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The IDE Geographical Simulation Model: Predicting Long-Term Effects of Infrastructure Development Projects

S. Kumagai[*a], T. Gokan[*b], I. Isono[*c] and S. Keola[*d]

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Abstract

It is important to be able to predict changes in the location of populations and industries in regions that are in the process of economic integration. The IDE Geographical Simulation Model (IDE-GSM) has been developed with two major objectives: (1) to determine the dynamics of locations of populations and industries in East Asia in the long-term, and (2) to analyze the impact of specific infrastructure projects on the regional economy at sub-national levels. The basic structure of the IDE-GSM is introduced in this article and accompanied with results of test analyses on the effects of the East West Economic Corridor on regions in Continental South East Asia. Results indicate that border costs appear to play a big role in the location choice of populations and industries, often a more important role than physical infrastructures themselves.

Keywords: Geographical Simulation Model, East Asia, spatial economics

JEL classification: D59, F29, R49, O53

[*a] Researcher, Economic Integration Studies Group, Inter-disciplinary Studies Center, IDE (kumagai@ide.go.jp); [*b] Researcher, Economic Integration Studies Group, Inter-disciplinary Studies Center, IDE (Toshitaka_Gokan@ide.go.jp); [*c] Researcher, Economic Integration Studies Group, Inter-disciplinary Studies Center, IDE (Ikumo_Isono@ide.go.jp); [*d] Researcher, Development Strategies Studies Group, Development Studies Center, IDE (Souknilanh_Keola@ide.go.jp)

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INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

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S. Kumagai[*a], T. Gokan[*b], I. Isono[*c] and S. Keola[*d]

Abstract

It is important to be able to predict changes in the location of populations and industries in regions that are in the process of economic integration. The IDE Geographical Simulation Model (IDE-GSM) has been developed with two major objectives: (1) to determine the dynamics of locations of populations and industries in East Asia in the long-term, and (2) to analyze the impact of specific infrastructure projects on the regional economy at sub-national levels. The basic structure of the IDE-GSM is introduced in this article and accompanied with results of test analyses on the effects of the East West Economic Corridor on regions in Continental South East Asia. Results indicate that border costs appear to play a big role in the location choice of populations and industries, often a more important role than physical infrastructures themselves.

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[*a] Researcher, Economic Integration Studies Group, Inter-disciplinary Studies Center, IDE (kumagai@ide.go.jp)

[*b] Researcher, Economic Integration Studies Group, Inter-disciplinary Studies Center, IDE (Toshitaka_Gokan@ide.go.jp)

[*c] Researcher, Economic Integration Studies Group, Inter-disciplinary Studies Center, IDE (Ikumo_Isono@ide.go.jp)

[*d] Researcher, Development Strategies Studies Group, Development Studies Center, IDE (Souknilanh_Keola@ide.go.jp)

1. INTRODUCTION

Economic integration in East Asia is expected to proceed steadily for the next few decades, although the realization of an East Asian Community (EAC) may still be far away. As economic integration grows deeper and deeper, what will happen to East Asia? An implication of spatial economics or new economic geography (NEG) is that inter and intra-regional income-gaps may become wider as various trade costs (including transport costs, tariffs, and/or "service link costs") are lowered.

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

However, there is virtually no comprehensive research related to the geographical structure of the East Asian economies. This is due to the lack of an integrated geographical data set for East Asia and also the lack of a well fitting economic model that can be used to analyze economic geography in the region. This study thus focuses on the geographical structure of regional economy, primarily from the viewpoint of NEG, and uses a geographical simulation model developed by the authors.

Analysis using the IDE Geographical Simulation Model (IDE-GSM) is the first step in research on the relationship between economic integration and regional economy at the sub-national level. The IDE-GSM is designed to predict the effects of regional economic integration, especially the development of transport infrastructures and reductions in "border costs."

The paper is structured as follows: Background and objectives of the IDE-GSM are explained in Section 2. Features of the IDE-GSM are then introduced in Section 3. Section 4 includes detailed explanation of the spatial economic model used in the IDE-GSM. Effects of a specific infrastructure development project, specifically the East West Economic Corridor (EWEC), are examined in Section 5 using the IDE-GSM, and major results are presented graphically. Conclusions are presented in Section 6.

2. BACKGROUND AND OBJECTIVES

2.1 Brief Survey of Literature

Since the beginning of the 1990's, spatial economics has been considered a cutting-edge field of economics. It explicitly incorporates a concept of "space" that has been not been handled well by mainstream economics and treats various geographic aspects of economic phenomena in the framework of general equilibrium. The dramatic increase in research on spatial economics in the last decade has coincided with globalization and regional integration of the world economy as represented in the formation of the EU and NAFTA.

In East Asia, the evolution of *de-facto* regional integration makes it apparent that traditional theories of international trade are not adequate to explain actual trade and flow of investment in this region. Spatial economics has become indispensable for analyzing regional integration in East Asia. China and India both have abundant low-cost labor and a huge domestic market, and these factors require a theory that incorporates the idea of increasing returns.

Although much theoretical progress has been made in spatial economics in the last decade, empirical application of theory has not flourished. In international economics, the "home market effect", an important concept in spatial economics, has been the focal point of empirical research, and much effort has been put into studying the existence (or non-existence) of this concept (Davis and Weinstein, 1999 and Hanson and Xiang, 2004). Unfortunately, most studies lack actual “geographic factors” because “nation” is used as the unit of analyses.

In research on the EU, several attempts have been made to simulate the effects of infrastructure development using the spatial CGE model. Bröcker (2002), for example, tried to check the effects of certain transport policies on regional inequality in the EU.

2.2 Objectives of the IDE-GSM

Analysis using the IDE-GSM has two major objectives: The first is to determine the dynamics of the location of populations and industries in East Asia in the long-term. There are many analyses using macro-economic models to forecast macro-economic indices in East Asia at national level. However, with the exception of only a few studies in the literature, there are no analyses using such models to forecast economic development in East Asia at the sub-national level. In an era of regional economic integration, economic analysis at the national-level is not fine enough to provide useful information for regional economic co-operation.

The second objective is to analyze the impact of specific infrastructure projects on the regional economy at a sub-national level. It is difficult to prioritize various infrastructure development projects without proper objective evaluation tools. The IDE-GSM has been developed to provide such an objective evaluation tool for policy recommendations related to infrastructure development.

2.3 Continental Southeast Asia as an Area for Testing Spatial Economics

The first step in the development of the IDE-GSM was to run the model on continental Southeast Asia (CSEA). There were two main reasons for choosing CSEA: The first is somewhat “backward looking”. In CSEA, land transport plays a dominant role, and it is relatively easy to model and analyze using spatial economics. However, East Asia as a region is also fragmented into several parts by the ocean, so air and sea transport play a major role in logistics. If all of East Asia is chosen as the base of the model, the modeling process is much more challenging. The costs of air and sea transport do not linearly increase as distance increases. Further, the modal choice between air, sea, and land transport makes economic modeling complicated.

The second reason is rather “forward-looking”. In CSEA, various major transport and infrastructure development projects are in progress, and more are planned. An important task for CSEA is to establish priorities for these projects. In order to determine such priorities, it is indispensable to analyze the impact of various projects on the regional economy at the sub-national level. The IDE-GSM seeks to provide an objective tool for the evaluation of various infrastructure development projects.

3. FEATURES OF THE SYSTEM

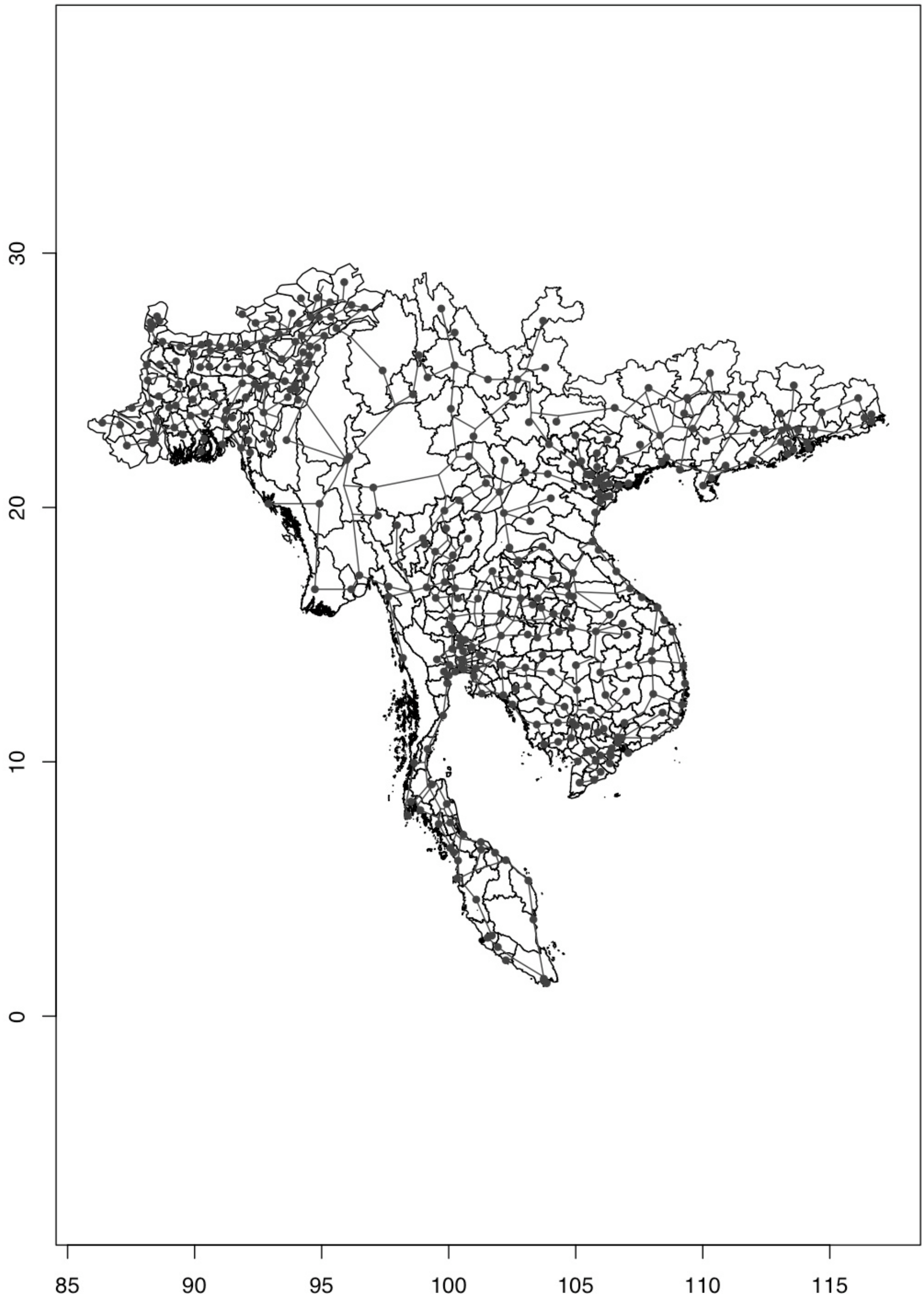
3.1. Basic Features of the System

For test analyses, the IDE-GSM covers the 10 countries shown in Table 1 and Figure 1.

Table 1. **Countries and Regions Covered in the Test Analyses**

Singapore	Malaysia (Peninsular)
Thailand	Myanmar
Cambodia	Laos
Vietnam	Yunnan, Guangxi, and Guangdong provinces of China
Bangladesh	Western India

Figure 1: Countries and Regions Covered in the Test Analyses



These 10 countries/regions comprise 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 361 sub-national regions. For each sub-national region, the IDE-GSM makes use of the following data:

- GDP by sector (primary, secondary, and tertiary industries)
- Employee[1] by sector (primary, secondary, and tertiary industries)
- Longitude and latitude
- Area of arable land[2]

Based primarily on the "Asian Highway" database of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) it is estimated that there about 700 routes between cities. The actual road distance between cities is used in the IDE-GSM. If road distance is not available, the slant distance is employed.

3.2. Advantages of the System

The IDE-GSM has the following three advantages:

3.2.1 Realistic enough to model the real world

The first advantage of the IDE-GSM is that it incorporates a realistic topology of cities[3] and routes that connect these cities. Some theoretical studies of spatial economics (see Fujita, Krugman, and Venables, 1999) incorporate "geography" in models as cities on

[1] The GMS treats populations and employees as the same in this version. A sectoral employment ratio is calculated from employee data and multiplied by the population. It is then used in the simulation.

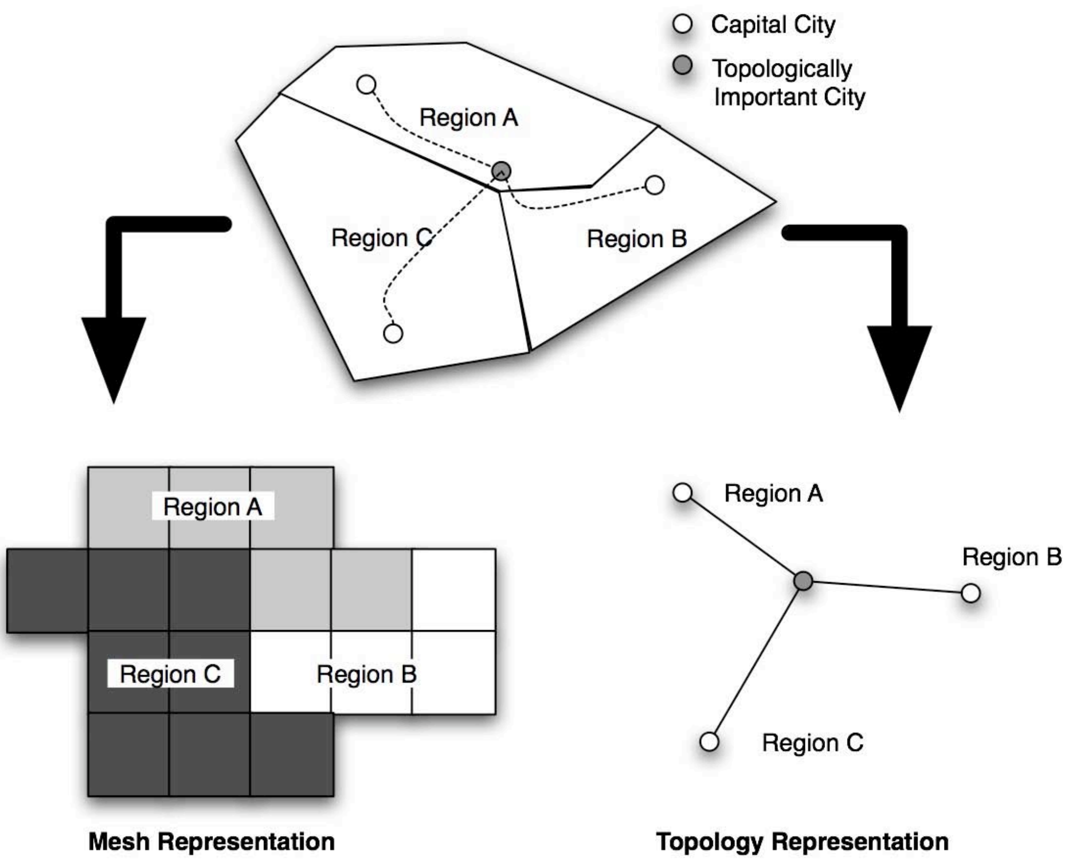
[2] If sub-national data of arable land is not available, then national level data is used. The national area of arable land is distributed to each sub-national geographical unit proportional to its land area.

[3] The variable "city" used in the GSM refers to an administrative city. But the GSM does not exclude the possibility of defining "city" as a more realistic area according to actual economic activities.

the line or cities on the circle (the so called "race-track economy"), while many other empirical models have set the precedent of incorporating geography as a "mesh" representation.

The IDE-GSM incorporates geography as "topology" of cities and routes. This representation of geography has two major advantages and several minor advantages over the mesh representation: First, it makes it possible to incorporate the realistic choice of routes in logistics; the mesh representation does not necessarily incorporate "routes" explicitly. A problem in topological representation is to calculate the minimal distance between any two citiesconsidering every possible route between them. Fortunately, the Warshall-Floyd method provides a solution for this problem, and it is used in the IDE-GSM.

Figure 2: Mesh vs. Topology Representations of Geography



The second advantage is that it requires less data on cities or points; the mesh representation requires various data for a large number of meshes. The IDE-GSM uses 361 capital cities and 184 topologically important cities to represent the whole CSEA. For example, if the mesh representation is used in a 10 km by 10 km area, data is required for more than 33,700 meshes for the region. Although a larger mesh may be used to reduce the number of meshes (100 km by 100 km by 337 meshes for example), this is too rough to capture the geographical features of CSEA.

In addition to these two major advantages, it is possible to add an "inter-change city", having no-population or industry, just to capture the realistic topology of cities and routes. It is also possible to put "border costs" explicitly at routes crossing the border, enabling the model to take into account various costs at border controls. Further, incorporating "routes" explicitly makes it possible to incorporate differences in the quality of a road by setting different "average speeds" for running on it.

3.2.2. Flexible enough for future extension

The IDE-GSM is programmed using Java™ which implements object-oriented programming (OOP). Thus, it is platform free. Such programming enables the IDE-GSM to be extended and modified easily. It is capable of running different economic models with minimal changes in the program.

The IDE-GSM is programmed as a three-layered hierarchy (World-Country-City), and it is possible to control various parameters in any member of the hierarchy. For example, it is possible to set different parameters of migration at both inter-national and intra-national levels.

3.2.3. Well-integrated with graphical output methods

For geographical simulations, it is quite important to check data graphically. As the geographical database is complicated, data must be checked graphically to assure that each city is located in the correct place, and that the routes between cities are collected topologically. It is also necessary to check results of simulations graphically in order to analyze the geographical tendency of the distributions of population and industries.

The IDE-GSM is well integrated with graphical output methods. Google™ mapping may be used to visualize the geographical dynamics of populations and industries, and more detailed graphical analysis is possible by using the statistical language R and *MapTools*.

4. EXPLANATION OF THE MODEL

4.1. Brief Explanation of Spatial Economics

Before detailing the structure of the IDE-GSM, some explanation of Spatial Economics as well as the theory behind the model seems necessary. Spatial economics explains the spread of economic activities within a general equilibrium framework. The main components of 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 that is implied in the spatial impossibility theorem. That is, imperfect competition (monopolistic competition) guarantees demand for goods even if transport costs are incurred. Love for variety implies that a large variety of consumption goods will improve consumer welfare (see Haig, 1926), and a large variety of input improves a firm's productivity. Such love for variety demands goods produced in distant markets. With regard to endogenous agglomeration forces, economic activities agglomerate as a consequence of exogenous and uneven distribution of resources ("first nature") or as a consequence of economic activities themselves ("second nature"). Spatial economics focuses primarily on the second nature, although the following simulation models adopt both first and second nature.

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

Endogenous agglomeration forces bring circular causality. Market-access effects and cost-of-living effects form circular causality. Relative to market-access effects, concentration (or an increase in demand by immigrants) enlarges the market. Suppliers locating in a large market can sell more because goods that are not transported between regions are cheaper. Obviously, this effect becomes weak when transport costs are low. Perhaps more importantly, under 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, goods in excess of local demand are exported.

Another force leading to concentration is the cost-of-living effect. 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 in turn induces more demand in the region.

This effect is more pronounced when transport costs are high and mill prices are low. Market-access and cost-of-living effects reinforce each other. Because the former lures supply and the latter attract demand, these two effects form a circular causality in which economic activities agglomerate in a region. An increase in either upstream or downstream firms encourages further increases in other types of firms in the region (see Hirschman, 1958). For this same reason, an increase in either consumers or producers provides incentive for the other to agglomerate in the region.

Krugman (1991) on the other hand, 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, and this results in lower demand for the goods. This effect becomes weaker as transport costs decrease.

In summary, Krugman (1991) shows that a symmetric structure is maintained when transport costs reach a high enough level; core-periphery structures emerge when transport costs reach a low enough level. Formalizing, 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 agglomeration forces. Firms cannot afford to play harsh competitive price games even in a somewhat larger market because profit from the distant market is small. Thus, economic activities disperse. However, as transport costs decrease to a low enough level, agglomeration forces surpass the dispersion force. Firms can enjoy large markets and low procurement costs even with harsh price competition by locating in a large market because the profits from such distant markets are large. Thus economic activities can agglomerate in the region.

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

To derive a policy implication for a particular circumstance, more realistic settings may need to be considered. In the literature, interaction can be followed in situations where the economy consists of two or three regions. For an economy with more regions, computer usage becomes more crucial.

4.2. Structure of the Model

The IDE-GSM is able to forecast the dynamics of populations and industries at the sub-national level. It works in the following steps:

1. Initial Data Load

The data on regions and routes are loaded from prepared CSV files. Regional and data related to the routes between regions must be compatible. For example, names of cities on route data must appear in the regional data together with other attributions of the cities (regions), especially latitude and longitude. Then, the parameter $A(r)$, "productivity," or "technology" is determined. $A(r)$ is calibrated just to absorb the difference between theoretically computed nominal wage and the actual nominal wage in each region.

2. Determination of Short-Run Equilibrium

   The IDE-GSM calculates the short-run equilibrium (equilibrium under a given population distribution) values of GDP by sector, employment by sector, nominal wage by sector, price index, and other variables based on the distribution of population. The IDE-GSM uses iteration techniques to solve the multi-equation model. Detailed equations may be found in the Appendix.

3. Calculation of Population Dynamics

   Once short-run equilibrium values are found, the IDE-GSM calculates the dynamics of population or movement of labor based on differences in real wages among countries, regions, and industries. The IDE-GSM is able to set the speed of adjustment for inter-country, inter-region, and inter-industry labor movements. Details are explained in Section 4.3.3.

4. Output Results

   To examine related variables in time series, the IDE-GSM exports equilibrium values of GDP by sector, employment by sector, nominal wages by sector, price index, and other factors for every single year in CSV and XML formats. These can then be checked using Google™ map or a statistical package.

5. Repetition of Step 2.

   New equilibrium under new distribution of population is found. This return to

Step 2 implies that time advances one year. In the analyses presented in this chapter, the simulation is run for 20 years.

4.3. Important Parameters

4.3.1. Transport Costs[4]

Transport costs are defined by industry: (1) T_M for the manufacturing sector, which equals 1.05 typically. (2) T_S for the service sector and typically equal to 50. Transport costs are standardized by assuming that goods are moving between Kuala Lumpur and Singapore (slant distance) at 40 km/h. Thus, T_M =1.05 means that 1.00 out of 1.05 units of manufactured goods shipped from Singapore and transported at 40 km/h arrive at Kuala Lumpur[5]. It can be understood that bringing goods from Singapore to Kuala Lumpur requires a 5 percent overhead cost on the price of the goods. T_S=50 means that bringing a service to another place is exorbitantly high; most service is consumed where the service is provided.

4.3.2. Elasticity of Substitution

Elasticity of substitution between goods is also defined by industry. σ_M represents the manufacturing sector and typically equals 3. σ_S represents the service sector and typically equals 50[6]. If σ=1.0, then two goods are perfectly differentiated and cannot be substituted for one another. Conversely, $\sigma = \infty$ means that the two goods are perfect substitutes for each other. Thus, σ_M =3 implies that goods are highly differentiated in the manufacturing sector, and σ_S =50 indicates that services are not highly differentiated; one can enjoy similar services wherever one is located.

[4] This study sets the transport cost for agricultural goods $T_A = 1.0$. This means that there is no cost in bringing agricultural goods to other places. This may be an extreme assumption, but it is quite common in the literature of spatial economics. While this standard is followed here, transport costs need to be incorporated in the agricultural sector in future studies.

[5] This specification is very popular in spatial economics and is known as "iceberg transport costs".

[6] Agricultural goods are treated as homogeneous goods and are not at all differentiated.

4.3.3. Parameters for Labor Mobility

Parameters within a region for labor mobility are set in three levels: (1) international labor mobility (γ_N), (2) intra-national (or inter-city) labor mobility (γ_C), and (3) interindustry labor mobility (γ_I). A value of $\gamma = 1.0$ indicates that a country or region having two times higher real wages than average induces 100 percent labor inflow in a year.

If γ_N=0 is set, international migration of labor is prohibited. Although this looks like an extreme assumption, it is reasonable given that most ASEAN countries strictly control incoming foreign labor[7].

If γ_C=0.02 is set, a region having two times higher real wages than the national average will induce 2 percent labor inflow in a year.

If γ_I=0.05 is set, an industrial sector having two times higher real wages than average in the region will induce 5 percent labor inflow from other industrial sectors in a year.

4.3.4. OtherParameters

Set the consumption share of manufactured goods (μ) at 0.4 and the same share of services (ν) at 0.2. Agricultural goods are then at 0.4. This must be calibrated and differentiated for each country. However, for simplicity, an identical utility function is used for consumers in all countries.

Set the cost share of labor in the production of agricultural goods (α) at 0.8 and that of manufactured goods (β) at 0.6. The input share of intermediate goods in manufactured goods production is 1-β=0.4. In the future, these parameters should be more carefully calibrated for each industry.

5. SCENARIOS AND RESULTS

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

5.1. Simulation Scenarios

Three scenarios reveal effects relative to the East West Economic Corridor (EWEC).

5.1.1 Base-line Scenario with Assumptions Maintained

Several macroeconomic and demographic parameters may be held constant, and only logistic settings (by scenario) changed. The following macro parameters are then maintained across scenarios:

- Other things being equal, GDP per capita of each country is assumed to increase by the average rate for the year 2000-2005[8];
- The national population of each country is assumed to increase at 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.

The assumptions in the base-line scenario are as follows:

- Asian Highway networks exist, and cars can run at 40km/h.
- Border costs, or 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

5.1.2 East West Economic Corridor (Physical Infrastructure Only)

Assumptions in this scenario are as follow:

- Cars can run on the EWEC at 80 km/h after the year 2011[9] and on other Asian Highways at 40km/h.
- The border costs are the same as 5.1.1.

[8] For various reasons, the growth rate of GDP per capita in each city is likely to differ from the national average and is considered so in the simulation.
[9] This setting indicates that the EWEC will be completed at the end of 2010.

5.1.3 East West Economic Corridor with Customs Facilitation

The assumptions in this scenario are as follows:

- Cars can run on the EWEC at 80 km/h after the year 2011 and on other Asian Highways at 40km/h.
- Border controls along the EWEC are as efficient as those at the Singapore-Malaysia border (taking 2.0 hours to cross national borders) after the year 2011.

5.2. Results of the Simulation[10]

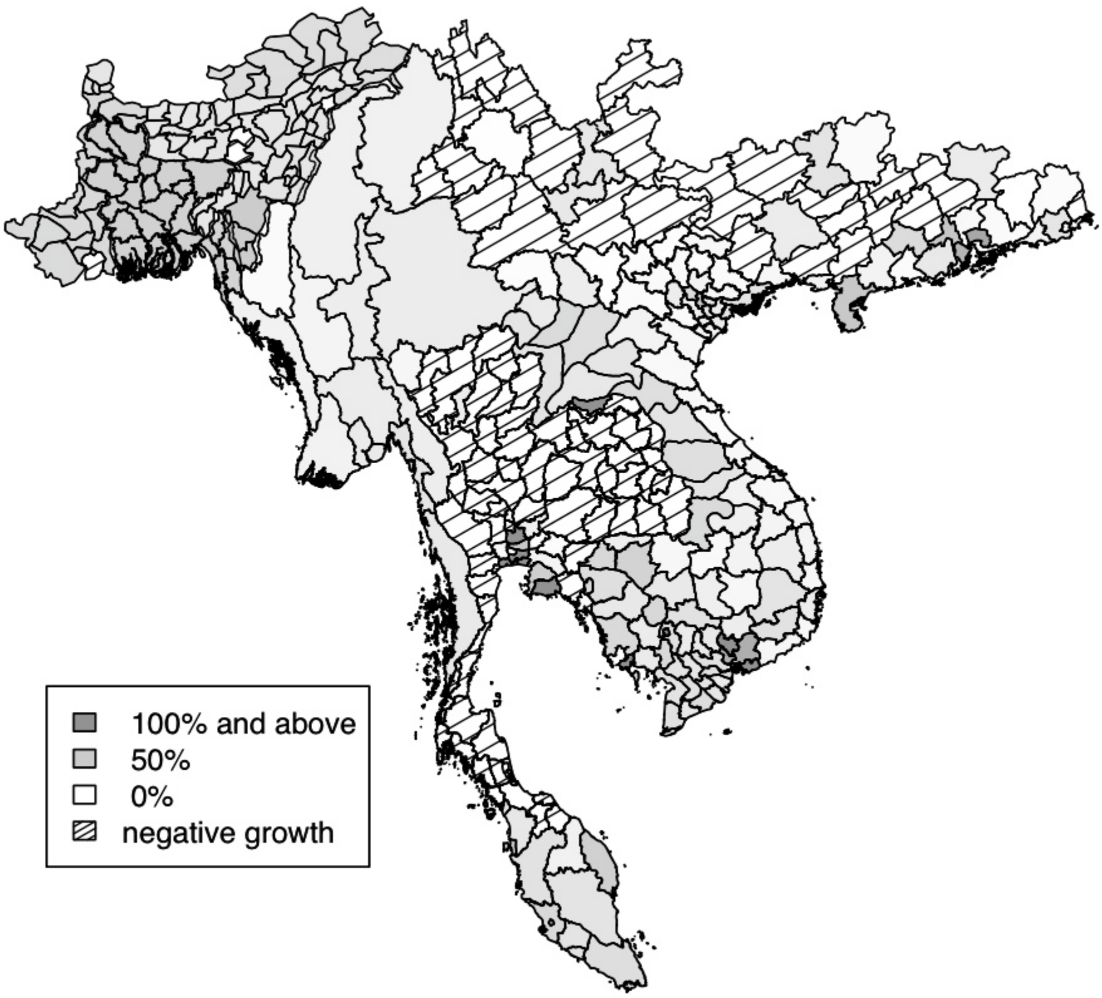
5.2.1 Baseline Scenario

Figure 2 shows population changes from 2005 to 2025 under the baseline scenario. A clear trend in the agglomeration of population can be seen. A few regions gain population such as those surrounding Bangkok, Ho Chi-Minh, andDongguan as well as Vientiane and Krong Preah Sihanouk.

However, some regions lose population such as those in Thailand (except those around Bangkok) and some in China. Thailand seems to be a *monocentric* country in 2025, and China seems to show clear "core-periphery" structure at that time.

[10] GSM is now under development, and various parameters must be carefully calibrated. Thus, absolute values in the population and GDP forecast are rough calculations, and their reliability is rather low. On the other hand, some qualitative results or "tendencies" reveled by the simulation are quite robust for a wide range of the parameters and have high levels of reliability.

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



Source: IDE-GSM Estimation.

Table 2 shows the population of the top 20 fastest growing regions of CSEA in 2025. Ba Ria-Vung Tau of Vietnam is expected to be the fastest growing region, multiplying its population 3.50 times in the years 2005 to 2025[11]. The Thai regions of Rayong (2.73 times) and Samut Sakhon (2.65 times) follow. These three regions are all near the

[11] GSM does not consider congestion in roads and the limitations in real estate for business and housing. These factors might lower the actual population of Bangkok in 2025 more than forecasted.

largest cities in each country, specifically Ho Chi-Minh and Bangkok[12].

Table 2: Populations of the Top 20 Fastest Growing Regions (2025)

Rank	Region	Country	Population(thousand) 2005	Population(thousand) 2025	Change
1	Ba Ria-Vung Tau	Vietnam	844	2,953	3.50
2	Rayong	Thailand	533	1,454	2.73
3	Samut Sakhon	Thailand	468	1,242	2.65
4	Krong Preah Sihanouk	Cambodia	256	650	2.54
5	Phnom Penh	Cambodia	1,212	2,908	2.40
6	Binh Duong	Vietnam	760	1,718	2.26
7	Dhaka	Bangladesh	6,477	13,099	2.02
8	Vientiane Capital	Laos	755	1,521	2.02
9	Samut Prakan	Thailand	1,040	2,080	2.00
10	Phra Nakhon Si Ayutthaya	Thailand	739	1,474	1.99
11	Dongguan	China	10,199	18,413	1.81
12	Kuala Lumpur	Malaysia	1,474	2,600	1.76
13	Dong Nai	Vietnam	2,111	3,698	1.75
14	Ranpur	Bangladesh	5,338	9,328	1.75
15	Comilla	Bangladesh	7,189	12,124	1.69
16	Medinipur	India	5,475	8,386	1.53
17	Pathum Thani	Thailand	686	1,045	1.52
18	Hanoi	Vietnam	2,837	4,323	1.52
19	Zhanjiang	China	1,267	1,923	1.52
20	Aizawl	India	661	984	1.49

Source: IDE-GSM estimation.

Table 3 shows the GDP of the top 20 richest regions of CSEA in 2025. Hong Kong is expected to keep the top position during the period. Bangkok is estimated to have the largest economy in ASEAN by 2025, surpassing Singapore. Singapore is expected to remain one of the largest economies in the region followed just behind by Dongguan in China. Some regions in Thailand and Vietnam also rise significantly in rank.

[12] Note that regions, not cities, are considered in these population estimates. There are seven regions of Myanmar in the top 20 list. This is partly because the administrative district in Myanmar is larger than in other CSEA countries. This is a prime reason why unified territorial units for geographical statistics are indispensable for properly conducting this kind of international comparison.

Table 3: GDP of Top 20 Richest Regions in 2025

Rank 2025	Rank 2005	Region	Country	GDP(million USD) 2005	GDP(million USD) 2025	Change
1	1	Hong Kong	China	212,802	905,839	4.26
2	3	Bangkok Metropolis	Thailand	48,333	437,816	9.06
3	2	Singapore	Singapore	105,141	264,961	2.52
4	4	Dongguan	China	33,587	242,005	7.21
5	5	Zhongshan	China	23,511	145,793	6.20
6	7	Foshan	China	13,557	80,268	5.92
7	16	Rayong	Thailand	7,184	78,987	10.99
8	6	Selangor	Malaysia	20,203	68,769	3.40
9	10	Samut Prakan	Thailand	10,020	68,699	6.86
10	9	Kuala Lumpur	Malaysia	11,735	49,639	4.23
11	35	Samut Sakhon	Thailand	4,635	45,843	9.89
12	13	Macao	China	8,253	41,289	5.00
13	45	Ba Ria-Vung Tau	Vietnam	3,523	39,759	11.29
14	20	Chon Buri	Thailand	6,837	38,474	5.63
15	11	Kunming Shi	China	8,865	38,203	4.31
16	23	Ho Chi Minh	Vietnam	6,335	36,697	5.79
17	29	Phra Nakhon Si Ayutthaya	Thailand	5,491	36,088	6.57
18	8	Johor	Malaysia	12,487	36,033	2.89
19	14	Jiangmen	China	8,030	33,586	4.18
20	17	Nanning	China	7,068	31,774	4.50

Source: IDE-GSM estimation.

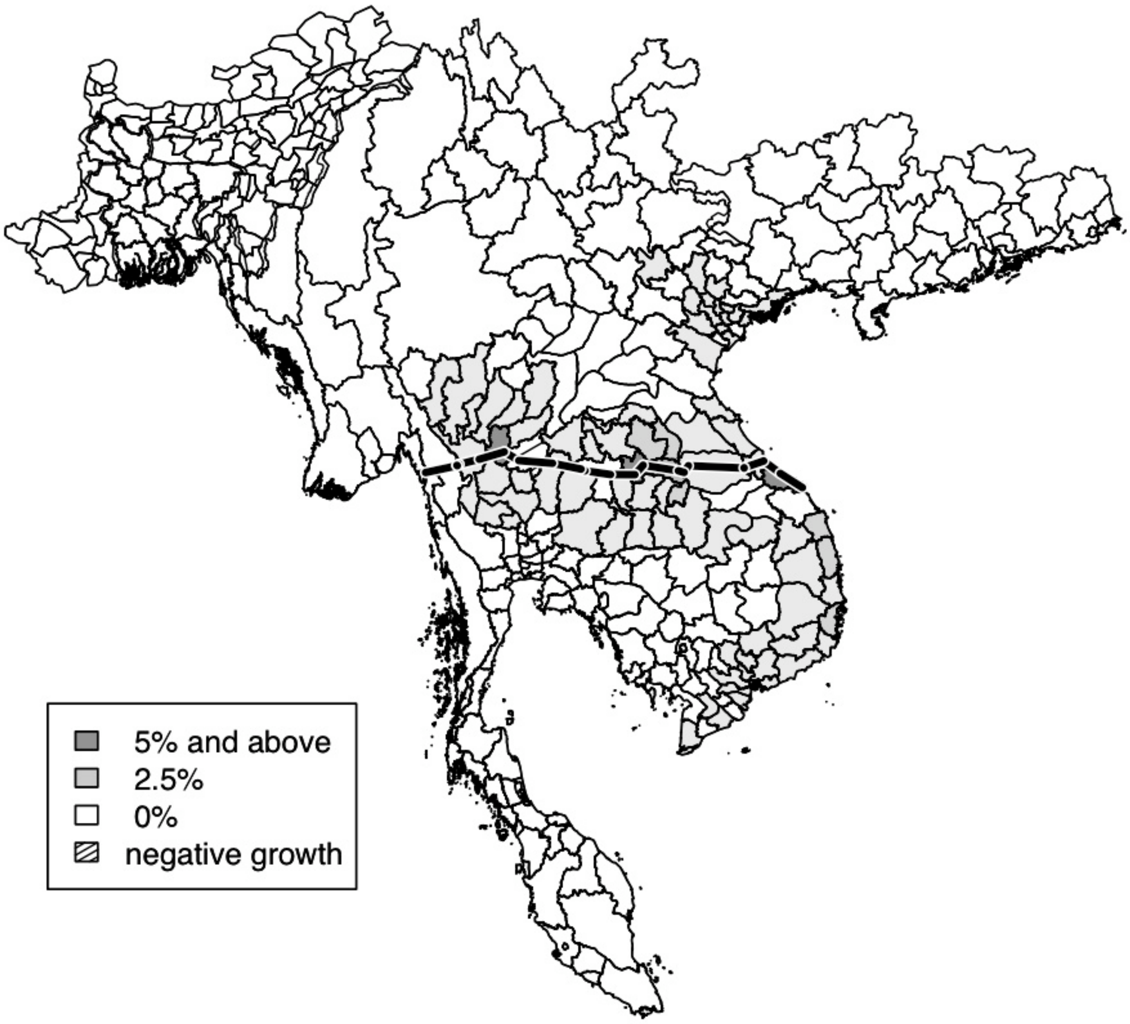
The baseline simulation shows that principal cities and the regions surrounding them gain more population; a "core-periphery" structure appears in most CSEA countries. Areas along the periphery of Thailand and China are expected to lose population, and intra-country disparity may be a severe problem.

5.2.2 The East West Economic Corridor (Physical Infrastructure Only)

Effects of the EWEC (physical infrastructure only) can be seen in this part of the study. Figure 3 compares this scenario and the baseline scenario in terms of GDP reached by

2025. Table 4 lists the top 10 regions in terms of gain in GDP, again comparing this scenario and the baseline. When compared with the baseline, the top gainer in GDP is Kalasin of Thailand (9.6 percent, compared with the baseline)[13]. The EWEC mainly benefits Northern Thailand, Vietnam, and some part of Laos. However, the degree of benefit is relatively low.

Figure 3: GDP Difference (2025). EWEC (Physical Infrastructure) vs. Baseline



Source: IDE-GSM estimation.

13 Note that GDP's are nominal and equated in US dollars.

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

Rank	Region	Country	GDP(mil. USD) baseline	GDP(mil. USD) EWEC	Gain
1	Kalasin	Thailand	1,311	1,438	9.6%
2	Thua Thien-Hue	Vietnam	773	837	8.3%
3	Sukhothai	Thailand	1,178	1,251	6.1%
4	Mukdahan	Thailand	524	541	3.2%
5	Da Nang	Vietnam	1,146	1,179	2.9%
6	Binh Dinh	Vietnam	1,452	1,487	2.4%
7	Khanh Hoa	Vietnam	1,492	1,527	2.3%
8	Quang Ngai	Vietnam	895	915	2.2%
9	Nakhon Phanom	Thailand	951	971	2.2%
10	Sakon Nakhon	Thailand	1,398	1,426	2.0%

Source: IDE-GSM estimation.

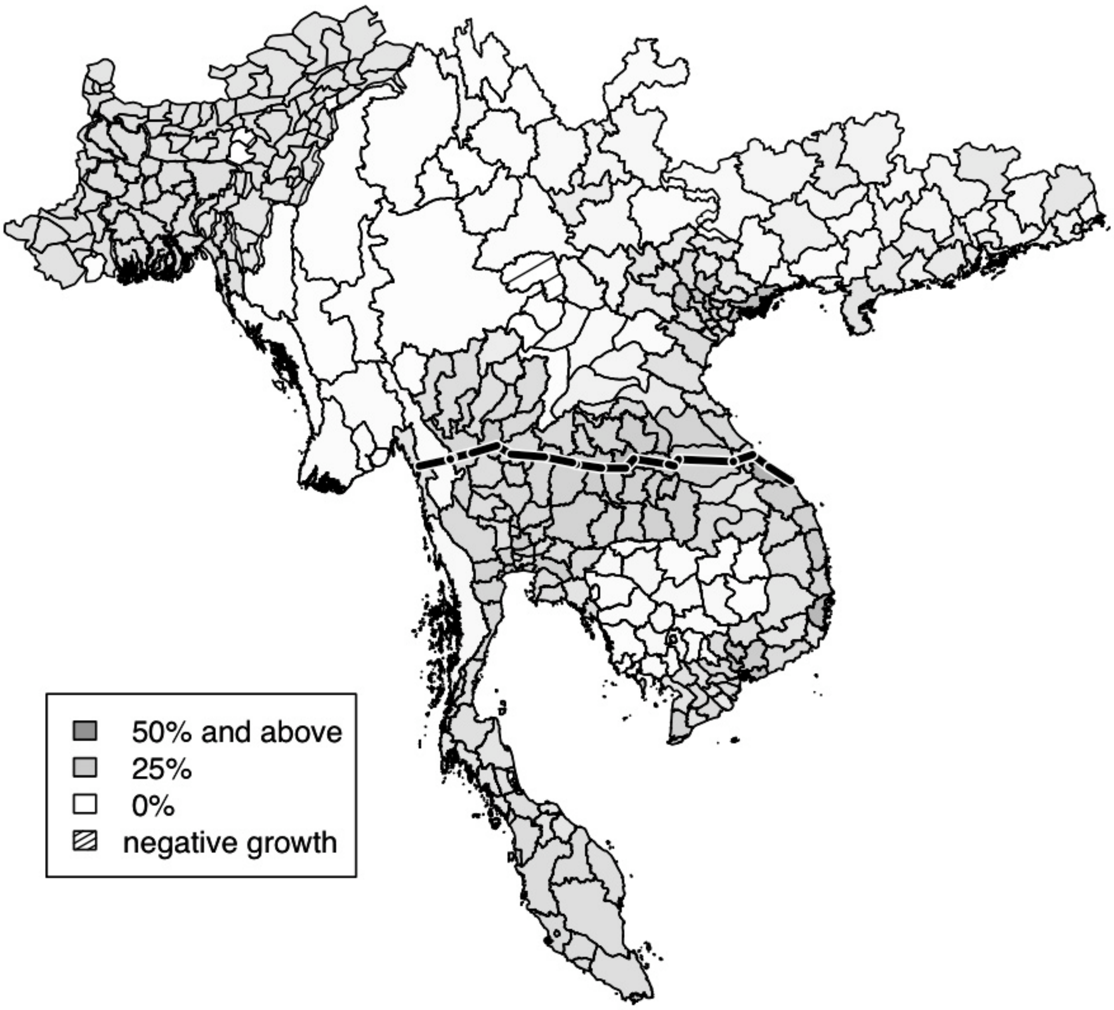
This result is understandable. Wasting time at customs clearance prevents the EWEC from benefiting from crossing national borders. Rather, only transactions within each country are facilitated.

5.2.3 The East West Economic Corridor with Customs Facilitation

Figure 4 shows differences up to 2025 in GDP between EWEC with customs facilitation and the baseline scenario. Table 5 lists the top 10 gainers in GDP for this scenario relative to the baseline. The top gainer in GDP is Da Nang of Vietnam (gaining 37.3 percent) when compared with the baseline[14]. The EWEC mainly benefits Vietnam, Northern Thailand, and some part of Laos. What is interesting is that geographical periphery of the region (specifically West India and Bangladesh, the Malay Peninsula, and Guangxi and Guandong provinces of China) benefits from the EWEC. This is because the EWEC reduces transport costs across all regions by going through four countries located in the center of CSEA.

[14] Note that GDP's are nominal and equated in US dollars.

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



Source: IDE-GSM estimation.

Table 5: Top 10 Gainers in GDP by EWEC (with Customs Facilitation, 2025)

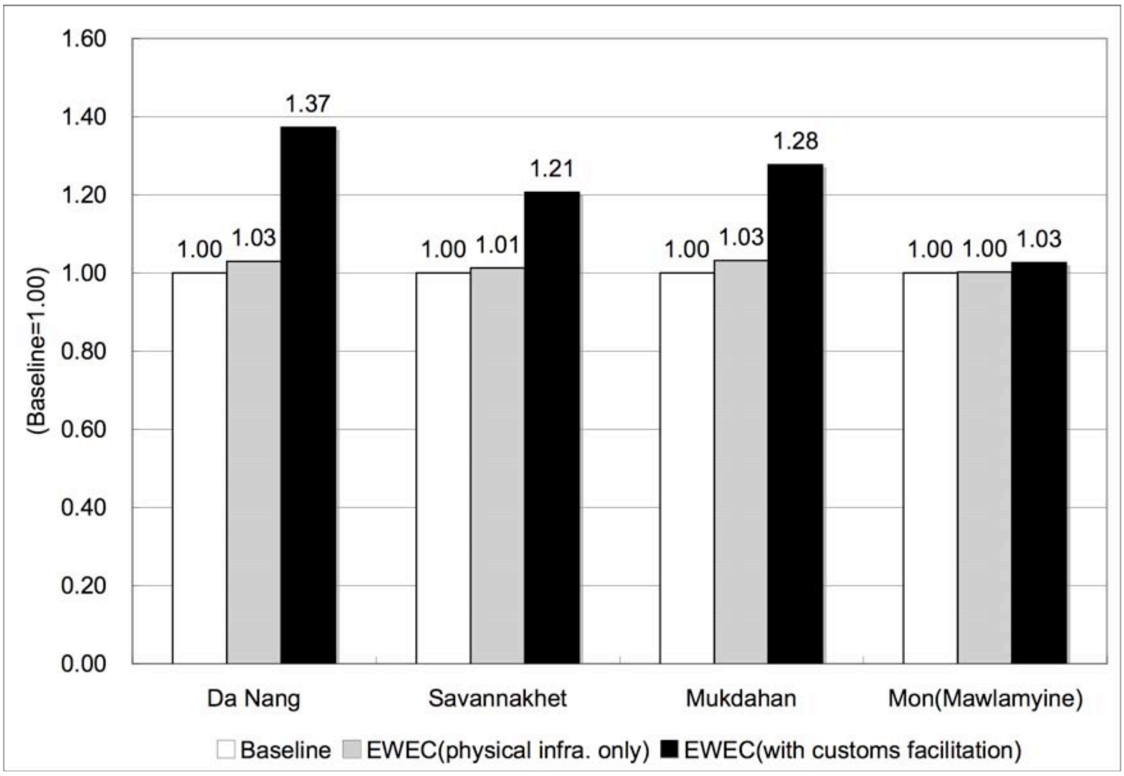
Rank	Region	Country	GDP(mil. USD) baseline	EWEC	Gain
1	Da Nang	Vietnam	1,146	1,573	37.3%
2	Thua Thien-Hue	Vietnam	773	1,054	36.3%
3	Kalasin	Thailand	1,311	1,751	33.5%
4	Khanh Hoa	Vietnam	1,492	1,978	32.6%
5	Quang Ninh	Vietnam	1,998	2,588	29.5%
6	Hanoi	Vietnam	8,158	10,426	27.8%
7	Ba Ria-Vung Tau	Vietnam	39,759	50,778	27.7%
8	Mukdahan	Thailand	524	669	27.7%
9	Ho Chi Minh	Vietnam	36,697	46,542	26.8%
10	Haiphong	Vietnam	2,976	3,749	26.0%

Source: IDE-GSM estimation.

5.3 Checking the effects of physical infrastructure and customs facilitation

The degree of benefit from physical infrastructure and customs facilitation respectively can be seen when comparing gains in GDP by scenario for specific cities along the EWEC. Figure 5 shows gains in GDP for three scenarios: (1) baseline, (2) EWEC (physical infrastructure only), and (3) EWEC with customs facilitation. With only the physical infrastructure, the EWEC affects regions very little. The EWEC increases Da Nang's GDP by only three percent and other regions less than that. On the other hand, the EWEC with both physical infrastructure and customs facilitation benefits regions along the way relatively well. It increases Da Nang's GDP by 37 percent and the GDP of Savannakhet's and Mukudahan's by 21 percent and 28 percent respectively. The GDP of Mon, Myanmar increases only three percent.

Figure 5: Gains in GDP by Scenario for Selected Regions in 2025



Source: IDE-GSM estimation.

5.4 Checking Sensitivity of the Results to Some Parameter Changes

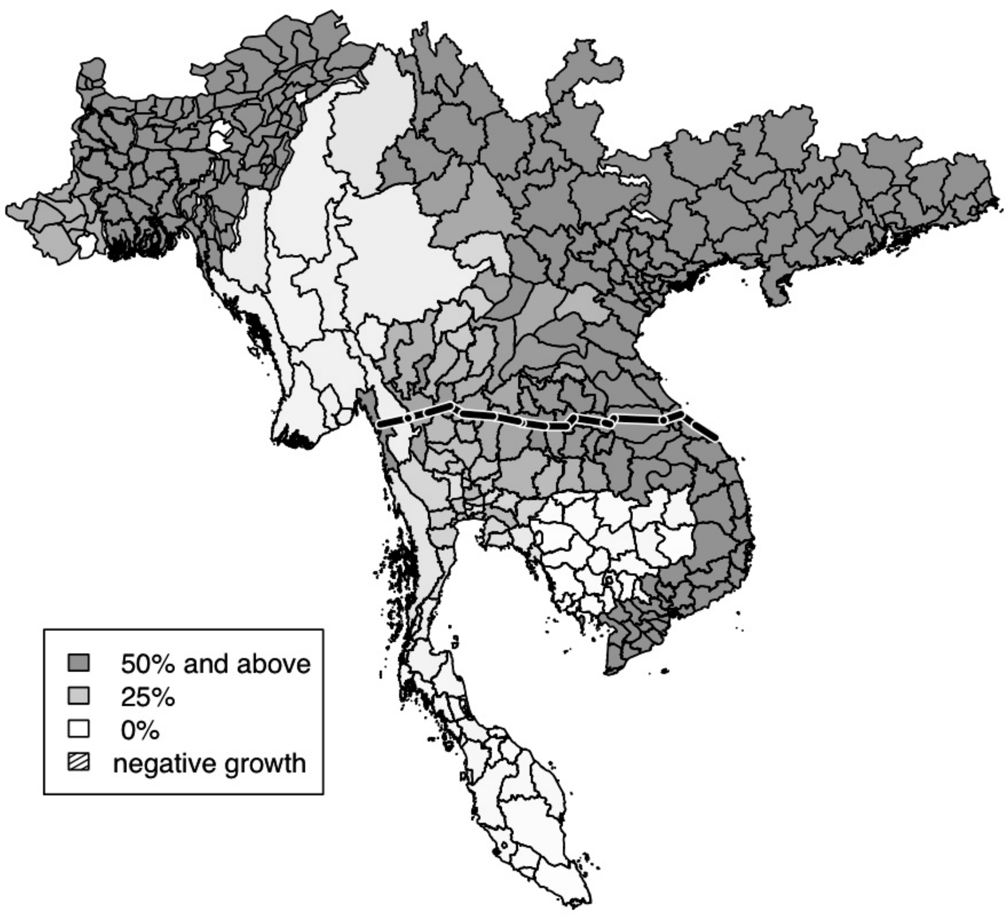
A quick check was also conducted on the sensitivity of economic effects within the EWEC to parameter changes. In resulting simulations, the cost of moving manufactured goods was assumed to be less expensive (T_M=1.05) and highly differentiated (σ_M =3.0). The following settings were tested:

(1) Manufactured goods are assumed to be costly to move (T_M=1.20).
(2) Manufactured goods are less differentiated (σ_M =5.0).

5.4.1 Manufactured Goods Costly to Move

Figure 6 shows the economic effects of the EWEC (with customs facilitation) in the case where manufactured goods are costly to move (T_M=1.20; other parameters unchanged). This is the case where goods are sensitive to the time of delivery, and the value of goods "melts" rapidly. If needed automotive parts arrive just in time, then goods lose their value rapidly as time passes in route. Table 6 lists the top 10 gainers in GDP by EWEC. The top gainer in this setting is Da Nang of Vietnam. It is unchanged relative to the case where T_M=1.05. However, the degree of gain is surprisingly much higher (209 percent). The EWEC mainly benefits Vietnam, Northern Thailand, and some part of Laos. In addition, West India and Bangladesh, and the Guangxi and Guandong provinces of China benefit; the Malay Peninsula does not.

Figure 6: Difference in GDP (2025). EWEC (with Customs Facilitation) vs. Baseline (T_M=1.20)



Source: IDE-GSM estimation.

Table 6: Top 10 Gainers in GDP by EWEC (with Customs Facilitation, 2025); T_M=1.20

Rank	Region	Country	GDP(mil. USD) baseline	GDP(mil. USD) EWEC	Gain
1	Da Nang	Vietnam	1,313	4,057	208.9%
2	Hanoi	Vietnam	11,270	32,748	190.6%
3	Thua Thien-Hue	Vietnam	854	2,471	189.2%
4	Quang Ninh	Vietnam	2,670	7,602	184.7%
5	Vinh Phuc	Vietnam	3,283	9,065	176.1%
6	Haiphong	Vietnam	3,856	10,636	175.9%
7	Bac Ninh	Vietnam	1,872	5,037	169.1%
8	Phu Tho	Vietnam	2,106	5,655	168.5%
9	Zhanjiang	China	31,594	84,585	167.7%
10	Thai Nguyen	Vietnam	1,231	3,245	163.6%

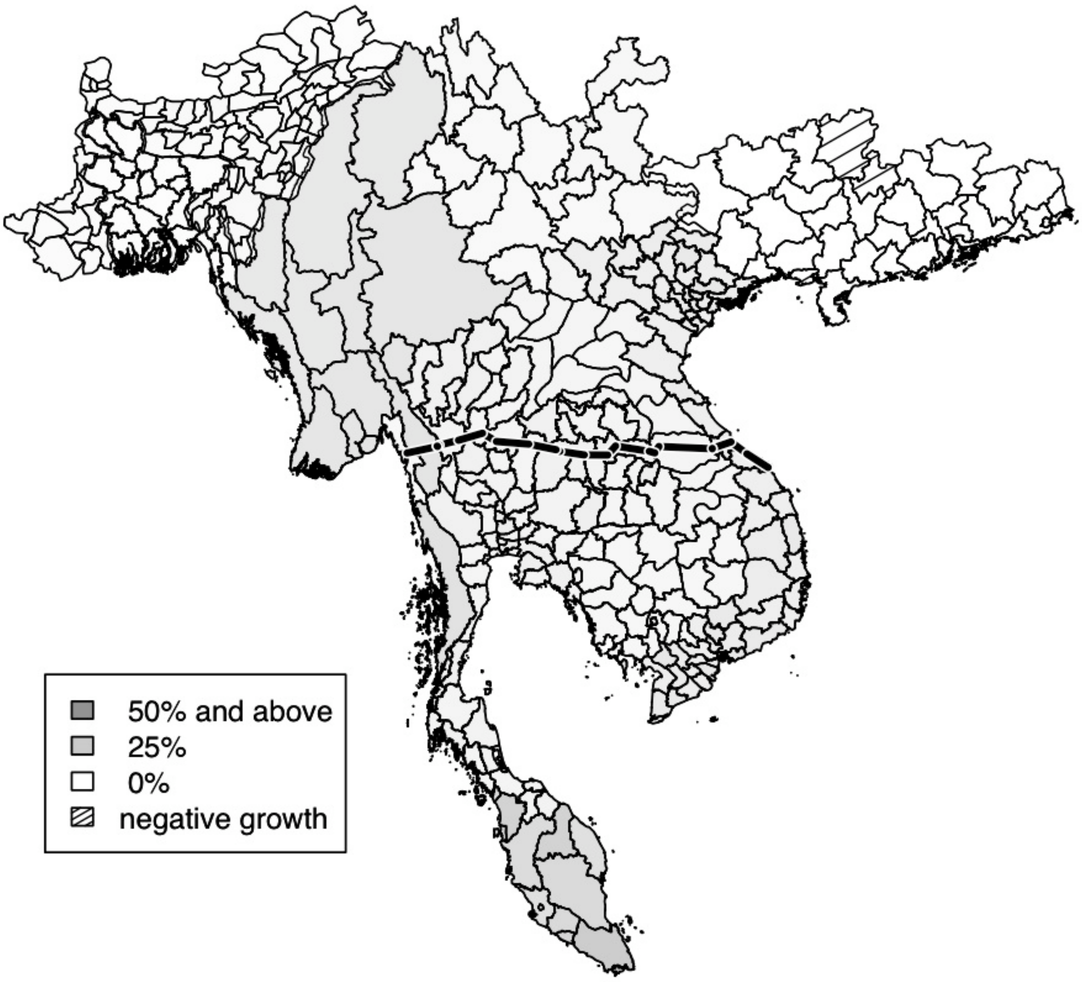
Source: IDE-GSM estimation.

By changing T_M from 1.05 to 1.20, several tendencies in the economic effects of the EWEC can be seen. First, for almost all regions, the degree of benefit from the EWEC is much higher where T_M=1.20. It is natural to believe that the benefit of the transport infrastructure is larger when the transport costs of manufactured goods are larger. Second, most regions in Cambodia do not benefit from the EWEC, regardless of the change in T_M. Myanmar also does not benefit much from the EWEC in both cases. Third, in the geographical periphery of CSEA, Guangxi and Guandong provinces of China benefit somewhat more from the EWEC when T_M=1.20, while the Malay Peninsula benefits more from the EWEC when T_M=1.05. It is not clear why this is the case.

5.4.2. Less Differentiated Manufactured Goods

Figure 7 shows the economic effects of the EWEC (with customs facilitation), in the case where manufactured goods are less differentiated (σ_M =5.0 with other parameters unchanged). Table 7 lists the top 10 gainers in GDP by EWEC in this setting. The top gainer is Thua Thien-Hue of Vietnam that gains a GDP of 25 percent. This is then followed by Da Nang.

Figure 7: GDP Difference (2025). EWEC (with Customs Facilitation) vs. Baseline; σ_M **=5.0**



Source: IDE-GSM estimation.

Table 7: Top 10 Gainers in GDP by EWEC (with Customs Facilitation, 2025); σ_M =5.0

Region	Country	GDP(mil. USD) baseline	GDP(mil. USD) EWEC	Gain
Thua Thien-Hue	Vietnam	676	848	25.36%
Da Nang	Vietnam	957	1,187	24.10%
Khanh Hoa	Vietnam	1,250	1,517	21.33%
Quang Ninh	Vietnam	1,643	1,993	21.31%
Hanoi	Vietnam	6,752	8,086	19.75%
Ba Ria-Vung Tau	Vietnam	32,565	38,388	17.88%
Kalasin	Thailand	1,152	1,354	17.57%
Haiphong	Vietnam	2,534	2,976	17.45%
Ho Chi Minh	Vietnam	30,278	35,430	17.02%
Vinh Phuc	Vietnam	2,127	2,480	16.58%

Source: IDE-GSM estimation.

Compared with the original case, the degree of gain is a bit lower for almost all regions, while the economic effects of the EWEC seem to be dispersed. Myanmar and Cambodia, the two countries that benefit less from the EWEC in the original setting, also gain in GDP with this setting.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1. Findings

6.1.1 Border Costs Play a Big Role

A major 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 regions. Physical infrastructures such as roads and railways are not enough to aid in the development of regions. In the simulations, elimination of border costs seems to be much more effective than development of physical infrastructure.

6.1.2 Nominal Wages Matter More than Expected

Another significant finding is that the difference in nominal wages is an important determinant of agglomeration. In CSEA, there is quite a large difference in nominal wages, not only inter-nationally but also intra-nationally. It is so large that small advantages in location cannot counter the centripetal force of some central regions that induces the inflow of population and is caused by higher nominal wages.

According to the study, Bangkok and its satellite regions, Ho Chi-Minh and its satellite regions, and other capital cities and surrounding regions provide higher nominal wages than the national average, and most of these have location advantages as well. Bangkok should be especially noted as a robust "core" having both higher nominal wages and advantages in location.

However, the importance of initial differences in nominal wages does not mean that spatial economics makes no difference. On the contrary, the development of infrastructure has the power to balance the regional inequality caused by initial differences in nominal wages, at least to some extent. As shown in the previous section, the EWEC tends to draw populations from the Bangkok metropolis to Northern Thailand and diverse populations from Vientiane to Savannakhet.

6.2. Policy Implications

6.2.1 Reduction in Border Costs

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

A possible way to reduce these “border costs” is to introduce the East Asian Common Radio Frequency Identification (RFID) System for Logistics. The RFID functions similarly to barcodes but can be read without being touched. Thus, it is possible to read multiple RFID’s at once and to check the contents of cargo without opening it. This system is expected to dramatically reduce lead-time and improve the ability to trace international transactions, thus contributing to further develop of effective “fragmentation” of production processes.

6.2.2 Establishment of an International Body of Planning and Coordination for Infrastructure Development

This study takes into consideration that the EWEC, NSEC, and SEC are highly complementary projects. By implementing all three, most of the regions in the Greater Mekong sub region may benefit from development. However, Myanmar is an exception. Although a few regions in Myanmar benefit from these economic corridors, the degree of the benefit is relatively small, and most of its regions do not benefit at all.

Such implications are not meant to be pessimistic regarding Myanmar’s economic development. On the contrary, Myanmar has a naturally high potential for economic growth in the baseline scenario. However, to enhance its economic development, some plan for an economic corridor is needed.

Coordination is required to plan and implement the development of infrastructures in CSEA. So, it is highly desirable to set up an international body for planning and coordinating development of infrastructure in East Asian counties.

6.3. Directions for Future Research

This study proposes analyses using the IDE-GSM and shows its potential as a tool of simulation. However, this is only a starting point, and there are two main issues to be addressed:

6.3.1 Further Accumulation of Sub-National Statistics

First, more precise regional economic and demographic data is needed at the sub-national level in each country and sub-provincial level in China and India. Specifically, the establishment of uniform territorial units for geographical statistics in East Asia is crucial. Without such uniform territorial units, various statistics cannot be compared directly across countries. For example, it is not proper to compare the concentration of populations at the "state" level in Malaysia versus those at the "provincial" level in China. In Europe, Eurostat established the Nomenclature of Territorial Units for Statistics (NUTS) more than 25 years ago. NUTS enables geographical analysis and formation of regional policies based on a single uniform breakdown of territorial units for regional statistics. An East Asian counterpart of NUTS (perhaps called EA-NUTS) seems necessary as well. With EA-NUTS, basic social and economic information such as population, GDP, industrial structure, and employment by sector for each sub-region could be collected or re-compiled from existing data sets obtained from statistical departments of member countries.

Second, more precise data on routes and infrastructures connecting regions is needed. Information on the main routes between regions such as physical distance, time distance, topology, and mode of transport (road, railway, sea, and air) appears indispensable. Data on "border costs" such as tariffs and time-costs due to inefficient customs clearance seems crucial. It might be necessary to measure and continuously update information on routes and border costs by conducting experimental distributions of goods and actual drives[15].

[15] Such a study was conducted by JETRO in 2007.

6.3.3 Further Refinement and Extension of the Model

In addition to collecting geographical data, it is necessary to refine and extend the IDE-GSM itself. Among various issues to be addressed, there are two that have priority:

First, the IDE-GSM has only three sectors: (1) agriculture, (2) manufacturing, and (3) service. It is useful to divide the manufacturing sector into sub-sectors such as electronics, automotive, or garment industries. Incorporating multiple manufacturing sectors enables analysis of the impact of specific infrastructure development projects on industrial agglomerations.

Second, at present, the IDE-GSM only considers land transport and ignores other modes of transportation. However, if the scope of the model is expanded from CSEA to all of East Asia, air and sea transport must be considered. In that case, “mode-choice” must be incorporated in the model.

Third, parameters used in the test simulations are all based on assumptions. To conduct more precise analyses, each parameter must be identified correctly.

The IDE-GSM is the first generation of models that incorporate factors of economic geography. It needs to be refined and extended further. However, the test simulation reported here shows its potential and makes future directions for the development of such models clear.

Appendix: DETAILS OF THE MODEL

Nominal Wages in the Agricultural Sector

The production function for the 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 production at location *r*, $L_A(r)$ the labor input, and $F(r)$ the area of arable land at location *r*. α is labor input share. Thus, nominal wages of the sector may be expressed as follows:

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

GDP

Firms engaging in production activity at location *r* set the price of manufactured goods as $p_M(r) = w_M(r)^{\beta} G_M(r)^{1-\beta}$, where $w_M(r)$ is the nominal wage of the manufacturing sector at location *r*, and $G_M(r)$ is the price index of manufacturing goods and represents intermediate input. β is labor input share (see Equation 14.1 on p. 242 of Fujita-Krugman-Venables, hereafter FKV). Here, the marginal input requirement is supposed to equal the price-cost markup.

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 nominal wages and labor input of sector *x* at location *r*. Note that the output of the agricultural sector is traded at no cost between any two regions and is chosen as the numeraire (see Equation 14.11 on p. 244 of FKV).

Output in the Manufacturing Sector

The output for final consumption and for intermediate input (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 share of expenditures on manufacturing goods (see Equation 14.10 on p. 244 of FKV).

Price Index

The price indices of manufactured and service goods are derived from Equation 14.6 on p. 243 of FKV and are, respectively, as follows: .

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

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

Nominal Wages in the Manufacturing Sector

Nominal wages in the manufacturing sector may be expressed as follows:

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

where $A_M(r)$ is the efficiency of production for manufactured goods at location *r*, and σ_M is the elasticity of substitution between any two differentiated manufactured goods.

Nominal Wages in the Service Sector

Nominal wages in the service sector are expressed as follows:

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

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

Average Real Wage among sectors

Real wages at location r may be expressed as follows:

$$\omega(r) = \frac{s_A(r)w_A(r) + s_M(r)w_M(r) + s_S(r)w_S(r)}{G_M(r)^{\mu} G_S(r)^{\nu}}. \tag{8}$$

where $S_I(r),\ I \in (A, M, S)$ is the employment share of industry *I* at location *r*.

This is derived from Equation 14.8 on p. 243 of FKV.

Three population shares

The poulation share for a region in country *c* is

$$\lambda(r) = \frac{L_A(r) + L_M(r) + L_S(r)}{\tilde{L}_A(c) + \tilde{L}_M(c) + \tilde{L}_S(c)} \tag{9}$$

where $L_I(r),\ I \in (A, M, S)$ is the number of employee of industry *I* at location *r*, and $\tilde{L}_I(c),\ I \in (A, M, S)$ is the number of employee of industry *I* at country *c* in which location *r* belongs.

The population share for a country in all country is

$$\tilde{\lambda}(c) = \frac{\tilde{L}_A(c) + \tilde{L}_M(c) + \tilde{L}_S(c)}{\sum_{s=1}^{N_c} (\tilde{L}_A(s) + \tilde{L}_M(s) + \tilde{L}_S(s))} \tag{10}$$

where N_c is the number of countries.

The population share for an industry within a country is

$$\lambda_I(r) = \frac{L_I(r)}{L_A(r) + L_M(r) + L_S(r)}. \tag{11}$$

Population Dynamics

- Intra Country Population Dynamics can be expressed as follows:

$$\dot{\lambda}(r) = \gamma_c \left(\frac{\omega(r)}{\overline{\omega}(c)} - 1 \right) \lambda(r) \tag{12}$$

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

- Inter Country Population Dynamics is expressed as follows:

$$\dot{\tilde{\lambda}}(c) = \gamma_w \left(\frac{\overline{\omega}(c)}{\overline{\omega}_w} - 1 \right) \tilde{\lambda}(c) \tag{13}$$

where $\dot{\tilde{\lambda}}(c)$ is the change in the labor (population) share for a country, and γ_w is the parameter for determining the speed of immigration between countries.

- Inter Industry Population Dynamics may be expressed as follows:

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

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

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

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