I_2	E_2	X_2
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
i	$t_{i1}\,X_1$	$t_{i2}\,X_2$	.	.	$t_{ij}\,X_j$	.	.	$t_{in}\,X_n$	C_i	I_i	E_i	X_i
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
n	t_{n1} X_1	t_{n2} X_2			$t_{nj}\,X_j$			t_{nn} X_n	C_n	I_n	E_n	X_n
Value added	V_1	V_2			V_j			V_n	V_C	V_I	V_E	V
Total inputs	$\boldsymbol{X_1}$	$\boldsymbol{X_2}$			$\boldsymbol{X_j}$			$\boldsymbol{X_n}$	$\boldsymbol{C}$	$\boldsymbol{I}$	$\boldsymbol{X_E}$	$\boldsymbol{X}$

Source: Authors.

Berman and Plemmons (1987) showed another way to calculate added value using an associated price valuation system, which gives the pricing or value side of the input–output relationship.

Let c_j be the cost of the *j* commodity given by the total sum of all cost of inputs contributed by all sectors.

(**equation 11**) $$c_j = \sum_{i=1}^{n} t_{ij} p_i \qquad \text{with } 1 \ll j \ll n$$

The net revenue per unit output of the *j* commodity or the value added per unit output v_j is given by the following equation.

(**equation 12**) $$v_j = p_j - \sum_{i=1}^{n} t_{ij} p_i$$

The relationship can also be represented by a system of linear equations:

(**equation 13**) $$v^t = p^t - p^t T$$

or

(**equation 14**) $$v^t = p^t A \qquad \text{where } A = I - T$$

p is the price vector and *v* is the valued added vector. **Equations (4)** and **(13)** can be linked in the following relation.

(**equation 15**) $$\sum_{i=1}^{n} v_i x_i = \sum_{j=1}^{n} p_j d_j$$

The left side of **equation (15)** can be called the national or regional product, while the right side can be called the national or regional income. Herewith, the national income equals the national product.

The above explanation represents what we can call the *open* and *static* Leontief model, which is the input–output technique that we use in this study. The term 'open' refers to the model's inclusion of an open sector that lies outside the system, i.e. final demand. In a 'closed' model, the open sector as the final demand does not exist, as it is absorbed into the system as just another industry. Finally, the term 'static' means that the technical coefficients and final demand (open sector) are assumed to be constant. In the 'dynamic' model, the temporal aspect is included to allow us to analyse the change of output in different time points.

2 Review of Input–Output Analysis Use on Electric Vehicle Penetration Impacts

Input–output analysis has been used to assess the impacts of xEV penetration usually through two aspects of a car's lifecycle, namely manufacturing and use. Manufacturing of xEVs may include not only all activities related to car construction, i.e. electrical equipment fabrication, battery production, all related supporting industries, metal products, textiles, etc., but also activities related to the construction of charging infrastructures. The use of xEVs signifies the shift of conventional transport fuel consumption to electric energy. Input-output technique allows simulating both aspects and capturing their impacts on various sectors.

In this sub-section, we review the use of input–output technique to analyse the impacts of xEV penetration. It does not aim to be comprehensive, but instead points out the main indications of what we can do to analyse xEV penetration using the technique.

Winnebrake et al. (2017), using some input–output analysis at city-, state-, and national-level studies in the US, but without giving too much detail, summarised how the effects of xEV penetration can be captured in the economy.

In terms of car manufacturing, Winnebrake et al. (2017) found it generated economic activity and job production through incremental increases in vehicle costs and increased demand in sector producing vehicles, components and charging infrastructures. Regarding car use, they found several impacts; amongst others, these were (i) the reduction of petroleum consumption and fuel costs that provided some savings to drivers' pocket and household budget; (ii) the injection of petroleum fuel savings towards other goods and services in local economy that created new jobs and boosts economic output typically measured as gross domestic product or GDP; and (iii) the potential reduction of electricity rates to all utility consumers.

Leurent and Windisch (2013) explained how they use input–output technique in their model to calculate costs and benefits of xEV regarding public finance in France. They created a new sector (commodity) of xEV and estimated its technical (input) coefficients based on detailed costs in producing xEVs with cost elements comparable to those of ICEV manufacturing. Included in the cost elements were, amongst others, automobile construction (engine), metallurgy and metal processing, equipment manufacture, electrical and electronic equipment and components, business services including research and development, etc. In terms of vehicle use, the authors calculated the annual per-car energy and fuel consumption, as well as the tax exclusive total costs of vehicle use (including insurance and maintenance), of both ICEVs and PHEVs based on assumptions on the average mileage, fuel economy, and battery efficiency. Finally, they set annual per-car value-added tax, energy surcharge, production tax, gross social contributions and unemployment benefits that differed based on the paper's simulated scenarios. Doing the latter allows the authors to play with fiscal instruments that affect the final demand (production tax, energy surcharge, value added tax, etc.) and the primary input (social contribution, unemployment benefits, etc.).

Finally, the effect of electric vehicle usage on the power generation sector, i.e. the energy used to generate electricity and the resulting emissions, is an important aspect that potentially can also be analysed using input–output technique. This effect has been much analysed since the existing input–output tables usually represent the power generation sector in an aggregated manner. Several authors have provided methods to disaggregate the sector. For example, Lidner et al. (2013) proposed a method to disaggregate the power generation sector in China into transmission and distribution sectors, as well as into eight sub-sectors representing different types of technology in power plants, e.g. subcritical coal, hydro, etc. The work of Marriott (2007) built upon the existing US economic input–output tool, adding detail about the electricity industry, specifically by differentiating amongst the various functions of the sector, and the different means of generating power. His work included construction of a flexible framework for creating new industry sectors, supply chains and emission factors for the generation, transmission and distribution portions of the electricity industry.

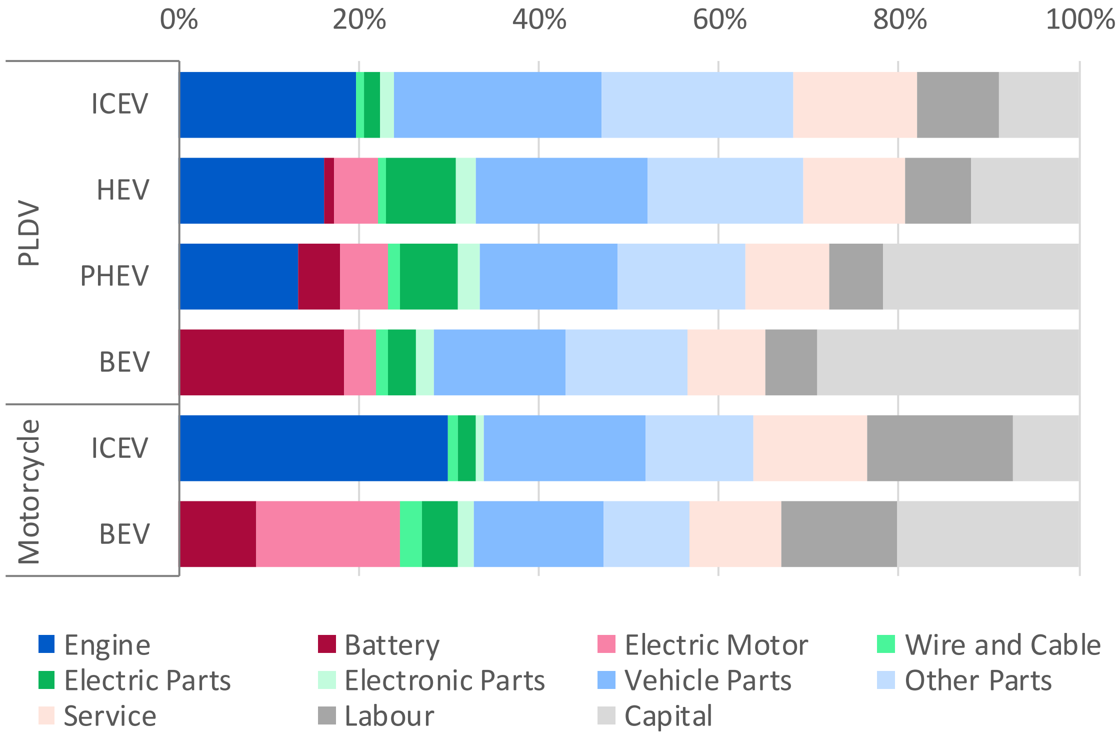
3 Modelling an Input–Output Analysis Framework

3.1 Creating Input–Output Tables for xEV Analysis

The input–output tables should be prepared for each country. We will use the input–output tables in the Global Trade Analysis Project (GTAP) 10 database because we can analyse commonly to all countries. The GTAP 10 database is the project's centrepiece, covering 121 countries, and the base year of the input–output tables is 2014. However, the input–output tables are classified into 65 industries, and there is only one automobile manufacturing sector, which this study addresses. Therefore, we add some xEV-related sectors for our analysis (Table 4-2).

We break down the automobile manufacturing sector into the four powertrain types (only for PLDVs and motorcycles). For the input columns, xEV input coefficients (input ratio of raw materials, etc. to production value) are estimated based on various information, including ICCT (2019) and CRISER (2015) (Figure 4-1). For estimation, the battery size is set as 2 kWh for HEVs, 10 kWh for PHEVs, 40 kWh for BEVs, and 1 kWh for e-motorcycles. The battery pack price is assumed to be US$160 per kWh. For the output rows, the final demand is only accounted, assuming there is no intermediate demand for the PLDVs and motorcycles by each industry.

Figure 4-1. Input Structure for xEVs



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle.
Source: Authors' analysis.

Table 4-2. Comparison of Industry Category (GTAP vs. This Study)

GTAP		This Study	
1	Rice	1	
2	Wheat	2	
3	Other Grains	3	
4	Veg and Fruit	4	
5	Oil Seeds	5	
6	Cane and Beet	6	
7	Fibres crops	7	
8	Other Crops	8	
9	Cattle	9	
10	Other Animal Products	10	
11	Raw milk	11	same as the left
12	Wool	12	
13	Forestry	13	
14	Fishing	14	
15	Coal	15	
16	Oil	16	
17	Gas	17	
18	Other Mining Extraction (formerly omn)	18	
19	Cattle Meat	19	
20	Other Meat	20	
21	Vegetable Oils	21	
22	Milk	22	
23	Processed Rice	23	
24	Sugar and molasses	24	
25	Other Food	25	
26	Beverages and Tobacco products	26	
27	Manufacture of textiles	27	
28	Manufacture of wearing apparel	28	
29	Manufacture of leather and related products	29	
30	Lumber	30	
31	Paper and Paper Products	31	
32	Petroleum and Coke	32	Petroleum
		33	Coke
33	Manufacture of chemicals and chemical products	34	
34	Manufacture of pharmaceuticals, medicinal chemical and botanical products	35	
35	Manufacture of rubber and plastics products	36	
36	Manufacture of other non-metallic mineral products	37	
37	Iron and Steel	38	
38	Non-Ferrous Metals	39	same as the left
39	Manufacture of fabricated metal products, except machinery and equipment	40	
40	Manufacture of computer, electronic and optical products	41	
41	Manufacture of electrical equipment	42	
42	Manufacture of machinery and equipment n.e.c.	43	
		44	Engine
		45	Electric Motor
		46	Electric Parts
		47	Wire and Cable
		48	Battery
		49	Electronic Parts
		50	Vehicle Parts
43	Manufacture of motor vehicles, trailers and semi-trailers	51	ICE
		52	HEV
		53	PHEV
		54	BEV
		55	Motorcycle
		56	E-motorcycle
		57	Manufacture of other motor vehicles, trailers and semi-trailers
44	Manufacture of other transport equipment	58	
45	Other Manufacturing	59	
46	Electricity; steam and air conditioning supply	60	
47	Gas manufacture, distribution	61	
48	Water supply; sewerage, waste management and remediation activities	62	
49	Construction	63	
50	Wholesale and retail trade; repair of motor vehicles and motorcycles	64	
51	Land transport and transport via pipelines	65	
52	Water transport	66	
53	Air transport	67	
54	Warehousing and support activities	68	same as the left
55	Information and communication	69	
56	Accommodation, Food and service activities	70	
57	Other Financial Intermediation	71	
58	Insurance (formerly isr)	72	
59	Real estate activities	73	
60	Other Business Services nec	74	
61	Other Services (Government)	75	
62	Education	76	
63	Human health and social work	77	
64	Recreation and Other Services	78	
65	Dwellings	79	

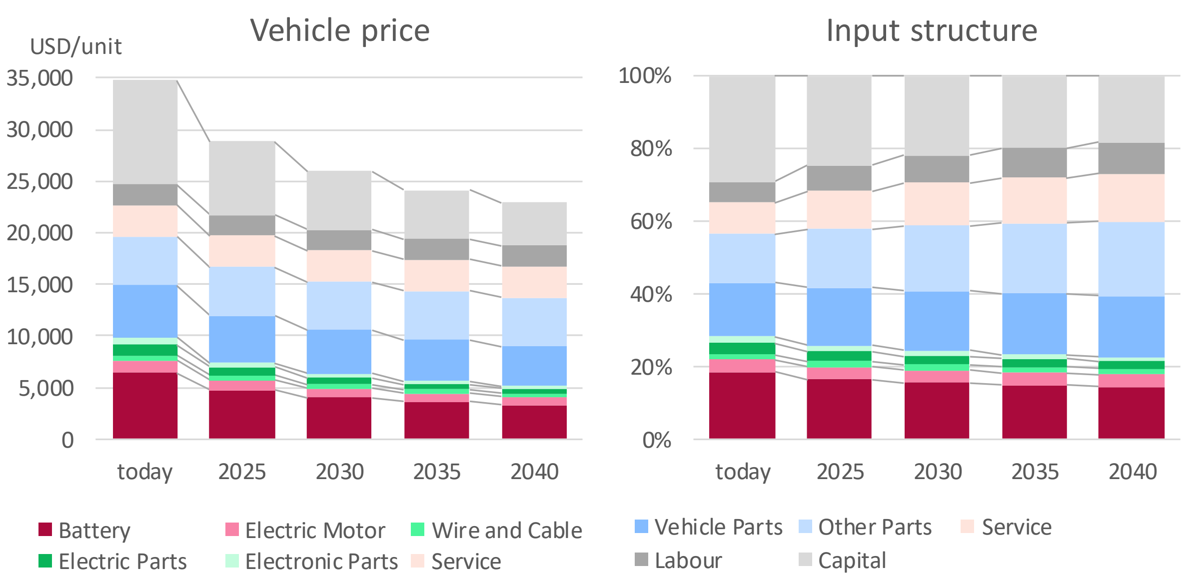
GTAP = Global Trade Analysis Project, BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle.
Source: GTAP (2019) and Authors.

Major auto parts, such as engines, motors, and batteries, should be also treated separately in order to understand the impact of xEV production. The input columns refer to a Japanese detailed input–output table (with 509 industries), because automobile production is systematised and the input structure of each part is generally considered to be common throughout the world. For the output rows, intermediate demand for the parts is assumed to be only from the automobile manufacturing industries and is estimated based on the input structure of xEVs.

In addition, we split the 'Petroleum and Coke' sector into petroleum and coal products to see the impact of xEVs' fuel demand. According to the IEA Energy Balance Table, no coal products are produced in any country, so petroleum product data for input column and output row are same as the original 'petroleum and coke' data, and the coal product column and row are treated as zero.

We assume that the industrial structures remain unchanged until 2040, except the xEV cost structure. The prices of xEVs are assumed to fall as shown in the Middle Battery Case in Figure 4-2.

Figure 4-2. Cost Structures for BEVs in the Middle Battery Price case



BEVs = battery electric vehicles.
Source: Authors' analysis.

3.2 Creating Employment Table

Employment tables (the number of employees in each industry sector) should be prepared to analyse the ripple effect on employment. We create an employment table for each country based on the International Labour Organization's (ILO) ILOSTAT database, since GTAP does not have employment tables. However, the statistics on the number of employees are categorised into only 14 industries in ILOSTAT (2020). Therefore, in order to split into 79 industries in the input–output tables in this study (Table 4-3), we estimate them based on the Japanese employment table (with 387 industries).

The estimation procedure is as follows.

First, for each industry (i) in the ILO category, the total of labour income (Y_{ij}) in the input–output table is divided by the number of employees (L_i) of the ILO statistics to calculate income per employee (w_i).

(equation 4) $w_i = \Sigma(Y_{ij}) / L_i$

Next, we estimate the income per employee in the ILO category (w^J_i) and the input–output category (w^J_{ij}) based on the Japanese 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 Japan, we get the income (w_{ij}), reflecting wage differences amongst industries.

(equation 5) $w_{ij} = w_i * w^J_{ij} / w^J_i$

Then, we divide the labour income by the income per employee to calculate the number of employees (L_{ij}) in the input–output category.

(equation 6) $L_{ij} = Y_{ij} / w_{ij}$

Finally, we handle them by multiplying adjustment factor (a_i) so that the total number of employees in the input–output category matches the number of employees in the ILO category. In this study, we use L^e_{ij} as the number of employees by industry in the input–output category.

(equation 7) $L^e_{ij} = L_{ij} * a_i, \Sigma(L_{ij} * a_i) = L_i$

Table 4-4 shows employment intensities (the number of employees per production value in each industry), calculated based on the estimated employment table. The ripple effects on employment are measured by multiplying those of production by the employment intensities.

Table 4-3. Comparison of Industry Category (ILO vs. This Study)

ILO		This Study	
1	Agriculture; forestry and fishing	1	Rice
		2	Wheat
		3	Other Grains
		4	Veg and Fruit
		5	Oil Seeds
		6	Cane and Beet
		7	Fibres crops
		8	Other Crops
		9	Cattle
		10	Other Animal Products
		11	Raw milk
		12	Wool
		13	Forestry
		14	Fishing
2	Mining and quarrying	15	Coal
		16	Oil
		17	Gas
		18	Other Mining Extraction (formerly omn)
3	Manufacturing	19	Cattle Meat
		20	Other Meat
		21	Vegetable Oils
		22	Milk
		23	Processed Rice
		24	Sugar and molasses
		25	Other Food
		26	Beverages and Tobacco products
		27	Manufacture of textiles
		28	Manufacture of wearing apparel
		29	Manufacture of leather and related products
		30	Lumber
		31	Paper and Paper Products
		32	Petroleum
		33	Coke
		34	Manufacture of chemicals and chemical products
		35	Manufacture of pharmaceuticals, medicinal chemical and botanical products
		36	Manufacture of rubber and plastics products
		37	Manufacture of other non-metallic mineral products
		38	Iron and Steel
		39	Non-Ferrous Metals
		40	Manufacture of fabricated metal products, except machinery and equipment
		41	Manufacture of computer, electronic and optical products
		42	Manufacture of electrical equipment
		43	Manufacture of machinery and equipment n.e.c.
		44	Engine
		45	Electric Motor
		46	Electric Parts
		47	Wire and Cable
		48	Battery
		49	Electronic Parts
		50	Vehicle Parts
		51	ICE
		52	HEV
		53	PHEV
		54	BEV
		55	Motorcycle
		56	E-motorcycle
		57	Manufacture of other motor vehicles, trailers and semi-trailers
		58	Manufacture of other transport equipment
		59	Other Manufacturing
4	Utilities	60	Electricity; steam and air conditioning supply
		61	Gas manufacture, distribution
		62	Water supply; sewerage, waste management and remediation activities
5	Construction	63	Construction
6	Wholesale and retail trade; repair of motor vehicles and motorcycles	64	Wholesale and retail trade; repair of motor vehicles and motorcycles
7	Transport; storage and communication	65	Land transport and transport via pipelines
		66	Water transport
		67	Air transport
		68	Warehousing and support activities
		69	Information and communication
8	Accommodation and food service activities	70	Accommodation, Food and service activities
9	Financial and insurance activities	71	Other Financial Intermediation
		72	Insurance (formerly isr)
10	Real estate; business and administrative activities	73	Real estate activities
		74	Other Business Services nec
11	Public administration and defence; compulsory social security	75	Other Services (Government)
12	Education	76	Education
13	Human health and social work activities	77	Human health and social work
14	Other services	78	Recreation and Other Services
		79	Dwellings

BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, ILO = International Labour Organization.
Source: ILOSTAT (2020) and Authors.

Table 4-4. Employment Intensity (Labours / million US$)

Sector	Indonesia	Thailand	Malaysia	Viet Nam
Rice	217.6	334.1	37.9	643.9
Wheat	195.0	460.1	0.4	29.2
Other Grains	943.2	912.6	20.8	2214.6
Veg and Fruit	225.5	213.9	17.6	554.6
Oil Seeds	873.5	841.6	88.7	1640.9
Cane and Beet	199.1	223.5	22.7	562.5
Fibres crops	520.3	394.9	28.0	501.3
Other Crops	267.0	326.9	30.0	712.8
Cattle	137.3	305.4	21.2	384.2
Other Animal Products	91.9	97.7	12.9	192.0
Raw milk	101.2	213.7	6.8	11.1
Wool	121.0	167.0	4.2	15.0
Forestry	125.1	224.3	16.6	497.6
Fishing	101.3	32.5	15.8	242.3
Coal	7.1	3.3	1.5	15.6
Oil	4.2	3.0	1.8	13.4
Gas	4.4	4.0	2.9	21.2
Other Mining Extraction (formerly omn)	39.7	6.8	1.9	36.9
Cattle Meat	33.6	24.5	19.4	4.5
Other Meat	99.7	21.7	21.7	48.3
Vegetable Oils	31.6	5.2	1.5	30.7
Milk	28.3	12.3	2.2	42.6
Processed Rice	2.7	12.8	0.9	15.8
Sugar and molasses	13.1	14.0	0.0	23.5
Other Food	38.5	17.5	7.1	29.9
Beverages and Tobacco products	34.3	14.5	4.5	65.4
Manufacture of textiles	29.4	25.5	6.8	37.6
Manufacture of wearing apparel	51.4	32.6	16.9	25.5
Manufacture of leather and related products	50.9	18.8	11.9	33.6
Lumber	46.5	30.2	12.2	36.9
Paper and Paper Products	22.3	16.0	7.7	30.7
Petroleum	0.0	0.0	0.0	0.0
Coke	1.7	1.9	0.3	5.1
Manufacture of chemicals and chemical products	13.4	7.6	2.6	21.8
Manufacture of pharmaceuticals, medicinal chemical and botanical products	23.9	16.4	4.7	37.3
Manufacture of rubber and plastics products	43.3	38.1	10.6	80.2
Manufacture of other non-metallic mineral products	35.9	15.4	10.4	42.8
Iron and Steel	12.6	10.2	3.2	13.7
Non-Ferrous Metals	16.8	18.3	3.8	24.2
Manufacture of fabricated metal products, except machinery and equipment	18.4	14.9	7.1	56.0
Manufacture of computer, electronic and optical products	9.1	6.4	5.8	19.5
Manufacture of electrical equipment	16.3	7.1	4.5	24.3
Manufacture of machinery and equipment n.e.c.	22.3	9.5	6.2	34.4
Engine	23.4	26.9	11.3	39.9
Electric Motor	39.1	45.1	18.8	66.9
Electric Parts	26.4	30.4	12.7	45.1
Wire and Cable	19.1	22.0	9.2	32.6
Battery	0.8	0.8	0.8	0.8
Electronic Parts	31.8	36.7	15.3	54.4
Vehicle Parts	21.1	24.3	10.1	36.0
ICE	10.7	12.4	5.2	18.3
HEV	8.8	10.1	4.2	15.0
PHEV	7.2	8.2	3.4	12.2
BEV	6.8	7.8	3.3	11.6
Motorcycle	20.1	23.2	9.7	34.4
E-motorcycle	16.1	18.5	7.8	27.5
Manufacture of other motor vehicles, trailers and semi-trailers	25.6	8.2	5.7	36.2
Manufacture of other transport equipment	26.5	13.3	5.3	44.0
Other Manufacturing	20.5	21.6	11.5	47.9
Electricity; steam and air conditioning supply	3.6	5.8	0.4	16.8
Gas manufacture, distribution	20.2	2.7	5.7	35.9
Water supply; sewerage, waste management and remediation activities	60.8	22.4	16.3	25.6
Construction	31.3	68.7	25.9	115.2
Wholesale and retail trade; repair of motor vehicles and motorcycles	151.3	70.8	21.2	301.4
Land transport and transport via pipelines	79.4	22.4	22.7	137.6
Water transport	17.6	17.9	1.8	50.5
Air transport	8.1	2.7	2.6	18.7
Warehousing and support activities	67.6	24.7	18.1	155.5
Information and communication	53.7	26.7	12.4	154.6
Accommodation, Food and service activities	145.7	108.8	63.1	330.9
Other Financial Intermediation	33.2	19.6	7.1	107.7
Insurance (formerly isr)	74.5	24.3	7.8	65.9
Real estate activities	34.2	13.1	9.0	33.6
Other Business Services nec	111.7	48.7	36.9	85.2
Other Services (Government)	106.4	68.5	40.8	304.5
Education	251.7	86.6	80.4	391.1
Human health and social work	32.2	25.7	23.5	63.9
Recreation and Other Services	148.0	50.1	45.4	468.4
Dwellings	0.0	0.0	0.0	0.0

BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle.
Source: Authors' analysis.

3.3 PLDV-related Expenditure

For the ripple effect analysis, we estimate the expenditure related to the xEV penetration for each scenario. Expenditure for PLDVs and motorcycles include the spending for vehicles, refuelling/charging equipment, and daily fuel/electricity. They are estimated for 2025, 2030, 2035, and 2040, and recalculated as additional expenditure from today.

The total spending per vehicle is calculated by summing up the sales volume times the vehicle prices for ICEVs and xEVs. Neither taxes, subsidies, insurance nor other peripheral expenses are included. The sales volume of each powertrain type naturally depends on each scenario and each vehicle price adopts the Middle Battery Price case (see Figure 3-7).

The installation cost of fuelling/charging equipment is calculated as the number of equipment units times the installation cost per unit. The installation cost per unit depends on the situation and additional functions, but we assume them as in Table 4-5 according to various information, including ERIA (2019).

Table 4-5. Assumptions for Costs of Refuelling / Charging Equipment

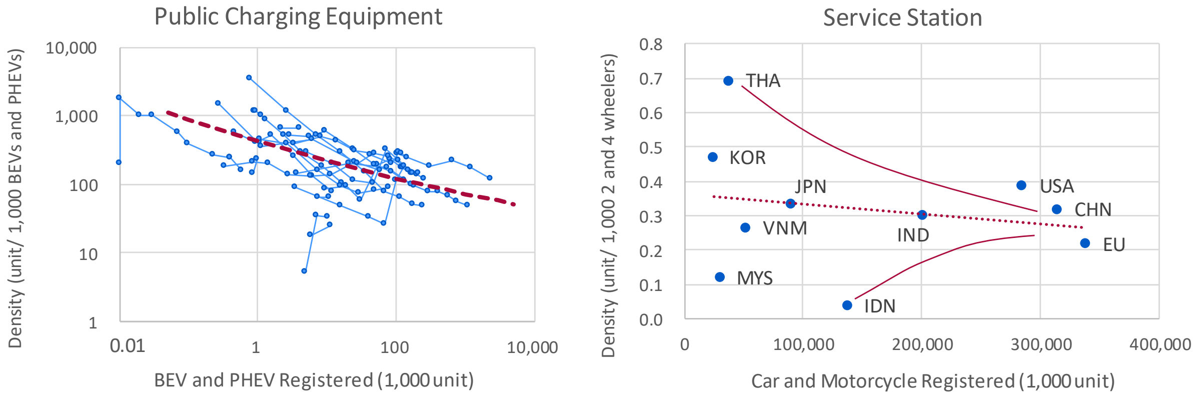
	Home/Public	Charging Levels	US$/unit
Charging Equipment	Home	Level 2	500
	Public	Level 2	5,000
		Level 3	25,000
Refuelling Station	Public	-	300,000

According to TriggerEnergy, Level 1; Chargers run off of standard 110v and very simple accessories typically included with most electric vehicles. Depending on your type of electric vehicle, a Level 1 Charger will take 8–15 hours to fully charge from 0%–100%.
Level 2; Chargers run off of 240v current and charge at a much faster rate. Depending on your type of electric vehicle, a Level 2 Charger will take approximately 4 to 8 hours to charge from 0%–100%.
Level 3; Fast Chargers are much higher-end units with their own dedicated electrical lines and can charge many electric vehicles from 0%–100% in as little as 20 minutes.
https://triggerenergy.com/how-much-do-ev-charging-stations-cost/ (accessed 20 January 2020)
Source: Authors' analysis.

The installed equipment number is calculated by multiplying the number of gasoline/electric vehicles registered by the equipment density rate (= number of equipment per number of vehicles). According to density rates for gas stations estimated based on various information, we assume that the rates converge to the level of developed countries along with the spread of car ownership (Figure 4-3 right). Further, we assume that the density rates will gradually decrease in Thailand and increase in Malaysia and Indonesia.

The density rates for public charging equipment are assumed to decrease gradually as BEVs and PHEVs spread, based on the time-series and cross-section data (IEA, 2019b) (Figure 4-3 left). Of these, we assume 10% are fast chargers (Level 3) and the rest are slow chargers (Level 2). The small chargers for home (and workplace, etc.) are assumed to be installed at the rate of one unit per BEV and PHEV.

Figure 4-3. Public Refuelling / Charging Station Density per Vehicles Registered

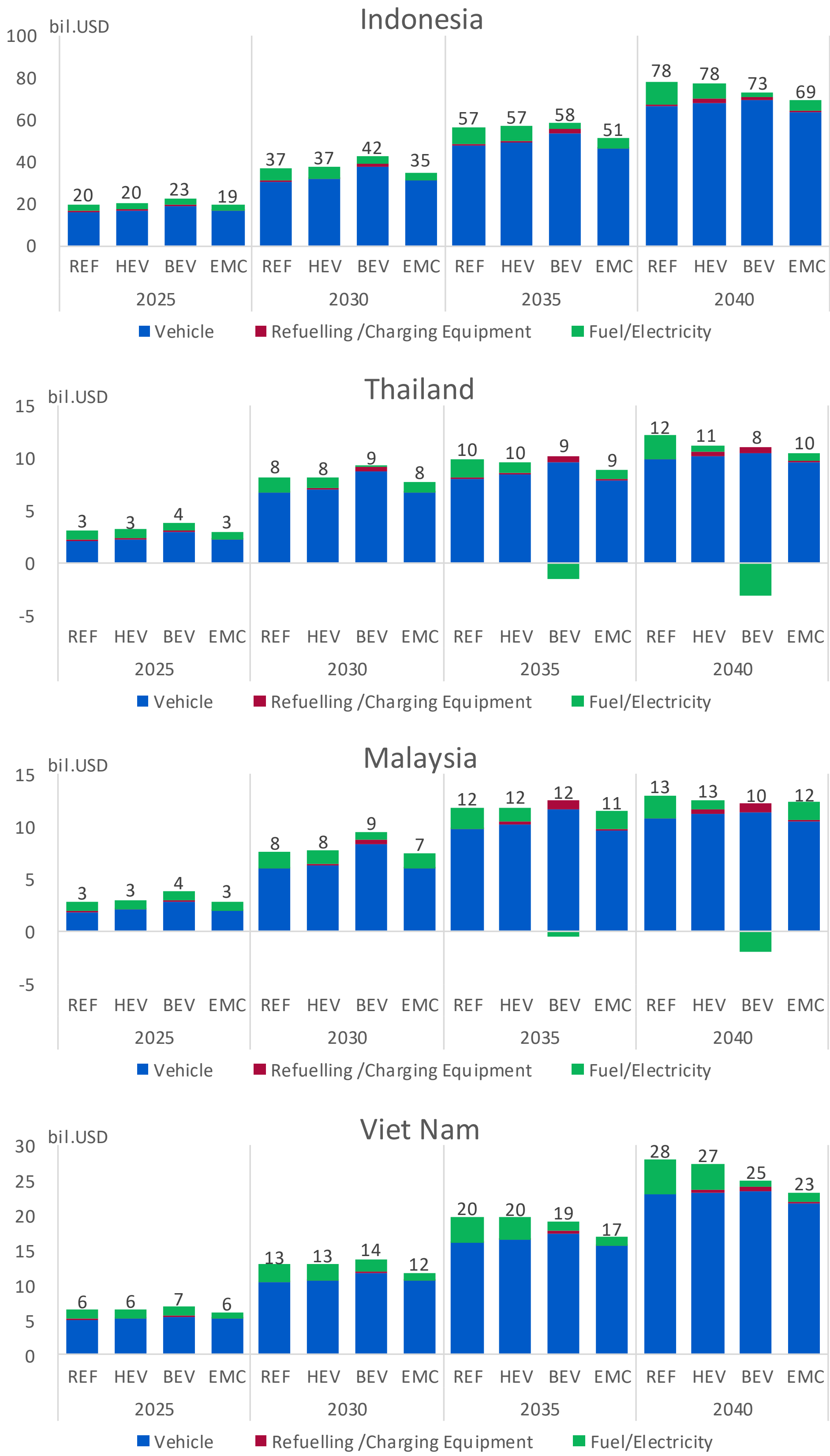


BEV = battery electric vehicle, PHEV = plug-in hybrid electric vehicle.
CHN = China, EU = European Union, IDN = Indonesia, IND = India, JPN = Japan, KOR = Korea,
MYS = Malaysia, THA = Thailand, USA = United States of America, VNM = Viet Nam.
Source: IEA (2019b) and Authors' analysis.

The daily fuel/electricity cost for running vehicles is calculated by multiplying gasoline / electricity price by average fuel efficiency and annual mileage, which are the same as section 3.1.

Figure 4-4 shows additional PLDV-related expenditures, needed from today. The expenditure for purchasing vehicles gradually increases as the car and motorcycle become widespread in the four countries. In the HEV Bridge and the BEV Ambitious scenarios, expenditures are more than in the reference scenario due to xEVs' cost. Although expenditures on installing refuelling/charging facilities are not large, they are higher in the BEV Ambitious scenario because the total amount for charging equipment is greater than on service stations. Daily fuel/electricity cost basically increases with the spread of motor vehicles, but they are suppressed in the alternative xEV scenarios. The spending in the BEV Ambitious scenario is even lower than at present in Thailand and Malaysia.

Figure 4-4. PLDV-related Expenditure by Scenario (including motorcycles)

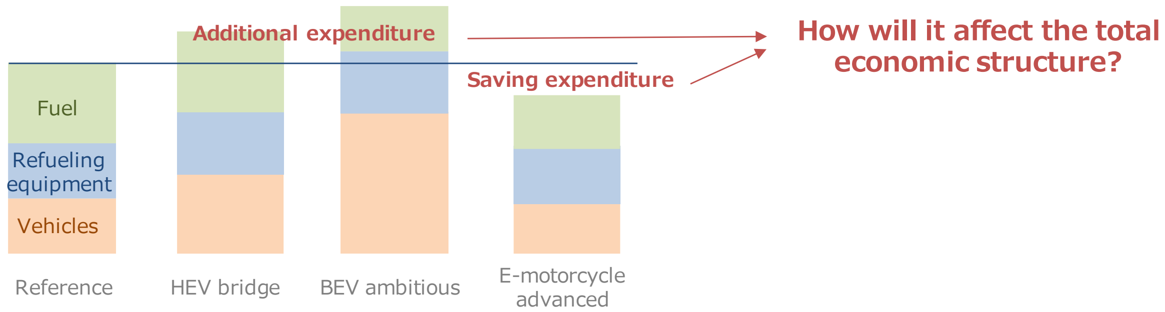


bil.US$ = billions of US dollars. REF=Reference, HEV= HEV Bridge, BEV= BEV Ambitious, EMC = E-Motorcycle Advanced, PLDV = passenger light duty vehicle.
Source: Authors' analysis.

4 Analysis Results and Implications

This section sees the ripple effects of PLDV-related expenditure on production and employment by the scenario. To evaluate the economic impacts of xEV penetration, the ripple effects in the alternative scenarios are assessed by using additional/saving spending relative to the reference scenario (Figure 4-5).

Figure 4-5. Concept of the Ripple Effect Analysis in this Study



BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Source: Authors.

We analyse the effects based on some cases. Sub-section 4.1 shows the results of the base case where some xEVs are produced in the domestic factories at the same ratio as ICEs are today and the necessary battery packs are also domestically produced. Sub-section 4.2 shows the results of the Importing Battery case, where they are fully imported from foreign countries, while sub-section 4.3 shows the ones in the Importing xEVs case, where they are fully imported. Finally, sub-section 4.4 shows the ripple effects when assuming the budget constraint, which means additional expenditure and savings are offset.

Table 4-6. Cases for Input–Output Analysis

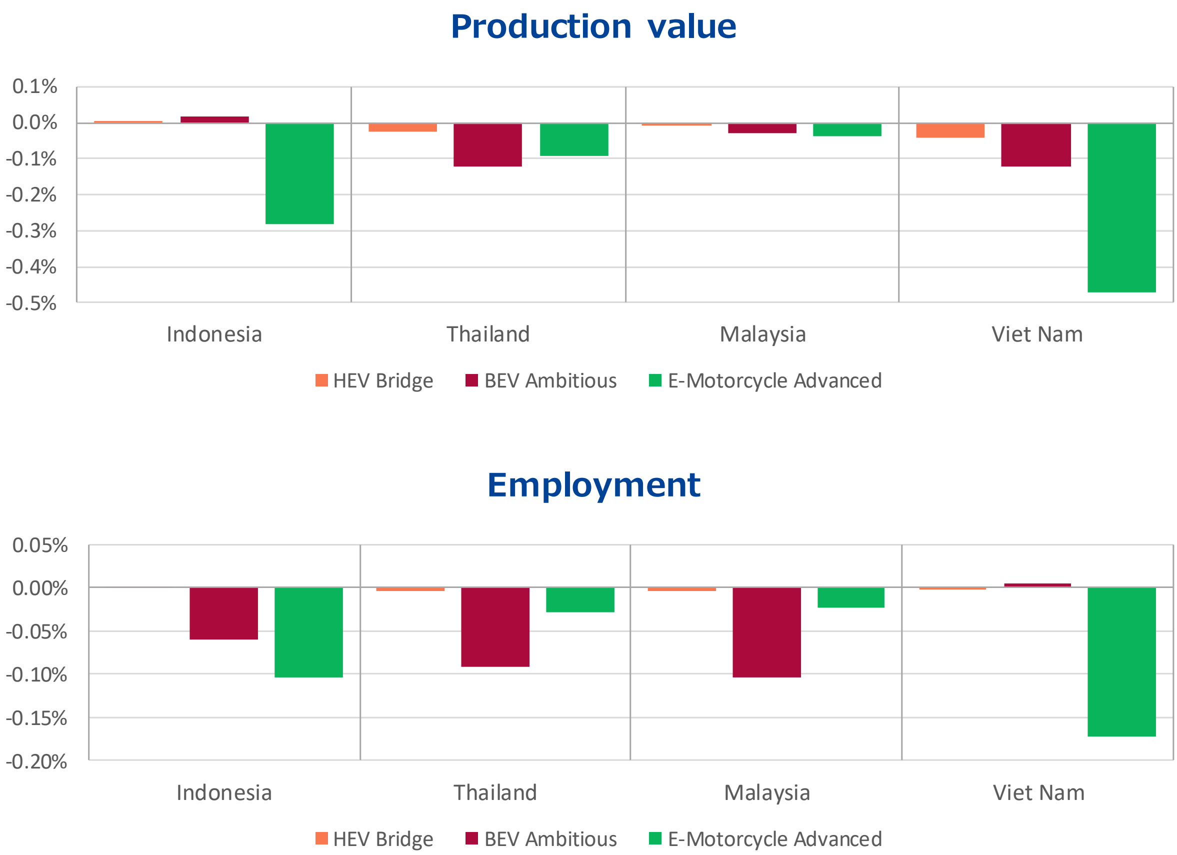
	Base case	Importing battery case	Importing xEVs case	Budget constraint case
xEVs supply	Today's ICEV production/import ratio	Same as Base	All imported	Same as Base
Battery supply	All domestically produced	All imported	None	Same as Base
Budget	Free	Same as Base	Same as Base	Constraint

ICEV = internal combustion engine vehicle, xEVs = electric vehicles.
Source: Authors.

4.1 Base Case

Figure 4-6 shows the cumulative ripple effects on production and employment up to 2040 for each scenario compared with the reference scenario. Negative numbers mean that the economic impacts by spreading xEVs are worse than the reference scenario.

Figure 4-6. Ripple Effects during Outlook Period vs. Today's Level



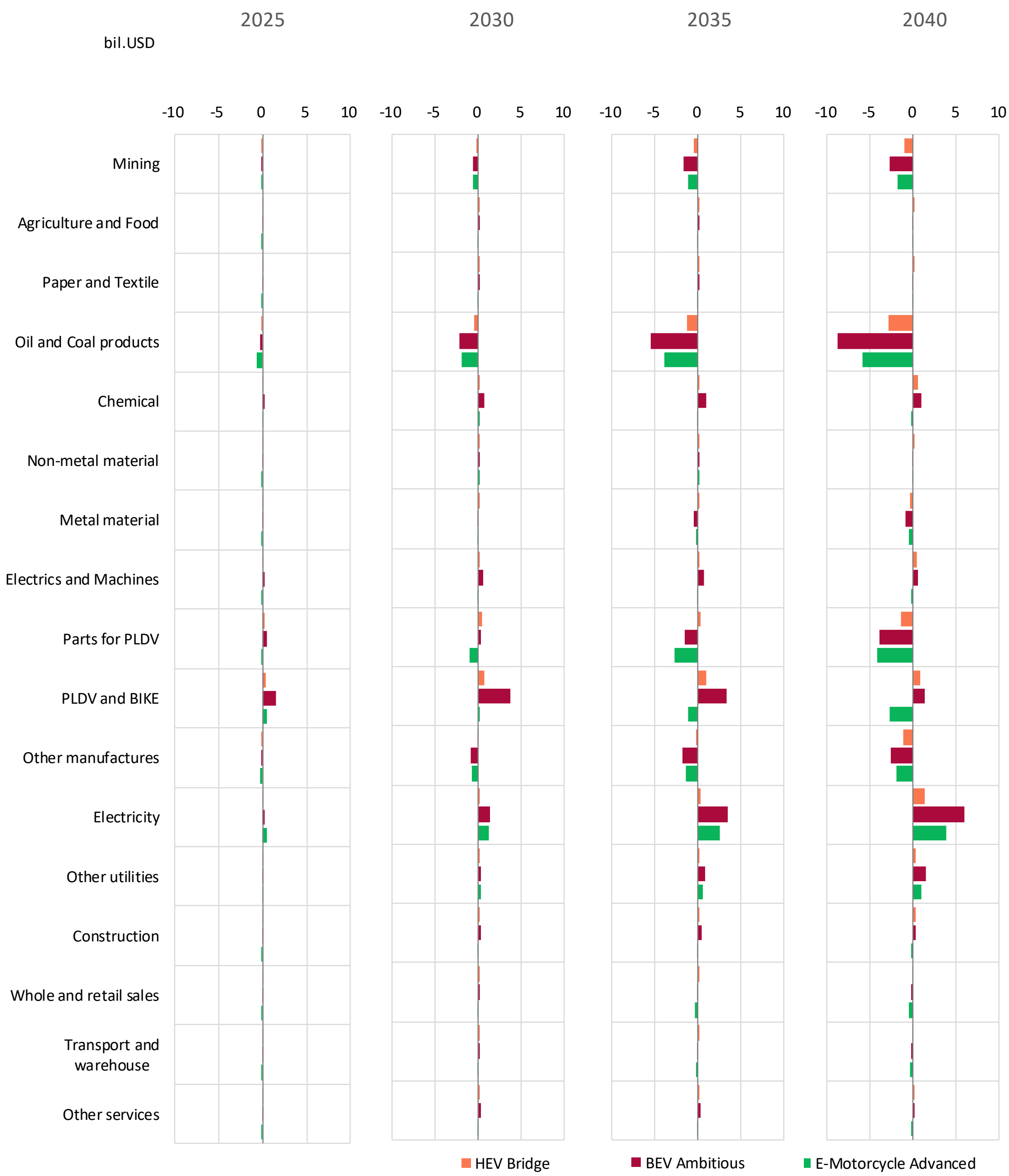
BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

Negative values in many regions and scenarios are seen. The E-Motorcycle Advanced scenario has a large negative ripple effect due to the small difference in vehicle prices between ICEs and BEVs, and the large savings in the daily fuel costs, particularly in Indonesia and Viet Nam, where motorcycles are widely spread. The BEV Ambitious and the HEV Bridge have negative effects (except in Indonesia, where they are barely positive), and the negative effects in the former are larger than those in the latter. This is because producing battery packs has a smaller ripple effect than producing parts related to internal combustion engines; further, the negative effects of petroleum fuel supply overwhelm the positive effects of electricity supply (Figures 4-7 to 4-10). Although the higher electricity demand needs more fuels such as coal and natural gas, economic impacts are negative in the mining industries.

In terms of employment, the negative ripple effects in the BEV Ambitious are much greater than that in the HEV Bridge, especially in Thailand and Malaysia, where the BEV Ambitious has the worst impact amongst the alternative xEV scenarios. Employment required to producing battery packs is less than the producing parts related to internal combustion engines, so that it shows noticeable negative effects in employment in the BEV Ambitious and the E-Motorcycle Advanced.

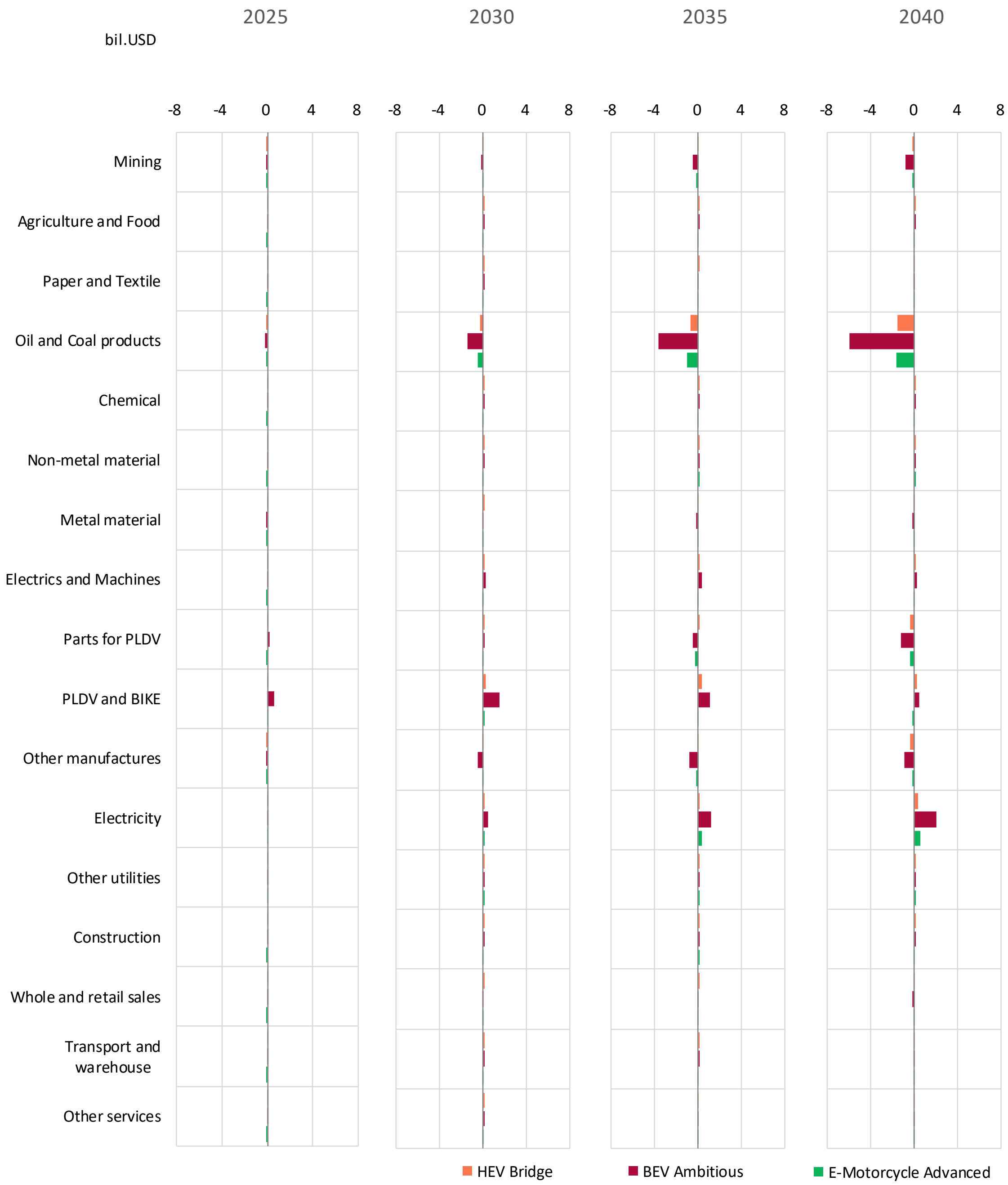
In Viet Nam, the HEV Bridge and the BEV Ambitious have little impact on domestic employment as most of the PLDV vehicles are produced in CKD style.

Figure 4-7. Production Ripple Effects by Sector (Indonesia)



bil.US$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

Figure 4-8. Production Ripple Effects by Sector (Thailand)

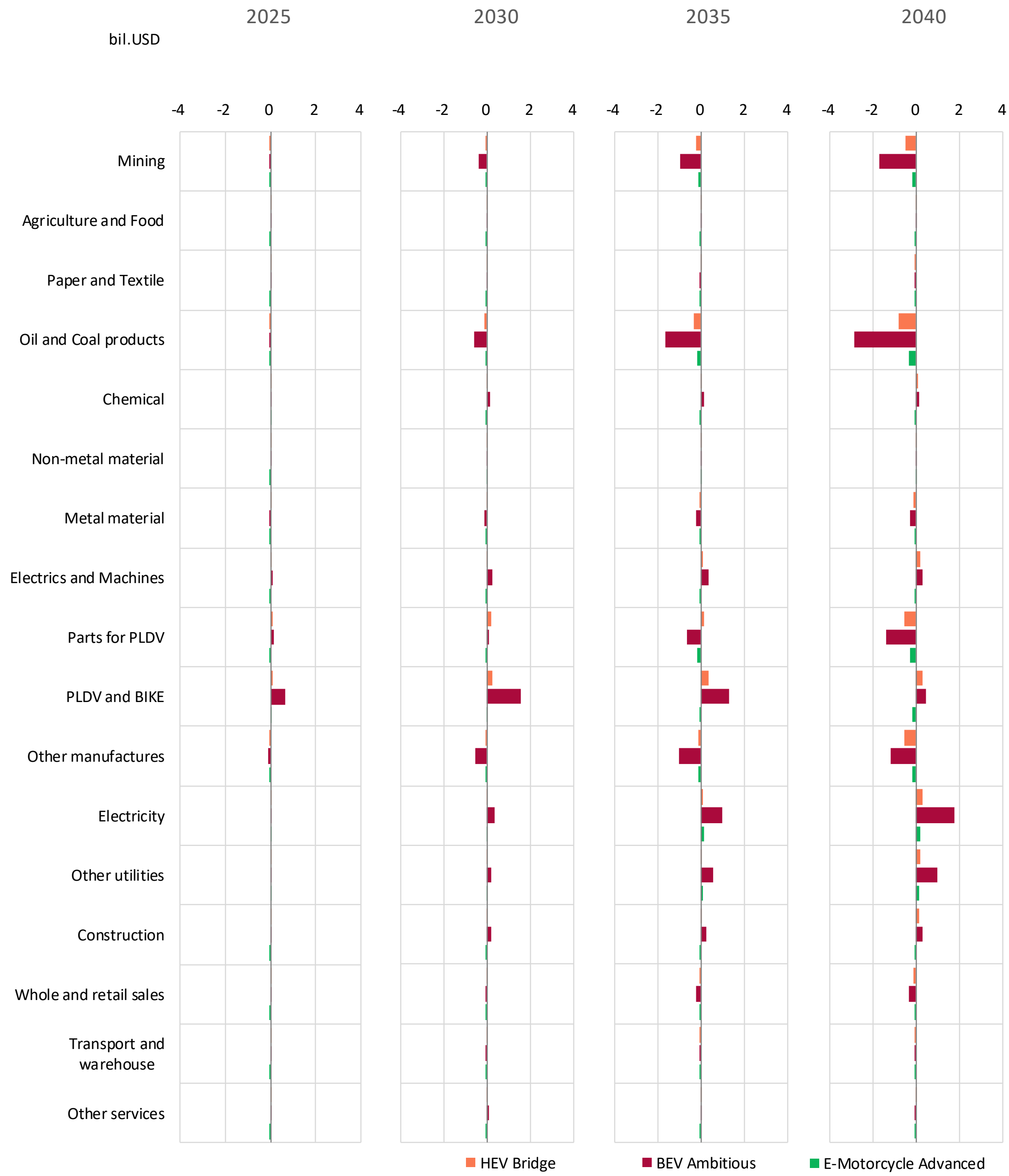


bil.US$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the Reference scenario.

Source: Authors' analysis.

Figure 4-9. Production Ripple Effects by Sector (Malaysia)

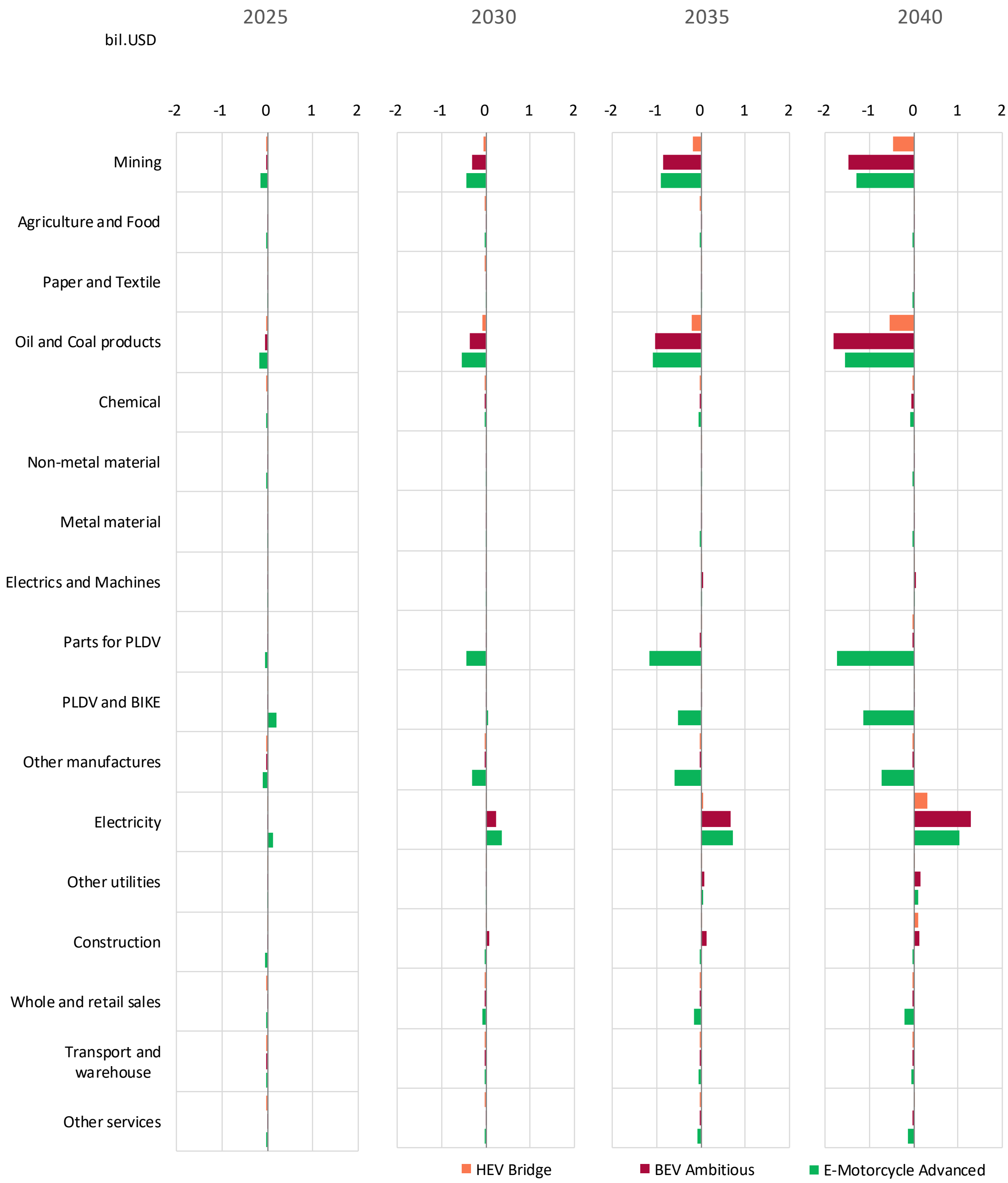


bil.US$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

Figure 4-10. Production Ripple Effects by Sector (Viet Nam)



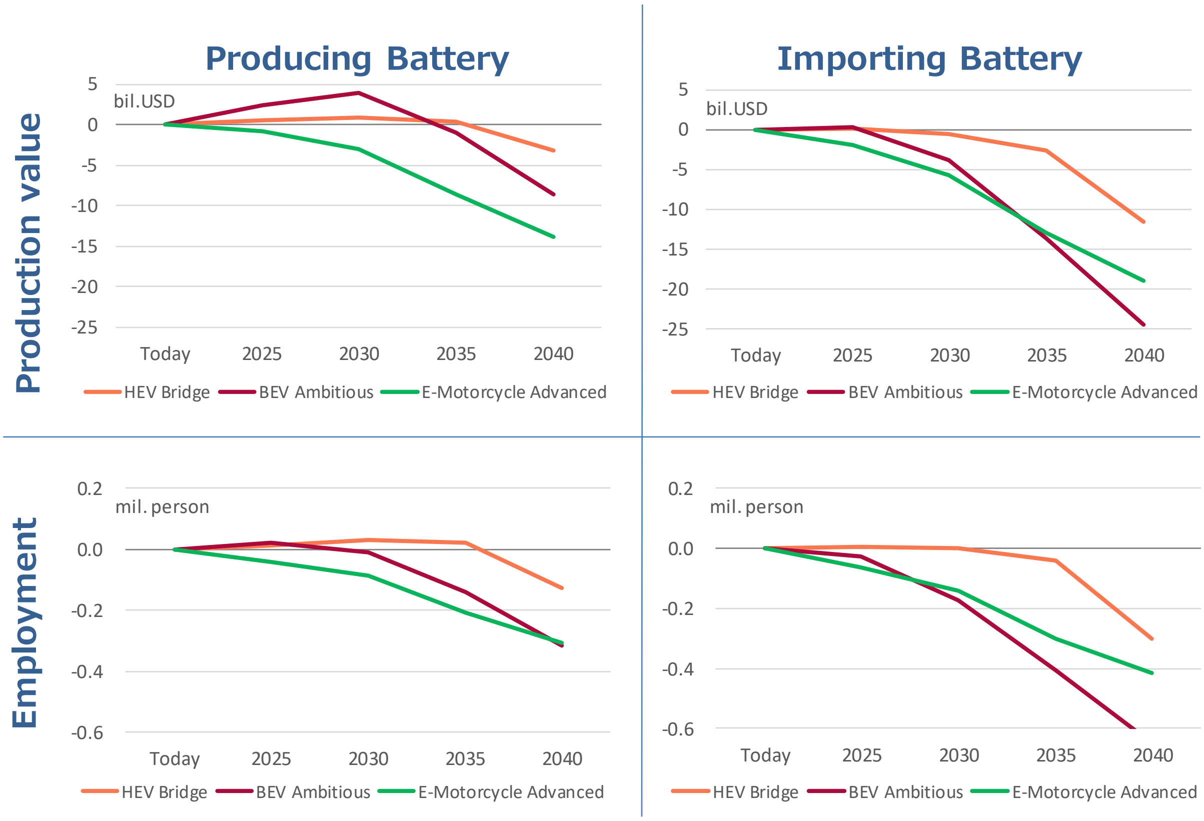
bil.US$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

4.2 Importing Battery Pack Case

The xEV penetration has even more negative effects when relying on importing battery packs (Figures 4-11 to 4-14). The BEV Ambitious scenario had positive ripple effects from around 2025 to 2030 when producing batteries domestically; meanwhile, the positive effects almost disappear when relying on imports. The negative effects of both production and employment become greater in 2040 than when using domestic batteries.

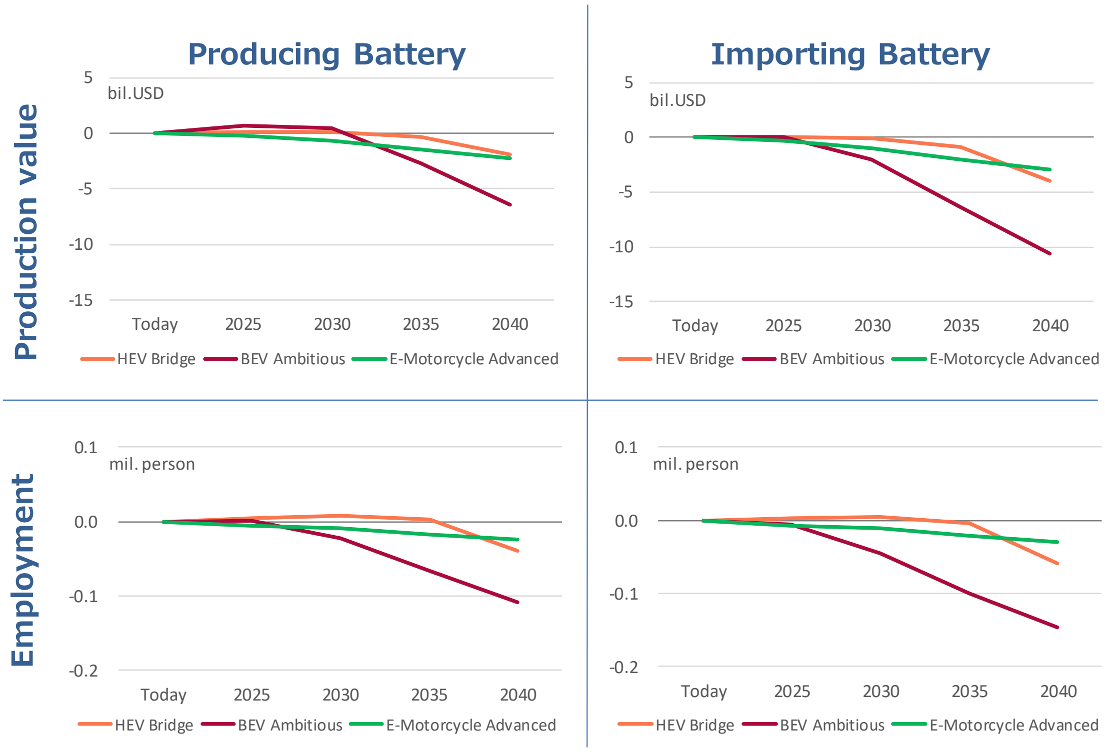
In Viet Nam, however, the economic impacts do not depend on whether producing or importing batteries in the BEV Ambitious and the HEV Bridge, due to PLDVs being produced in CKD style.

Figure 4-11. Ripple Effects (Indonesia)



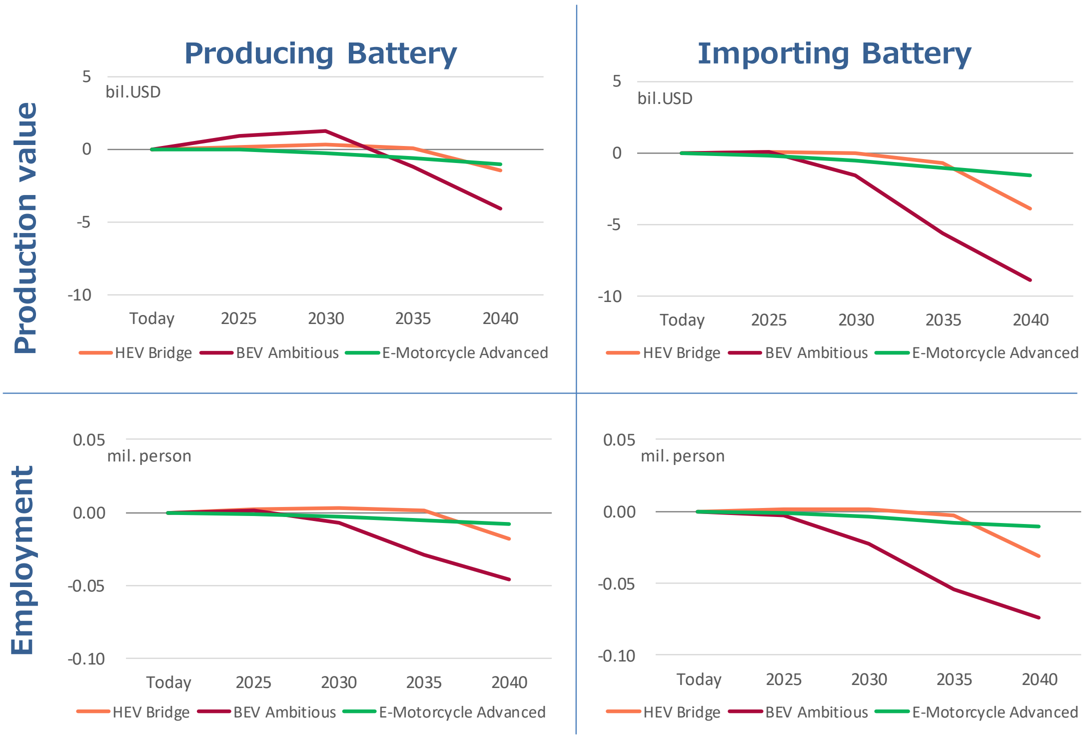
bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario at the base case.
Source: Authors' analysis.

Figure 4-12. Ripple Effects (Thailand)



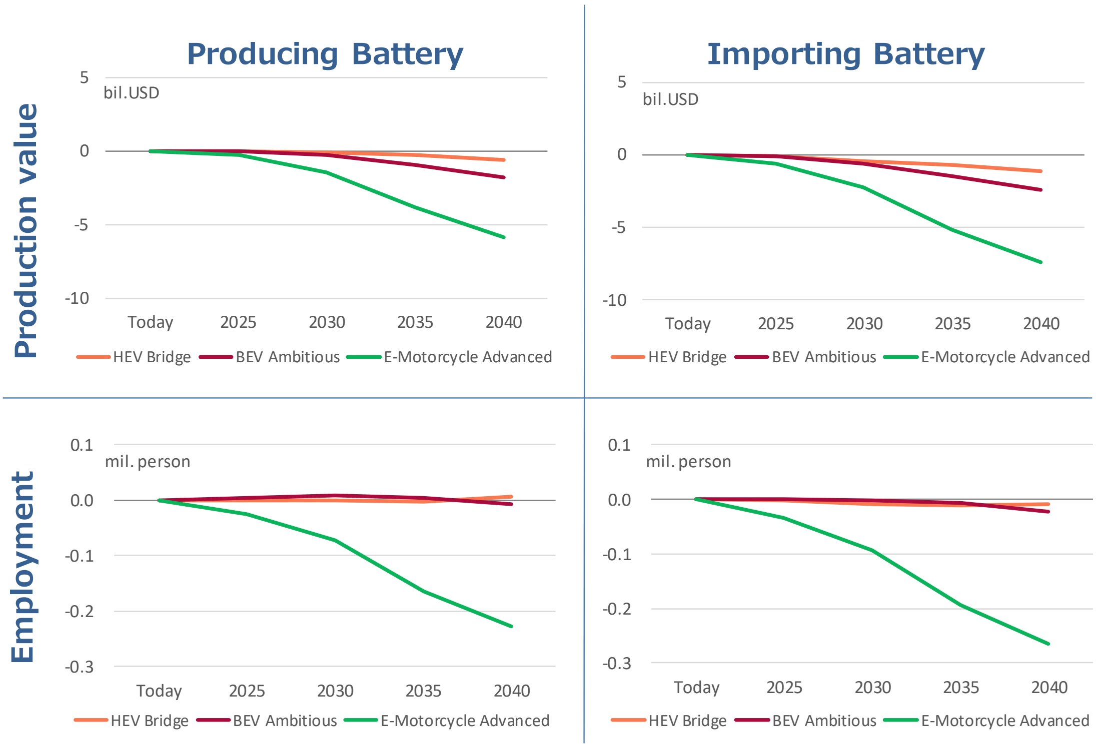
bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario at the base case.
Source: Authors' analysis.

Figure 4-13. Ripple Effects (Malaysia)



bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario at the base case.
Source: Authors' analysis.

Figure 4-14. Ripple Effects (Viet Nam)



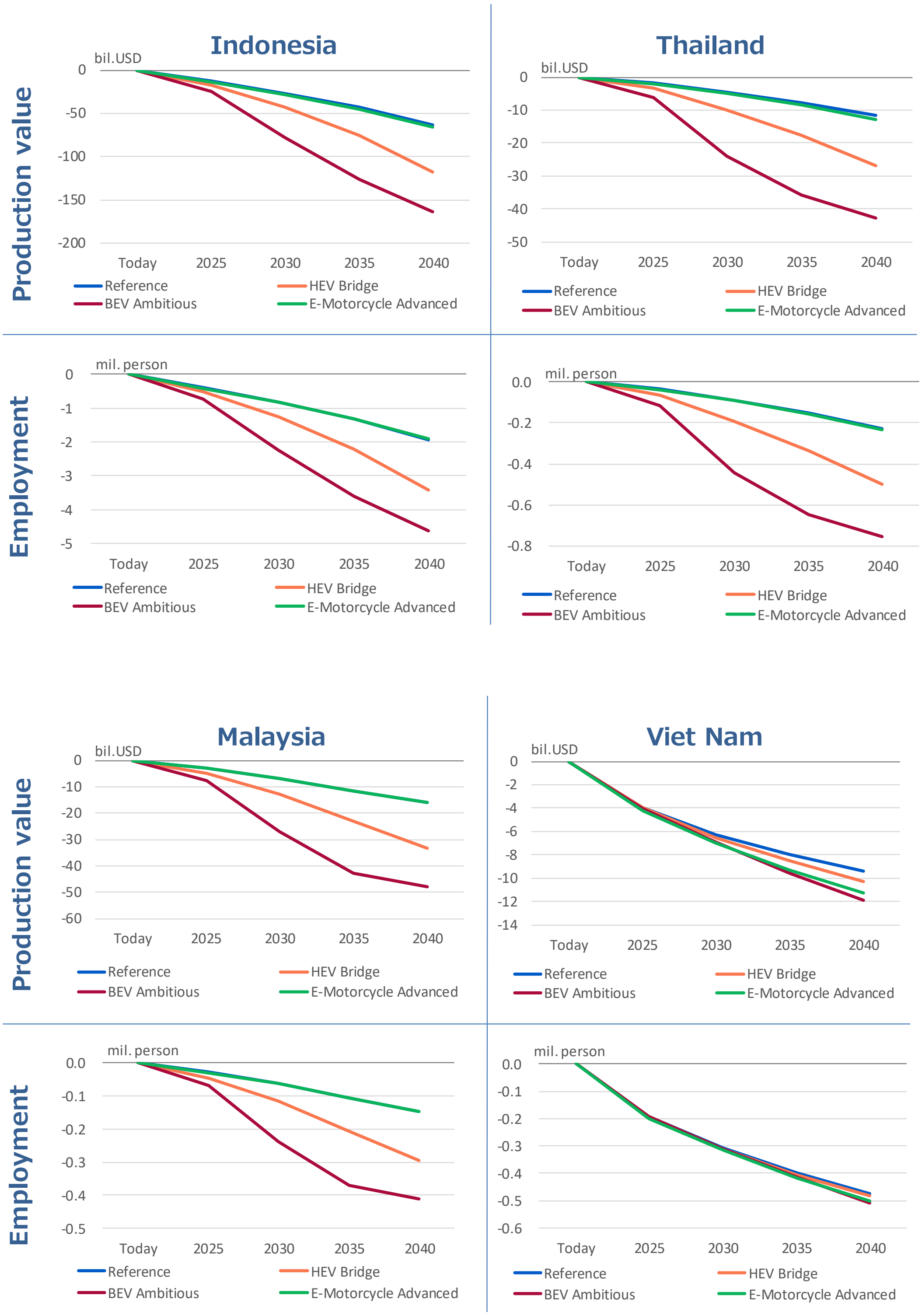
bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario at the base case.
Source: Authors' analysis.

4.3 Importing xEVs Case

The xEV penetration has many more negative effects when relying on also importing xEVs, and not only battery packs (Figure 4-15). The BEV Ambitious scenario, in which a large number of expensive BEVs are imported, has the greatest negative impacts on the economy and employment throughout the period.

In Viet Nam, most of the automobiles depend on imports and CKD production; therefore, the impacts in both the HEV Bridge and the BEV Ambitious scenarios are not much different from ones in the Reference scenario, compared to other countries. Rather, the effects due to the shift from domestic motorcycle production to e-bike imports are more noticeable than in other countries.

Figure 4-15. Ripple Effects at the Importing xEVs case

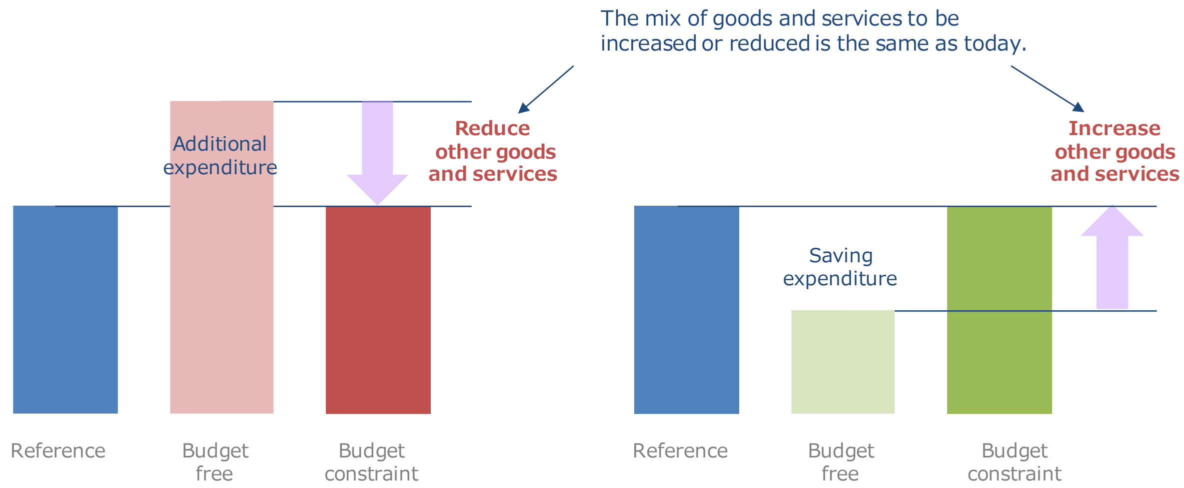


bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario at the base case.
Source: Authors' analysis.

4.4 Budget Constraint Case

Here, we estimate the ripple effects when expenditure on other goods and services increase/decrease in the same amount of money as the changes in xEV-related expenditure relative to the reference scenario, namely, under the budget constraint (Figure 4-16). Spending/saving amounts regarding goods and services are applied at the same ratio as the current expenditure composition. The total expenditure amount for each alternative xEVs scenario is the same as the reference scenario, but the ripple effect depends on the expenditure composition.

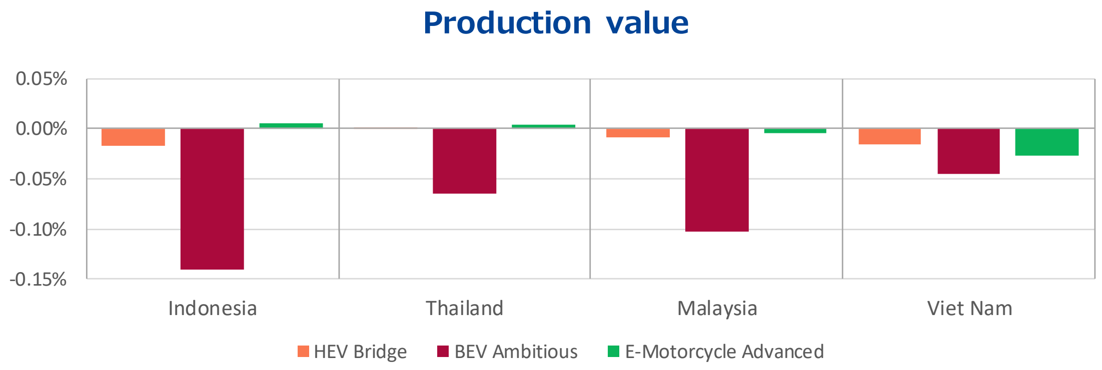
Figure 4-16. Concept of the Budget Constraint in this Study

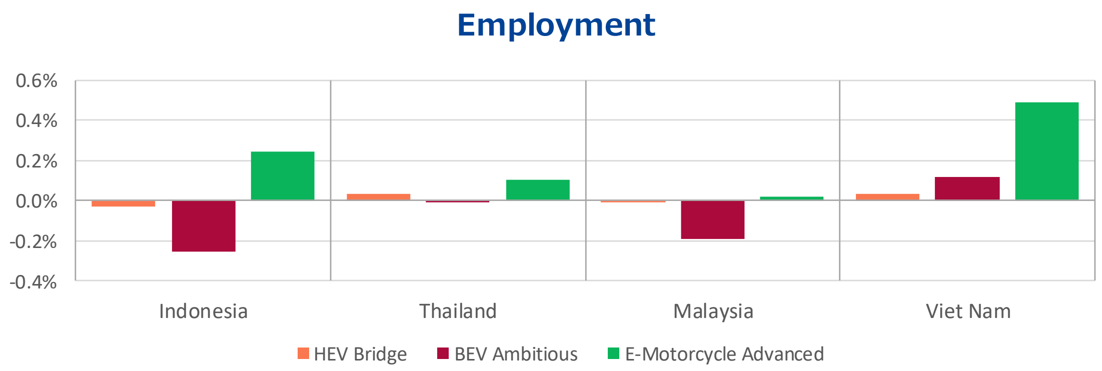


Source: Authors.

The production ripple effect is naturally smaller than when there is no budget constraint (Figure 4-17). Amongst the scenarios, the BEV Ambitious has the largest negative impacts on any country. This is because producing battery packs has a smaller ripple effect than producing parts related to internal combustion engines. On the other hand, the impacts on employment are larger than without budget constraints. This is because, in general, the agriculture and service industries are more labour-intensive than the manufacturing industries, and therefore have greater effect on employment per unit of production. The positive effect of the E-Motorcycle Advanced is greatest, particularly in Indonesia and Viet Nam. Being able to turn the expenditure on vehicle fuels into other goods and services has a greater job creation effect, particularly in the service sectors and the agricultural sectors (through the expansion of food demand). On the other hand, the BEV Ambitious has large negative effects in Indonesia and Malaysia.

Figure 4-17. Ripple Effects during Outlook Period vs. Today's Level (Budget Constraint)



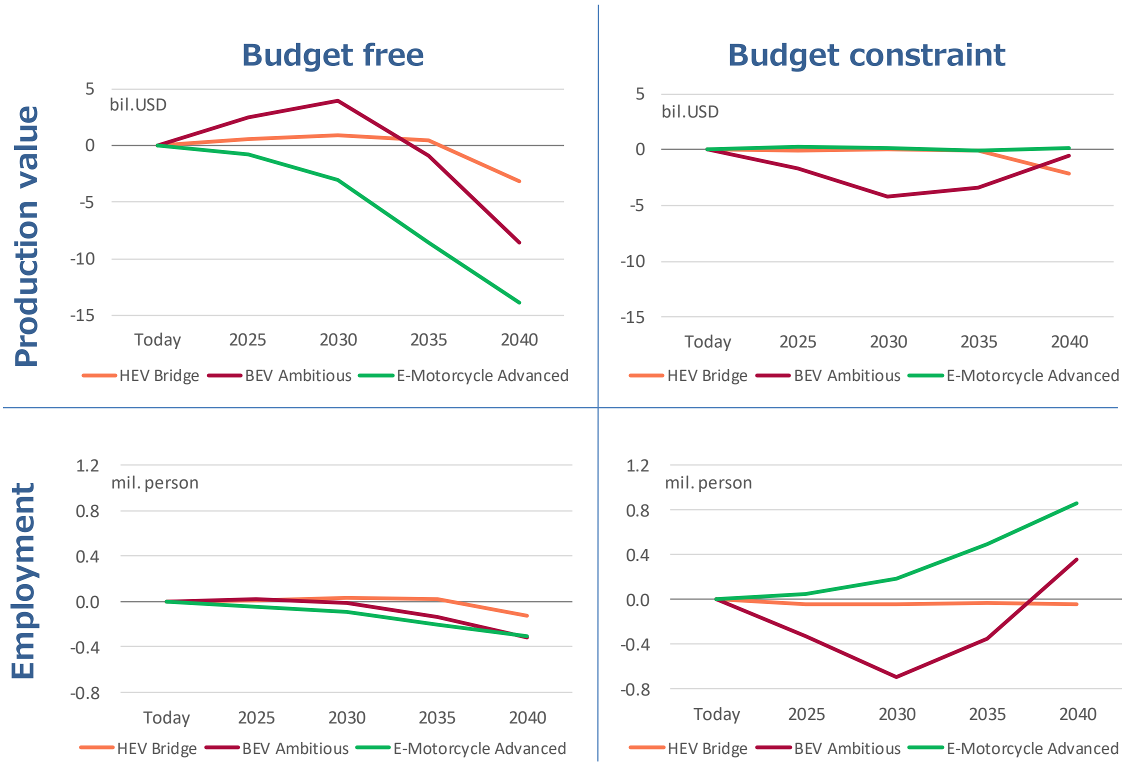


BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

Looking at the time series results on the production effects, the deviations from the reference scenario are naturally tiny due to the assumptions of the budget constraint, but the slightly negative effects are seen in the BEV Ambitious scenario (Figures 4-18 to 4-21). On the other hand, looking at the impacts on employment under the budget constraint, the BEV Ambitious has negative effects, but they turn positive along with increasing fuel cost savings.

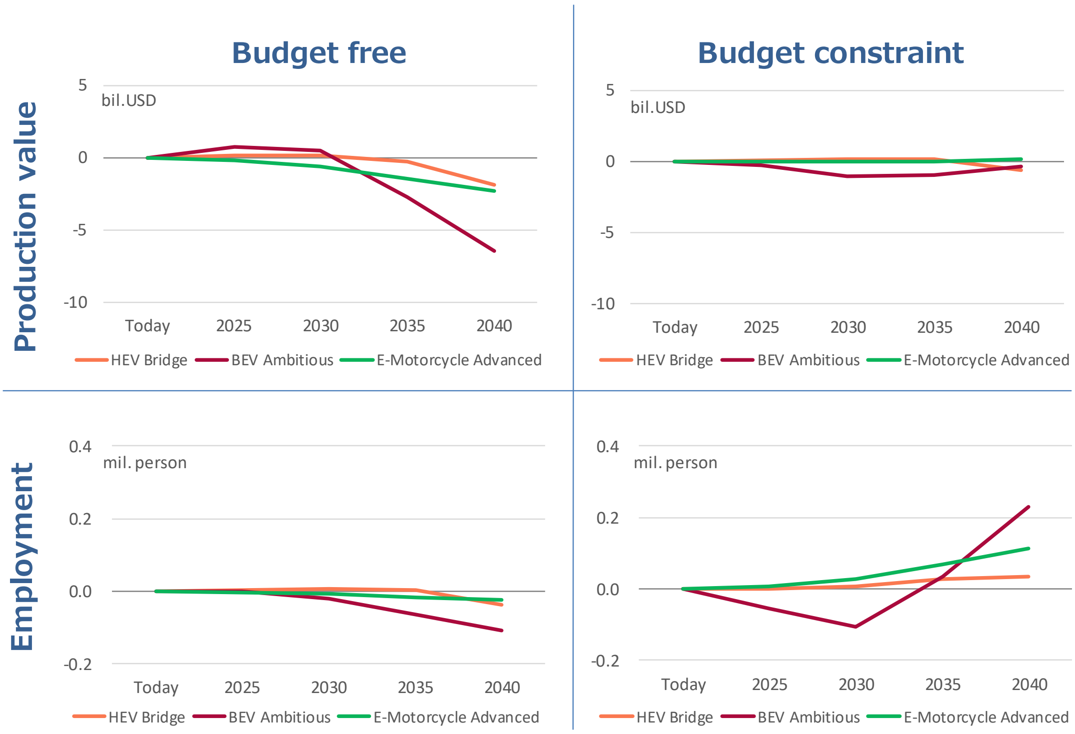
As of 2040, the BEV Ambitious will have the largest positive effect amongst the scenarios in Thailand and Malaysia. The E-Motorcycle Advanced will enhance job creation effects along with increasing spending on other goods and services, and have the largest positive effect amongst the scenarios in Indonesia and Viet Nam.

Figure 4-18. Ripple Effects (Indonesia)



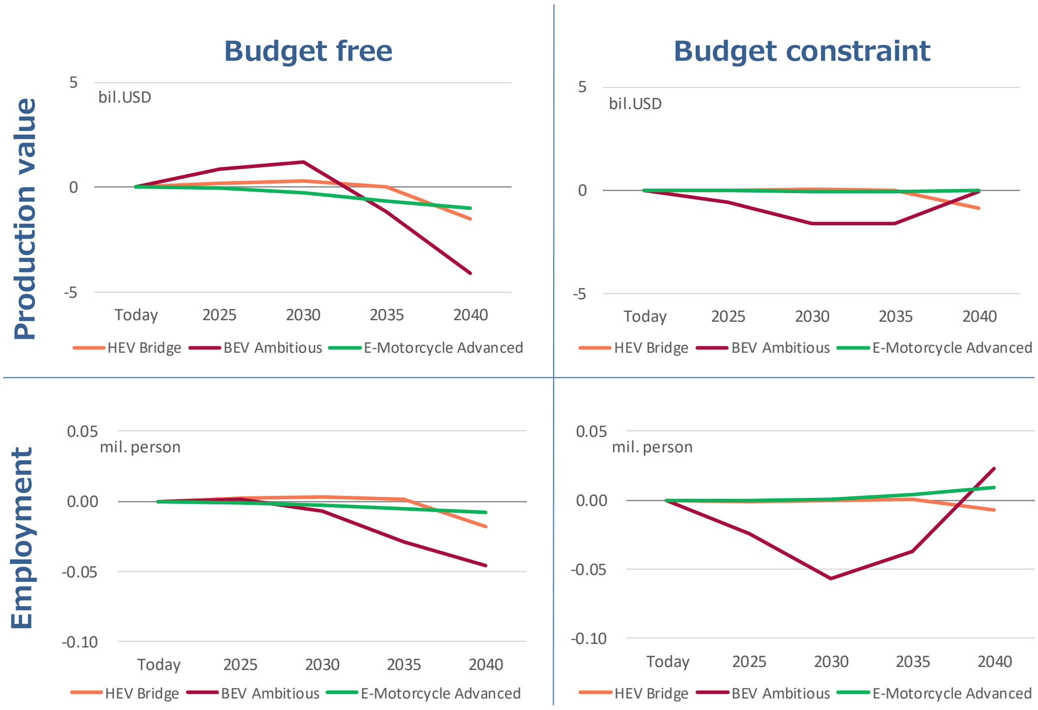
bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

Figure 4-19. Ripple Effects (Thailand)



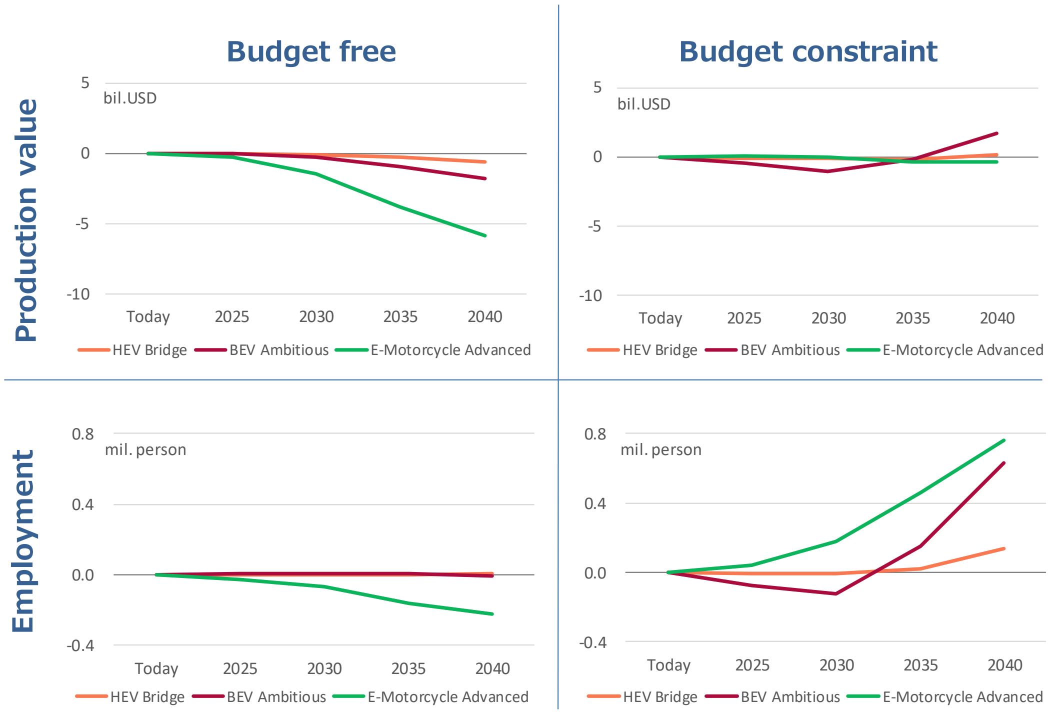
bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

Figure 4-20. Ripple Effects (Malaysia)



bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

Figure 4-21. Ripple Effects (Viet Nam)



bil.US$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Note: Effects comparing with the reference scenario.
Source: Authors' analysis.

4.5 Key Implications from Input–Output Analysis

The ripple effects of xEV-related expenditure on production and employment are almost negative in the four countries. This is because the production ripple effects of the battery packs are smaller than that of the internal combustion engines, and the total expenditure decreases due to the daily fuel expenditure savings. The negative effects will be even greater if they rely on importing xEVs / battery packs.

On the other hand, in the case of budget constraint, the job creation effects are quite large in the E-Motorcycle Advanced scenario. When the money from the fuel savings is used for other goods and services, employment increases in the agriculture and the service industries. Meanwhile, the BEV Ambitious scenario has negative effects on employment because the expensive xEVs curtail other expenditures, but they turn into positive effects by 2040 due to the larger fuel saving effects. In terms of cumulative effects over the estimation period, however, the effects on employment are negative.

Assuming the budget constraint, Indonesia and Viet Nam, which have many motorcycles, should adopt the E-Motorcycle Advanced scenario from the viewpoint of job creation. In Thailand as well, the E-Motorcycle Advanced scenario has the largest employment effects amongst the scenarios, even though they are relatively small. In Malaysia, only the E-Motorcycle Advanced scenario has positive effects, but they are quite small. In Thailand and Malaysia, the BEV Ambitious scenario has the greatest employment effects as of 2040, but they should consider the path leading to them.