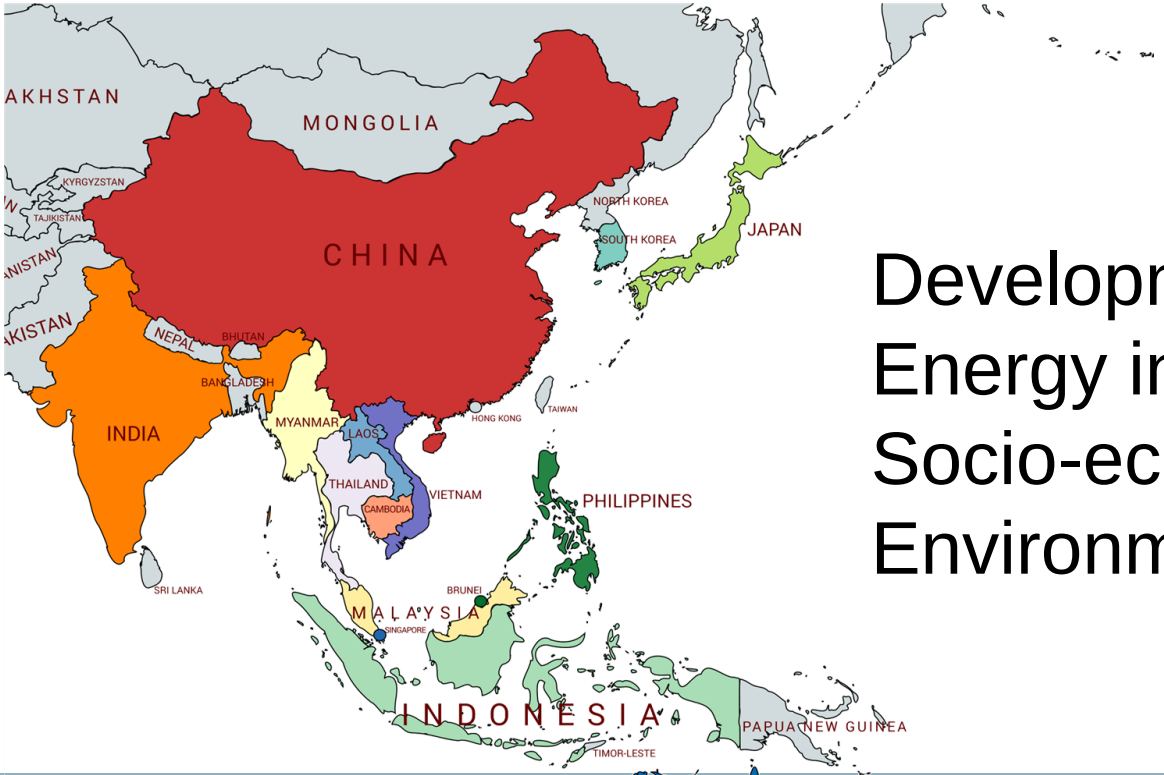
Australian National University



Development of Renewable Energy in ASEAN Countries: Socio-economic and Environmental Impacts

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Introduction

Increasing electricity consumption across ASEAN countries

	Total Electricity Generation (GWh)			Electricity Consumption (MWh per capita)		
	2000	**2010**	**2017**	**2000**	**2010**	**2017**
Brunei	2,543	3,792	4,157	7.55	8.81	8.60
Indonesia	93,325	169,755	254,868	0.39	0.64	0.90
Cambodia	448	1,000	6,998	0.03	0.14	0.50
Myanmar	5,758	7,543	22,413	0.08	0.12	0.30
Malaysia	70,458	124,787	164,503	2.75	4.15	4.80
Philippines	45,521	67,892	94,847	0.50	0.64	0.80
Singapore	31,759	46,547	52,364	7.58	8.68	9.20
Thailand	96,096	159,867	186,505	1.45	2.31	2.90
Vietnam	26,741	94,940	198,659	0.29	1.02	1.90
World	15,518,865	21,616,255	25,720,185	2.39	2.96	3.20

Notes: LAO PDR data are not available.
Source: IEA (2020)

There has been a significant increase in electricity generation and electricity consumption per capita amongst ASEAN countries.

How to generate sufficient electricity in Southeast Asia region?

Introduction

Electricity supply issue in ASEAN

- Provision of electricity supply is an important issue for ASEAN member countries.
  - can be generated by mixing energy resources from either fossil fuels or renewable energy.
  - fossil fuel electricity generations deteriorate environmental condition due to their carbon emissions (Goh, Ang and Xu 2018).
  - ASEAN region has a great potential to develop renewable energy: a significant investment in renewable energy & untapped renewable energy potential (IRENA, 2018).
    - To achieve 23% of renewable energy share in 2030, ASEAN need 290billion USD, around 27 billion annually.

Introduction

Previous studies on renewable energy

- impacts of renewable energy technology on human health globally (Gibon et al. 2017).
- marginal external benefits of wind turbines and solar panels on carbon emissions in Texas (Novan 2015).
- estimate socio-economic and environmental life cycle impacts of Concentrated Solar Power (CSP) by using multiregional input-output analysis in Spain (Corona et al. 2016) .
- **Fewer comprehensive studies on how increasing renewable energy could affect the economy, income distribution, and carbon emissions across countries in a specific region such as ASEAN**

Introduction

Objective of this study

- Observe the socioeconomic and environmental impacts of renewable energy development in ASEAN countries
- Socioeconomic and environmental impacts:
  - macroeconomic indicators such as GDP changes, sectoral changes, and factor income changes
  - Socio-microeconomic indicators such as poverty incidence and income per percentile households in rural and urban areas
  - environmental indicator is carbon emission changes

Introduction

Contributions

- Introduces Inter-Regional Constrained Fixed Price Multiplier (IRCFPM)
  (Lewis and Thorbecke 1992, Resosudarmo and Thorbecke 1998, and Hartono and Resosudarmo 2008).
- Develops a household income microsimulation model
  (Nurdianto and Resosudarmo 2016).
- Connects IRSAM to a satellite carbon emission model
  (Resosudarmo and Thorbecke, 1998).

Methodology

Three analysis

	Analysis	Objectives
Macro	Inter-Regional Constrained Fixed Price Multiplier -CFPM- method (Hartono and Resosudarmo 2008; Resosudarmo and Thorbecke 1996; Lewis and Thorbecke 1992).	Measure changes in production activities and production factor income
Micro	IRSAM based micro-simulation (Nurdianto and Resosudarmo 2016)	Compute changes in the poverty incidence (Yusuf and Resosudarmo 2015) Pattern of income distribution (Nurdianto and Resosudarmo 2016)
Carbon emission	Carbon emission model (Nurdianto and Resosudarmo 2016)	Measure the changes on carbon emission (Nurdianto and Resosudarmo 2016)

Methodology

Macroeconomics Impacts

Inter-regional Constrained Fix Price Multiplier IRSAM

Structure of two regions IRSAM with constrained sectors.

	Region 1	Region 2	ROW	TOTAL
Region 1	A_C^{11} R^{11} Q^{11} A_{NC}^{11}	R^{12} A_{NC}^{12}	X_C^1 X_{NC}^1	Y_C^1 Y_{NC}^1
Region 2	Q^{21} A_{NC}^{21}	A_{NC}^{22}	X_{NC}^2	Y_{NC}^2
ROW	l^1	l^2	t	Y_E
TOTAL	$(Y_C^1)'$ $(Y_{NC}^1)'$	$(Y_{NC}^2)'$	$(Y_E\ )'$	

$$d\begin{bmatrix} Y_{NC}^1 \\ X_C^1 \\ Y_{NC}^2 \end{bmatrix} = \begin{bmatrix} -R^{11} & -I & -R^{12} \\ (I - A_{NC}^{11}) & 0 & -A_{NC}^{12} \\ -A_{NC}^{21} & 0 & (I - A_{NC}^{22}) \end{bmatrix}^{-1} \begin{bmatrix} -(I - A_C^{11}) & 0 & 0 \\ Q^{11} & I & 0 \\ Q^{21} & 0 & I \end{bmatrix} d\begin{bmatrix} Y_C^1 \\ X_{NC}^1 \\ X_{NC}^2 \end{bmatrix}$$

A_C : matrix of average expenditure propensities of the constrained sector;

A_{NC} : matrices of average expenditure propensities of non-constrained sector .

X_C , X_{NC}: vectors of injections;

Y_C : total income vectors of constrained;

Y_{NC} : total income vectors of non-constrained;

Methodology

Microsimulations

Computing each percentile HH income (H_c^{ur})

$$H_c^{ur} = \sigma_c^{ur} sl^{ur} \sum_v \sum_q \frac{N_c^{v,q}}{\sum_c N_c^{v,q}} lb^{v,q} + \varsigma_c^{ur}\, inc\_sh_c^{ur} sh^{ur} \sum_w \sum_q nlb^{w,q}$$

where
ur = index for urban or rural household;
c = index for 100 groups of household based on population percentile
v = index for labour income type: skilled and unskilled labour;
w = index for non-labour income type: land, natural resources, and capital;
q = index for sector in IRSAM;
σ_c^{ur} = scaling factors of total labour income to IRSAM value;
sl^{ur} = shares of labour factor incomes to the total income of an urban or rural household;
$N_c^{v,q}$ = number of labour type v by sector q in household c;
$lb^{v,q}$ = total type v labour income in sector q;
ς_c^{ur} = scaling factors of total non-labour income to IRSAM value;
sh^{ur}= shares of non-labour factor incomes to the total income of an urban or rural household;
$inc\_sh_c^{ur}$ = percentage of income based on population percentile;
$nlb^{w,q}$ = total type w non-labour income in sector q.

Methodology

Carbon Emissions Changes

- Computes sectoral emissions per unit output in each sector,
  - which is sectoral emissions divided by sectoral output.
- sectoral emissions per unit output are multiplied by sectoral output changes that are extracted from the inter-regional CFPM results.
- changes in carbon emissions can be computed by comparing the summation of sectoral emissions to the baseline emissions values by each country.

Data

East Asia IRSAM as main dataset

- Macro dataset: East Asia IRSAM
  - extracted from GTAP Power 9 Database, base year 2011
- There are 12 regions
  - Seven ASEAN member countries (Indonesia, Malaysia, Thailand, Singapore, Viet Nam, the Philippines and other ASEAN) plus Australia, China, Japan, South Korea, and India
- East Asia IRSAM features:
  - disaggregated electricity sector: wind, hydro, solar, & other electricity (nuclear, coal, oil, gas).
  - allow direct connection between private household and government accounts to capital account
  - has inter-institutional transfer from the government to the household in the form of social expenditures by the government.
  - has government fiscal balance which implies that the government has a surplus or deficit in their account.

Scenarios

Increasing electricity demand

- There are four scenarios

Scenarios	Description
SIM1	electricity demand increase by 10% for each ASEAN member country and it is supplied by coal-fired power plants.
SIM2	increase in electricity demand will be supplied by wind power electricity powerplants.
SIM3	increasing in the electricity demand is fulfilled by increasing output from hydropower electricity power plants
SIM4	increase in electricity demand will be supplied by solar powerplants

Results

- Macroeconomics impacts
- Microeconomics impacts
- Environmental impacts

Results

Macroeconomics Impacts

Gross Domestic Product Changes

	SIM1 (mn USD)	SIM2 (% change)	SIM3 (% change)	SIM4 (% change)
Indonesia	809,163	0.18	0.18	0.12
Malaysia	276,704	0.00	0.21	-0.21
Philippines	215,123	0.15	0.14	0.17
Singapore	254,131	-0.10	-0.10	0.84
Thailand	311,507	0.17	0.17	0.17
Vietnam	112,934	0.28	0.26	-0.83
Rest of ASEAN	87,448	-0.16	0.07	0.07

- development of renewable electricity in SIM2 to SIM4 eventually induces higher GDP than SIM1
- There are several ASEAN countries without particular renewable electricity sources such as Malaysia, Singapore, and Vietnam. In these cases, the macroeconomic impacts of renewable electricity development are negative compared to SIM1.

Results

Macroeconomics Impacts

Impacts on Energy Sectors

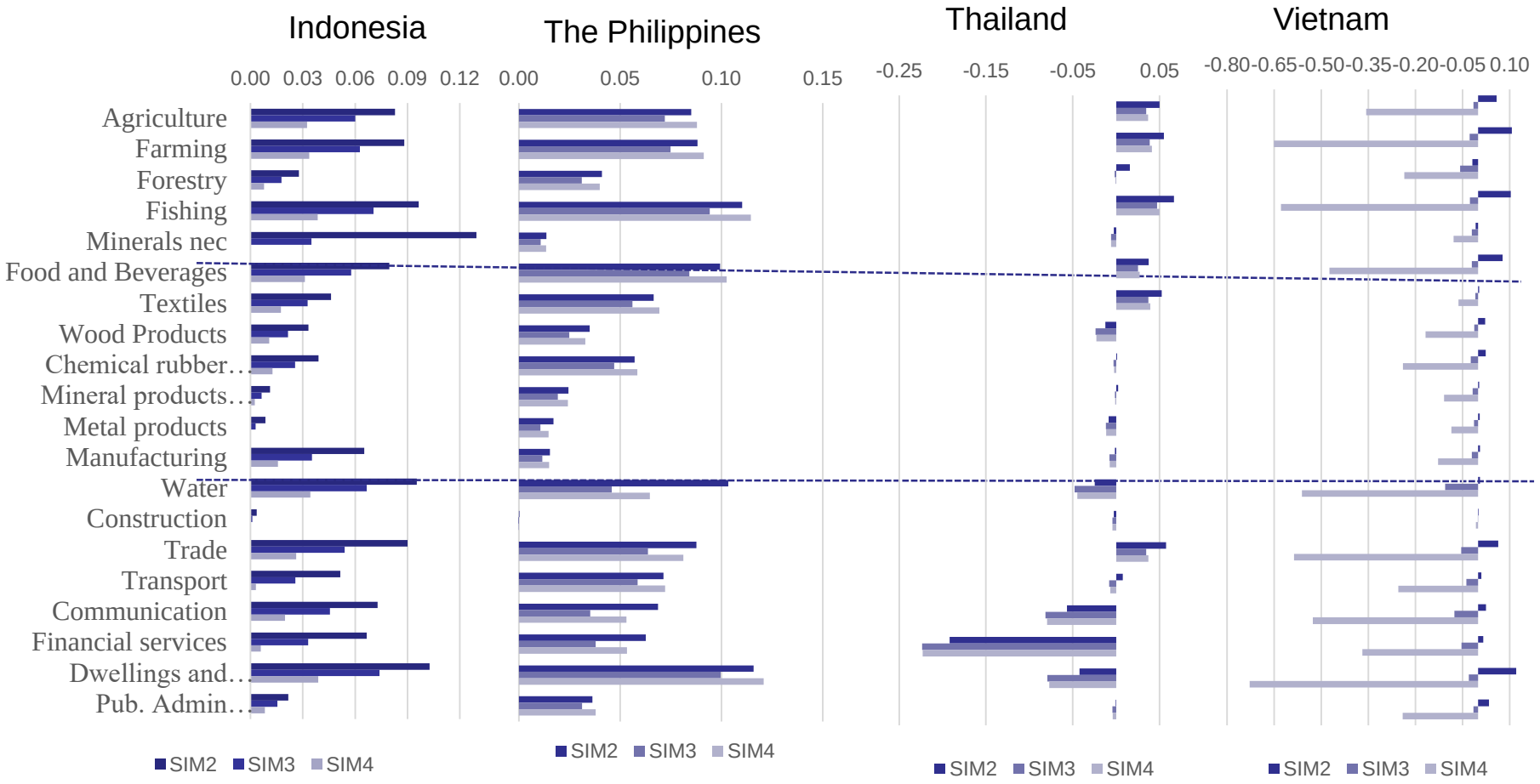
		Coal	Oil	Gas	PCP	GMD
Indonesia	SIM1 (mn USD)	33,851.65	33,984.15	15,978.37	54,807.63	7,624.27
	SIM2 (% Change)	-0.80	-0.82	-0.30	-1.22	-3.20
	SIM3 (% Change)	-0.80	-0.83	-0.31	-1.23	-3.21
	SIM4 (% Change)	-0.80	-0.85	-0.31	-1.25	-3.21
The Philippines	SIM1 (mn USD)	423.80	593.27	4.40	14,508.70	939.14
	SIM2 (% Change)	-5.31	-0.26	-1.30	-0.31	-8.74
	SIM3 (% Change)	-5.31	-0.27	-1.30	-0.32	-8.74
	SIM4 (% Change)	-5.31	-0.26	-1.29	-0.31	-8.74
Thailand	SIM1 (mn USD)	770.73	7,327.62	3,093.38	70,335.09	8,894.60
	SIM2 (% Change)	-6.96	-0.10	-3.95	-0.09	-6.68
	SIM3 (% Change)	-6.96	-0.11	-3.96	-0.10	-6.69
	SIM4 (% Change)	-6.96	-0.11	-3.96	-0.10	-6.69
Vietnam	SIM1 (mn USD)	4,076.55	11,098.16	97.04	8,470.33	2,383.74
	SIM2 (% Change)	-1.88	-0.20	-0.53	-0.29	-8.13
	SIM3 (% Change)	-1.90	-0.23	-0.62	-0.39	-8.14
	SIM4 (% Change)	-1.99	-0.40	-1.01	-0.84	-8.15

- there is a significant decrease in the energy-related sectors' output relative to SIM1.
- the impacts of the energy sector are relatively similar across ASEAN countries.

Results

Macroeconomics Impacts

Impacts on Non-Energy Sectors of ASEAN countries (in %, relative to SIM1)



The spillover is now dispersed into other sectors compared to SIM1.

Results

Microeconomics Impacts

Changes in Percentage of Poverty Incidence

		Urban			Rural		
		Base	**Sim**	**Δ**	**Base**	**Sim**	**Δ**
SIM2	Indonesia	9.76	9.76	0.00	12.90	12.90	0.00
	Malaysia	2.32	2.33	0.01	4.21	4.23	0.02
	Philippines	11.69	11.69	0.00	41.05	41.04	-0.01
	Thailand	5.42	5.44	0.02	15.91	15.94	0.03
	Vietnam	8.32	8.33	0.01	64.60	64.66	0.06
	Rest of ASEAN	7.72	7.73	0.01	55.50	55.55	0.05
SIM3	Indonesia	9.76	9.77	0.01	12.90	12.90	0.00
	Malaysia	2.32	2.32	0.00	4.21	4.22	0.01
	Philippines	11.69	11.69	0.00	41.05	41.05	-0.01
	Thailand	5.42	5.44	0.02	15.91	15.94	0.04
	Vietnam	8.32	8.34	0.02	64.60	64.68	0.08
	Rest of ASEAN	7.72	7.72	0.00	55.50	55.50	0.00
SIM4	Indonesia	9.76	9.76	0.00	12.90	12.90	0.00
	Malaysia	2.32	2.33	0.01	4.21	4.23	0.02
	Philippines	11.69	11.69	0.00	41.05	41.04	-0.01
	Thailand	5.42	5.44	0.02	15.91	15.94	0.04
	Vietnam	8.32	8.39	0.07	64.60	64.78	0.18
	Rest of ASEAN	7.72	7.72	0.00	55.50	55.51	0.01

- development of renewable electricity seems to have relatively lower impacts on poverty incidence reductions compared to SIM1
- poverty incidence difference between SIM1 and other simulations are relatively higher in rural households compared to urban households

Results

Microeconomics Impacts

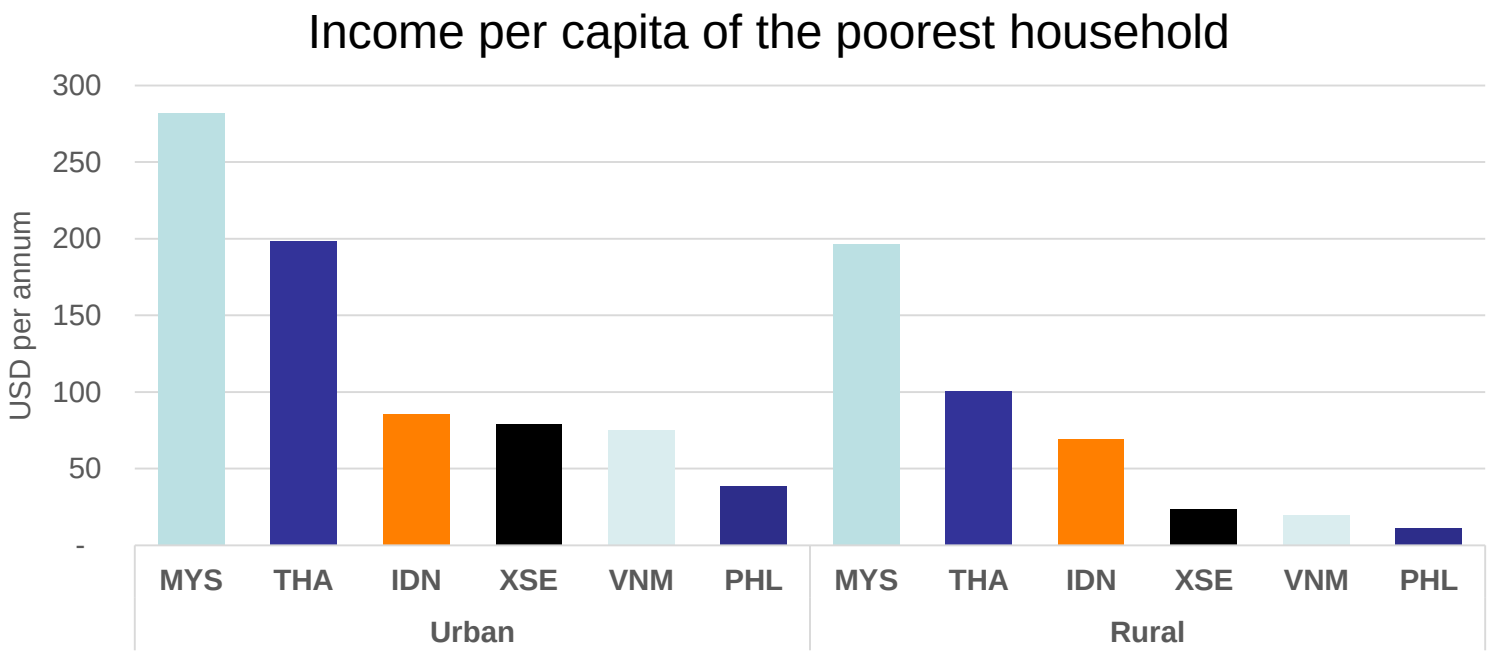
Three factors determines poverty incidence reduction across simulations:

- the initial level of income per capita;
- the pattern of income distribution; and
- income flow in an economy.

Results

Microeconomics Impacts

The initial level of income per capita



- Rural income per capita usually lower than urban income per capita.
- Indonesia has a relatively higher income per capita for the poorest household compared to Vietnam and the Philippines.
- **Any small increase in income per capita, hence, will have more effects on Vietnam and the Philippines, in particular in the rural areas.**

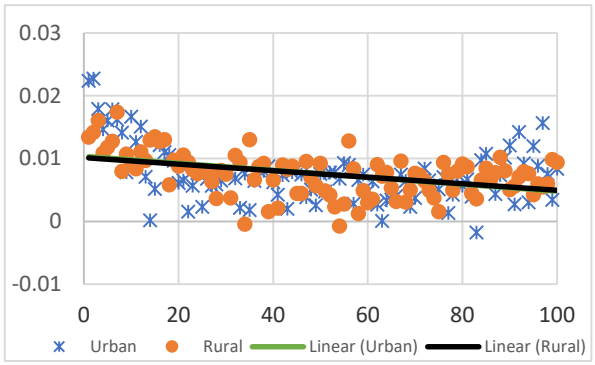
Results

Microeconomics Impacts

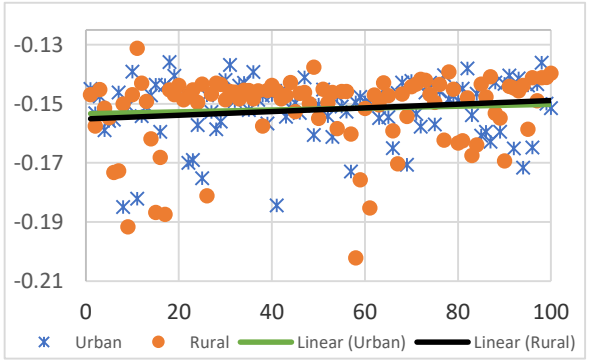
The pattern of income distribution

Income Distribution Difference of SIM2 to SIM1 (percentage changes)

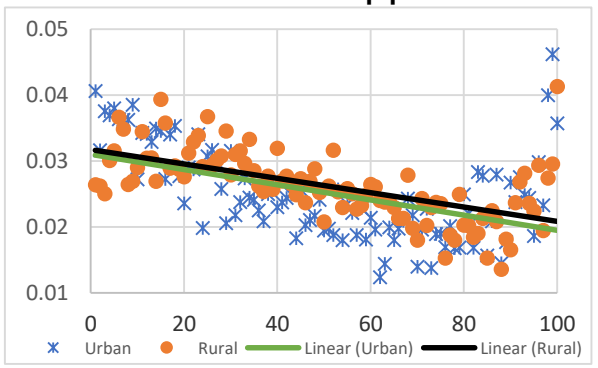
Indonesia



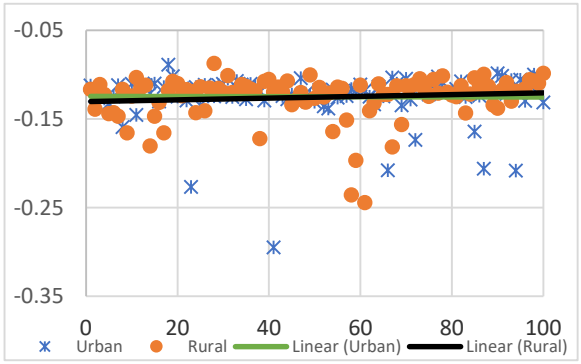
Malaysia



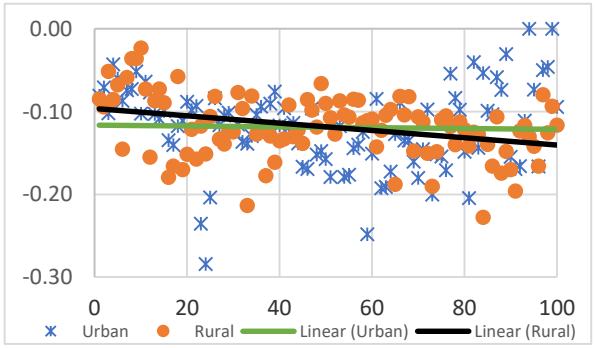
The Philippines



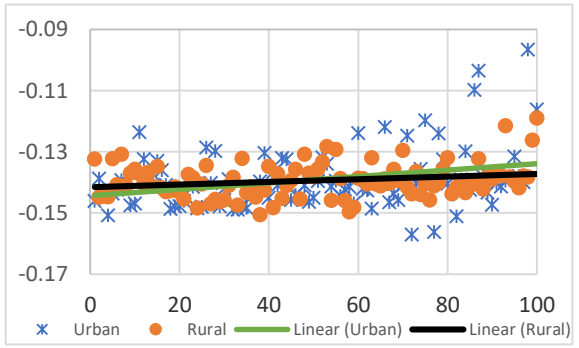
Thailand



Vietnam



Rest of ASEAN



Results

Microeconomics Impacts

Flow of income

Indonesia

- Increasing renewable electricity leads to an increase in the primary and tertiary sectors'output.
  - In the primary sectors, the incomes are distributed mostly to unskilled labour.
  - In the services sectors such as communication and dwellings are most likely are the source of incomes for skilled labours who usually belong to the rich group households.
- Nonetheless, the magnitude of the income distribution difference compared to SIM1 in Indonesia are relatively small. As a result, households in Indonesia have relatively unchanged poverty incidences across simulations.

Vietnam

- Increasing renewable electricity output leads to the decreased income of skilled and unskilled labour for almost all simulations.
  - the urban and rural households in Vietnam obtain their incomes most likely from skilled and unskilled labours by more than 62 per cent.
- The negative sectoral impacts are outweighed the regressive pattern of income distribution and hence lead to relatively higher poverty incidence for all simulations compared to SIM1.

Results

Environmental Impacts

Changes in Carbon Emissions

	SIM1 (mt CO2)	SIM2 (% change)	SIM3 (% change)	SIM4 (% change)
Indonesia	259.37	-0.21	-0.23	-0.25
Malaysia	94.77	-0.42	-0.33	-0.42
Philippines	35.14	-0.50	-0.47	-0.50
Singapore	23.81	-0.17	-0.17	-0.11
Thailand	149.27	-0.54	-0.55	-0.55
Vietnam	77.44	-1.31	-1.01	-1.66
Rest of ASEAN	13.78	-0.32	-0.15	-0.22

- SIM2, SIM3, and SIM4 results indicate that renewable electricity development does lead to lower carbon emissions.
- Energy mix in the electricity sector and carbon emissions during electricity generation could be one possible explanation of different macroeconomics and environmental impacts on each ASEAN country.

Environmental Impacts

Carbon Emissions of the electricity sector

	IDN	MYS	PHL	SGP	THA	VNM	XSE
Total Carbon Emissions (in million tonne CO_2)							
	124.64	42.73	16.53	3.47	50.02	35.47	4.76
Carbon Emissions Contribution (in %)							
Coal	69.66	14.99	49.63	0.00	33.70	55.51	14.06
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	0.78	0.01	0.02	0.00	0.01	0.07	54.44
Petroleum coal products	15.14	11.53	8.65	99.72	2.31	1.38	6.12
Gas manufacture distribution	14.42	73.47	41.70	0.28	63.98	43.05	25.39
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

- Energy mix in producing electricity is important.
- A country has more diversified electricity sources, such as Vietnam and the Philippines, can reduce carbon emissions more than a country that has a heavy reliance on fossil fuel electricity such as Indonesia.

Conclusions

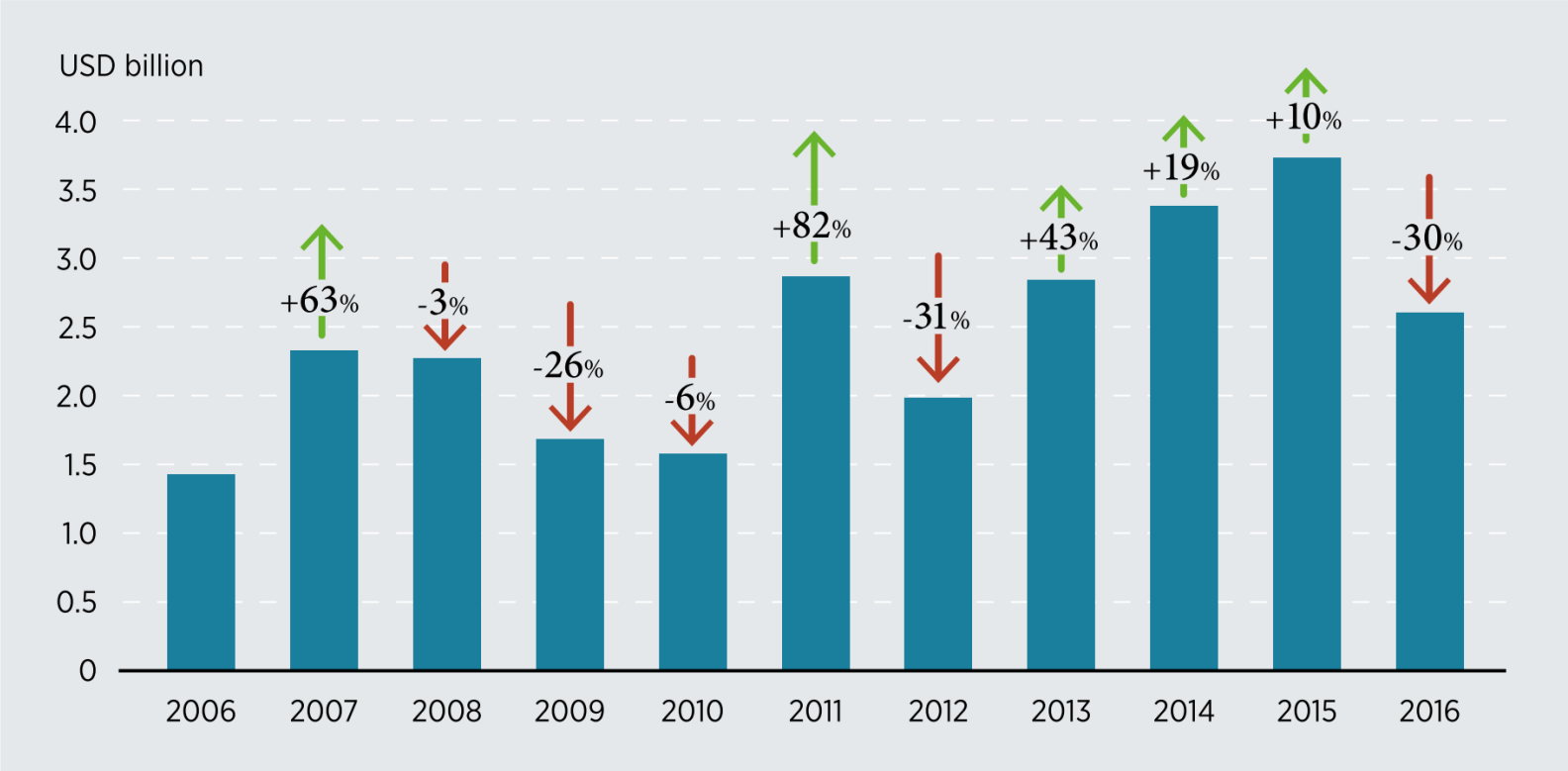
- Renewable electricity development could be a way to induce higher GDP while keeping carbon emissions relatively low.
  - Renewable electricity development allows a disperse spillover of the shock into non-energy sectors such as primary sector, such as farming and fishing and tertiary sectors, such as financial services and dwelling.
- Nonetheless, this paper finds that renewable electricity development leads to lower rate of poverty incidence reduction compared to that of fossil fuel electricity.
  - This paper argues that the initial level of income per capita, income distribution pattern, and income flow in an economy matter in determining the reduction of poverty.
  - If a country has a high income per capita, it is expected to have a lower poverty reduction, vice versa.
  - Also, this paper finds that the main contributor of poverty reduction is non-energy sectoral outputs' changes that contribute more on the poverty reduction than energy sectoral outputs changes since it allows more income being distributed across the economy

Thank you

Appendix

Introduction

Investment in renewable energy in ASEAN



Source: BNEF, 2017.
Note: Based on power sector asset finance data for Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam.

To achieve 23% of renewable energy share in 2030, ASEAN need 290billion USD, around 27 billion annually.

Methodology

Microsimulations

Computing poverty incidence (Yusuf and Resosudarmo 2015)

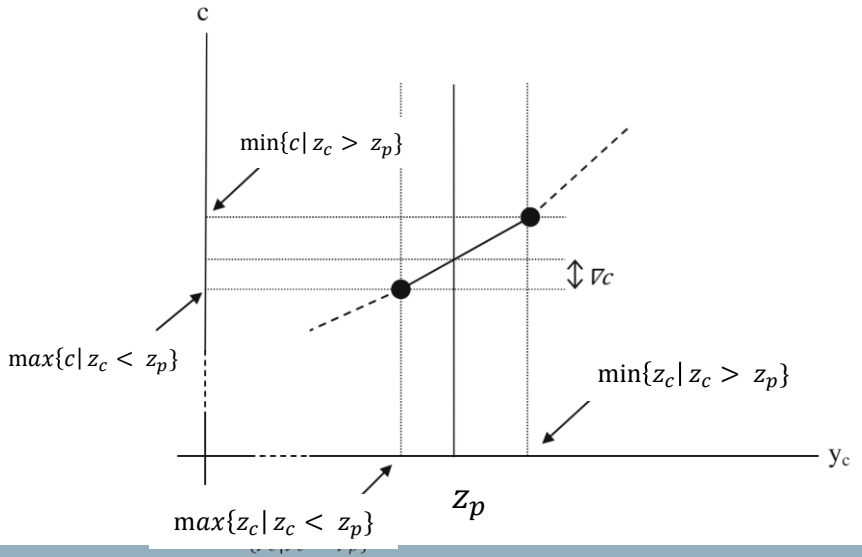
Let z_c is the real income per capita of household percentile c and z_p is poverty line which lies between two levels of real income per capita. Thus, the poverty rate is:

$$p(z_c, z_p) = \max\{c|\, z_c < z_p\} + \nabla c$$

$$\nabla c = \frac{z_p - \max\{z_c|z_c < z_p\}}{\min\{z_c|z_c > z_p\} - \max\{z_c|z_c < z_p\}} . \min\{c|\, z_c > z_p\} - \max\{c|\, z_c < z_p\}$$

Change in the poverty rate is

$$\Delta p = p(z'_c, z'_p) - p(z_c, z_p)$$



Data

Structure of East Asia IRSAM

- There are 12 regions
  - Seven ASEAN member countries (Indonesia, Malaysia, Thailand, Singapore, Viet Nam, the Philippines and other ASEAN) plus Australia, China, Japan, South Korea, and India
- 29 production activities → 4 different types of electricity sources+ 5 energy related sectors
- five value added (land, unskilled labour, skilled labour, capital, and natural resource),
- two types of tax (indirect tax and import tax), two household accounts (rural household and urban household),
- a firm, a government accounts, and a savings-investment account

Data

Selected Socio-economic Indicators of East Asia Countries in IRSAM

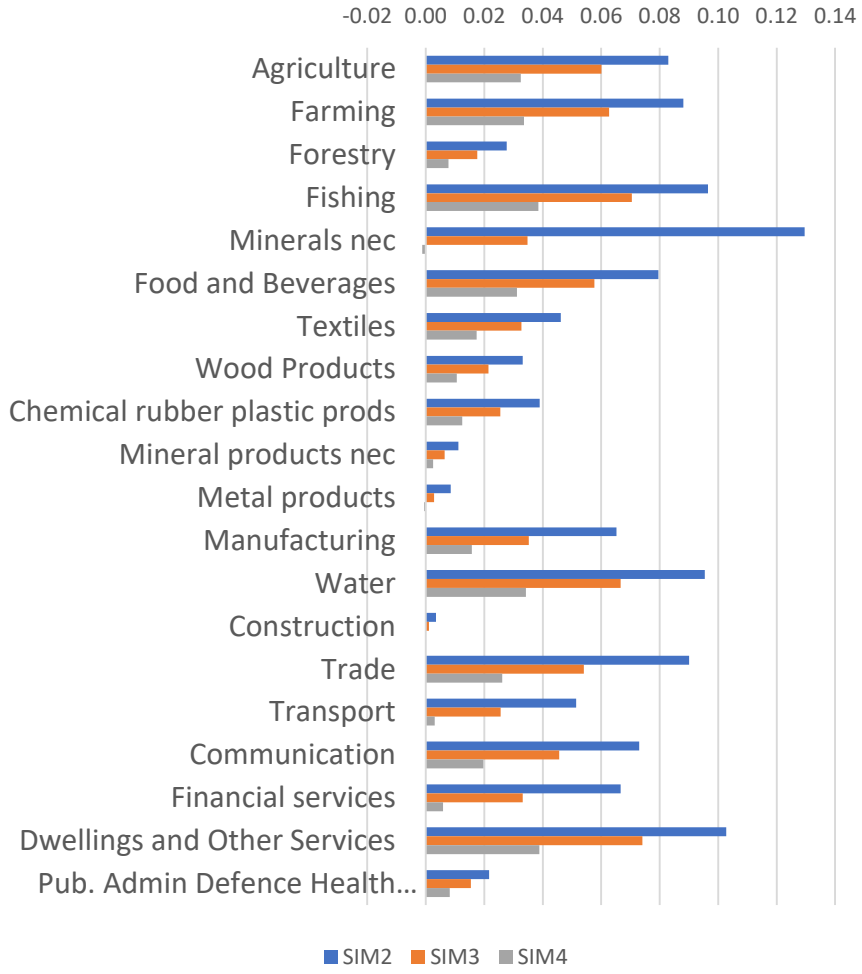
	IDN	MYS	PHL	SGP	THA	VNM	XSE
GDP (in million USD)	807,817	276,128	214,283	253,874	310,442	111,994	87,306
CO2 Emissions (in million tonnes)	259	95	35	24	149	77	14
Energy Sectors (in million USD)							
Electricity	16,631	10,190	7,435	8,002	12,834	16,933	1,896
- Wind	0	0	9	0	0	19	0
- Hydro	98	77	976	0	86	5,350	584
- Solar	0	0	0	3	3	0	0
- Others	16,534	10,113	6,450	7,999	12,745	11,564	1,312
Coal	33,580	160	401	0	717	3,995	25
Oil	33,680	17,625	591	117	7,314	11,054	5,875
Gas	15,927	8,580	4	0	2,970	96	6,152
PCP	54,084	35,568	14,440	73,102	70,207	8,399	1,732
GMD	7,377	5,393	857	12	8,298	2,190	905
Production Factor (in million USD)							
Unskilled Labour	262,496	62,916	39,962	25,684	69,465	34,774	22,597
Skilled Labour	79,387	56,173	42,103	87,989	46,382	16,256	8,706
Non-Labour	465,919	157,040	132,219	140,201	194,592	60,964	56,003
Poverty Incidence (using the World Bank poverty line)							
Urban	9.77	2.33	11.73		5.46	8.39	7.73
Rural	12.91	4.23	41.15		15.97	64.78	55.55
Urban and Rural	13.03	2.40	25.99		9.38	35.05	20.78

Notes: IDN: Indonesia; MYS: Malaysia; PHL: Philippines; SGP: Singapore; THA: Thailand; VNM: Vietnam; XSE: Rest of ASEAN (Brunei, Lao, Myanmar, Cambodia); PCP :Petroleum coal products; GMD: Gas manufacture distribution

Results

Flow of income

Indonesia

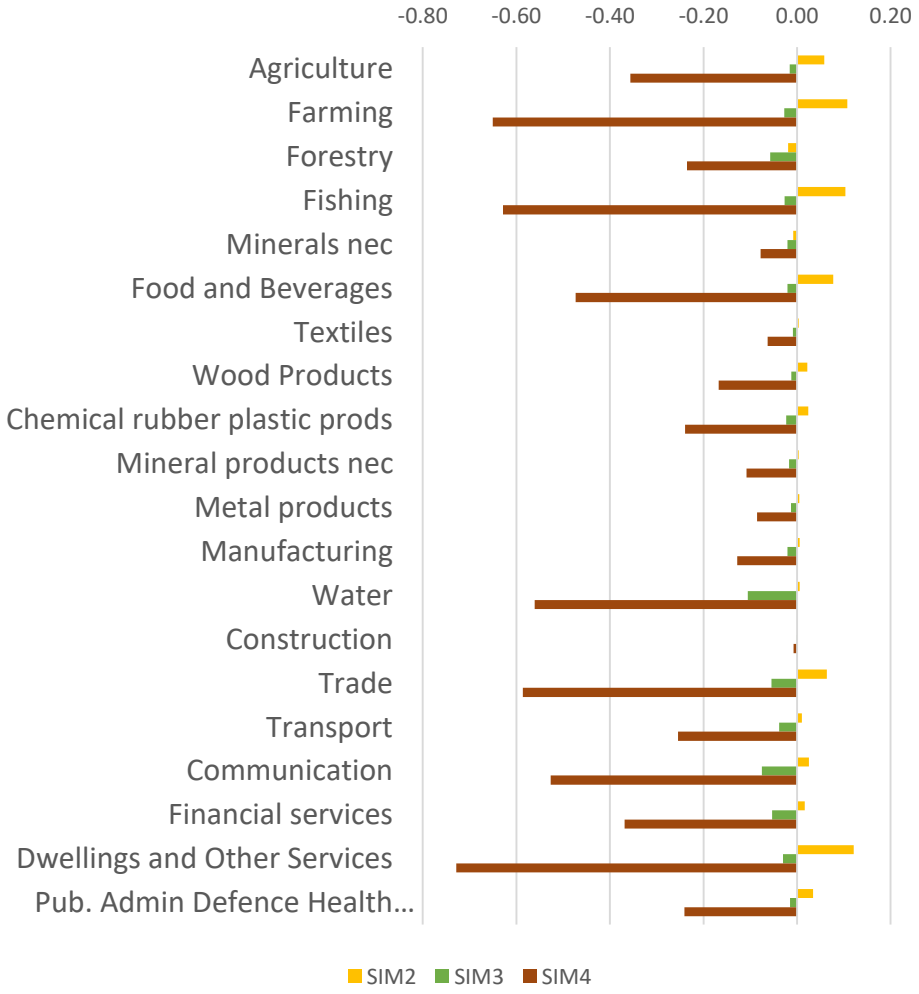


- Increasing renewable electricity leads to an increase in the primary and tertiary sectors'output.
- In the primary sectors, the incomes are distributed mostly to unskilled labour.
- In the services sectors such as communication and dwellings are most likely are the source of incomes for skilled labours who usually belong to the rich group households.
- Nonetheless, the magnitude of the income distribution difference compared to SIM1 in Indonesia are relatively small.
- As a result, households in Indonesia have relatively unchanged poverty incidences across simulations.

Results

Flow of income

Vietnam

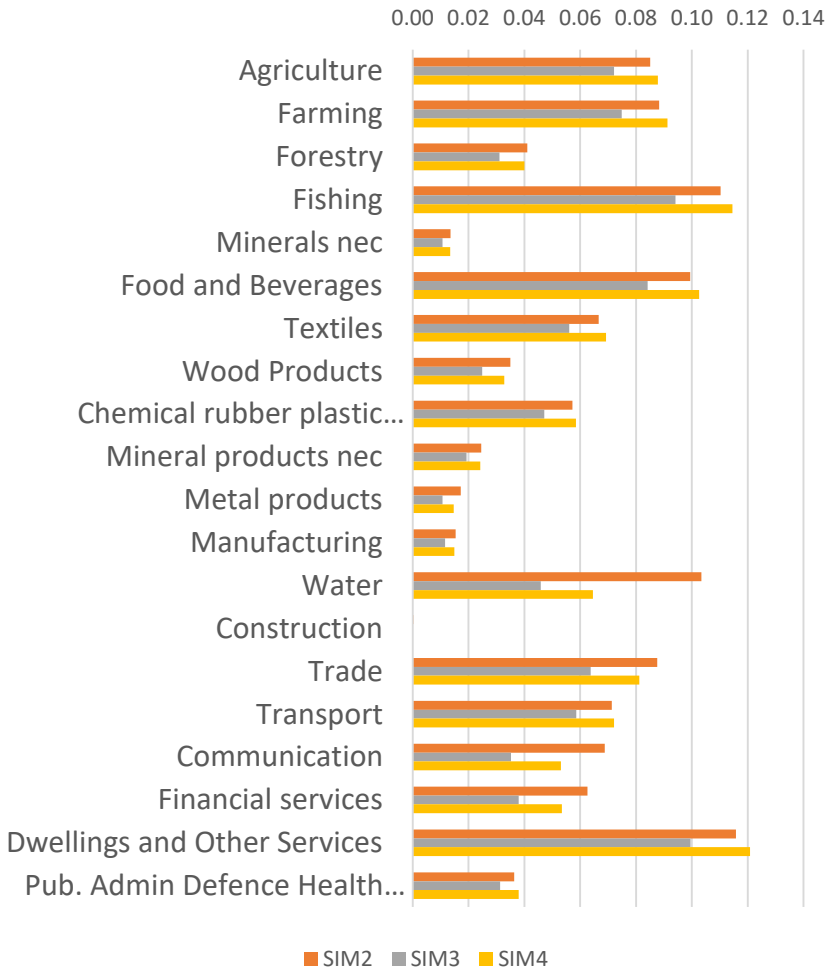


- SIM2 : a relatively small increase in the primary sectors
- SIM3 and SIM4 : reduces the sectoral outputs significantly
- Rich households receive less income → skilled labour income comes from the financial services sector by more than 15.56%.
- Increasing renewable electricity output leads to the decreased income of skilled and unskilled labour for almost all simulations.
- the urban and rural households in Vietnam obtain their incomes most likely from skilled and unskilled labours by more than 62 per cent

Results

Flow of income

The Philippines



- An increase in the renewable electricity output most likely beneficial for all sectors, in particular fishing and dwelling sectors.
- Most of the income in these two sectors are distributed to capital through natural resource and capital ownerships.
- Even with a progressive income distribution pattern and positive difference in income distribution changes compared to SIM1, the poverty incidence is barely changed in the Philippines.