Chapter 12

Geographical Simulation Model for ERIA: Predicting the Long-run Effects of Infrastructure Development Projects in East Asia

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Chapter 12: Geographical Simulation Model for ERIA: Predicting the Long-run Effects of Infrastructure Development Projects in East Asia

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1. INTRODUCTION

The economic integration in East Asia is expected to proceed steadily for the next few decades, although the realization of an East Asian Community (EAC) is still a long way to go. What will happen to East Asia as the economic integration goes deeper and deeper? An implication of spatial economics, or new economic geography (NEG) is that inter- and intraregional income-gap would be wider as various trade costs, including transport costs, tariffs or "service link costs," are lowered.

It is quite important to trace the historical changes in the disparity among regions for the future research on East Asian economic and social issues. In the European Union (EU), various researches on the relationship between economic integration and changes in the geographical structure of regional economy, especially the location of industries and income disparity, have been conducted extensively (Midelfart-Knarvik, Overman and Venables 2001; Midelfart-Knarvik, Overman Redding and Venables 2002).

In contrast, there is little or no comprehensive research on the geographical structure of the East Asian economy as meticulously as that on their EU counterpart. This is partly because there is no integrated geographical data set for East Asia at this point. That is why this study aims to focus on the geographical structure of the regional economy, mainly from the viewpoint of spatial economics, using a Geographical Simulation Model (GSM) developed by the authors.

The analysis using Geographical Simulation Model for the Economic Research Institute for ASEAN and East Asia infrastructure project (IDE/ERIA-GSM) is the first step of

ERIA's research on the relationship between economic integration and regional economy at subnational level. The GSM is designed to predict the effects of the regional economic integration, especially the development of transport infrastructure and reduction in "border costs", and fits very well in the ERIA infrastructure project.

2. OBJECTIVES

The analysis using IDE/ERIA-GSM has two major objectives. The first objective is to know the dynamics of the location of population and industries in East Asia for the long term. Although there are many analyses using macro-economic models to forecast the macro-economic indices in East Asia at the national level, there is no or little analysis using the models to forecast the economic development in East Asia at subnational level. In the era of regional economic integration, the economic analysis at the national level is not enough to provide useful information for regional economic cooperation.

The second objective is to analyze the impacts of specific infrastructure projects on the regional economy at subnational level. It is difficult to prioritize various infrastructure development projects without proper objective evaluation tools. The GSM was developed to provide such an objective evaluation tool for the policy recommendations on infrastructure development.

3. FEATURES OF THE SYSTEM

The IDE/ERIA-GSM covers the following eight countries and regions in the model (Figure 1).

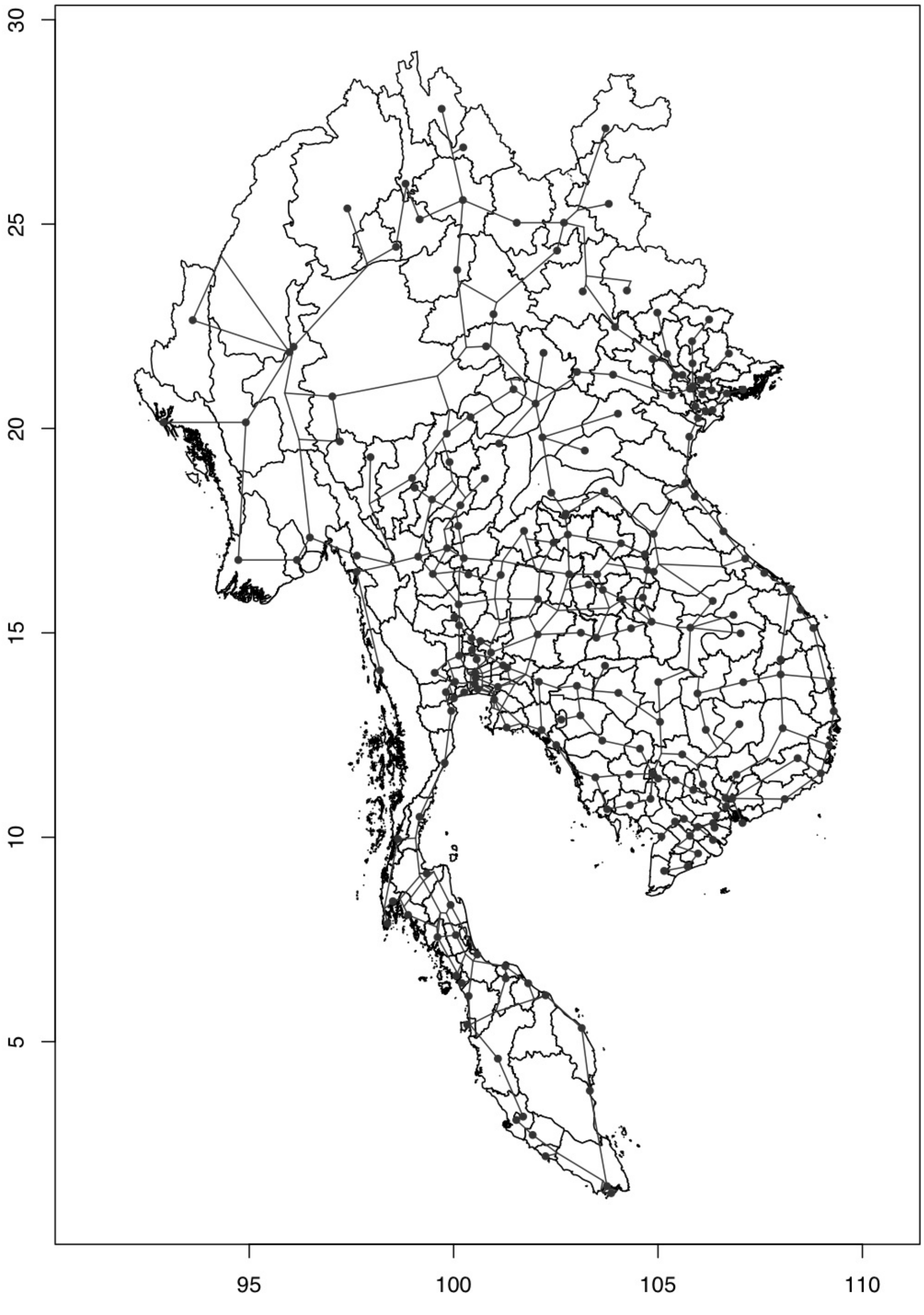
- Singapore
- Malaysia (Peninsular)
- Thailand
- Myanmar
- Cambodia
- Laos
- Vietnam
- Yunnan province of China

Here, these eight countries/regions shall be called the Continental South East Asia (CSEA). Each country/region is subdivided into states/provinces/divisions. Each state/province/division is represented by its capital city, and there are a total of 220 subnational regions. The following data are used on each subnational region:

- GDP by sector (primary, secondary and tertiary industries)
- Employee by sector (primary, secondary and tertiary industries)
- Longitude and latitude
- Area of arable land

About 457 routes between cities are involved, mainly based on the "Asian Highway" database of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) . The actual road distance between cities is used; if road distance is not available, slant distance is employed.

Figure 1: The Map of Continental South East Asia



4. EXPLANATION OF THE MODEL

The IDE/ERIA-GSM is able to forecast the dynamics of population and industries at the subnational level. It works as follows:

1. Load initial data

   The data on regions and routes are loaded from prepared CSV files. The regional data and the routes data between them should be compatible. For instance, all the names of cities on the routes data should appear in the regional data, together with other attributions of the city (region), especially the latitude and longitude.

2. Find short-run equilibrium

   The IDE/ERIA-GSM calculates the short-run equilibrium values of the GDP by sector, the employment by sector, the nominal wage by sector, the price index and so on, based on the distribution of population. The IDE/ERIA-GSM uses the iteration technique to solve the multi-equation model.

3. Population Dynamics

   Once the short-run equilibrium values are found, IDE/ERIA-GSM calculates the dynamics of the population or the movement of labor, based on the differences in the real wages between countries/regions/industries. The IDE/ERIA-GSM is able to set the speed of adjustment differently for inter-country/inter-region/inter-industry labor movement.

4. Output Results

   To examine the related variables in time series, IDE/ERIA-GSM exports the equilibrium values of the GDP by sector, the employment by sector, the nominal wage by sector, the price index, and so on, for every single year in CSV and XML formats. These can be checked using Google™ map or a statistical language.

5. Back to 2.

   Now, back to (2), find the short-run equilibrium, and the time in the simulation moves one year forward. In the analyses in this chapter, the simulation is ran for 20 years.

5. SCENARIOS AND RESULTS

5.1. Scenarios of the simulation

Four scenarios were set to see the effects of East West Economic Corridor (EWEC) but first, the following section explains two of these: the baseline scenario and the fully developed EWEC scenario.

5.1.1. Maintained assumptions

Several macroeconomic and demographic parameters were held constant and only logistic settings by scenario were changed. The following macro parameters are maintained across scenarios:

- GDP per capita of each country is assumed to increase by the average rate for the year 2000-2005, other things being equal[1];
- National population of each country is assumed to increase by the rate forecasted by the United Nations Population Fund (UNFPA) until year 2025;
- There is no immigration between CSEA and the rest of the world.

5.1.2. Base-line scenario

The assumptions in this scenario are as follows:

- The Asian Highway networks all exist and cars can run on it at 40km/h.

[1] The growth rate of GDP per capita in each city is likely to differ from the national average for various reasons, and actually so in the simulation.

- The border costs, or the times required for custom clearance are as follows:

Singapore – Malaysia	2.0 hours
Malaysia – Thailand	8.0 hours
All other national borders	24.0 hours

5.1.3. Fully-developed East West Economic Corridor

The assumptions in this scenario are as follows:

- Cars can run on the EWEC at 80 km/h, and on other Asian Highway at 40km/h;
- There is no border control along EWEC (taking 0.0 hour for crossing national borders).

5.2. Results of the simulation[2]

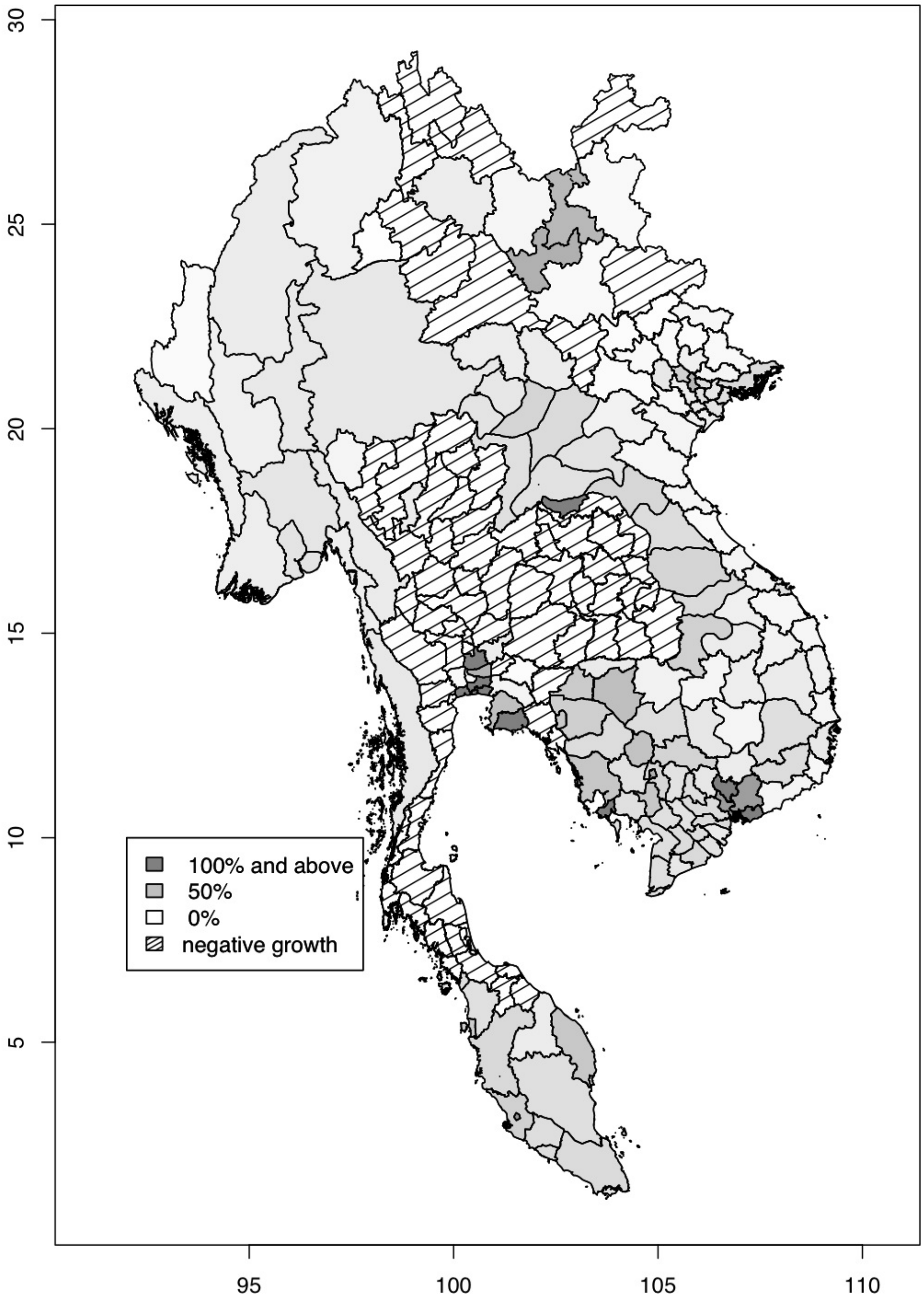
5.2.1. Baseline scenario

Figure 2 shows the population changes from 2005 to 2025 under the baseline scenario. One can see a clear trend in the agglomeration of population. There are a few regions gaining population, such as the regions surrounding Bangkok, those surrounding Ho Chi-Minh, and those surrounding Kunming as well as Vientiane.

On the other hand, some regions are losing their population such as regions in Thailand except those around Bangkok. Thailand seems to be a *monocentric* country in 2025.

[2] GSM is now under development and various parameters shoule be caribrated carefully. So, here we state that the absolute values in the population and GDP forecast are rough calculation, and reliability is rather low. On the other hand, some qualitative results or "tendency" revlead by the simulation are quite robust for the wide range of the parameters, having high reliability.

Figure 2: Population Changes (2005-2025), Baseline Scenario



Source: IDE/ERIA-GSM estimation.

Table 1 shows the population of the top 10 largest regions of CSEA in 2025. Bangkok has the largest population of 13 million[3], followed by Ho Chi-Minh (9.5 million) and Mandalay (8.0 million). Note that this is not the population of each city but that of the region[4].

Table 1: Population of Top 10 Largest Regions (2025)

Rank	Region	Country	Population(thousand) 2005	2025	Change
1	Bangkok Metropolis	Thailand	6,477	13,037	2.01
2	Ho Chi Minh	Vietnam	5,338	9,464	1.77
3	Mandalay	Myanmar	6,821	7,997	1.17
4	Ayeyarwady	Myanmar	7,034	7,981	1.13
5	Kunming Shi	Yunnan	4,933	7,622	1.55
6	Yangon	Myanmar	5,769	6,979	1.21
7	Sagaing	Myanmar	5,694	6,564	1.15
8	Bago	Myanmar	5,290	6,347	1.20
9	Selangor	Malaysia	4,491	6,090	1.36
10	Shan	Myanmar	5,033	5,937	1.18

Source: IDE/ERIA-GSM estimation.

Table 2 shows the GDP of the top 10 largest regions of CSEA in 2025. Bangkok is estimated to have the biggest economy by 2025, surpassing Singapore. The second biggest economy is Singapore, and Rayong of Thailand comes in third.

The baseline simulation shows that principal cities gains more population, i.e., “core-periphery” structure appears in most of the CSEA countries. Among them, the periphery of Thailand and Yunnan province is expected to lose their population, and intra-country/provintial disparity would be a severe problem.

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[3] GSM doesn’t consider the congestion in roads, and the limitation in real-estate for business and housing. These factors might lower the actual population of Bangkok in 2025 than that forecasted.

[4] There are seven regions of Myanmar in the top 20 list. This is partly because the administrative district in Myanmar is larger compared with other Continental South East Asia Region (CSEA) countries. That is why unified territorial units for geographical statistics is indispensable to conduct this kind of international comparison properly.

Table 2: GDP of Top 10 Largest Regions (2025)

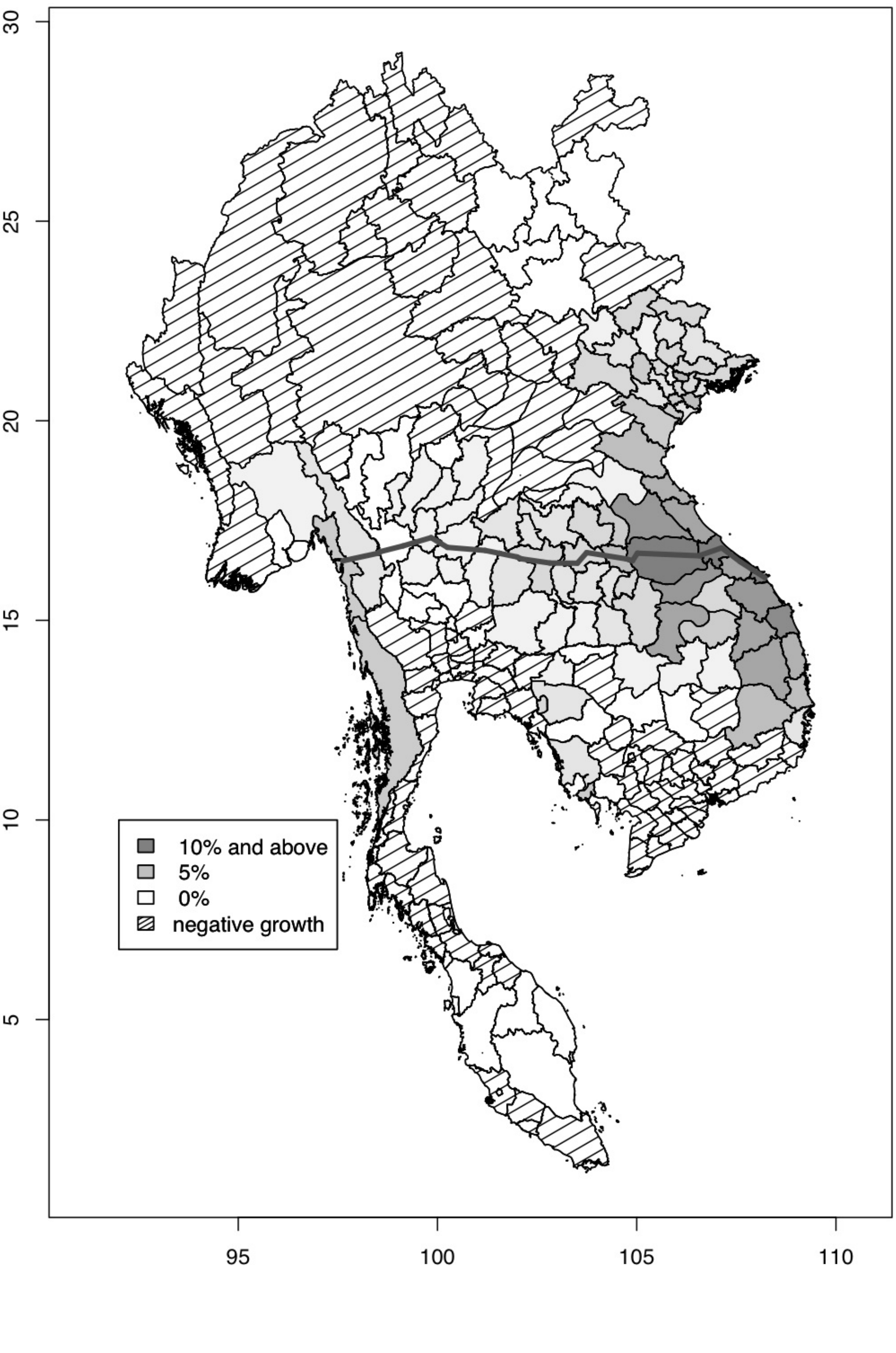
Rank	Region	Country	GDP(million USD) 2005	2025	Change
1	Bangkok Metropolis	Thailand	48,333	287,147	5.94
2	Singapore	Singapore	105,141	180,124	1.71
3	Rayong	Thailand	7,184	55,854	7.77
4	Samut Prakan	Thailand	10,020	54,095	5.40
5	Selangor	Malaysia	20,203	51,238	2.54
6	Kuala Lumpur	Malaysia	11,735	40,396	3.44
7	Kunming Shi	Yunnan	8,865	39,060	4.41
8	Samut Sakhon	Thailand	4,635	36,721	7.92
9	Chon Buri	Thailand	6,837	28,056	4.10
10	Phra Nakhon Si Ayutthaya	Thailand	5,491	27,978	5.10

Source: IDE/ERIA-GSM estimation.

5.2.2. Fully-developed East West Economic Corridor

In this part of the study, one can see the effects of the fully-developed EWEC (both physical infrastructure and custom facilitation at the borders). Figure 3 shows the differences in population at 2025 between this scenario and the baseline scenario, and Table 3 shows the top 10 gainers in population in this scenario against the baseline. The top gainer in population is Savannakhet, gaining 15.8 percent, compared with the baseline. The regions in Laos and Vietnam occupy the rest of the list.

Figure 3: Population Difference (2025). EWEC vs. Baseline



Source: IDE/ERIA-GSM estimation.

Table 3: Top 10 Gainers in Population by EWEC (2025)

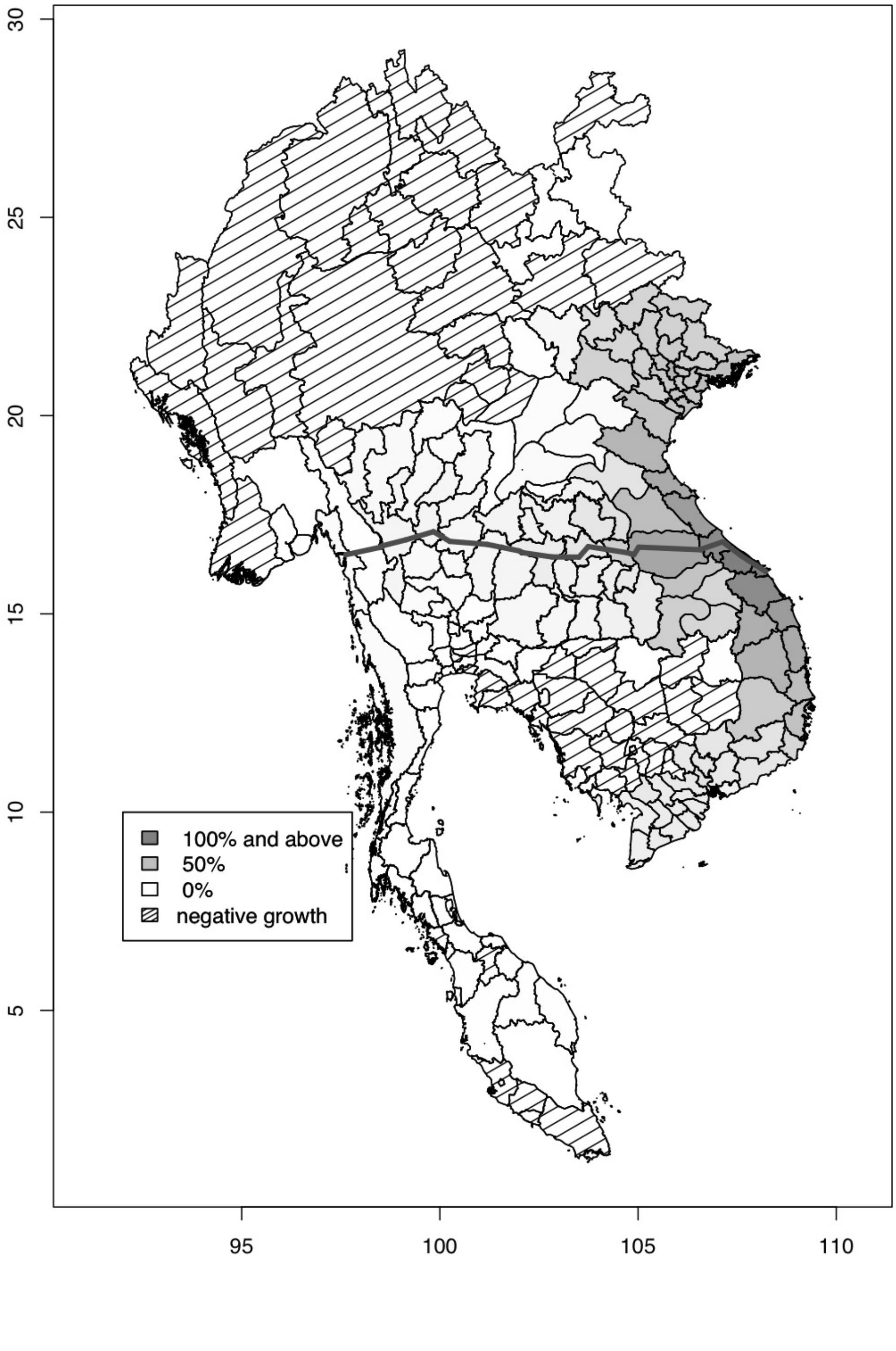
Rank	Region	Country	Population(thousand) baseline	EWEC	Gain
1	Savannakhet	Laos	1,190	1,379	15.8%
2	Da Nang	Vietnam	891	984	10.5%
3	Quang Tri	Vietnam	655	719	9.8%
4	Quang Ngai	Vietnam	1,346	1,464	8.8%
5	Saravan	Laos	448	486	8.5%
6	Khammouan	Laos	462	501	8.4%
7	Quang Nam	Vietnam	1,545	1,663	7.6%
8	Thua Thien-Hue	Vietnam	1,192	1,280	7.4%
9	Quang Binh	Vietnam	871	934	7.3%
10	Gia Lai	Vietnam	1,192	1,277	7.1%

Source: IDE/ERIA-GSM estimation.

Figure 4 shows the differences in GDP by 2025 between this scenario and the baseline scenario, and Table 4 lists the top 10 gainers in GDP for this scenario as against the baseline. The top gainer in GDP is Da Nang, at 135 percent, compared with the baseline, which is surprising[5]. The EWEC almost doubles the GDP of Da Nang.

[5] Note that GDPs are nominal, and equated in US dollars.

Figure 4: GDP Difference (2025). EWEC vs. Baseline



Source: IDE/ERIA-GSM estimation.

Table 4: Top 10 Gainers in GDP by EWEC (2025)

Rank	Region	Country	GDP(mil. USD) baseline	GDP(mil. USD) EWEC	Gain
1	Da Nang	Vietnam	827	1,939	134.5%
2	Thua Thien-Hue	Vietnam	592	1,264	113.5%
3	Quang Nam	Vietnam	752	1,431	90.4%
4	Quang Tri	Vietnam	357	677	89.6%
5	Quang Ngai	Vietnam	713	1,273	78.4%
6	Quang Binh	Vietnam	347	611	76.2%
7	Savannakhet	Laos	2,169	3,694	70.3%
8	Ha Tinh	Vietnam	722	1,204	66.9%
9	Binh Dinh	Vietnam	1,136	1,887	66.2%
10	Kon Tum	Vietnam	247	402	63.0%

Source: IDE/ERIA-GSM estimation.

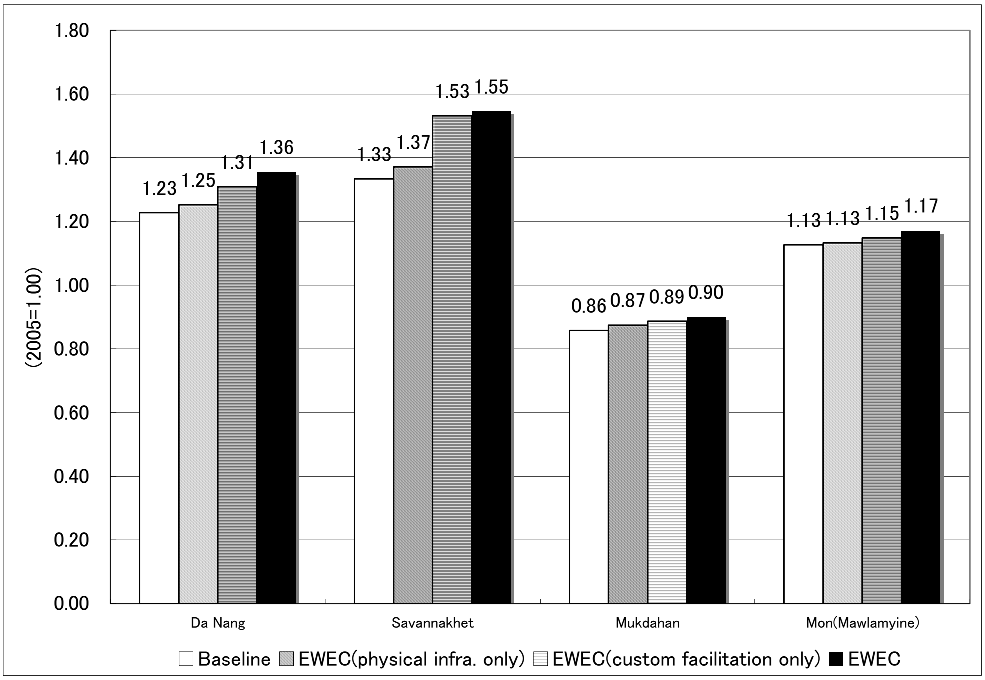
The EWEC mainly benefits the regions in Southern Laos, Central Vietnam and Northen Thailand.However, some regions are not benefited from EWEC. It is understandble that the population in Northen Laos and Southern Vietnam decline slightly due to the EWEC. Because the international immigration is prohibited in the simulation, population gained in one site means such population came from somewhere else in the same country. On the other hand, it is quite interesting to know that some regions away form the EWEC lose their GDP due to the EWEC, compared with the baseline scenario. This result shows one of the important characteristics of the model based on spatial economics.

5.3. Scenarios to check the effects of "border costs" and their results

This study also tested the two intermediate scenarios: These are EWEC (physical infrastructure only) and EWEC (custom facilitation at borders only)[6]. Figures 5 and 6 show the gains in population and GDP by scenario for selected regions along EWEC.

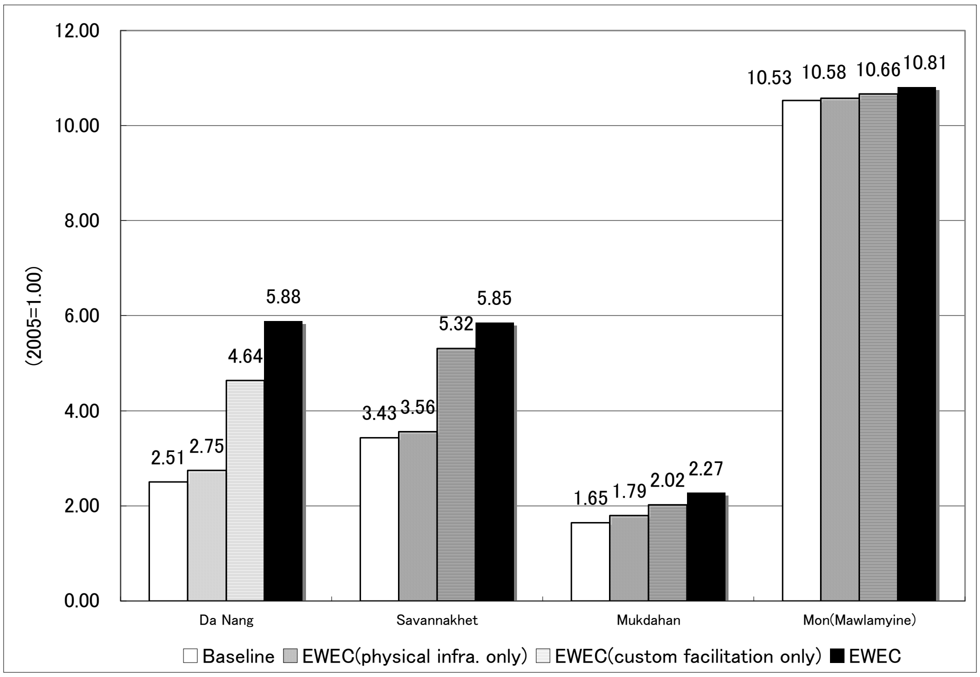
[6] The former scenario is that (1) they can run on EWEC at 80 km/h, and on other Asian Highway at 40km/h; and (2) The border costs, or the times required for custom clearance, are the same as the baseline scenario. The latter scenario is that (1) the Asian Highway networks all exist, and cars can run on it at 40km/h; and (2) there is no border control along EWEC.

Figure 5: Gains in Population by Scenario for Selected Regions (2025)



Source: IDE/ERIA-GSM estimation.

Figure 6: Gains in GDP by Scenario for Selected Regions (2025)



Source: IDE/ERIA-GSM estimation.

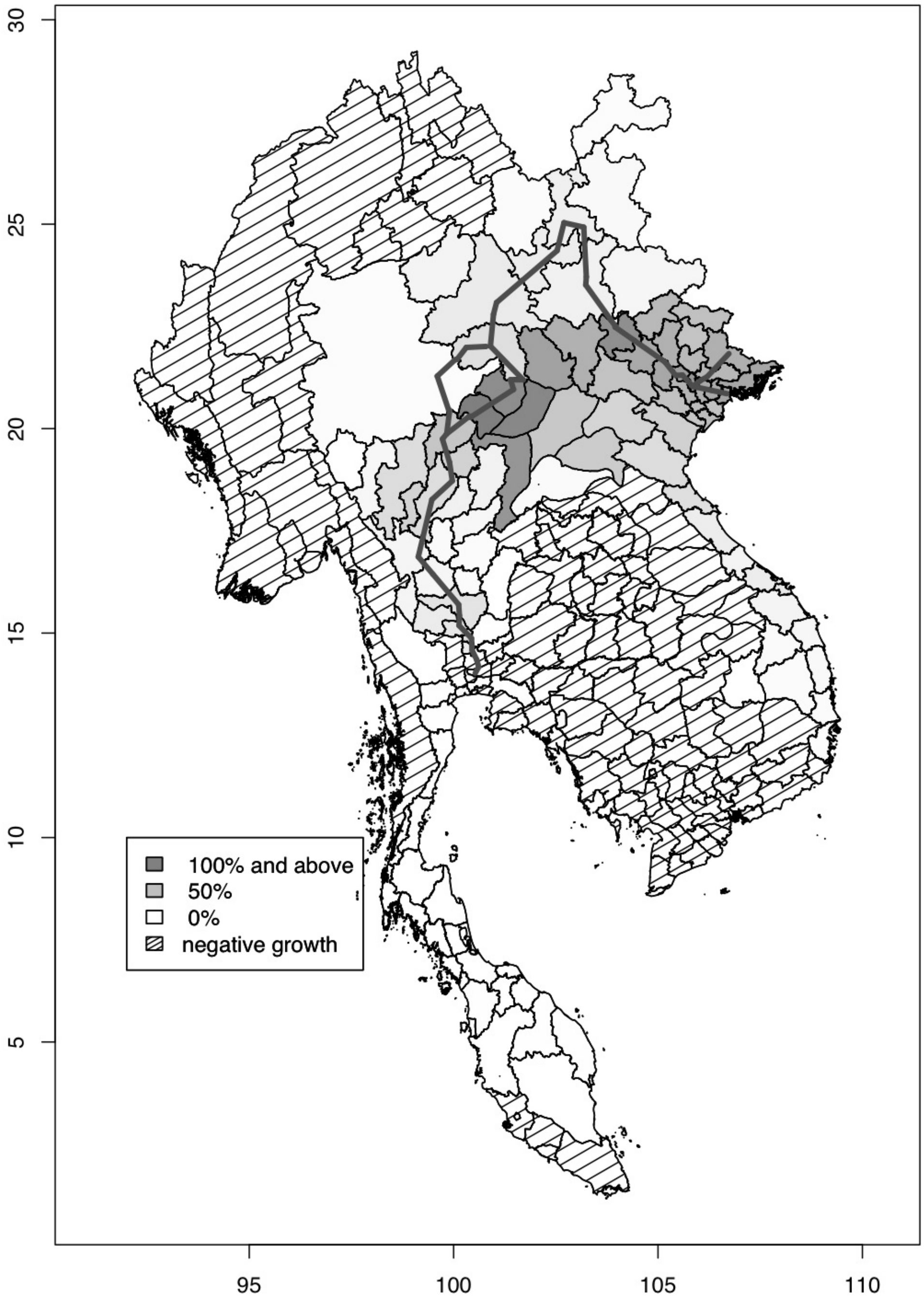
In terms of population, the EWEC (both physical infrastructure and custom facilitation) brings up Savannakhet's population to 1.55 times in 2025 compared with that in 2005. However, this increase is reduced to 1.37 times if only the physical infrastructure is constructed while there is no change in custom clearance. This is not much different from the 1.33 times for the baseline scenario.

As for GDP, EWEC (both physical infrastructure and custom facilitation) increases Savannakhet's GDP 5.85 times in 2025 compared with that in 2005. On the other hand, EWEC (physical infrastructure only) increases the GDP 3.56 times, which again is not much different from the 3.43 times for the baseline scenario.

5.4. Comparison to other economics corridor

This study further did a quick check on the economic effects of other economics corridors. Figures 7 and 8 show the changes in GDP against the baseline for the North South Economic Corridor (NSEC) and Southern Economic Corridor (SEC). It is obvious that NSEC benefits Northern Vietnam, Northern Laos and the southern part of the Yunnan province. On the other hand, SEC benefits most of the Cambodian regions and Southern Vietnam. The EWEC, NSEC and SEC seem to be highly complementary projects.

Figure 7: GDP Difference (2025). NSEC vs. Baseline



Source: IDE/ERIA-GSM estimation.

Figure 8: GDP Difference (2025). SEC vs. Baseline

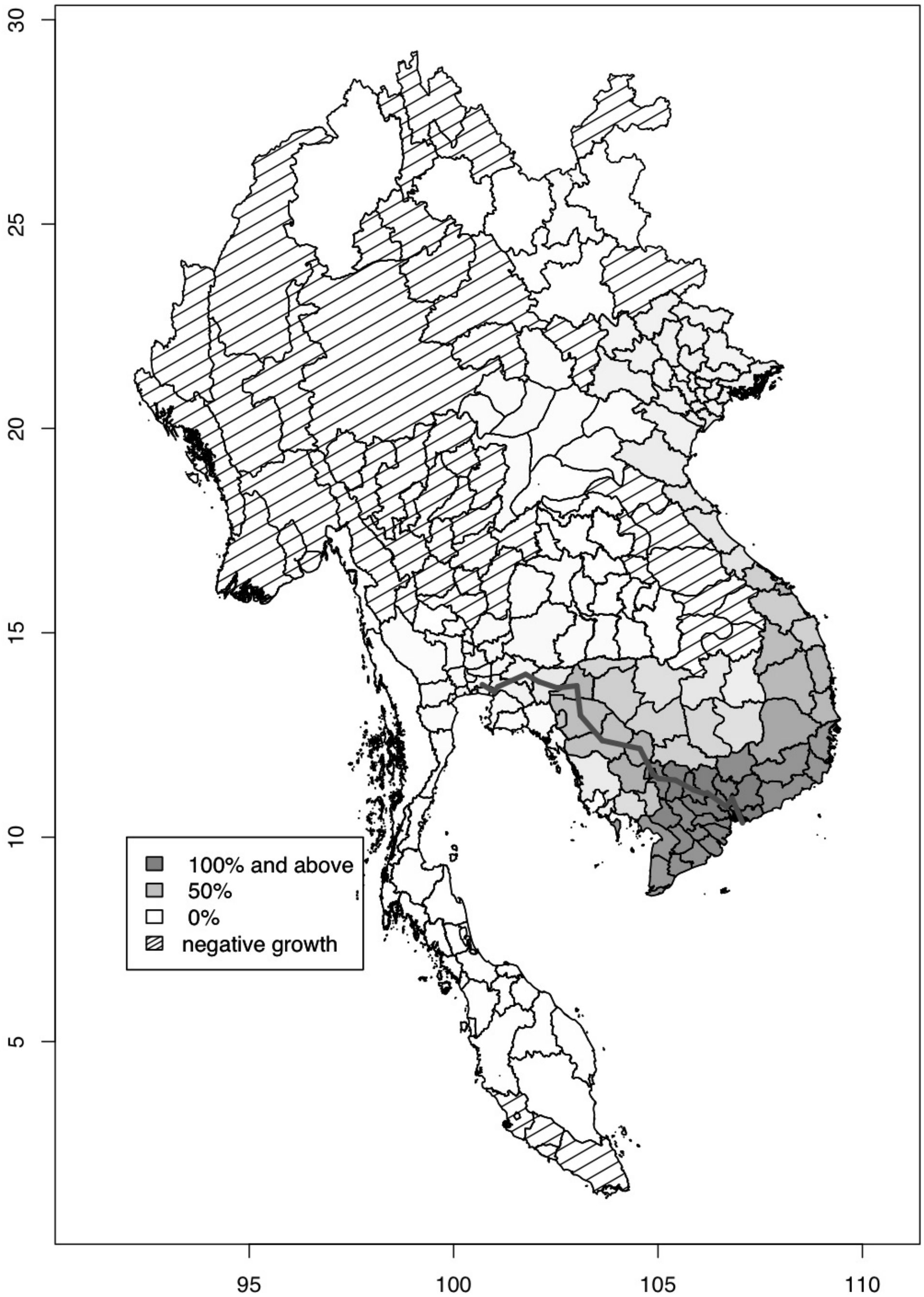


Table 5: Top 10 Gainers in GDP by NSEC (2025)

Rank	Region	Country	GDP(mil. USD) baseline	NSEC	Gain
1	Bokeo	Laos	268	619	131.4%
2	Oudomxai	Laos	488	943	93.2%
3	Louang Namtha	Laos	219	414	89.4%
4	Lao Cai	Vietnam	256	478	86.7%
5	Xaignabouri	Laos	706	1,285	81.9%
6	Hanoi	Vietnam	6,250	11,317	81.1%
7	Vinh Phuc	Vietnam	2,019	3,569	76.8%
8	Phongsali	Laos	211	365	73.1%
9	Haiphong	Vietnam	2,368	4,039	70.6%
10	Quang Ninh	Vietnam	1,640	2,769	68.8%

Source: IDE/ERIA-GSM estimation.

Table 6: Top 10 Gainers in GDP by SEC (2025)

Rank	Region	Country	GDP(mil. USD) baseline	SEC	Gain
1	Svay Rieng	Cambodia	281	1,190	323.98%
2	Prey Veng	Cambodia	485	1,460	201.14%
3	Ba Ria-Vung Tau	Vietnam	27,710	73,179	164.09%
4	Phnom Penh	Cambodia	2,576	6,232	141.96%
5	Tay Ninh	Vietnam	1,207	2,855	136.64%
6	Ho Chi Minh	Vietnam	26,417	62,408	136.25%
7	Binh Duong	Vietnam	6,046	13,912	130.09%
8	Dong Nai	Vietnam	11,900	25,067	110.64%
9	Long An	Vietnam	2,360	4,761	101.73%
10	Ben Tre	Vietnam	1,444	2,816	95.02%

Source: IDE/ERIA-GSM estimation.

Figure 9 shows economic effects of the case where all the economic corridors are developed together. Surprisingly, most of the regions in the Greater Mekong Subregion, except for Myanmar, benefited from the development

Figure 9: GDP Difference (2025). All GMS Economic Corridors vs. Baseline

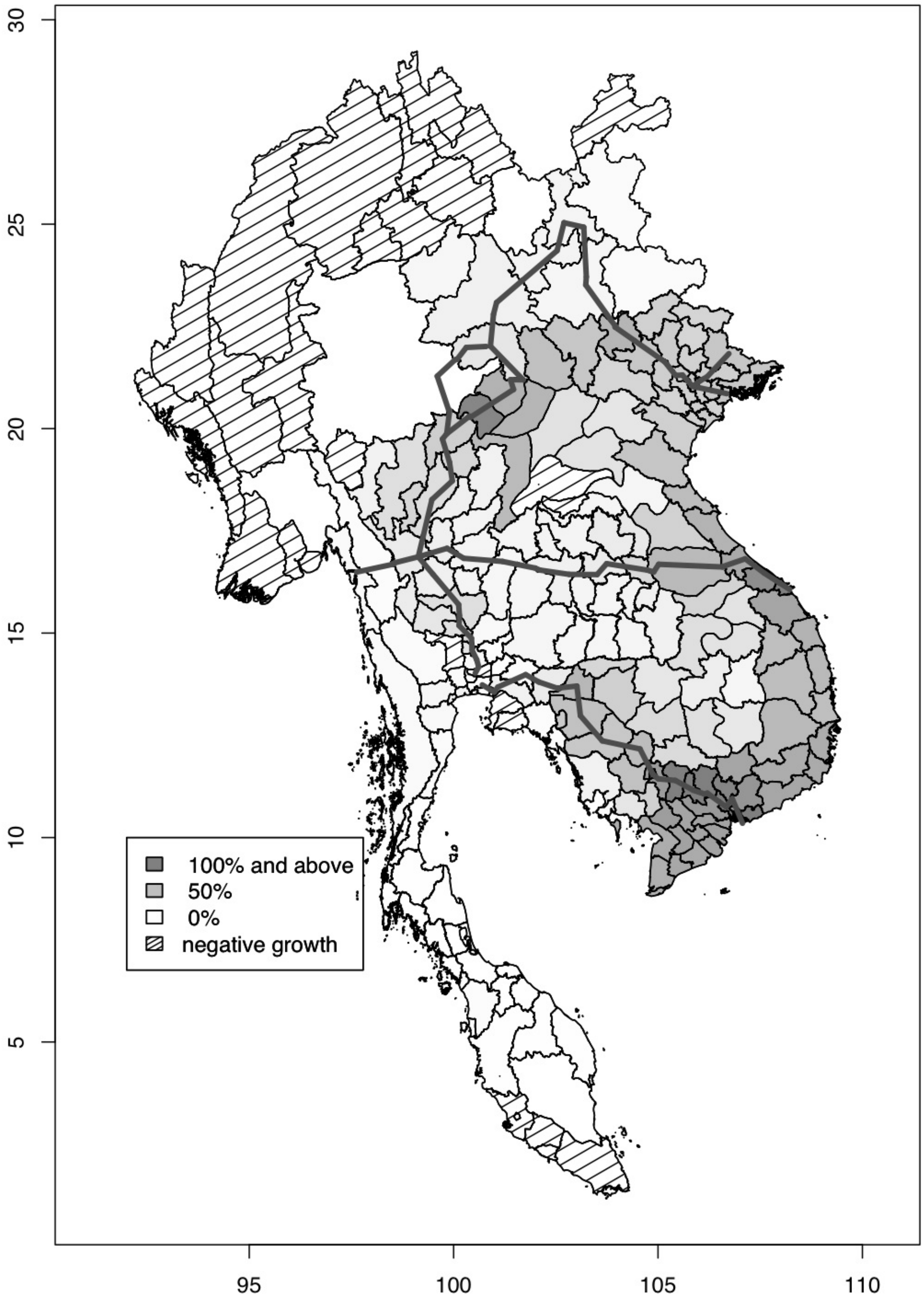


Table 7: Top 5 Gainers in GDP by All GMS Corridors in Each Country (2025)

Cambodia				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Svay Rieng	281	1,068	280.5%
2	Prey Veng	485	1,317	171.5%
3	Phnom Penh	2,576	5,603	117.5%
4	Kandal	785	1,387	76.6%
5	Banteay Meanchey	664	1,037	56.1%

Yunnan Province of China				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Xishuangbanna Daizu Zizhizhou	2,523	3,023	19.8%
2	Simao Diqu	2,553	2,829	10.8%
3	Yuxi Diqu	19,927	21,817	9.5%
4	Kunming Shi	39,060	42,002	7.5%
5	Honghe Ha'nizu	7,244	7,718	6.5%

Laos				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Bokeo	268	520	94.1%
2	Louang Namtha	219	351	60.4%
3	Oudomxai	488	768	57.4%
4	Savannakhet	2,169	3,346	54.2%
5	Xaignabouri	706	1,078	52.6%

Thailand				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Chiang Rai	1,522	2,093	37.5%
2	Sing Buri	713	936	31.3%
3	Lamphun	2,730	3,583	31.2%
4	Phayao	638	837	31.2%
5	Mukdahan	401	519	29.4%

Myanmar				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Tanintharyi	2,410	2,512	4.2%
2	Mon	3,251	3,375	3.8%
3	Kayin	2,143	2,178	1.7%
4	Shan	7,246	7,255	0.1%
5	Bago	7,942	7,947	0.1%

Malaysia				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Perlis	1,389	1,418	2.1%
2	Kedah	10,173	10,380	2.0%
3	Pulau Pinang	15,718	16,018	1.9%
4	Terengganu	12,951	13,102	1.2%
5	Kelantan	5,129	5,183	1.0%

Vietnam				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Ba Ria-Vung Tau	27,710	59,414	114.4%
2	Tay Ninh	1,207	2,541	110.6%
3	Ho Chi Minh	26,417	53,572	102.8%
4	Da Nang	827	1,659	100.6%
5	Binh Duong	6,046	11,804	95.2%

Singapore				
Rank	Region	GDP(mil. USD) baseline	GDP(mil. USD) All GMS	Gain
1	Singapore	180,124	179,323	-0.4%

Source: IDE/ERIA-GSM estimation.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1. The findings

6.1.1. Border costs play a big role

The first important finding is that border costs play a big role in the location of populations and industries. As shown in the previous section, physical infrastructure alone is not enough to capitalize on its advantages.

It is obvious that border costs are obstacles to the development of the regions. Physical infrastructure such as road and railways are not enough to assist in the development of the regions. In the simulations, the elimination of border costs seems to be much more effective than physical infrastructure development.

6.1.2. Nominal Wage matters more than expected

The second finding is that the difference in nominal wage is an important determinant of agglomeration. In CSEA, there is quite a large difference in nominal wage not only internationally but intranationally as well. It is so large that small locational advantages could not overturn the centripetal force caused by higher nominal wage of some central regions, which induce the inflow of population.

According to the study, Bangkok and its satellite regions, Ho Chi-Minh and its satellite regions, Kuala Lumpur and Selangor, Vientiane and Kunming are regions that provide higher nominal wage than the national average, and most of these have location advantages, too. Bangkok should be noted as a robust “core” region, having both higher nominal wage and locational advantages.

However, the importance of initial difference in nominal wage does not mean that spatial economics does not matter at all. On the contrary, infrastructure development has the power to amend the regional inequality caused by the initial difference in nominal wage in some extent. As shown in the previous section, EWEC tends to draw population from the Bangkok metropolis to Northern Thailand, and diverse population from Vientiane to Savannakhet.

6.2. Policy implications

6.2.1. Further accumulation of sub-national statistics

Although this study has proposed the analyses using IDE/ERIA-GSM and showed its potential, it is only a starting point and there are two main issues to be addressed.

First, one needs to collect more precise regional economic and demographic data at the subnational level in each country. More precisely, the establishment of uniform territorial units for geographical statistics for East Asia is crucial. Without the uniform territorial units, one could not compare various statistics directly across countries. For instance, it is not proper to compare the concentration of population at "state" level in Malaysia versus at "provincial" level in China. In Europe, Eurostat established the Nomenclature of Territorial Units for Statistics (NUTS) more than 25 years ago. The NUTS enables geographical analysis and formation of regional policies based on a single uniform breakdown of territorial units for regional statistics. In this regard, there ought to be an East Asian counterpart of NUTS as well (Call it EA-NUTS here). Based on EA-NUTS, basic social and economic information, such as population, GDP, industrial structure and employment by sector for each subregion should be collected or re-compiled from existing data sets from statistical departments of member countries.

Second, one needs to collect more precise data on routes and infrastructure connecting regions. Information on the main routes between regions such as distance, time distance, topology and mode of transport (road, railway, sea and air) is also indispensable. One also needs the data on the "border costs" such as tariffs and time-cost caused by inefficient customs clearance. It might be necessary to measure and continuously update the information on routes and border costs by experimental distribution of goods and actual drive, such as one study from JETRO (2007).

6.2.2. Reduction in border costs

While various logistic infrastructure connecting East Asian countries are now under construction, simulations suggest that just connecting regions by highways is not enough to facilitate the international trade of goods. Actually, subcontracting one manufacturing process internationally requires crossing national borders four times at least, and incurring various overhead costs such as explicit costs (e.g., tariffs) and implicit costs (e.g., time wasted during customs checks at the borders). One of the important implications of IDE/ERIA-GSM is that such border costs affect the geographical distribution of population and industries more than expected.

A possible measure to reduce these "border costs" is the introduction of East Asian Common Radio Frequency Identification (RFID) System for Logistics. The RFID has a similar function as barcodes but can be read without touching it. Thus, it is possible to read multiple RFIDs at once and to check contents of cargoes without opening them. This system is expected to reduce the lead-time and improve the traceability of the international transaction dramatically, contributing to further develop effective "fragmentation" of production processes.

6.2.3. Establishment an international body of planning and coordination for infrastructure development

This study realizes that the EWEC, NSEC and SEC are highly complementary projects. By implementing all three, most of the regions in the Greater Mekong Subregion benefit from the development. However, one exception is Myanmar. Although a few regions in Myanmar benefit from these economic corridors, the degree of the benefit is not much, and the rest of its regions do not benefit at all.

This study does not mean to be pesimistic toward Myanmar's economic development. On the contrary, Myanmar is found to have a naturally high potentional of economic growth in the baseline scenario. However, to enhance the economic development of Myanmar further, some plan on an economic corridor for Myanmar is needed, too.

As mentioned above, some coordination is required to plan and implement the infrastructure development in CSEA. So, it is highly desireable to set up an international body for planning and cordination of infrastructure development in East Asian counties.

APPENDIX A: BRIEF EXPLANATION ON SPATIAL ECONOMICS

Spatial economics explains the spread of economic activities within a general equilibrium framework. The main ingredients of the spatial economics are (1) increasing returns; (2) imperfect competition; (3) love of variety; and (4) endogenous agglomeration forces. With increasing returns in production activity, firms can enjoy externalities as explained by A. Marshall (1890, 1920). Imperfect competition avoids backyard capitalism implied in the spatial impossibility theorem. That is, imperfect competition (monopolistic competition) guarantees the demand for goods even if transport costs are incurred. Furthermore, love for variety implies that a large variety of consumption goods improves consumers' welfare as explained by Haig (1926) and a large variety of input improves firms' productivity. Such love for variety demands any goods produced in distant markets. With regard to endogenous agglomeration forces, economic activities agglomerate as a consequence of exogenous uneven distribution of resources or as a consequence of the economic activities themselves. Do call the former "first nature" and the latter "second nature". The spatial economics mainly focuses on the second nature, although the following simulation models adopt both the first nature and second nature.

The distribution of economic activities is decided by the balance of *agglomeration forces* against *dispersion forces*. There are many types of agglomeration and dispersion forces. Therefore, the observed spatial configurations of economic activities have varieties. With exogenous shocks, the spatial structure is organized by itself and the core-periphery structure evolves through structural changes.

The endogenous agglomeration forces bring circular causality. Circular causality is formed by market-access effects and cost-of-living effects. In terms of market-access effects, concentration (or an increase in demand by immigrants) enlarges the market. Suppliers locating in a large market can sell more since goods that are not transported between regions are cheaper. Obviously, this effect becomes weak when transport costs are low. More importantly, under the increasing-returns-to-scale production technology, the increase in the number of suppliers in a larger market is more than proportional to the expansion of the home market. As a result, the excess goods over local demand are exported.

The second force causing a concentration is cost-of-living effects. The price index of goods becomes lower in a region where many suppliers gather. As goods are produced locally, the prices of a large share of such goods do not include transport costs. This allows prices of goods to remain low, which then induces more demand in the region.

This effect works better when transport costs are high and the mill price is low. The market-access effects and cost-of-living effects reinforce each other. Because the former lures supply and the latter attracts demand, these two effects form a circular causality in which economic activities agglomerate in a region. That is, an increase in either upstream or downstream firms encourages further increase in the other type of firms in the region, as explained by Hirschman (1958). For this same reason, an increase in either consumer or producer provides the incentive for the other to agglomerate in the region.

On the other hand, Krugman (1991) uses market crowding effects as the dispersion force. Because of the decrease in the general price index due to concentration, the price charged by a specific firm becomes relatively high, resulting in lower demand for the goods. This effect becomes weaker as transport costs decrease.

Summing up these three effects, Krugman (1991) shows that the symmetric structure is maintained when transport costs are high enough, whereas core-periphery structure emerges when transport costs are low enough. In the formalization, transport costs between regions are exogenous factors and express all distance resistance. Mobile workers choose a preference between regions based on wage rates and prices in both regions. When transport costs are large enough, the dispersion force overcomes the agglomeration forces. Firms could not afford to play harsh price competition even in a slightly larger market because the profit from the distant market is small. Thus, economic activities disperse. On the other hand, as transport costs decrease enough, agglomeration forces surpass the dispersion force. Firms could enjoy large markets and low procurement cost even with harsh price competition by locating in a large market. This is because the profits from distant market are large. Therefore, economic activities agglomerate in a region.

By introducing another dispersion force (such as land use and the agricultural good) with positive transport costs, economic activities may disperse even if the transport costs are extremely low.

Consequently, to derive a policy implication for a circumstance, one may need to consider more realistic settings. Furthermore, the interaction here can be followed, in a situation where the economy consists of two or three regions in literatures. For an economy with more regions, the usage of a computer in the study becomes more crucial.

Appendix B: DETAILS OF THE MODEL

B-1 Nominal Wage in Agriculture Sector

Production function for Agricultural sector is $f_A(r) = A_A(r)L_A(r)^{\alpha}F(r)^{1-\alpha}$, where $A_A(r)$ is the efficiency of produciton at location *r*, $L_A(r)$ is the labour input and $F(r)$ is the area of arable land at location *r*. α is labor input share. So, the nominal wage of the sector is expressed as follows:

$$w_A(r) = A_A(r)\alpha(\frac{F(r)}{L_A(r)})^{1-\alpha} \tag{1}$$

B-2 GDP

Firms set the price of the manufacturing goods as $p_M(r) = w_M(r)^{\beta}G_M(r)^{1-\beta}$, where $w_M(r)$ is the nomianl wage of the manufacturing sector at location *r*, and $G_M(r)$ is the prince index of manufacturing goods, which represents intermediate input. β is labor input share(see Equation 14.1 in p.242, Fujita-Krugman-Venables: FKV).

GDP at location r is expressed as follows:

$$Y(r) = w_M(r)L_M(r) + f_A(r) + w_S(r)L_S(r) \qquad (2)$$

where $w_X(r)$ and $L_X(r)$ are the nominal wage and the labor input of sector x at location r respectively. See Equation 14.11 in p.244 of FKV.

B-3 Output

The output (GDP + the value of intermediate goods) at location r is expressed as follows:

$$E(r) = \mu Y(r) + \frac{1-\beta}{\beta} w_M(r)L_M(r) \qquad (3)$$

where μ is the shere of expenditure on manufacturing goods. See Equation 14.10 in p.244 FKV.

B-4 Price Index

The price indices of manufacturing goods and service goods are as follows, derived form Equation 14.6 in p.243 of FKV.

$$G_M(r) = [\sum_{s=1}^{R} L_M(s) w_M(s)^{(1-\sigma)\beta} G_M(s)^{\sigma(1-\beta)} (T_{rs}^M)^{1-\sigma}]^{\frac{1}{1-\sigma}} \qquad (4)$$

$$G_S(r) = [\sum_{s=1}^{R} L_S(s)(w_S(s)T_{rs}^S)^{1-\sigma}]^{\frac{1}{1-\sigma}} \qquad (5)$$

B-5 Nominal Wage in Manufacturing Sector

The nominal wage in manufacturing sector is expressed as follows:

$$w_M(r) = A_M(r)[\frac{\beta^{\frac{1}{\sigma_M}} [\sum_{s=1}^{R} E(s) G_M(s)^{-(1-\sigma_M)} T^{1-\sigma_M}]^{\frac{1}{\sigma_M}}}{G_M(r)^{1-\beta}}]^{\frac{1}{\beta}} \qquad (6)$$

where $A_M(r)$ is the efficiency of produciton for manufacturing goods at location r, σ_M is the elasticity of substitution between manufacturing goods.

B-6 Nominal Wage in Service Sector

The nominal wage in service sector is expressed as follows:

$$w_S(r) = A_S(r)[\sum_{s=1}^{R} Y(r)(T_{rs}^{S})^{1-\sigma_S} G_S(s)^{-(1-\sigma_S)}]^{\frac{1}{\sigma_S}} \tag{7}$$

where $A_S(r)$ is the efficiency of produciton for service sector at location *r*, σ_S is the elasticity of substitution between service goods.

B-7 Real Wage

The real wage is expressed as follows:

$$\omega(r) = \frac{average(w_A(r), w_M(r), w_S(r))}{G_M(r)^{\mu} G_S(r)^{\nu}} \tag{8}$$

which is derived form Equation 14.8 in p.243 of FKV.

B-8 Population Dynamics

- Intra Country Population Dynamics is expressed as follows:

$$\lambda(r) = \frac{L_A(r) + L_M(r) + L_S(r)}{\sum_{s=1}^{R(c)} (L_A(s) + L_M(s) + L_S(s))} \tag{9}$$

$$\dot{\lambda} = \gamma_c(\frac{\omega(r)}{\overline{\omega}(c)} - 1) \tag{10}$$

where $\dot{\lambda}(r)$ is the change in the labour(population) share for a region in a country, and γ_c is the parameter to determine the speed of immigrating between regions in a country.

- Inter Country Population Dynamics is expressed as follows:

$$\lambda(c) = \frac{L_A(c) + L_M(c) + L_S(c)}{\sum_{s=1}^{c} (L_A(s) + L_M(s) + L_S(s))} \tag{11}$$

$$\dot{\lambda}(c) = \gamma_w\left(\frac{\overline{\omega}(c)}{\overline{\omega}_w} - 1\right) \qquad (12)$$

where $\dot{\lambda}(c)$ is the change in the labour(population) share for a country, and γ_w is the parameter to determine the speed of immigrating between countries.

- Inter Industry Population Dynamics is expressed as follows:

$$\lambda_I(r) = \frac{L_I(r)}{L_A(r) + L_M(r) + L_S(r)} \qquad (13)$$

$$\dot{\lambda}_I(r) = \gamma_L\left(\frac{\omega_I(r)}{\overline{\omega}(r)} - 1\right) \qquad (14)$$

$I \in \{A, M, S\}$

where $\dot{\lambda}_I(r)$ is the change in the labour(population) share for a industry within a region, and γ_L is the parameter to determine the speed of job change within a city.

APPENDIX C: IMPORTANT PARAMETERS

C-1. Transport Costs

Transport costs are defined by industry: T_M is for the manufacturing sector, which equals 1.25, typically. T_S is for the service sector and equals 50, typically[7]. The transport costs are standardized by assuming that one is moving a good between Kuala Lumpur and Singapore (slant distance) at 40km/h. Thus, T_M=1.25 means that 1.00 unit of manufacturing goods arrives at Kuala Lumpur out of 1.25 unit of the goods shipped from Singapore, after transported at 40km/h[8]. Or it is understood that bringing goods from Singapore to Kuala Lumpur requires 25 percent overhead costs on the price of the

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[7] This study sets the transport cost for agricultural good $T_A = 1.0$. This means that there is no cost to bring agricultural goods to other places. It seems to be an extreme assumption, but it is quite common in the literature of spatial economics. This standard is followed at this point, but the transport costs needs to be incorporated in the agricultrural sector in future studies.

[8] This type of specification of transport costs is very popular in spatial economics as "ice berg" transport costs.

good. As for service sector, T_S=50 means that bringing a service to another place costs exorbitantly high---i.e., most of the service is consumed at the place in which the service is provided.

C-2. Elasticity of Substitution

The elasticity of substitution between goods is also defined by industry. σ_M is for the manufacturing sector and equals 1.5, typically. σ_S is for the service sector and equals 50, typically[9]. If σ=1.0, it means that two goods are perfectly differentiated and cannot substitute each other. On the other hand, If $\sigma = \infty$, two goods are perfect substitutes. So, σ_M=3 means the goods are highly differentiated in the manufacturing sector, and σ_S=50 means that services are not differentiated much, and one can enjoy similar services wherever one is located.

C-3. Parameters on Labor mobility

Parameters on labor mobility is set in three levels, namely, international labor mobility (γ_N), intranational (or intercity) labor mobility (γ_C), and interindustry labor mobility (γ_I) within a region. What does $\gamma = 1.0$ means? It means that a country/region having two times higher real wage than the average induces 100 percent labor inflow a year.

Set γ_N=0 here. That is, the international migration of labor is prohibited. Although this looks like a rather extreme assumption, it is reasonable enough, taking into account that most ASEAN countries strictly control incoming foreign labor[10].

Set γ_C=0.02. This means that a region having two times higher real wage than the national average induces 2 percent labor inflow a year.

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[9] Agricultral goods is treated as homogenious goods, and not differentiated at all.

[10] There are large numbers of foreign workers in Singapore and Malaysia. However, these two countries set strict quota on foreign workers.

Set γ_I=0.05, too. This means that an industrial sector having two times higher real wage than the average in the region induces 5 percent labor inflow from other industrial sectors a year.

C-4. Other parameters

Set consumption share of manufacturing goods (μ) at 0.4 and the share of service sector (ν) at 0.2, respectively. Thus, that of agricultural goods is at 0.4. This must be calibrated and differentiated for each country. However, identical utility function is used for consumers for all countries for simplicity.

Set labor requirement in the production of agricultural goods (α) at 0.8 and that of manufacturing goods (β) at 0.6. Thus, the input share of intermediate goods in manufacturing goods production is 1-β=0.4. These parameters should be calibrating for each industry more carefully in the future.

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