Impact of Cross Border Energy Infrastructure Investment on Regional Environment, Society and Climate Change

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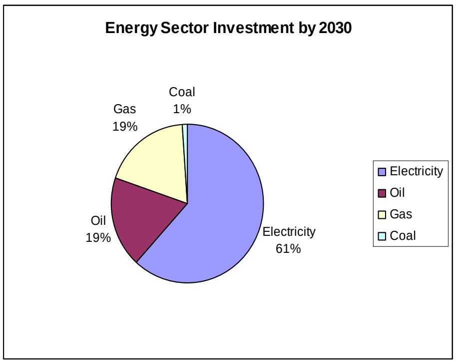
Energy sector investment scenario

- Cumulative total global investment in the energy sector to meet the energy demand by 2030 is around **USD 16 trillion** between 2003 and 2030, out of which around **USD 4 to 5 trillion are required by Asian developing countries** to fuel their economic growth.



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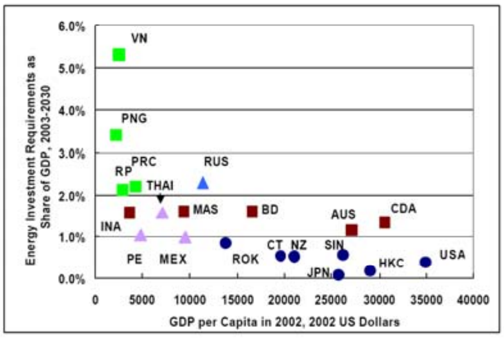
Paradox of energy sector investment

- Lower the economic development and per capita GDP higher the need for energy sector investment.
- Viet Nam（VN in the figure）needs around 5.2% of its GDP to meet the energy sector investment while the United States (USA in the figure) needs only 0.3% of its GDP.



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Importance of cross border energy projects

- *Synchronizing the locational difference between energy demand points and primary energy supply points*.
- *Energy security improvement through energy trade*.
- *Substantial financial benefits for less developed exporting countries*.
- *Significant relief for the energy deficit for importing countries*.
- *Environmental and social co-benefits*.

Potential of cross border energy projects in Asia – Sub regional level

Classification of sub-regions in terms of cross border energy project development potential in Asia:

- South Asia (SA)— comprising Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka;
- East Asia (EA)— com prising China, Japan, Republic of Korea and 10 ASEAN countries; and
- West and Central Asia (WCA)— comprising Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, Kyrgyz Republic,

Availability of energy in South Asia sub-region

Country	Oil Reserve (Mt)	Oil Production (Mt/y)	Gas Reserve (bcm)	Gas production (bcm/y)	Coal Reserve (Gt)	Coal Production (Mt/y)	HP Potential (MW)	HP Develop ment (MW)
Afghanistan	1010-15/100	0.025	28.3/142	0.114	0.1	0.044	745	262
Bangladesh	7.8	0.34	580/810	13.8	2.2	n/a	755	230
Bhutan	0	0	0	0	0	0	23,760/ 30,000	468
India	786	33	948	32.7	25/285	409	840,00/ 150,000	32,300
Nepal	0	0	0	0	0	0	43,000/ 83,000	600
Pakistan	105	3.1	1300/5700	28	185	3,300	54,000	6500
Sri Lanka	14-18	0	0	0	0	0	9100	1250

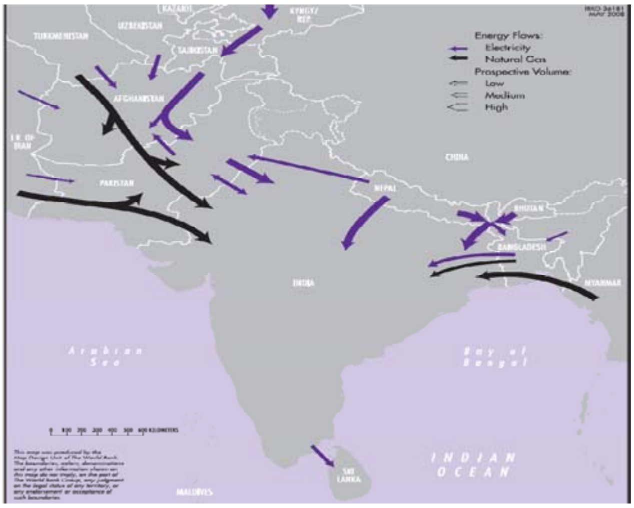
Source: World Bank, South Asia Region, 2007 (figures before and after / mean: Proven and Probable reserves respectively)

Investment potential of cross border energy projects in South Asia sub-region

Name of the project	Total Investment (Mill. USD)
Bhutan -India hydro power plant (HPP) Projects;	**3,744.14**
Nepal - India HPP Projects;	**4,248.0**
Myanmar-India HPP Projects:	**5,175.0**
Bangladesh - India (TATA Group Proposal) Power Project	**1,025.0**
India- Sri Lanka Grid Interconnection:	**133**
Bangladesh-Bhutan-Nepal-India Multilateral Power Line Interconnection	**9**
North East Power System (NEP), Afghanistan	**270**
Total of 7 projects **(Installed capacity: 11934 MW Power transmission: 58.2 TWh)**	**14603.5**

Source: World Bank, South Asia Region, 2007 (total power transmission has been estimated by the authors using the PLF of 40% for the hydro projects, 80% for the combined cycle gas turbine and thermal power projects and 90% for the pure grid interconnection projects) . Costs have been estimated based on the data provide in the Energy Investment Outlook 2003, IEA.

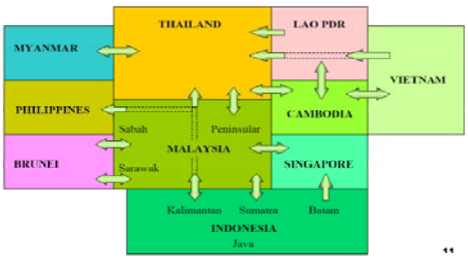
Schematic view of the cross border energy projects in SA sub-region

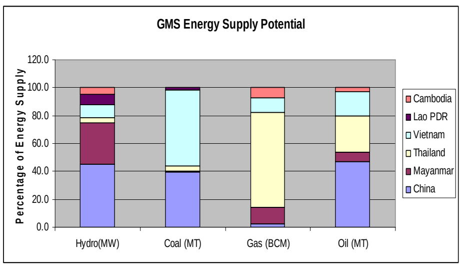


Map is not to Scale :
Used only for visual understanding

Availability of energy in East Asia sub-region

- ASEAN has the total energy generation potential as follows:
  - 22 billion barrels of oil,
  - 227 tcf of natural gas,
  - 46 billion tons of coal,
  - 234 GWh of hydro power
  - 20 GWh of geothermal
- GMS is endowed with
  - 330,000 MW of hydro power,
  - 59,340 million tons of coal,
  - 1,378 billion m3 of natural gas
  - 478 million tons of oil





Investment potential of cross border energy projects in East Asia sub-region…contd.

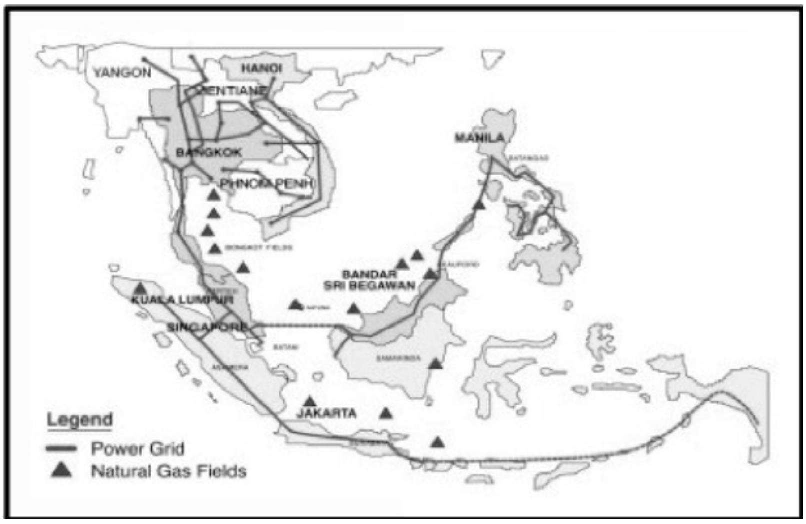
Name of the project	Project Description	Expected Total Investment (Million USD)*
Thailand - Cambodia PTL Projects;	Total Capacity 300 MW, Type: HVAC EE Maximum power transmission: 2.3 TWh/y Year: 2007	7.0
Peninsular Malaysia- Sumatra, Indonesia PTL Projects;	Total capacity 600 MW; Type: HVDC EE Maximum power transmission: 4.6 TWh/year Year : 2012	143.0
Batam (Indonesia) – Singapore PTL Project	Total capacity:200 MW; Type: HVDC EE Maximum power transmission: 1.5 TWh/year Year : 2015	177.0
Malaysia - Brunei PTL Project	Total capacity:300 MW; Type: HVDC EE Maximum power transmission: 2.3 TWh/year Year : 2015	18.4
Malaysia - West Kalimantan PTL	Total capacity:300 MW; Type: HVDC EE Maximum power transmission: 2.3 TWh/year Year : 2012	18.4

Investment potential of cross border energy projects in East Asia sub-region

Name of the project	Project Description	Expected Total Investment (Million USD)*
Thailand – Lao PRD PTL Project	Total capacity:2000 MW; - Roi Et- Nam Theun by 2009 - Udon- Nabong by 2010 - Mae Mo- Hong Sa by 2013 Maximum power transmission: 15.6 TWh/year	124.8
Thailand – Myanmar PTL Project	Total capacity: 1500 MW; Type: HVDC EE Maximum power transmission: 11.4 TWh/year Year : 2014	91.2
Lao PDR – Viet Nam PTL Project	Total capacity: 1887 MW; Type: HVDC EE Maximum power transmission: 14.7 TWh/year Year : 2010	117.6
Viet Nam- Cambodia PTL Project	Total capacity: 120 MW; Maximum power transmission: 0.9 TWh/year Year : 2008	7.2
Total of 9 projects in SA	**Transmission capacity: 7200 MW;** **Power transmission: 55 TWh/year**	**697.6**

Source: ASEAN Centre for Energy, 2008 (Maximum power transmission has been estimated by the authors considering 90% of the transmission capacity utilisation).

Schematic view of the cross border energy projects in EA sub-region



Availability of energy in West & Central Asia sub-region

Country	Oil Reserves (Billion bbl)	Oil Production (Million bbl/d)	Gas Reserves (tcf)	Gas production (tcf/y)	Coal Reserves (Billion ton)	Coal Production (Mt/y)	HP Potential (MW)	HP Developme nt (MW)
Kazakhstan	29	1.3	70	0.57	37.5	95	20,000	2,000
Turkmenistan	0.54	0.26	71	2.1	N/A	N/A	N/A	N/A
Uzbekistan	0.59	0.15	66.2	2.07	4	2.8	N/A	1700
Tajikistan	N/A	N/A	N/A	N/A	3.6	0.03	40,000	4,000
Kyrgyz Republic	N/A	N/A	N/A	N/A	0.8	0.4	26,000	3,000
Iran	132.5	4.2	971	3.5	0.46	1.1	42,000	2,000
Total	***162.63***	***5.9***	***1178.2***	***8.24***	***46.36***	***99.3***	***128,000***	***12,700***

Source: World Bank, South Asia Region, 2007

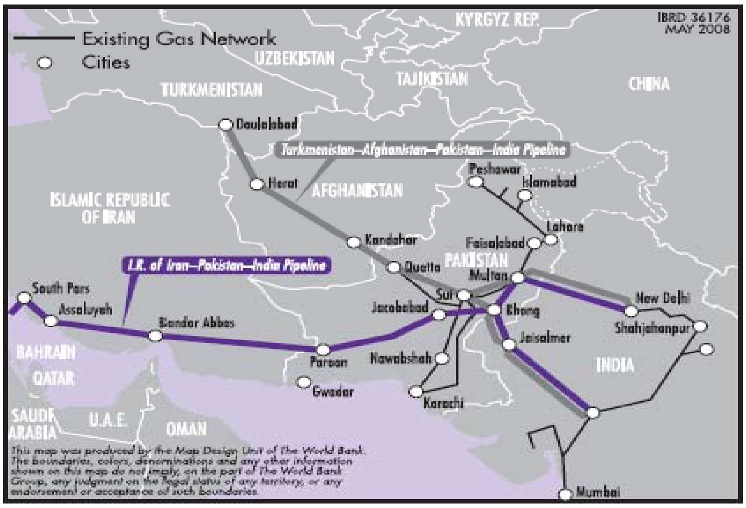
Investment potential of cross border energy projects in West & Central Asia sub-region

Name of the project	Project Description	Expected Investment (Million USD)	Total
North-South Kazakhstan PTL	Total capacity: 600 MW; 500kv, 1115 Km Maximum power transmission: 4.6 TWh/year	375.34	
Kyrgyz, Datka - Tajikistan, Khodjent PTL	Total capacity: N.A 500kv, 350 Km Maximum power transmission: N/A	117.8	
Kambarata II HPP, Kyrgyz + PTL	Total capacity: 360 MW; 500kv, Maximum power transmission: 1.1 TWh/year	288.8	
Kambarata I HPP, Kyrgyz + PTL	Total capacity: 1900 MW; 500kv, Maximum power transmission: 5.1 TWh/year	1980.8	
Nurek HPP, Tajikistan	Total capacity: 500 MW; 500kv, Maximum power transmission: 0.3 TWh/year	402.4	
Sangtuda I HPP, Tajikistan	Total capacity: 570 MW; 500kv, Maximum power transmission: 2.7 TWh/year	721.6	
Sangtuda II HPP, Tajikistan	Total capacity: 220 MW; Maximum power transmission: 0.9 TWh/year	207.2	

Investment potential of cross border energy projects in West & Central Asia sub-region

Name of the project	Project Description	Expected Investment (Million USD)	Total
Rogun Storage HPP, Tajikistan	Total capacity: 3600 MW; Maximum power transmission: 13 TWh/year	2554.0	
Tajikistan North South Power Transmission Line	Total capacity: 800 MW; 500 kv , 350 Km Maximum power transmission: 6.2 TWh/year	117.8	
Syrdarya TPP - Sogdiana Sub St, Uzbekistan	Total capacity: N/A; 500 kv , 200 Km Maximum power transmission: N/A	67.3	
Sogdiana SS - Talimardjan TPP	Total capacity: N/A; 500 kv , 217 Km Maximum power transmission: N/A	73.05	
Surhan SS - Guzar SS, Uzbekistan	Total capacity: N/A; 500 kv , 190 Km Maximum power transmission: N/A	63.9	
Yavan HPP, Tajikistan	Total capacity: 150 MW; Maximum power transmission: 0.5 TWh	264.5	
Fon Yagnob TPP, Tajikistan	Total capacity: 1000 MW Maximum power transmission: 6 TWh	1648	
Total of 14 projects within WCA	**Installed capacity: 9700 MW; Power transmission: 40.4 TWh/year**	**8882.6**	

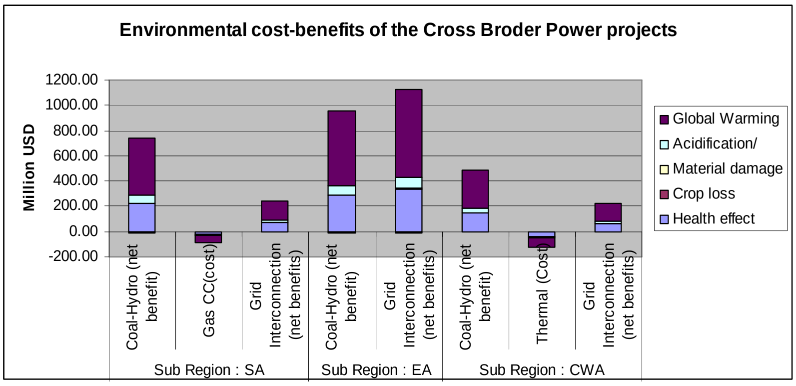
Schematic view of the cross border energy projects in West & Central Asia sub-region



Future potential cross border power projects in Asia

Sub Region	Total Installed Capacity (MW)	Maximum Power Transmission (Twh/y)
South Asia (SA)	***11,934*** - Hydro: 8934 (75) - NG: 1500 (12.5) - Grid Interconnection: 1500 (12.5)	***58.2*** *- Hydro: 36.4* *- NG: 10* *- Grid interconnection:11.8*
East Asia (EA)	***20,825*** - Hydro: 13,625 (65) - Grid Interconnection: 7200 (35)	***102*** *- Hydro: 47* *- Grid Interconnection:55*
West and Central Asia (WCA)	***9,700*** - Hydro: 7,300 (75) - NG/Thermal: 1000 (10) - Grid Interconnection: 1400 (15)	***40.4*** *-Hydro:23.6* *-Thermal:6* *-Grid interconnection:10.8*
Total	***42,459*** - Hydro: 29,859 (70) - NG/Thermal: 2,500 (6) - Grid Interconnection: 10,100 (24)	***200.6*** *-Hydro:107* *-NG/Thermal:16* *- Grid interconnection:77.6*

Environmental costs & benefits of cross border power projects in Asia



Source: Voss (2000),
a) Valuation based on marginal abatement costs required to achieve the EU "50% – Gap Closure" target to reduce acidification in Europe. b) Valuation based on marginal CO2-abatement costs required to reduce CO2 emissions in Germany by 25% in 2010 (19 Euro/t-CO2).
* All Euro figures are converted to US Dollar by using year 2000 Euro-Dollar average exchange rate of 1 Euro=1 Dollar
** Estimated costs and benefits were further discounted by 20% to reflect the lower damage costs of human health, materials and environment in Asia compared to Europe.

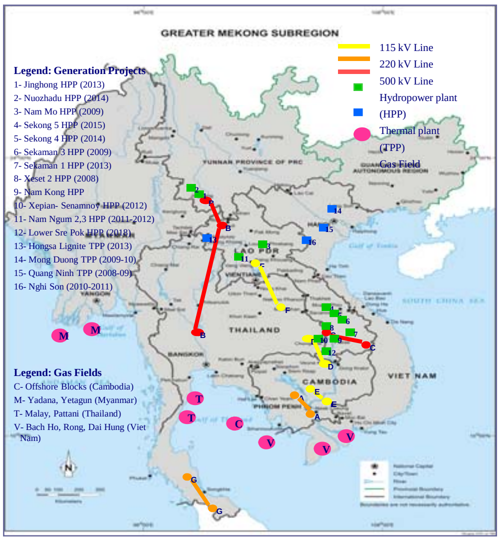
Net benefits of cross border power projects in Asia (Annual estimate)

Sub Regions	Net-Benefit (Million USD)
South Asia (SA)	880.3
East Asia (EA)	2055.4
West and Central Asia (CWA)	568.8
Total	3504.6

This benefit cost estimation doesn't include the social costs of human habitat displacement due to large hydro power projects and the costs of loss of ecology if any due to the dam construction.

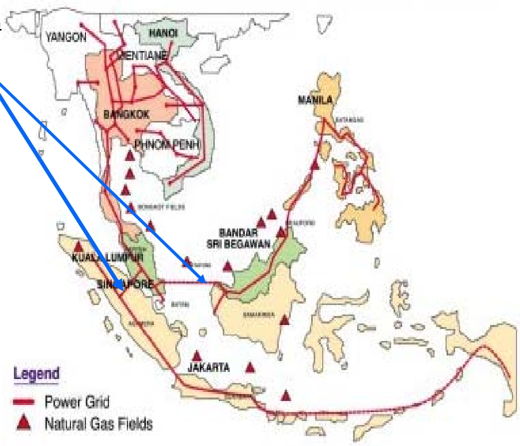
Case study cross border power projects in Asia

- **China – Thailand Power Trading: Jinghong and Nuozhadu HPP Project**
  - Jinghong has 1500 MW installed capacity and with 5 terawatt hours of electricity supply capacity
  - Nuozhadu site will have installed capacity of 5500 MW with active storage of 12,300 mill m³ of water and with around 19 terawatt hours of supply capacity.
  - These are the largest projects in the Lancang-Mekong river basin



Case study cross border power projects in Asia

- **Peninsular Malaysia- Sumatra, Indonesia 600 MW PTL and Malaysia - West Kalimantan 300 MW PTL,**
  - Total investment costs for the two projects: 173 Million USD
  - Total avoided generation costs for the two projects : 500 Million USD
  - Gross cumulative cost savings for the two countries including resource costs, daily O&M costs, financing costs etc are 2 Billion USD by 2020



Methodology : Model Specification

Model used :

Regional Environmental Policy Assessment model (Kojima,2008)

Model feature:

1. Its a multiregional computable general equilibrium (CGE) model developed based on the GTAP-E model with the employed dataset of 12-region and 33- economic sector aggregation of the original GTAP Data Base
2. It incorporates dynamics towards 2020 by solving for a series of static equilibrium connected by exogenous evolution of macroeconomic drivers compared to the GTAP static model.
3. It is able to assess environmental impacts of policy shocks in terms of changes in emissions of CO_2, SOx, etc.
4. It has ability to assess poverty impacts of policy shocks in terms of estimating the change in poverty head count

Methodology : Simulation Setting

We assume that the cross border electricity infrastructure projects will substitute a part of electricity sector development in both the two countries. Based on this assumption simulation tries to capture the following anticipated costs and benefits of public investment in energy infrastructure including cross border electricity infrastructure projects:

- Benefits from increased electricity supply due to public investment
- Economic costs of public investment through earmarked private consumption tax
- Saved public investment in electricity importing countries
- Increased revenue from electricity export

Methodology: Shock assumptions

1. Half of the public investment directly contributes to capital accumulation of the electricity sector and the remaining portion is spent on government purchase of the outputs of the other services sector that include public administration etc.
2. CBEI investment costs are equally shared by each county involved in it.
3. Under both scenarios (BAU and CBEI) for each country, total electricity generation requirement by 2020 remains the same.
4. In terms of public investments, it is assumed that there is no relief for exporting countries on future investment requirement by each country to meet the domestic energy demand for the importing countries, it is assumed that there will be an overall decrease of 2.5% of total energy sector investment requirement by 2020 under the baseline scenario

Methodology: Simulation Shocks

Given shocks:

The following four types of exogenous shock were given to the database corresponding to the year 2020:

1. Total baseline public investment by 2020 for electricity sector without CBEI projects
2. Incremental power generation between 2001 and 2020 due to the above baseline investment without CBEI project
3. Total public investment by 2020 for electricity sector with CBEI projects
4. Value of power traded between two countries due to CBEI projects

Simulation Result: Impacts of baseline investment

1. The GDPs of China and Thailand increase by 1.15 percent and 3.45 percent, respectively.
2. Factor payments for both skilled and unskilled labour increase in China (0.4%) and Thailand (1.4%) due to the baseline investment.
3. Factor payment for labour in the electricity sector reduces by 2.8% in China and 17% in Thailand.
4. The baseline investment significantly reduces the CO2 emissions in China and Thailand. This is mainly due to energy substitution between electricity and fossil fuels as a result of a drastic increase in electricity supply.

Shocks for baseline investment simulation

	Public investment	Incremental electricity supply
	(million USD)	(% change)
China	1,102,901	12.0
Thailand	111,791	47.0

5. The baseline investment increases SOx emissions both in China and Thailand by around 6%.
6. The baseline investment results in increasing poverty both in China and Thailand by 1.8% in terms of poverty head count.

Simulation Result: Impacts of China – Thailand Power Trading: Jinghong and Nuozhadu HPP Project investment

Shocks for China-Thailand Power Trading investment simulation (Case-1)

	Public investment	Incremental electricity supply	Incremental electricity exports
	(million USD)	(% change)	(million USD)
China	1,111,086	12.0	1208.99
Thailand	116,878	47.0	-1208.99

Impacts of CBEI project: difference from baseline simulation

	GDP (million USD)	Labour payment (million USD)		SOx (1000 t)	CO_2 (million t-CO_2)	Poverty headcount (thousand)
		Skilled	Unskilled			
China	75.9	3.7	-13.8	0.9	-1.0	10.0
Thailand	45.7	-1.0	-6.1	-0.2	-0.9	0.0

Simulation Result: Impacts of simultaneous baseline investment in four countries

- The baseline investment in Malaysia and Indonesia boosts the GDP in these countries by 0.11 percent and 1.01 percent, respectively.
- The GDP increase due to the baseline investment in Thailand slightly decreases from 3.45 percent in Case 1 to 3.43 percent in Case 2
- The baseline public investment in Indonesia increases the labour payment but that in Malaysia decreases.
- It slightly reduces the increase in labour payment due to the baseline investment in China and Thailand from the Case 1.
- The baseline investment in Indonesia and Malaysia reduces the CO_2 emissions in these countries by 4.58 percent and 2.34 percent, respectively.
- The baseline investment increases the poverty headcounts in Indonesia and Malaysia, in particular in Malaysia by 10.92 percent.

Simulation Result: Impacts of Malaysia- Indonesia PTL investment

Shocks for Malaysia-Indonesia PTL investment simulation

Countries	Public investment (million USD)	Incremental electricity supply (% change)	Incremental electricity exports (million USD)
Indonesia	168,028.8	-14.2	-876.0
Malaysia	77,428.9	12.2	876.0

Impacts of Malaysia-Indonesia PTL investment shocks

	GDP (million USD)	Labour payment (million USD)		SOx (1000 t)	CO_2 (million t-CO_2)	Poverty headcount (thousand)
		Skilled	Unskilled			
China	75.5	3.4	-13.8	0.9	-1.0	10.0
Thailand	46.3	-1.0	-6.1	-0.2	-0.8	0.0
Indonesia	8.9	-0.9	0.1	0.0	-0.4	10.0
Malaysia	-45.8	1.0	6.3	n.a.	0.8	0.0

Conclusions

Baseline energy sector investment

- Increases the national GDP of the invested countries. This result is consistent with our expectation that these investment projects are planned to improve economic performance of these countries.
- CO2 emissions in the invested countries are reduced by the baseline energy sector investments. This is due to energy substitution from fossil fuels to electricity in the production processes that surpasses the increased CO2 emission from power generation.
- It increases the SOx emissions in the invested countries. There seems to be a trade-off between global environmental issue (CO2) and local air pollution (SOx).
- It increases the poverty headcount (population below USD 2 per capita per day). This is due to price escalation mainly caused by uniform private consumption tax financing the energy sector investment.

Conclusions

Cross Border Energy infrastructure investment

- The economic impacts of CBEI projects were positive in China, Thailand and Indonesia but negative in Malaysia. Similarly, the impacts on labour payment are mixed.
- In terms of the environmental impacts, the CBEI projects reduced the CO2 emissions in China, Thailand and Indonesia but increased those in Malaysia. The impacts on SOx emissions are also mixed: positive (increase) in China and Indonesia and negative in Thailand.
- Impacts on poverty head count remains unaffected which means that the CBEI projects are not suitable to reduce number of people living below USD2/day in the region.
- When numbers of CBEI projects get implemented simultaneously in the region, it creates some mixed impacts on the issues like employment generation and GDP growth.

Thank You for your attention!

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