On A Korean Reunification*

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Abstract

This paper constructs an overlapping generations model of general equilibrium with two regions and examines the macroeconomic impacts of economic integration between North Korea and South Korea. Depending on factor mobility, three hypothetical integration types are explored. We find that South Korea's income per capital falls about 15 to 30 percent during the first decade after economic integration. The integration type wherein both capital and labor markets are open shows better outcomes in terms of per capita income. Finally, we show that the regime to open up both capital and labor markets hampers regional development in North Korea by concentrating all economic activity on South Korea.

Keywords: Korean Unification, Economic Integration, Overlapping Generations Model

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1 Introduction

This study examines the macroeconomic impacts of economic integration between North Korea and South Korea. To quantitatively evaluate the effects, we construct an overlapping-generations model with two regions in which households are subject to idiosyncratic income risk. The focus is on the transitional dynamics of the model economy following economic integration.

We investigate and compare three different types of economic integration. The first is the benchmark type, in which capital is mobile but people are not allowed to move between regions. In this first type, interest rates are equal across regions but wages are different. In the second type of economic integration, we open up the labor markets and allow people to move across regions. Both wages and interest rates are equal. Finally, in the third type of integration, we shut down the capital markets and neither capital nor labor is mobile across the two regions. When the capital markets are closed, North Korea's interest rate is enormously high because of a very low level of capital compared with the productivity level, but South Korea's interest rate is rarely changed.

An economic integration proceeds, investments in infrastructure financed from fiscal transfers made by South Korea increase the productivity level in North Korea, thereby enhancing the latter's catch-up process in terms of income per capita. For the baseline case, it is assumed that South Korea has provided the subsidies for 30 years, and that the productivity level in North Korea reached 90 percent of South Korea's productivity level. The initial level in North Korea is assumed to be about 20 percent of that in South Korea.

Our model delivers two main results. First, South Korea's income per capita falls about 15 to 30 percent during the first decade after economic integration. Second, income per capita in the integration type of opening-up the labor markets is higher than in other integration types on the transitional dynamics.

Although per capita income does not fall much further when the labor markets are open, North Korea grows at a much slower pace. A low level of productivity causes capital and labor to stream out of North Korea and concentrate on South Korea. Hence, we argue that the

regime to open up both capital and labor markets may hamper regional development in North Korea.

There are numerous studies that analyze the impacts of Korean unification in the general equilibrium setup. Among others, Noland et al. (2000) construct a two-country computable general equilibrium model (CGE) of Korean economic integration and examine various issues such as product market integration and factor market integration in a comparative static framework. Funke and Strulik (2005) use a two-region endogenous growth model to investigate the macroeconomic impacts of unification. More recently, St. Brown et al. (2012) study the economic impacts of hypothetical economic integration by calibrating a catch-up growth model and examine issues involving labor migration and capital transfers. [1]

There are also several studies that explore the issues associated with opening-up the labor markets. Among others, Chun (2012) employs the data on East-West German migration after unification and estimates that more than one million North Koreans cross the border into South Korea. This size is comparable with the current size of foreign workforce in South Korea. He concludes that the effects of migration will be significant.

Of course, this paper is a complement to other approaches to the Korean unification issue. However, we take a novel approach in which an overlapping generations model of general equilibrium with heterogeneous households is constructed and the transitional dynamics of the model economy is examined. This approach is particularly useful in analyzing the distributional effects of government transfers.

This paper is organized as follows. Section 2 presents the model and describes the integration types to be examined. Section 3 discusses the calibration and parameterizations. Section 4 provides the steady-state properties of the model economy. Section 5 presents the simulation results and compares the benchmark integration type with other integration types. Section 6 deals with some issues involving institutions and concludes.

2 Model

[1] An excellent summary is provided in Wolf and Akramov (2005).

We use a standard dynamic general equilibrium, life-cycle model with a novel feature: the model economy consists of two separate regions of the North and the South. Households supply factors of production, such as labor, capital and land, and receive income payments in exchanges for their services. Perfectly competitive firms combine capital, labor and land using a constant returns-to-scale technology to produce output.[2] The government taxes wages, capital income, land rent to finance government expenditures.

2.1 Households

The economy of region $i \in \{N, S\}$ is populated by overlapping generations of households of age $j = 1,2,\cdots,J$. Each household is assumed to consist of one person. The lifespan may be uncertain; thus, households of age j can survive until the next period with probability ψ_j. Households remain employed in the market until the mandatory retirement age, denoted by j_w. No altruism is assumed, so accidental bequests are collected by the government and distributed as a lump-sum transfer to the entire population. Each household is endowed with an equal amount of land, denoted by λ_i, and supply to firms at the given rental rate.

Each household in region i has the utility function given by

$$E\left[\sum_{j=1}^{J} \beta^{j-1} \frac{\left(c_j^{\gamma} \ell_j^{1-\gamma}\right)^{1-\sigma}}{1-\sigma}\right], \tag{1}$$

where β denotes a discount factor, c_j denotes consumption, and ℓ_j denotes leisure. The expectation is with respect to uncertainty in longevity and time-varying labor productivity shocks. In each period, households have an endowment as one unit of time. When a household is working, household's earnings are given as $w_i x e h_j$, where w_i is the market wage rate in region i, x is the household's time-varying labor productivity, e is returns to

[2] We assume that all firms produce the same final good, and thus we do not consider trade between the two regions.

years of schooling, and h_j is the household's hours of work that are endogenously chosen.[3] Time-varying productivity follows an AR(1) process in logs expressed as

$$\ln x' = \rho_x \ln x + \varepsilon', \tag{2}$$

where ε is a normal random variable with zero mean and variance σ_x^2.

Following Bewley (undated), Huggett (1993) and Aiyagari (1994), markets are assumed to be incomplete, and thus, households cannot insure themselves against labor productivity and mortality risks by trading Arrow-type securities. Moreover, households are not allowed to borrow. However, they are allowed to accumulate one-period riskless assets to self-insure themselves against uncertainty.

The budget constraints that a household of age $j(\leq j_w)$ faces are given by

$$c_j + a_{j+1} = [1 + (1 - \tau_i)r_i]a_j + (1 - \tau_i)w_i x e h_j + (1 - \tau_i)p_i\lambda_i + tr_i \tag{3}$$

$$a_{j+1} \geq 0, \tag{4}$$

where a_{j+1} is savings, a_j is the current asset holdings, r_i is the interest rate, τ_i is the tax rate on earnings, p_i is the rental price of land, λ_i is the land supply, and tr_i is transfer payments from the government. The second constraint states that borrowing is not allowed.

The budget constraints that a retiree of age $j(\geq j_w + 1)$ faces are given by

$$c_j + a_{j+1} = [1 + (1 - \tau_i)r_i]a_j + (1 - \tau_i)p_i\lambda_i + tr_i \tag{5}$$

$$a_{j+1} \geq 0, \tag{6}$$

2.2 Firms

Competitive firms produce output according to a constant returns-to-scale technology of the three factors of production, namely, capital, labor and land as expressed in

$$Y_i = Z_i K_i^{\alpha} H_i^{\theta} L_i^{1-\alpha-\theta}, \tag{7}$$

[3] For South Korea, e is normalized to unity.

where Y_i denotes aggregate output, K_i denotes the aggregate capital input, H_i denotes the aggregate labor input, L_i denotes the aggregate land input, and Z_i denotes a parameter representing the level of productivity. Parameter α is the capital share, and θ is the labor share. Given that the technology exhibits a constant returns-to-scale, all firms can be represented by a single firm. The representative firm rents capital and land, and hires labor from households in competitive factor markets. We assume that land is a fixed input and not a mobile factor.

The profit-maximization conditions for the representative firm are given by

$$r_i + \delta = \alpha \frac{Y_i}{K_i}, \tag{8}$$

$$w_i = \theta \frac{Y_i}{H_i}, \tag{9}$$

$$p_i = (1 - \alpha - \theta) \frac{Y_i}{L_i}, \tag{10}$$

where δ denotes the capital depreciation rate. The capital stock evolves according to the law of motion given by

$$K_i' = (1 - \delta)K_i + I_i. \tag{11}$$

2.3 Government

We assume that each region has its own set of self-governing local authorities that are responsible for income redistribution through taxes and transfers. Each government levies a proportional tax on the households' income. The households' income is comprised by the earnings from the three factors of production (i.e., capital, labor, and land), and all taxes are borne by households based on the earnings from those factors. We also assume that all earnings are taxed at the same rate, denoted by τ_i. Aggregate tax revenues can thus be expressed as

$$T_i = \tau_i(r_i A_i + w_i H_i + p_i L_i), \tag{12}$$

where A_i is aggregate assets, H_i is the aggregate labor, and L_i is aggregate land, respectively.

The government uses tax revenues to make transfers to all residents of its region. Each government is assumed to balance its budget constraint every period. We investigate the case that after unification, a productivity gap may exist between the North and the South, and that the infrastructure stock may play a role in promoting the level of productivity in the North. The productivity-enhancing infrastructure stock of North Korea is assumed to be accumulated through transfers from the government of South Korea. The budget constraint for the North Korean government is given by

$$TR_N = T_N, \tag{13}$$

where TR_N is the aggregate transfers of the Northern government.

On the other hand, the budget constraint that the South Korean government faces is different from the North Korean government because of infrastructure transfers. First, the budget constraint of the South Korean government during T periods after unification is given by

$$TR_S + I^G = T_S,$$

where TR_S is the aggregate transfers of the Southern government and I^G is productivity-enhancing infrastructure transfers from the South to the North. Second, the budget constraint after T periods is given by

$$TR_S = T_S, \tag{14}$$

2.4 Recursive Equilibrium

Households are heterogeneous in three dimensions summarized by $\omega \equiv \{ j, a, x\}$, where j is age, a is assets accumulated and carried over from the previous period, and x is the time-varying labor productivity. Given ω, in every period, households choose consumption, hours worked, and savings to maximize their life-time utilities. Representing the household problem in a recursive form is useful. The household's value function in region i and state ω, denoted by $V_i(\omega)$, is given by

$$V_i(\omega) = \max_{c,h,a'} \left\{ \frac{\left(c^{\gamma} \ell^{1-\gamma}\right)^{1-\sigma}}{1-\sigma} + \beta \psi_j E[V_i(\omega')|\omega] \right\} \quad \text{for } j \leq J-1, \tag{15}$$

subject to (3) and (4) for workers $(j \leq j_w)$ and subject to (5) and (6) for retirees $(j > j_w)$. In the last period of life, $j = J$, the value function is given by

$$V_i(\omega) = \frac{\left(c^{\gamma} \ell^{1-\gamma}\right)^{1-\sigma}}{1-\sigma}, \tag{16}$$

where $c = [1 + (1-\tau_i)r_i]a + (1-\tau_i)p_i\lambda_i + tr_i$ and $\ell = 1$. From the recursive problem, optimal consumption $c_i(\omega)$, optimal saving $a_i'(\omega)$, and optimal hours worked $h_i(\omega)$ can be derived.

In this paper, we investigate three different unification regimes. The first regime is the benchmark regime, in which capital is mobile but people are not allowed to move between regions. Under this regime, the wage rates can be different across regions even though the interest rates are equal, and this is expressed as

$$r_N = r_S = r.$$

In the second regime of economic integration, we open up the labor markets and allow people to move across regions. Under this regime, the associated factor prices, such as the interest rate and the wage rate, are equal across regions, which is expressed as

$$r_N = r_S = r \quad \text{and} \quad w_N = w_S = w.$$

In the third regime, we shut down both the capital and labor markets, and thus, neither capital nor labor is mobile across the two regions. For this reason, the factor prices are expected to differ across regions.

Defining a stationary competitive equilibrium for each regime is necessary. Hence, we start with the definition of a stationary equilibrium for the benchmark regime. [4]

2.5 Definition of Stationary Equilibrium: The Benchmark Regime

[4] For the second and third regimes, see Appendix.

A stationary competitive equilibrium under the benchmark regime consists of the value functions $\{V_N(\omega), V_S(\omega)\}$, the optimal consumption functions $\{c_N(\omega), c_S(\omega)\}$, the optimal saving functions $\{a'_N(\omega), a'_S(\omega)\}$, the optimal labor supply functions $\{h_N(\omega), h_S(\omega)\}$, capital, efficiency unit of labor and land $\{K, H_N, H_S, L_N, L_S\}$, the factor prices $\{r, w_N, w_S, p_N, p_S\}$, the government policy variables $\{\tau_N, tr_N, \tau_S, tr_S\}$, and the law of motions for the time invariant measures μ_N and μ_S, such that

i. Given the factor prices and the policy variables, the optimal consumption, saving, and labor supply functions solve Eq. (15) for each region.

ii. For each region, the representative firms maximize their profits, and thus, Eqs. (8), (9), and (10) are satisfied.

iii. The government budget constraints, Eqs. (12), (13), and (14), are satisfied for each region.

iv. The goods markets clear:

$$\int \big(c_N(\omega) + a'_N(\omega)\big)\mathrm{d}\mu_N + \int \big(c_S(\omega) + a'_S(\omega)\big)\mathrm{d}\mu_S = Y_N + Y_S + (1-\delta)\big(K_N^d + K_S^d\big) \tag{17}$$

v. The factor markets clear:

$$K^d\big(= K_N^d + K_S^d\big) = \int a d\,\mu_N + \int a\mathrm{d}\mu_S, \tag{18}$$

$$L_N^d = \int \lambda_N \mathrm{d}\mu_N, \tag{19}$$

$$L_S^d = \int \lambda_S \mathrm{d}\mu_S. \tag{20}$$

where L_N^d denotes aggregate demand for land in region i, and the following labor market equilibrium conditions hold:

$$H_N^d = \int x h_N(\omega)\mathrm{d}\mu_N, \tag{21}$$

$$H_S^d = \int x h_S(\omega)\mathrm{d}\mu_S. \tag{22}$$

vi. The measures μ_N and μ_S are time-invariant, and the law of motions for the measures over the state space satisfy $\mu_N = \Gamma_N(\mu_N)$ and $\mu_S = \Gamma_S(\mu_S)$.

2.6 Transitional Dynamics

We assume that South Korea is in a steady state before unification. After unification, a unified Korea must be out of the steady state and converge to a different steady state that depends on the unification regimes. We solve the model recursively to determine how the model economy operates on the transitional dynamics. For each regime, we first characterize the corresponding steady state, in which all variables of interest do not vary over time. We then allow the model economy to have enough time to adjust to changes resulting from each unification regime. Our computations on the transitional dynamics focus on finding the time paths of factor prices and government policy variables.

3 Calibration and Parameterization

The model operates on annual frequency. Households enter the economy at age 23, retire from work at age 66, and live up to the maximum age of 85 years. Age-dependent conditional survival probabilities ψ_j are assumed to be constant over time. The process of time-varying labor productivity is determined by two parameters, namely, ρ_x and σ_x. Following Kim and Chang (2008), we set ρ_x to 0.8 and σ_x to 0.3. For σ_x, we choose a lower value than 0.354 used in Kim and Chang (2008). The annual depreciation rate of capital, δ, is 0.1 and the coefficient of relative risk aversion (or the inverse of the intertemporal elasticity of substitution), σ, is set to 4. Parameter γ, which determines the consumption share of the utility function, is set to 0.4881 such that average hours worked are equal to 0.4. We set the capital share, α, to 0.3 and the labor share, θ, to 0.6, so that the share of land $1 - \alpha - \theta$ equals 0.1.[5]

[5] Echevarria (1998) estimates a constant returns-to-scale production function of the three factors with capital, labor and land using Canadian data. She finds that the share of land is 16 percent. We think this estimate is quite

Before unification, South Korea is assumed to be in a steady state. The steady state interest rate in South Korea is set to 2.5 percent and we find the discount factor, β, such that the asset market clears. Thus, β is set to 0.9442. The level of aggregate productivity in South Korea, Z_S, is pinned down by normalizing the level of output to 1, and thus, Z_S is set to 1.45. The initial level of capital in the North is set to 0.5 percent of the capital stock of the South.

Regarding taxes and transfers, the amount of government income transfers for the South is assumed to be exogenous and is set to 0.114, which is determined by the condition that the government budget constraint of South Korea before unification is balanced under a tax rate of 15 percent. We fix the amount of income transfers because our purpose is to analyze the effect of unification regimes on the tax rate of South Korea. For North Korea, on the other hand, the tax rate is fixed at 15 percent.

We normalize the population size for South Korea to unity and assume the population size for North Korea is 0.5. To capture lower labor productivity in the North than in the South, we assume that the average number of years of schooling in the North is lower than in the South. The average number of years of schooling in South Korea is set to 14 and is assumed to remain not only in the steady state, but also on the transitional dynamics.[6] The average number of individual schooling years in North Korea is set to nine before unification. Once unified, years of schooling for young people who enter the economy of North Korea increase by one in every year for the first five years on the transitional dynamics and remain constant after they reach 14 years. Even though new entrants have a higher level of education than existing workers, the level of education for all workers in North Korea are lower than in South Korea for a certain period of time on the transitional dynamics.

We follow Psacharopoulor (1994) and Hall and Jones (1999) to convert average years of schooling to the rate of return to education. According to Psacharopoulor (1994) and Hall and Jones (1999), the rate of return to education is 6.8 percent for those with more than eight years of schooling. We also normalize South Koreans' labor productivity to unity. The

high for Korea because the output share of the agricultural sector in Korea is lower than in Canada.

[6] Individual schooling decisions are exogenous.

relative productivity of North Koreans with nine years of schooling right before unification can be expressed as $1.068^{-5} = 0.72$. In the first year after unification, for example, new entrants' relative productivity will be 1.068^{-4} in North Korea.

Next, we set the initial level of productivity and capital for the North. To calibrate the level of productivity in the North, we employ development accounting. For region i, output per capita, denoted by $y_i \equiv Y_i/N_i$ where N_i denotes the size of population in region i, is expressed as

$$y_i = Z_i \left(\frac{K_i}{N_i}\right)^{\alpha} \left(\frac{H_i}{N_i}\right)^{\theta} \left(\frac{L_i}{N_i}\right)^{1-\alpha-\theta}. \tag{23}$$

Given that households are endowed with an equal amount of land $\lambda_i = L_i/N_i$, we can rewrite per capita output as

$$y_i = Z_i \lambda_i^{1-\alpha-\theta} \left(\frac{K_i}{N_i}\right)^{\alpha} \left(\frac{H_i}{N_i}\right)^{\theta}. \tag{24}$$

We assume that the size of land available in each region is equal to the size of population (i.e., $\lambda_N = \lambda_S = 1$) and the efficiency units of labor per person across regions are equal (i.e., $H_N/N_N = H_S/N_S$). Under the assumptions, the ratio of output per person between two regions is given by

$$\frac{y_N}{y_S} = \frac{Z_N}{Z_S} \left(\frac{K_N}{K_S} \frac{N_S}{N_N}\right)^{\alpha}. \tag{25}$$

For the North, Mun and Yoo (2012) report that the capital stock is about USD 19.9 billion in 2010. For the South, the average fixed capital formation from 2008 to 2012 is USD 236.8 billion.[7] With 10 percent depreciation rate as in the model, the steady state capital stock in the South is USD 2,368 billion. The ratio, K_N/K_S, is equal to 0.0084. In our calibration, however, we use a slightly lower value because the level of capital in the North would be lower than in the South in terms of quality.

$$\frac{K_N}{K_S} = .005. \tag{26}$$

[7] The exchange rate of 2010, 1,134.8 Won/$ applies.

Given that the population ratio, N_S/N_N, is 2, we have the following:

$$\left(\frac{K_N}{K_S}\frac{N_S}{N_N}\right)^{\alpha} = (0.01)^{0.3}. \tag{27}$$

Mun and Yoo (2012) also report that the per capita GDP ratio is approximately 5 percent, $y_N/y_S = .05$. Therefore, the initial productivity ratio is given by

$$\rho_0^Z \left(\equiv \frac{Z_N}{Z_S}\right) = \frac{y_N}{y_S}\left(\frac{K_N}{K_S}\frac{N_S}{N_N}\right)^{-\alpha} = (0.05)(0.01)^{-0.3} \tag{28}$$

Thus, the productivity level in the North is 19.9 percent of the productivity level in the South.

We turn to discuss how productivity of the North grows. We assume that infrastructure transfers made by the South contribute to the productivity growth in the North after unification. We do not explicitly model a channel from infrastructure stocks to productivity, and instead, we assume that T years is needed for the productivity level in the North to reach 90 percent $(= \rho_T^Z)$ of the productivity level in the South when annual infrastructure transfers are about 20 percent of per capita GDP of North Korea. To be more concrete, suppose that the level of productivity in the North is a function of the infrastructure stock denoted by G:

$$Z_N(t) = \left(1 - \zeta G\,(t)^{-\phi}\right)Z_S, \tag{29}$$

for $t \leq T$. The infrastructure stock evolves according to the law of motion given by

$$G(t+1) = G(t) + I^G, \tag{30}$$

where I^G denotes annual infrastructure transfers from the South to the North.

More specifically, we set the *ex ante* level of output in the North to 2 percent of the output level in the South. The amount of annual infrastructure transfers is set to 20 percent of the *ex ante* output level of the North. Hence, I^G is equal to 0.004, because the output level of the South is normalized to unity.

We have to determine two parameters (ϕ and ζ) and the initial infrastructure stock ($G(0)$). Regarding parameter ϕ which measures the convergence speed on the transitional dynamics, we set ϕ to 0.9, which is equal to the sum of the capital and labor shares. We find the relationship between the initial and period-T levels of infrastructure from Eq. (30), which

shows that $G(T) = G(0) + I^G \cdot T$. Using Eq. (29), we can express the initial and period-T levels of Northern productivity as the ratios to the level of productivity in the South:

$$\frac{Z_N(0)}{Z_S} = 1 - \zeta G\,(0)^{-\phi} \text{ and } \frac{Z_N(T)}{Z_S} = 1 - \zeta G\,(T)^{-\phi}.$$

Note that the initial productivity ratio, $\rho_{0,}^{Z}$ is 0.199 and the period-T productivity ratio, ρ_T^Z, is assumed to be 0.9.

$$\frac{\zeta G\,(0)^{-\phi}}{\zeta G\,(T)^{-\phi}} = \frac{1 - \frac{Z_N(0)}{Z_S}}{1 - \frac{Z_N(T)}{Z_S}} \quad \Leftrightarrow \quad \left(\frac{G(T)}{G(0)}\right)^{\phi} = \frac{1 - \rho_0^Z}{1 - \rho_T^Z}$$

$$\Leftrightarrow \quad \frac{G(0) + T \cdot I^G}{G(0)} = \left(\frac{1 - \rho_0^Z}{1 - \rho_T^Z}\right)^{\frac{1}{\phi}}$$

Hence, the initial infrastructure stock can be determined by

$$G(0) = T \cdot I^G \left[\left(\frac{1 - \rho_0^Z}{1 - \rho_T^Z}\right)^{\frac{1}{\phi}} - 1\right]^{-1}.$$

For the baseline case of $T = 30$, the initial infrastructure stock is equal to 0.0132. Finally, we can pin down parameter ζ from the period-T productivity ratio, $\rho_T^Z (= Z_N(T)/Z_S) = 1 - \zeta G\,(T)^{-\phi}$, using the expression given by

$$\zeta = (1 - \rho_T^Z) G(T)^{\phi},$$

where $G(T) = G(0) + I^G \cdot T$.

In the steady state of the unified economy, the levels of productivity in both regions should be equal; hence, we make a further assumption about the steady state productivity level of the North. As the productivity level in the North reaches 90 percent of that in the South (Z_S), it grows at a constant rate for 50 years and then is equal to the productivity level in the South. The exogenous productivity growth rate in the North after the T periods is given by

$$g = \left(\frac{1}{\rho_T^Z}\right)^{\frac{1}{50}} - 1, \tag{31}$$

where ρ_T^Z is 0.9. The exogenous annual growth rate for productivity is 0.21 percent. Table 1 summarizes the values of the parameters.

Table 1. Parameters

Parameters	Description	Values
	North and South Korea	
J	life span	63
j_w	retirement age	44
ρ_x	persistence parameter of individual labor productivity shocks	0.8
σ_x	standard deviation of individual labor productivity shocks	0.3
δ	depreciation rate	0.1
σ	Inverse of the intertemporal elasticity of substitution	4
γ	consumption share	0.4881
β	discount factor	0.9442
α	capital share	0.3
θ	labor share	0.6
	South Korea	
N_S	population size	1
Z_S	aggregate productivity level	1.45
r_S	steady state interest rate	0.025
tr_S	income transfer	0.114
I^G	infrastructure transfer from the South to the North	0.004
	North Korea	
N_N	population size	0.5
$K_N(0)$	initial level of capital stock	$(0.005)K_S$
$Z_N(0)$	initial level of aggregate productivity	$(0.199)Z_S$
τ_N	tax rate	0.15
T	time period required to have $Z_N(T)/Z_S = 0.9$	30
g	exogenous growth rate after T	0.0021

Note: K_S denotes the steady state capital stock of South Korea. We investigate what happens when T varies.

4 Steady State

We present the steady state outcomes of the model economy under the benchmark regime. In fact, all regimes have the same steady state implications. Regarding the productivity difference between the North and the South, our focus is not on the transitional dynamics, but on the steady state. The steady state outcomes discussed in this section are derived under the assumption that productivity difference disappears right after unification. A detailed discussion of the productivity difference is postponed to the next section. Table 2 shows the steady state outcomes.

Table 2. Steady State

	Y	H	A	T	tr	r	w	p
South	1.0	0.348	2.4	0.114	0.114	0.025	1.73	0.1
North	0.5	0.174	2.4	0.057	0.114	0.025	1.73	0.1

Note: Y is aggregate output, H is the efficiency unit of labor, A is the aggregate asset holdings, T is aggregate tax revenues, tr is the per capita income transfer, r is the interest rate, w is the wage rate, and p is the rental price of land. Note that all regimes have the same steady state implications.

Under the given parameters and the assumption that the level of productivity in North Korea is eventually improved to the same level of productivity in South Korea after unification, the capital-labor ratios are equal across regions, and thus, the wage rates are also equal.[8] The steady state equilibrium interest rate is given by 2.5 percent and the wage rates in the North and in the South are equal at 1.73.

When we open up the labor markets, the equilibrium factor prices, such as interest rate and wage, are determined at which aggregate factor demand and aggregate factor supply are equal. Like the benchmark regime, the equilibrium interest rate is 2.5 percent and the equilibrium wage rate is 1.73 for both regions. All other variables are equal in terms of per

[8] The rates of capital depreciation are equal across both regions.

capita.

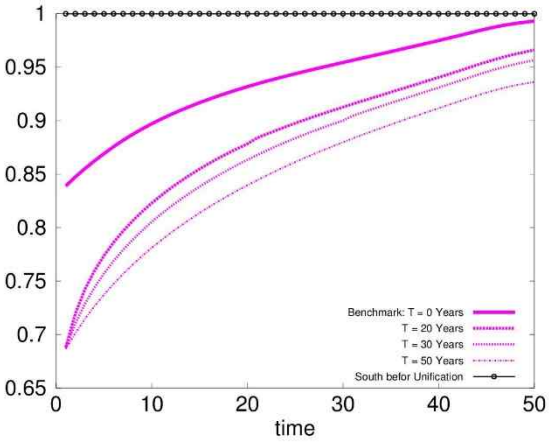
An interesting feature is that the regional capital and labor markets clear under the equilibrium prices. In other words, factor demand and factor supply are equal not only in each region but also in the aggregate level. This result, in turn, implies that the rental rates are equal for both regions. Notice that North Korea has the same economic structure as South Korea with respect to technology and parameters in the long run. The only difference is in the size of population. Therefore, in terms of output per capita, the steady state of the North is the same as that of the South.

5 Transitional Dynamics

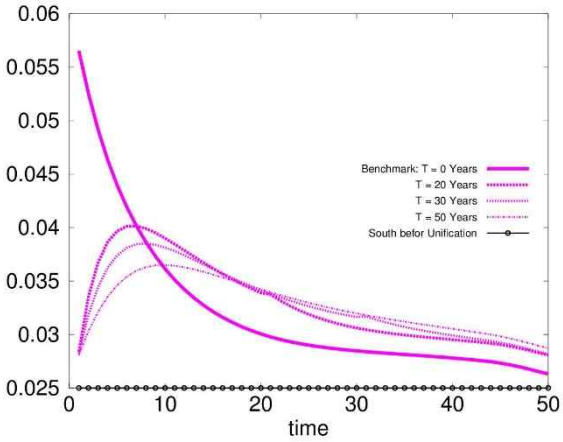
5.1 Benchmark Regime

We report the simulation results under the benchmark regime as the first hypothetical economic integration scenario with the assumption that capital markets are open but the labor markets are closed. Compared with the South Korean economy, which is assumed to be in the steady state before unification, the unified economy has a lower level of per capita GDP under the benchmark regime. Panel (a) in Figure 1 illustrates South Korea's output per capita before unification and the unified Korea's output per capita for the different values of T. For $T = 0$, which implies that the difference in the levels of productivity between North Korea and South Korea disappears right after unification, output per capita of the unified Korea is about 84 percent of South Korea's output per capita before unification. For the baseline case $T = 30,$ which implies that 30 years have to pass for the northern productivity level to reach 90 percent of the Southern productivity level, output per capita is about 68.7 percent of the level of South Korea's output per capita before unification.

(a) Output per capita (combined)



(b) Interest rate (South=North)



(c) Wage rate: South only

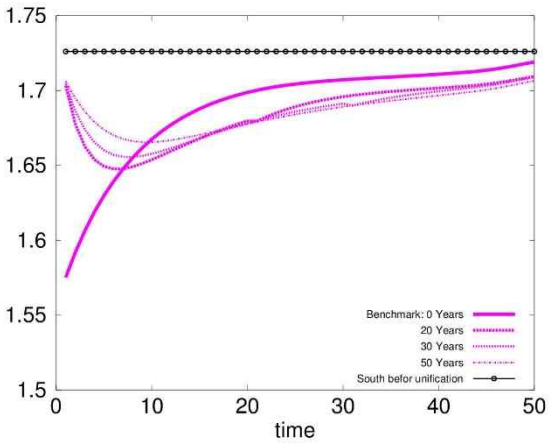


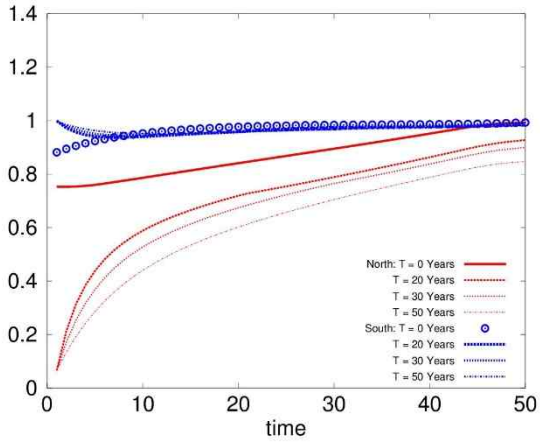
Figure 1. Unified Korea under the Benchmark Regime

Panel (b) in Figure1 shows the different transition paths of the interest rate. Under the benchmark regime, the interest rates are equal across regions because capital is allowed to move. For $T = 0$, the interest rate rises sharply right after unification and falls continuously toward the long-run equilibrium rate of 2.5 percent. When the productivity gap disappears right after unification, a significant rise in demand for capital exists in the North. However, the initial level of capital in the North is very low and a certain period of time has to pass to accumulate capital to meet the sharp increase in demand for capital. This excess demand leads to a sudden increase in the interest rate.

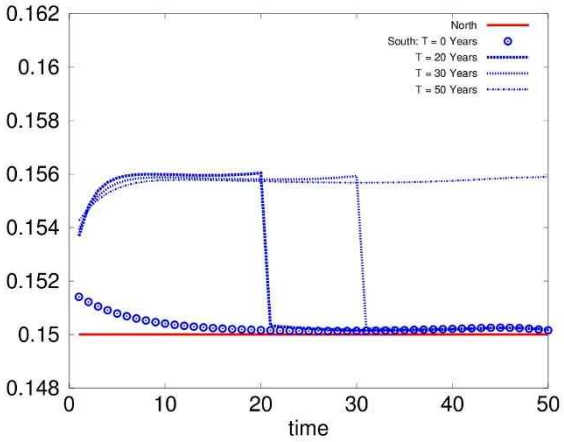
For the baseline case of $T = 30$, an increase in the interest rate is not quite dramatic compared with the case of $T = 0$. The level of productivity in the North remains low even after unification. North Korea's productivity improves as the infrastructure stock accumulates with the transfers from South Korea. The Northern demand for capital increases with productivity at a faster rate than the supply for capital; thus, the interest rate rises during the first several years.

Meanwhile, the wage rate in the South moves in the opposite direction of the interest rate. Economic integration causes capital in the South to move to the North, where the capital-to-labor ratio is significantly low. As capital flight occurs in the South, the marginal product of labor falls and so does the wage rate.

(a) Output per capita (regional)



(b) Tax rate



(c) Wage rate

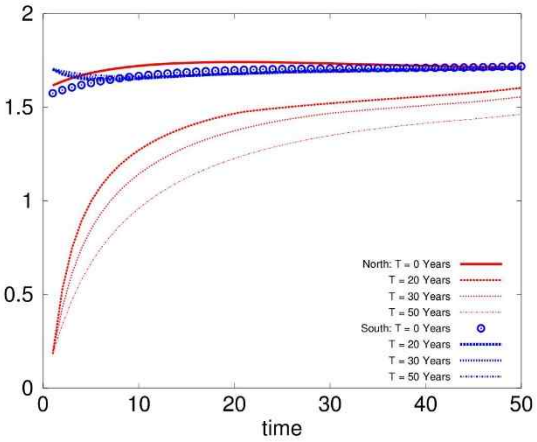


Figure 2. Regional Difference under the Benchmark Regime

Figure 2 shows the transition paths of key variables such as output per capita, wage rates and tax rates. Under the benchmark regime, as mentioned above, the labor markets are not open and people are not allowed to move across regions.

According to Panel (a) of Figure 2, which shows the cases wherein the productivity level of the North depends on infrastructure transfers from the South ($T = 20$, 30, and 50), output per capita in the North falls sharply to 7 percent of that in the South at the moment of reunification. Even though productivity of the North is catching up quickly through infrastructure transfers, the model predicts that more than 30 years have to pass for output per capita in the North to reach 80 percent of that in the South.

Panel (b) of Figure 2 displays the transition paths of the tax rates in the South. Notice that the tax rate in the North is fixed at 15 percent, but the tax rate in the South varies according to T, the time period over which infrastructure transfers occur. We assume that the amount of annual infrastructure transfers from the South to the North is about 0.4 percent of output per capita in South Korea prior unification, hence, the tax rate goes up by 0.4 to 0.6 percentage point with unification.

Even though the interest rates are equal across regions, the wage rates can be different under the assumption of a constant returns-to-scale production technology because of the existence of a fixed input (i.e., land). The regional difference in educational attainment leads to the regional difference in efficiency units of labor per person. If no productivity difference exists between the regions ($T = 0$) and both regions have the same land-to-population ratio, the regional difference in efficiency units of labor per person implies that the region with more efficiency units of labor per person (the South) must have more capital per person. While more capital per person raises the wage rate, more efficiency units of labor per person reduces the wage rate. The latter dominates the former, and thus, the region with more efficiency unit of labor per person (the South) has the lower wage rate. This feature is shown in Panel (c) of Figure 2.

5.2 Opening Up the Labor Markets

As the first alternative scenario, we consider opening up the labor markets. We have already

assumed open capital markets in the benchmark regime. The alternative regime of economic integration, therefore, looks like laissez-faire with respect to the factor markets. We refer to this regime as the "open-labor-market" regime. As people are allowed to move across regions, the wage rates are equal across regions as well.

We highlight that the open-labor-market regime delivers better outcomes with respect to output per capita. Table 3 demonstrates that once the labor market is open, output per capita under the open-labor-market regime is higher than that under the benchmark regime for different values of T. Such outcome is mainly due to the fact that enabling factors of production to move across regions brings efficiency gains.

Table 3. Output under Different Regimes

		Benchmark Regime			Open-Labor-Market			Closed-Capital-Market		
		$T=0$	$T=30$	$T=50$	$T=0$	$T=30$	$T=50$	$T=0$	$T=30$	$T=50$
Year 1	y	.8390	.6847	.6865	.8397	.8047	.8048	.7340	.6788	.6788
	(y_N/y_S)	(.85)	(.066)	(.067)	(1.00)	(.00)	(.00)	(.20)	(.038)	(.038)
Year 20	y	.9318	.8643	.8397	.9329	.8860	.8813	.9250	.8530	.8289
	(y_N/y_S)	(.86	(.70)	(.63)	(1.00)	(.21)	(.10)	(.78)	(.57)	(.49)
Year 30	y	.9545	.9002	.8799	.9551	.9122	.9059	.9527	.8964	.8755
	(y_N/y_S)	(.91	(.79)	(.73)	(1.00)	(.34)	(.19)	(.86)	(.70)	(.63)
Year 50	y	.9931	.9567	.9362	.9932	.9624	.9503	.9932	.9563	.9356
	(y_N/y_S)	(.99	(.91)	(.86)	(1.00)	(.52)	(.34)	(.98)	(.87)	(.82)

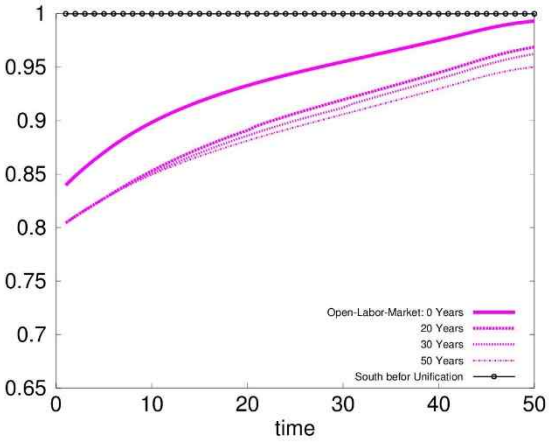
Note: y is output per capita of the unified Korea, $y=(Y_N+Y_S)/(N_N+N_S)$ and $y_i=Y_i/N_i$ for $i\in\{N,S\}$.

Panel (a) of Figure 3 shows the associated transition paths of output per capita. Under the open-labor-market regime, North Koreans are allowed to work in South Korea. At the moment that economic integration is achieved, productivity and wages become much lower in the North than in the South. North Koreans have a strong incentive to work in South Korea because they get paid more in the South than in the North. At this point, although the

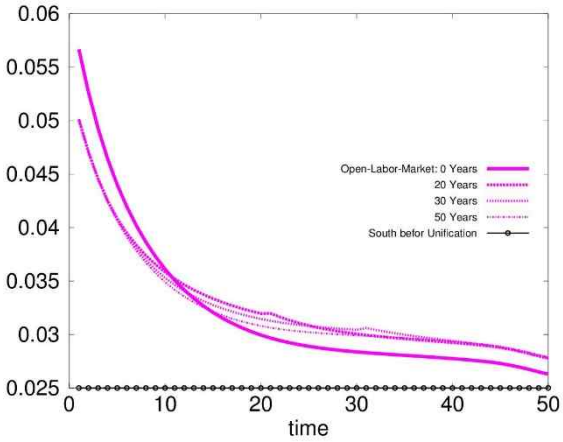
capital markets are open, capital is less likely to flow into the North because the level of Northern productivity increases at a very slow rate. Thus, most production takes place in the South in equilibrium. Even in the case that T is set to 30 years, 50 years must pass for output per capita in the North to reach 50 percent of that in the South.

As previously mentioned, production activity is concentrated in the Southern region. North Korea is capital-scarce, and thus, the Northern capital stock does not have significant impacts on the integrated capital market. The channel through which the interest rate responds is that most people work in the South which increases the marginal product of capital and the interest rate. Panel (b) of Figure 3 shows that the interest rate increases to 5 percent during the first year of unification when technology gaps between the North and the South still exist.

(a) Output per capita (combined)



(b) Interest rate (South=North)



(c) Wage rate (South=North)

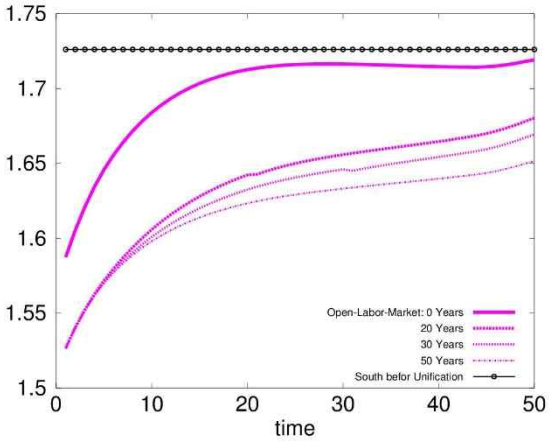
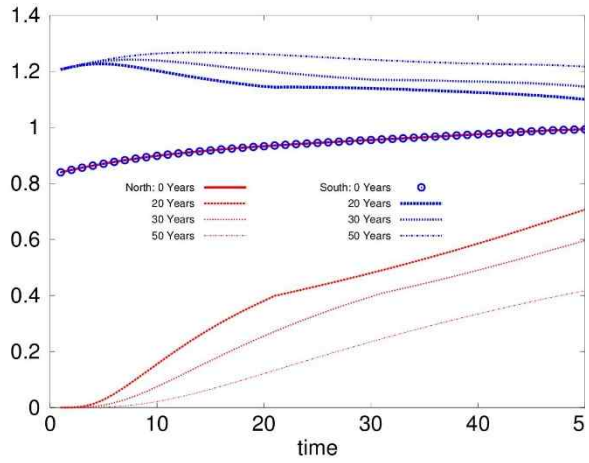


Figure 3. Unified Korea under the Open-Labor-Market Regime

The transition paths of the wage rate are illustrated in Panel (c) of Figure3. Economic integration under the open-labor-market regime brings down equilibrium wages. As the countries are unified as one, the relative abundance in labor causes the marginal product of labor and equilibrium wages to fall. During the first year of unification, the scale of the wage fall is about 8 percent for $T = 0$ (1.59 vs. 1.73 in the South before unification) and 11.6 percent for other values of T (1.53 vs. 1.73). When the productivity differences vanish with unification ($T = 0$), the equilibrium wage rate is very close to the steady state wage rate within 20 years, and the wage gap is less than 0.8 percent. By contrast, a 5 to 6 percent wage gap would exist even 20 years after unification unless the productivity difference disappears between the regions.

The left panel of Figure 4 demonstrates that the Northern economy is growing at a very slow pace with respect to output per capita when productivity differences exist. This phenomenon occurs because the Southern economy exhibits a relatively higher level of productivity and all factors of production are concentrated in the South. Under the regime in which the factors of production are allowed to move between the two regions, the income disparity between the North and the South is much bigger in the decades following unification than that under the benchmark regime.

(a) Output per capita (regional)



(b) Tax rate

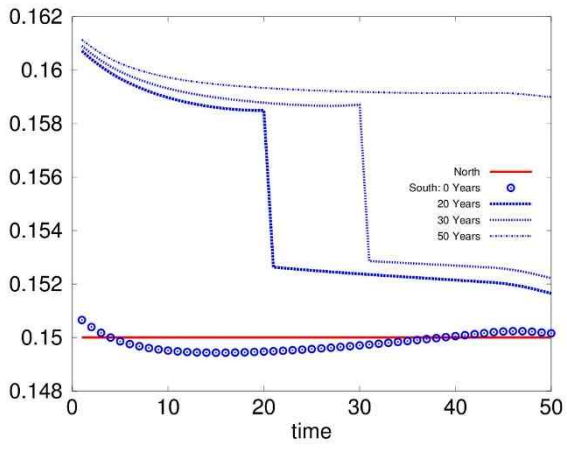


Figure 4. Regional Difference under the Open-Labor-Market Regime

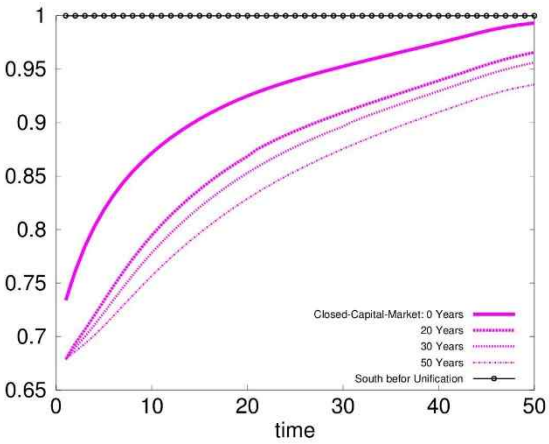
Panel (b) of Figure 4 shows the different transition paths of the tax rate in the South. Under the open-labor-market regime, the tax rate in the South goes up more than 1 percentage point in the first couple of years of unification. As previously mentioned, the scale of the wage fall is much greater under the open-labor-market regime than under the benchmark regime. Given the fixed amount of infrastructure transfers from the South to the North, a fall in wages is associated with an increase in tax rate.

5.3 Shutting Down the Capital Markets

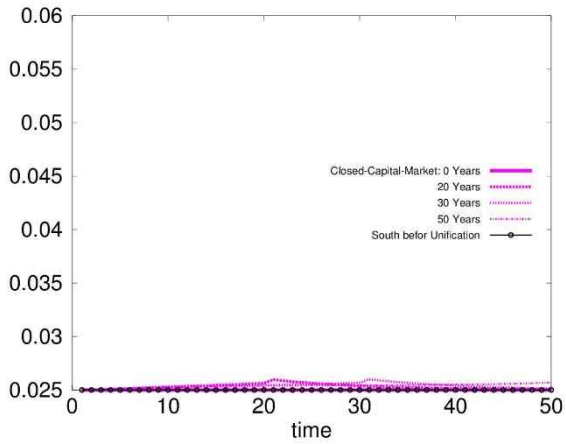
In addition to the open-labor-market regime, we also investigate shutting down the capital markets as another sensitivity analysis. In doing so, we move to the other direction from the benchmark regime. Given that the labor markets are segmented, we shut down the capital markets. Therefore, we look at the regime under which both factor markets are closed. In what follows, we refer to this regime as the "closed-capital-market" regime.

To evaluate the results of unification under the closed-capital-market regime, comparing the performance of economic integration under different regimes is useful. Table 3 reports different levels of output per capita under three different unification regimes. In terms of combined output per capita, denoted by y, the closed-capital-market regime exhibits the worst performance. In terms of the ratio of output per capita between the North and the South, denoted by y_N/y_S, the closed-capital-market regime shows better performance compared with the open-labor-market regime. For the case of $T = 50$ under the closed-capital-market regime, 20 years must pass for output per capita in the North to reach half of that in the South. Thus, the closed-capital-market regime is able to reduce regional income inequality.

(a) Output per capita (combined)



(b) Interest rate: South only



(c) Wage rate: South only

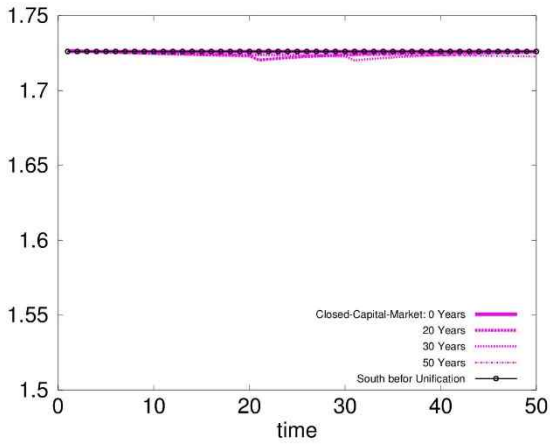


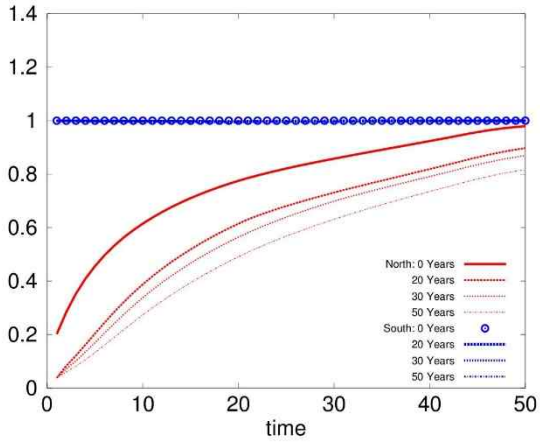
Figure 5. Unified Korea under the Closed-Capital-Market Regime

Panels (b) and (c) of Figure 5 show the transition paths of the interest rate and wage rate in the South, respectively. Given that the factor markets are separated between the two regions, the factor prices in the South barely change over the transition period. There are minor fluctuations in the factor prices because the tax rate changes according to the termination of infrastructure transfers to the North.

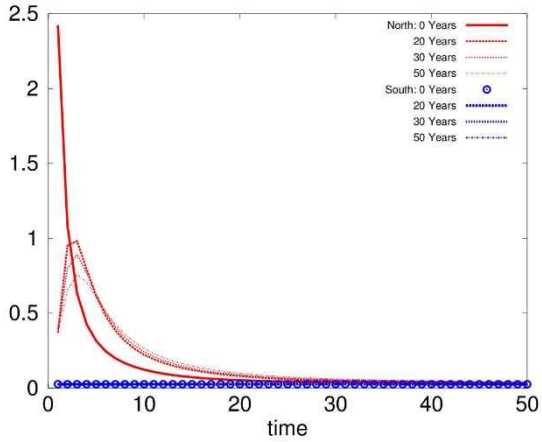
While the interest rate and wage rate in the South are almost unchanged, the wage rate in the North, which is very low during the early stages of unification, continues to rise as productivity is steadily improved and assets are accumulated. At this point, the interest rate increases rapidly to an unrealistically high level with unification. Noting that the capital and labor markets are shut down, the North is relatively labor abundant but capital-scarce. In the supply side of the Northern economy, this relative scarcity of capital leads to a low capital-to-labor ratio, which is inversely related to a high interest rate. Owing to high interest rates, a relatively rapid growth in assets outpaces productivity growth. Hence, interest rates start to fall.

Panel (b) shows the different paths of the tax rate. The amount of infrastructure transfers from the South to the North is assumed to be fixed and the factor prices in the South are almost unchanged under the closed-capital-market regime. The tax rate tends to remain constant during T, the time period over which transfers occur.

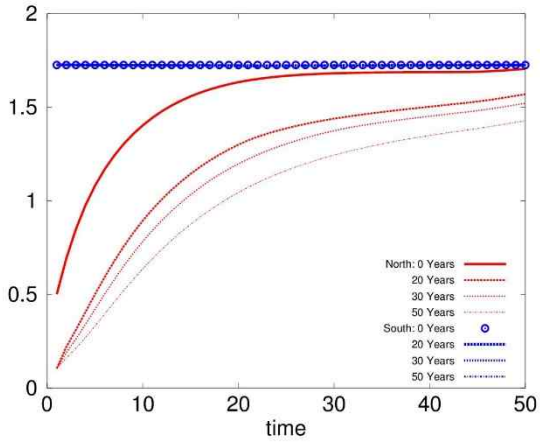
(a) Output per capita (regional)



(b) Interest rate



(c) Wage rate



(d) Tax rate

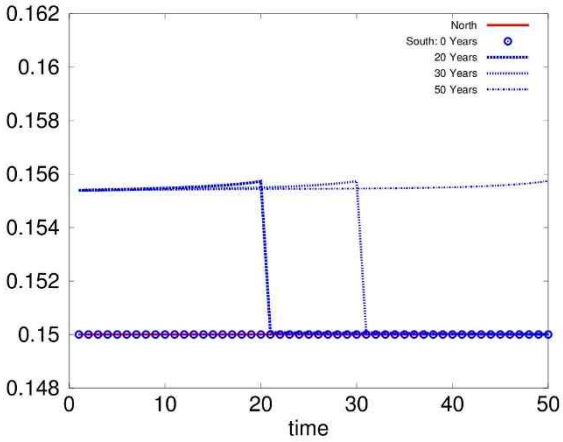


Figure 6. Regional Difference under the Closed-Capital-Market Regime

6 Concluding Remarks

Thus far, we have examined three different types of economic integration. We focus on the first two regimes (i.e., the benchmark and open-labor-market regimes) because shutting down the capital markets is not easy. Table 3 demonstrates that a trade-off exists between the first two regimes. Except for the case of $T = 0$, in which the open-labor-market regime shows better outcomes in terms of combined output per capita and the per capita output ratio, a trade-off between combined output per capita and regional development arises as T increases. If too much time is needed for the productivity gap to disappear, the Northern regional economy grows at a very slow pace under the open-labor-market regime, because capital and labor fly out of the North and move to the South. As production activity is concentrated in the Southern region, production in the Northern region almost stagnates right after unification.

If the policy goal is to improve overall income per capita, the open-labor-market can be adopted. However, people of the unified economy have to incur costs associated with severe regional disparity of economic development. As differences in productivity are persistent, inequalities in regional development would deepen. Assuming that the open-labor-market regime is adopted, more active redistribution policies may be desired. In addition to such policies, the excessive influx of migrants (Northern labor) is perceived to be regulated even though the labor markets are open. Regarding migration, an important question arises as to how much wage subsidies are needed to make Northern workers indifferent between staying in the North and moving to the South. We leave this question for our future research.

By contrast, if the policy goal is to reduce disparities in economic development between the North and the South, the benchmark regime can be considered an alternative integration type. The associated cost that people would incur is the output sacrifice. However, a legal system must first be institutionalized for the regime to be feasible. This legal institution should prohibits people from working outside their region of origin. This kind of institution can be introduced when a country has two different systems, i.e., the so-called “one country, two systems”.

Appendix A. Recursive Equilibrium

Definition of a Stationary Equilibrium: Open-Up the Labor Markets

A stationary competitive equilibrium under the second regime of the opening-up of the labor markets consists of the value functions $\{V_N(\omega), V_S(\omega)\}$, the optimal consumption functions $\{c_N(\omega), c_S(\omega)\}$, the optimal saving functions $\{a'_N(\omega), a'_S(\omega)\}$, the optimal labor supply functions $\{h_N(\omega), h_S(\omega)\}$, capital, efficiency unit of labor and land $\{K, H, L_N, L_S\}$, the factor prices $\{r, w, p_N, p_S\}$, the government policy variables $\{\tau_N, tr_N, \tau_S, tr_S\}$, and the law of motions for the time invariant measures μ_N and μ_S, such that

i. Given the factor prices and the policy variables, the optimal consumption, saving, and labor supply functions solve Eq. (15) for each region.

ii. For each region, the representative firms maximize their profits and thus Eqs. (8), (9), and (10) are satisfied.

iii. The government budget constraints, Eqs. (12), (13), and (14), are satisfied for each region.

iv. The goods markets clear: Eq. (17) holds.

v. The factor markets clear: Eqs. (18), (19), and (20) hold, and for the labor markets,

$$H^d\left(= H_N^d + H_S^d\right) = \int x h_N(\omega) \mathrm{d}\mu_N + \int x h_S(\omega) \mathrm{d}\mu_S, \tag{A-1}$$

vi. The measures μ_N and μ_S are time-invariant, and the law of motions for the measures over the state space satisfy $\mu_N = \Gamma_N(\mu_N)$ and $\mu_S = \Gamma_S(\mu_S)$.

Definition of a Stationary Equilibrium: Shut-Down the Capital Markets

A stationary competitive equilibrium under the third regime of the shutting-down of both capital and labor markets consists of the value functions $\{V_N(\omega), V_S(\omega)\}$, the optimal consumption functions $\{c_N(\omega), c_S(\omega)\}$, the optimal saving functions $\{a'_N(\omega), a'_S(\omega)\}$, the optimal labor supply functions $\{h_N(\omega), h_S(\omega)\}$, capital, efficiency unit of labor and land

$\{K_N, K_S, H_N, H_S, L_N, L_S\}$, the factor prices $\{r_N, r_S, w_N, w_S, p_N, p_S\}$, the government policy variables $\{\tau_N, tr_N, \tau_S, tr_S\}$, and the law of motions for the time invariant measures μ_N and μ_S, such that

i. Given the factor prices and the policy variables, the optimal consumption, saving, and labor supply functions solve Eq. (15) for each region.

ii. For each region, the representative firms maximize their profits and thus Eqs. (8), (9), and (10) are satisfied.

iii. The government budget constraints, Eqs. (12), (13), and (14), are satisfied for each region.

iv. The goods markets clear:

$$\int \big(c_N(\omega) + a'_N(\omega)\big)\mathrm{d}\mu_N = Y_N + (1-\delta)K_N^d, \tag{A-2}$$

$$\int \big(c_S(\omega) + a'_S(\omega)\big)\mathrm{d}\mu_S = Y_S + (1-\delta)K_S^d \tag{A-3}$$

v. The factor markets clear: Eqs. (19), (20), (21), (22), and the following capital market equilibrium conditions hold.

$$K_N^d = \int a\mathrm{d}\mu_N, \tag{A-4}$$

$$K_S^d = \int a\mathrm{d}\mu_S. \tag{A-5}$$

vi. The measures μ_N and μ_S are time-invariant, and the law of motions for the measures over the state space satisfy $\mu_N = \Gamma_N(\mu_N)$ and $\mu_S = \Gamma_S(\mu_S)$.

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