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Abstract

This paper constructs a dynamic specific factors model to examine the impact of the economic reunification of North and South Korea. The model is a compromise between the highly stylized neoclassical models of trade found in the theoretical trade literature, and the highly aggregated models used in dynamic macroeconomics. We find that the policies with the biggest effects on aggregate output are changes in government tax and spending rates, particularly spending on infrastructure. In contrast, we find that both skilled and unskilled wages are much more responsive to the particulars of trade policy, particularly openness to intra-Korea trade and intra-Korea labor mobility. The location of production in a fully integrated Korean economy is determined by the location of infrastructure.

1 Introduction

When World War II ended on August 15, 1945, Japanese forces occupying Korea south of the 38th parallel were directed to surrender to US forces. Those in the North surrendered to Soviet forces and Korea was effectively divided. Ideological differences led to the establishment of two separate governments in 1947 and 1948. In June of 1950 war broke out and the ensuing stalemate has left Korea divided ever since.

Recent political events have made the prospects for Korean reunification quite dim. Despite this, Koreans on both sides of the border express strong desires to reunite. There seems little doubt that given the right political climate reunification will occur.

In the six decades since Korea was divided much has changed. The economic miracle in South Korea is well documented and widely studied. Following the Japanese model of export oriented growth, output grew rapidly in the 1970's and 1980's and the South still maintains a relatively high annual average real growth rate. South Korea today enjoys a robust, healthy economy.

The Japanese occupation left the North with greater industrial capacity, but much of this was destroyed by the Korean War. During the Cold War, the North nimbly played on animosities between its two main benefactors, China and the Soviet Union, and made remarkable progress in standards of living. However, things have changed since the demise of the Soviet Union. Markets for North Korean manufactures have all but disappeared. While China does supply some aid, it is nowhere near the levels the Soviet Union used to provide. Famines have repeatedly swept through the country in recent years due to a combination of poor agricultural management policies and unfortunate weather conditions.

While the South has continued to grow and now enjoys per capita GDP on par with those of many developed nations, the North has slowly slid into poverty. South Korea trades heavily with the rest of the world. North Korea is isolated and its economy bears a remarkable resemblance to old Korea, which was often called the Hermit Kingdom for its closed borders and reluctance to deal with outsiders.

If reunification occurs anytime in the near future the huge differences in standards of living are likely to cause radical adjustments. With 22 million people in the North and another 47 million in the South the problems will be at least as daunting as those that confronted East and West Germany over a decade ago. Indeed, given the larger difference in standards of living and relatively larger population in North Korea, they are likely to be much bigger.

This paper focuses on the likely consequences of the reunification of the two Koreas. We are interested in several questions. There is little doubt that North Korea will benefit from almost any change in economic policy. We examine the effects of various kinds of reform on the North Korean economy. These range from internal reforms that encourage the establishment of markets to complete economic integration with the South. While happenings in the North are of vital importance to the lives of millions, the questions facing the South are more subtle, and hence have less obvious answers. Will the South benefit on net from reunification? Who will gain and who will be harmed? South Korea is already an open economy. How large can the benefits of preferential trade with an economy as backward as the North be? How much will South Korean wages and standards of living be lowered due to competition from workers in the North? We attempt to address these questions using a calibrated dynamic general equilibrium model of the North and South Korean economies.

Of course, we are not the first researchers to examine the economic consequences of reform and reunification on the Korean peninsula. For obvious reasons, researchers in Korea have examined this issue for many years. Shim (1993) is a good example; it focuses on the optimal timing of various reform and unification policies. Most work in this literature has concentrated on the politics of reunification, however, and the economics have not kept pace with developments in macroeconomic and international trade modeling.

Notable exceptions to this generalization are Noland, Robinson & Liu (1999) and Funke & Strulik (2005). The first paper calibrates a multi-sectoral computable general equilibrium model (CGE) for North and South Korea for 1990. Funke & Strulik (2005) set up an endogenous growth model and examine the dynamics of reunification. They consider the role of interregional transfer payments and government budgets, issues which we ignore in this paper.

The biggest area of difference between our model and these is in the dynamics. Our model is based on discrete-time dynamic programming tools used widely in dynamic stochastic general equilibrium (DSGE) macroeconomic models, albeit the simulations we perform are non-stochastic. Noland, Robinson & Liu (1999) impose calibrated reduced-form dynamic equations, while Funke & Strulik (2005) calibrate continuous time structural dynamic equations. Our characterization of technology and its evolution over time also differs. Our model focuses on implementation of the current best worldwide technology and the role of infrastructure.

Our choice of a modeling framework is not entirely new, though its application to Korean unification certainly is. Both Eaton (1987) and Roldos (1991) presented early work on dynamic specific factors models. Eaton viewed land and capital as specific factors that could also be used as optimally acquired financial assets. Using labor as the mobile factor, he focuses on the conditions under which the dynamic model displays behavioral properties similar to the static model. Roldos used a model conceptually very similar to ours to examine the effects of various types of tariffs on the current account. More recent uses include: Kose (2002), which uses a similar model to find the proportion of business cycle movements in developing economies attributable to international price fluctuations; and Albert & Meckl (1998), which examines the role of qualitatively rational expectations in capital accumulation.

Our choice of a model is motivated by the simple and well-understood properties of the specific factors model along with a desire to build a model that can be calibrated to reasonably mimic the actual North and South economies.

We model skilled labor as specific factors and capital and unskilled labor as mobile factors. We also model defense considerations by having a government that invests in military capital and conscripts workers to provide some chosen level of defense.

Once this model is calibrated we can examine a variety of reforms and types of reunification. We first derive and calibrate a baseline model in sections 2 and 3. This baseline model assumes profit maximizing firms and utility maximizing consumers. For this reason it does not correspond to the current situation in North Korea. We interpret this baseline as the situation that would prevail if the North were to adopt internal economic market reforms, while remaining closed to trade and maintaining defense parity with the South. Section 4 examines the impact of trade liberalization, defense reduction, a free trade arrangement, coordination of common macroeconomic policies and full integration. It also considers a scenario where these reforms are phased in over time. Section 5 concludes with a summary of the results and suggestions for further research.

2 A Dynamic General Equilibrium Model

We build a model with infinitely-lived households that maximize discounted lifetime utility. They derive utility from consumption of a single non-traded final good, which can also be used to form capital of various types. This final good is produced using a set of J intermediate goods. We treat this good as non-traded because we consider the production of final consumption and capital goods as something that must be done on site. To build a factory, a firm may purchase all the necessary materials, but it still needs to assemble the parts – it cannot import the factory completely preassembled. Assuming non-traded capital means that the capital account is always zero, and trade must balance each period. All trade is conducted in tradable intermediate goods.

Intermediate goods are produced using three factors: capital, unskilled labor, and skilled labor. We choose these three factors based on data from the Global Trade Analysis Project (GTAP) which reports payments to five different factors. Two of these, natural resources and land, are not used in the manufacture of all goods and together contribute less than five percent of national income. We ignore these two and build a model around the remaining three factors. Skilled labor is assumed to be specific to the industry in which it is used; that is, it cannot be used to produce any other intermediate good. Both capital and unskilled labor are mobile across all J sectors. Skilled and unskilled labor are assumed to be fixed by endowment, while capital is accumulated optimally over time. Capital and both kinds of labor are non-traded. Intermediate goods can be traded or non-traded and we calibrate the model accordingly once we identify each of these sectors.

Conceptually, it might seem more natural to think of capital as a specific factor; capital goods are certainly more specialized for specific tasks than skilled labor is. However, capital is accumulated and depreciates over time making it a *de facto* mobile factor. If we were to model capital as having J different types, each specific to a particular intermediate good, the only substantive difference between that model and ours would be a non-negativity constraint on investment for each type of capital. Since skills are generally task specific, skilled labor is more likely than unskilled labor to be immobile across sectors.

The government engages in two activities, accumulation of infrastructure capital and provision of national defense. We assume it imposes lump-sum taxes each period to provide public investment in infrastructure and military capital. It also imposes conscription on unskilled labor which is used along with military capital to provide a desired level of national defense. We impose conscription on unskilled labor only as this seems closest to what is actually done. Most soldiers are conscripted at relatively young ages before they have acquired any special job skills.

In the long-run the economy grows because of exogenous technical progress. Since both countries are small, the progress comes primarily from overseas and we impose a constant growth rate for this external process. Domestic productivity levels are assumed to be influenced by the level of infrastructure, however, and changes in the stock of infrastructure can therefore have short-run effects on the growth of domestic productivity.

We now proceed to formally setup and solve the model for a single economy.

Households

Households are infinitely-lived and maximize the discounted sum of all lifetime utility. We write this optimization as a standard dynamic programming problem using the following Bellman equation:

$$V(K,\Theta) = \underset{K'}{\text{Max}}\, U(C) + \beta E\{V(K',\Theta')\} \tag{2.1}$$

where C is the household's consumption, β is the rate of time preference, K is capital stock, Θ is its information set used to take expectations, and the primes indicate values of variables next period.

Consumption is income from skilled labor (L), unskilled labor (N), and capital, less depreciation, investment in new capital, and lump-sum taxes (T) as below.

$$C = \sum_i w_i \overline{L}_i + v(1-f)\overline{N} + (1+r-\delta)K - K' - T \tag{2.2}$$

where w_i is the wage rate for skilled labor in sector i, v is the wage for unskilled labor, r is the rental rate for capital, δ is the depreciation rate, and f is the government conscription rate.

We assume a constant elasticity of substitution utility function of the following form:

$$U(C) = \tfrac{1}{1-\sigma} C^{1-\sigma} \tag{2.3}$$

Hence, the Euler equation associated with this optimization problem is:

$$C^{-\sigma} = \beta E\{C'^{-\sigma}(1+r'-\delta)\} \tag{2.5}$$

Final Goods Producers

The final goods sector is perfectly competitive with free entry and zero profits. Firms therefore solve the following profit maximization each period:

$$\underset{\{F_j\}}{\text{Max}}\ \Pi_F = \prod_j F_j^{a_j} - \sum_j P_j F_j ; \sum_j a_j = 1 \tag{2.6}$$

where F_j is the amount of good j used in production of the final goods and P_j is its price.

The first-order conditions reduce to the following J conditions:

$$P_j F_j = a_j Y ;\ Y \equiv \prod_j F_j^{a_j}\ \ \forall j \tag{2.7}$$

Intermediate Goods Producers

Intermediate goods are also competitively produced and the firms solve the following problem:

$$\underset{K_j, L_j, N_j}{\text{Max}}\ \Pi_j = P_j K_j^{\,b} (ZN_j)^c (ZL_j)^{1-b-c} - rK_j - w_j L_j - vN_j \tag{2.8}$$

where Z is an economy-wide level of domestic productivity which is driven by external productivity and domestic infrastructure.

The first-order conditions reduce to the following 3J conditions:

$$rK_j = bP_jY_j\,;\; Y_j \equiv K_j^{\,b}(ZN_j)^c(ZL_j)^{1-b-c} \;\; \forall j \tag{2.9}$$

$$vN_j = cP_jY_j \;\; \forall j \tag{2.10}$$

$$w_jL_j = (1-b-c)P_jY_j \;\; \forall j \tag{2.11}$$

Government

The government imposes taxes to build up the domestic stock of military capital (M) and infrastructure (I). Gross investment in these two capital stocks is indicated by a preceding Δ. The government's budget constraint is:

$$T = \Delta M + \Delta I \tag{2.12}$$

Military capital and infrastructure evolve over time according the following two laws of motion:

$$M' = (1-\delta)M + \Delta M \tag{2.13}$$

$$I' = (1-\delta)I + \Delta I \tag{2.14}$$

The government also conscripts soldiers from the ranks of unskilled labor. It combines these soldiers with the military capital to produce a level of national defense as shown below:

$$D = M^d(ZfN)^{1-d} \tag{2.15}$$

Technology

There are many ways that infrastructure may influence technology[1]. We assume the economy-wide technology level, Z, evolves over time as a function of the external level of technology and the domestic level of infrastructure per unskilled worker:

$$Z = z^h(I/N)^{1-h} \tag{2.16}$$

where z is the world technology level.

This formulation is intended to capture movements in total factor productivity (TFP) that are unrelated to technology, *per se*. It explains how, even though the North has access to the same technology internationally, it has generally lower total factor productivity than the South. Using

[1] See Agénor & Moreno-Dodson (2006) for an excellent review.

infrastructure per unskilled worker assumes that infrastructure is primarily rival in nature and that greater amounts are needed for a larger population. We use unskilled workers rather than the sum of skilled and unskilled labor for analytical ease in simulations with internationally mobile factors. As a result, when skilled labor is mobile between the North & South, these movements will not generate congestion effects, but mobility of unskilled workers will.

External technology grows at a predetermined constant rate of g_z each period.

$$z' = (1 + g_z)z \tag{2.17}$$

Combining (2.16) and (2.17) gives a law of motion for Z that depends on last period's level and the growth rate of the infrastructure stock.

$$Z' = (1 + g_z)^h (1 + g_I)^{1-h} Z \; ; \; 1 + g_I \equiv \tfrac{I'}{I} \tag{2.18}$$

Aggregation and Market-Clearing

The final goods market and the markets for capital and both kinds of labor are closed to imports, so domestic supply must equal domestic demand. Intermediate goods may be either closed or open to trade. We adopt notation that allows for all intermediate goods to be traded, but will impose zero export restrictions in the appropriate industries.

The aggregation and market-clearing conditions are:

capital stock aggregation,

$$K = \sum_j K_j \tag{2.19}$$

unskilled labor market clearing,

$$(1 - f)\overline{N} = \sum_j N_j \tag{2.20}$$

skilled labor market clearing,

$$\overline{L}_j = L_j \;\; \forall j \tag{2.21}$$

intermediate goods market clearing,

$$Y_j = F_j + X_j \;\; \forall j \tag{2.22}$$

and final goods aggregation

$$Y + (1 - \delta)K = C + K' + \Delta M + \Delta I \tag{2.23}$$

Solving the Model

The above sections define a model with growth. Some variables - such as, consumption, capital stocks and production - grow at the rate g_z in the steady state. Others, such as goods prices, remain constant. In order to solve the household's dynamic programming problem we rewrite the system in a stationary form by dividing all growing variables by Z. This yields a steady state where all values are constant and where the off-steady-state dynamics are characterized by convergence to these constant values. We solve this altered set of equations, but then readjust once we are done so that all growing variables have the appropriate growth component added back in our simulations.

The model as a whole has three endogenous state variables, K, M & I. It also has three exogenous policy variables which should also be viewed as state variables. These are the conscription rate, f, and decisions about the accumulation of infrastructure and military capital. We choose to characterize government policy as the percent of Y that will be allocated as investment in these two stocks. We define the following $i \equiv \Delta I / Y$ and $m \equiv \Delta M / Y$ and model the government as setting these exogenously. Hence, the exogenous state variables are f, i & m.

We solve the model first by searching for a set of prices that yield steady state exports and imports equal to the averages observed in the GTAP dataset. We treat the prices for sectors the traded intermediate goods as fixed international prices and use these constant relative values for all simulations. The prices in the non-traded sectors are autarky prices and are part of the solution for each simulation.

As long as the North and South have no unique trading relations, we can treat each as an economy in isolation[2] and solve a one-economy model for each country. We treat production capital, K, and infrastructure I, as our endogenous state variables. We also solve for the non-traded intermediate goods prices as endogenous non-state variables. We impose the stationary versions of (2.5) and (2.18) along with four restrictions of zero imports for the non-traded sectors, three restrictions on relative prices for the traded sectors, and one price aggregation constraint relating intermediate good prices to the price of final output (our numeraire) to give us a system of ten equations in ten unknowns which describes the steady state.

In the scenarios where there is a free trade arrangement or intra-Korea mobility of labor, we solve a two-country version of the model. In this case we have capital and infrastructure in both regions as endogenous state variables and prices as endogenous non-state variables. We impose the North and South versions of (2.5) and (2.18) as above. For the non-traded sectors we impose

[2] They are small open economies, but not specifically linked to each other.

the constraint that the sum of exports from both regions must be zero. All other conditions are the same as the one-country case. This yields a system of 12 equations in 12 unknowns.

In addition to the steady states, we are also interested in transition dynamics. The numerical techniques for solving these types of dynamic problems are well-known.[3] They require the use of the same system of equations used to find the steady state. We use the method of undetermined coefficients to solve for a linear approximation to the intertemporal decision rules for capital and infrastructure about their steady state values. With these rules in hand, we are able to examine the path of key macroeconomic variables from some initial state to the steady state that are implied by a variety of policies.

3 Baseline Model Calibration & Simulation

We calibrate our model by choosing a baseline scenario where both the North and South are open to trade. From this baseline we consider various degrees of economic cooperation and integration between the North and South. We base much of our calibration on data from South Korea. Where possible we use the limited data on the North Korean economy. In many cases, however, we are forced to assume that the North looks similar to the South and calibrate using data from South Korea.

Our first task is to aggregate the 57 industries in the GTAP dataset into a smaller and more manageable number. We distinguish between foods, processing, manufactured goods, utilities and other services. We examine the GTAP data for South Korea and discover that foods and services have a great deal of variation of total trade as a percentage of output across the various GTAP industries. We divided each of these sectors into traded and non-traded sectors using a cutoff of 10% of output as the criterion for a traded good. Non-traded foods include grains and other staples. While North Korea trades very little, these foodstuffs are a large portion of that trade. Since these foods are non-traded in the South due to trade barriers, we will continue to treat them as non-traded in the North Korean case, under the assumption that the North will impose similar agricultural protection. GTAP does not report imports and exports of oil and natural gas which are not produced in Korea. We assume that our last industry, traded services, includes imports and exports of oil, natural gas. Table 1 summarizes this information.

For calibration purposes our time-period is one year and we choose our parameter values accordingly. We need to set the following parameter values for both countries:

[3] See, for example, Uhlig (1999) or Christiano (2002)

$\{a_i\}, b, c, h, \beta, \delta, \sigma, g_z$. In addition we need to pick values for labor endowments, $\{\overline{L}_i\}$ & N, and world prices, $\{P_i\}$, for traded intermediate goods.

β, the time discount factor is set to .975, implying a subjective discount rate of 2.56%; δ, the depreciation rate is set to .10, and g_z, the international trend growth rate of technology is set to .015. The steady state version of equation (2.5), written below as (3.5), is used to choose the value of σ, the intertemporal elasticity of substition.

$$1 = \beta(1 + g_z)^{-\sigma}(1 + \bar{r} - \delta)\} \tag{3.1}$$

We set the user cost of capital, $\bar{r} - \delta$, equal to 3% and solve to get σ=.087. All these values apply to both the North and South.

We use data from GTAP (version 5) to find the share of capital and unskilled labor in GDP for South Korea. These values are b=.4414 and c=.3943.

The values for the a_i's come from aggregating the 57 industries in the GTAP dataset into eight and finding their output shares as a percent of total output. Again, this is done for South Korea.

The GTAP data show that total compensation for skilled workers is about 40% of the total compensation of unskilled workers. Since wages should be higher for skilled workers this is an upper bound on their number. We assume an unskilled labor force of 300 and a skilled labor force of 100. To calibrate the distribution of skilled labor over our eight industries we assume a common real wage and make each labor endowment proportional to total compensation. When we calibrate North Korea we will choose different values for the L_i's, using this baseline as a reference.

For 2002 – 2004, the Republic of Korea spent 2.21% of GDP on "social infrastructure and housing" and "information technology" and another 2.45% on defense. We therefore set m=.0245 and i=.0221. The population aged 15 or older is 33 million and the non-military labor force is 22 million. Figures for the military are harder to document, but most sources indicate it has roughly three-quarters of a million men under arms. Since we have already assumed that three-fourths of the labor force is unskilled, the conscription rate on unskilled workers is either 2.92% of the population or 4.18% of the labor force. We use the latter value.

For North Korea we keep the same values for b, c, h, g_z, β, δ & σ. The total population in North Korea is around 23 million versus South Korea's 48 million. We set overall labor to 180; forty-five percent that of South Korea. The distribution of skilled versus unskilled labor is more difficult to pin down. For lack of defensibly better numbers, we assume that the percent of the total labor force that is skilled is half the value we use for South Korea. That is 12.5%, rather than 25%. This gives N=157.5 and L_i's that sum to 22.5. The allocation of skilled labor across industries is calibrated using data on similar industrial classifications from South Korea's Ministry of Unification. When this data does not match our 8 industries exactly we impose ratios similar to those observed in South Korea. The exact distribution of skilled labor is shown in the first panel of Table 2.

For policy variables we take a military force of one million and divide by 87.5% of the 9.2 million labor force and round to get f=.124. Determining the values of military and infrastructure parameters is the most problematic of all. The value of m=.25 is chosen to give the North and the South roughly equal levels of defense in the steady state for our baseline. i is set to half the value of the South. We note that our simulation is for a case where reforms have been instituted in North Korea and need not reflect exactly current economic policy.

The values of all the parameters and the steady state values for this baseline model are also reported in table 2.

We assume that initially neither the South nor the North is in the steady state. This means we need to choose starting values for five values: capital stocks in both countries, infrastructure in both countries, and the relative level of technology in the North.[4]

South Korean growth rates per capita are greater than our steady state value of 1.5% per year, and have a gradual downward trend. We constrain the initial ratio of private capital to infrastructure to be equal to the steady state ratio and then choose initial values for the capital stock and infrastructure so that the initial growth rate in the South is 5% per annum, roughly the average real growth rate over the last five years.

We need to know the difference between technology in North and South Korea. We use (2.16) and define the relative technology measure, $\xi \equiv Z_N / Z_S$ to get

$$\xi = \left(\frac{I_N N_S}{I_S N_N} \right)^{1-h} \tag{3.2}$$

[4] We can normalize the initial level of technology in the South to one.

Choosing a value for the initial infrastructure in the North also determines the initial level of technology. We assume that infrastructure in the North begins 15% below its steady state value. We assume capital is also 15% below steady state.

These assumptions yield an initial per capita income level in the North that is 16% of the South's. The baseline model assumes that North Korea is characterized by agents responding optimally to market signals. Since this is obviously not the case now, we must interpret this model as a scenario where the North has already engaged in some kind of market reform. Our starting values give GDP in the South that is almost fourteen times that in the North. However, the Ministry of Reunification estimates that South Korea's GDP was actually 26.8 times that of North Korea in 2001. This implies that internal reform in the North would result in efficiency gains that roughly double output.[5]

We wish to remphasize that the values used in our simulations are very rough approximations. As a result we have little confidence in the exactness of the numbers from our simulations. Particularly for the North our numbers can serve only as very rough guides as to the general direction and magnitude of changes.

Given these starting values we proceed to simulate the model economies.

4 Scenarios

With the model solved, calibrated and simulated for a baseline case, we now proceed to consider various steps on the road to unification. These steps include changes in international trade policy and in other economic polices. We consider the steady states of six scenarios in addition to the baseline. Some scenarios are unlikely. Our baseline where the North institutes market reforms but does not open to international trade, for example. We present them nonetheless to isolate the effects of each of the various policy changes.

These are as follows:

- Scenario 2 –Baseline, plus North opens to world trade.
- Scenario 3 – Scenario 2, plus both North and South reduce defense.
- Scenario 4 – Scenario 3, plus North and South form a free trade area
- Scenario 5 – Scenario 4, plus North and South adopt identical government policies.
- Scenario 6 – Scenario 5, plus North and South allow skilled laborers to migrate across the border. We show that in the steady state this is identical to a fully integrated economy

[5] Noland, Robinson & Liu (1999) find efficiency gains of 60% in their model.

where all goods are tradable and all factors are mobile between the North and the South. Away from the steady state however, the dynamics will differ from a fully integrated economy. We discuss this in more detail below.

We also present a final simulation with off-steady-state dynamics that illustrates the phased implementation of each of the policies above.

Scenario 2 – The North Opens to World Trade

In this case we maintain the baseline model for the South and have the North trade intermediate goods, 3, 4, 5 and 8 at the same relative prices as the South. Table 3 shows the steady state values for this scenario and compares them with the baseline.

In the North, output, production capital, military capital and infrastructure rise by 29% in the steady state. The level of defense rises by 20% due to the higher level of military capital. Unskilled wages rise by 29%. Skilled wages fall by an average of 23%. However, skilled wages in specific sectors vary dramatically[6]. In processing they rise by 349%. In traded services they fall by 90% and they fall by between 54% and 57% in the other six industries.

Scenario 3 – Defense Reductions

In this case we have both the North and South reduce their conscription rates and military investment rates by 50%. This frees up both capital and workers for employment in the production of goods and services. Table 4 shows the steady state values.

Increases are modest in the South. Output, production capital, military capital and infrastructure rise by 2%. Unskilled wages fall by 1% and skilled wages rise by 2% across the board

In the North output, production capital, military capital and infrastructure rise and become 39% higher than the baseline. Unskilled wages rise to 30% higher than the baseline while skilled wages recover, though they still remain 17% below the baseline.

The steady state level of defense falls 50% in the South, but only 37% in the North. The difference is due to the fact that there are much larger gains in productivity in the North than in the South in the long-run, leading to relatively more military capital there.

[6] To make the tables more readable we do not report skilled wages in each industry, but report important changes in the text.

Scenario 4 – A Free Trade Arrangement

In this scenario both the North and South retain their new lower levels of defense, but also allow free trade in all intermediate goods with each other. Intermediate goods 1, 2, 6 & 7 are still non-traded outside Korea. Prices of these goods must now adjust each period to ensure that what is exported from one half the country is imported by the other half. Table 5 shows the steady state values for this scenario.

Again, the gains from a free trade area are small, but nontrivial, in the South. Output, production capital, military capital and infrastructure are 2% higher than the baseline. Skilled wages, however, drop by an average of 24%. Given the South has a relative abundance of skilled labor, the drop is not too surprising, but the size of the drop is quite large. A closer looks shows that skilled wages in non-traded foods and natural resource extraction fall by over 60% of their baseline values. These are the industries where the North actually has more skilled labor and where the goods are not internationally traded, giving the North a comparative advantage vis-à-vis the South. In the other two non-traded industries, utilities and non-traded services, the South has a higher endowment of skilled labor and these wages rise to 17% above the baseline. Skilled wages in the traded industries rise less than 1%. Unskilled wages also remain virtually unchanged.

In the North we observe a symmetrical pattern with huge increases in skilled wages in industries 1 & 2 (140% above baseline), and large declines in industries 5 & 6 (87% below baseline). The movements in other skilled wages are smaller, but still large with a falling wage in industries 4, 5 & 8 and a rising wage in industry 3. Output, production capital, military capital and infrastructure rise an additional 21%. Unskilled wages rise 19%

Scenario 5 – Common Economic Policy

This scenario requires a great deal more political cooperation than previous ones. It is hard to imagine this occurring without some sort of political unification. We assume that the South keeps its economic policies unchanged, but the North lowers its conscription rates and military investment rates to the same levels as the South, while simultaneously raising the infrastructure investment rate to also match the South. Table 6 show steady state values.

Not surprisingly, there are only small changes in the South’s steady state values. The only substantial change is further movements in skilled wages. Falling in industries 1 & 2, and rising in industries 5 & 6.

There are huge movements in the North, however. Infrastructure quadruples, while output, production capital and military capital double. Unskilled wages rise to 391% of the baseline and the average skilled wage is 24% higher than the baseline..

The policy with the biggest effect, by far, is this one where the North reduces defense spending and puts more into infrastructure.

Scenario 6 – Mobility for Skilled Labor or a Fully Integrated Economy

There is only one specific factor, skilled labor, for each intermediate good. If skilled labor is allowed to migrate between the North and the South it will do so based upon the relative levels of skilled wages in these two regions.

It is straightforward to show that the return on any particular type of skilled labor does not depend on the amount of skilled labor employed as long as each sector is small. Intuitively, this is because skilled labor is the unique factor which defines the industry. Capital and unskilled labor are mobile across industries and the market will allocate them optimally across the available skilled labor. If skilled labor were to expand in one small sector only, the market would allocate a proportional increase in capital and unskilled labor to that sector. This would have only an infinitesimal effect on the capital and unskilled labor in other sectors. Since we have assumed constant returns-to-scale production this would lead to only infinitesimal changes in marginal products of the factors leaving the equilibrium factor prices unchanged.

This means that allowing mobility of one kind of skilled labor only will not result in an equalization of its wages between the North and South. Rather, all the skilled labor in that particular industry would migrate from the low wage country to the high wage country, and the skilled wage would remain unchanged.

If skilled labor of all types is allowed to migrate then factor prices will be effected since the reallocation of capital and unskilled labor will no longer be infinitesimal. This means the amount of skilled labor migration in any particular industry is indeterminate, but the total migration of skilled labor of all types is uniquely determined. To resolve this indeterminacy we assume that the percent of the total skilled labor endowment for the North and South actually present in the South is the same for all industries. That is

$$L_i^S = \mu(L_i^S + L_i^N); \quad L_i^N = (1-\mu)(L_i^S + L_i^N) \ \ \forall i \tag{4.1}$$

A little algebra allows us to solve for this percentage,

$$\mu = \frac{\nu}{1+\nu};\ \nu \equiv \left(\frac{Z^S}{Z^N}\right)^{\frac{1-b}{b+c}} \left(\frac{K^S}{K^N}\right)^{\frac{b}{b+c}} \left(\frac{(1-f^S)\overline{N}^S}{(1-f^N)\overline{N}^N}\right)^{\frac{c}{b+c}} \tag{4.2}$$

which is identical for all industries.

In the case where economic policy is the same in both the North and the South, technology levels will be equal in the steady state. Both capital and skilled labor will be present in both regions in the same proportion as the endowment of unskilled labor and all prices will be the same as well. Thus, skilled labor mobility with identical economic policies amounts to the same thing as a fully integrated economy, at least in the steady state.

Table 7 shows a fully integrated economy. The location of production is indeterminate if both types of labor are freely mobile across regions. For this table we assume skilled labor is mobile, but that unskilled labor is not[7]. In this case, skilled labor will migrate out of the South and into the North. We observe small drops in output, capital and infrastructure in the South. In the North, we have increases in output, capital and infrastructure (on the order of 30%). The average skilled wage falls by a third, and the unskilled wage almost doubles.

A Timed Phase-in of Reforms and Openness

Given currently political realities, it is difficult to predict what form unification of North and South Korea would take. Unification could happen suddenly, as in the German case, with a collapse of the political system in the North. It could also take the form of a military invasion. We focus on a more gradual transition.

We imagine each of the previous scenarios occurring in succession with delays of five years. Hence, we begin the simulation under the assumption of market reforms in the North. After five years the North opens to trade with the rest of the world imposing tariff and non-tariff barriers identical to those imposed by the South. After a further five years both the North and South agree to cut military spending and conscription by half. In year 16, the North and South adopt a free trade arrangement where intermediate goods from all sectors are freely traded across the border, including those that are not currently traded internationally. Five years after this the North adopts the same economic policy as the South. In year 26, migration of skilled laborers is allowed, though unskilled laborers are not allowed to migrate. Finally, in year 31 we allow unskilled workers to migrate as well. This leads to movements in technology levels through

[7] We allow unskilled labor intra-Korea mobility in the phased implementation scenario below. The steady state is the same as this one, but the transition dynamics are different.

congestion effects. As unskilled workers migrate from one region to the other, the effective level of technology falls in the immigrant region and rises in the emigrant region such that unskilled wages and technology are the same.

It is tedious, but straightforward to solve for the unique level of unskilled migration that equalizes unskilled wage rates, which turns out to be the same as the migration rate for skilled labor, μ.

$$N^N = (1-\mu)(\overline{N}^N + \overline{N}^S);\ N^S = \mu(\overline{N}^N + \overline{N}^S) \tag{4.3}$$

$$\mu = \frac{1}{1+\nu};\ \nu \equiv \left(\frac{I^S}{I^N}\right)^{-\frac{(1-b)(1-h)}{(1-b)(1-h)+b}} \left(\frac{K^S}{K^N}\right)^{-\frac{b}{(1-b)(1-h)+b}} \tag{4.4}$$

Since the capital to infrastructure ratio is not the same in both regions, the economy is not fully integrated in the sense that the North and the South are not simply scaled versions of each other. This is because capital and infrastructure accrue historically at different rates. However, it is possible for the government to engage in infrastructure investment that equalizes the capital to infrastructure ratios. Even if infrastructure investment is irreversible, this can be accomplished via depreciation of the stock in one region and putting all new investment in the other region. Since we are dealing with a single government (or at the very least, two highly cooperative ones) we assume the government does this at the same time it allows unskilled labor mobility. This gives us a fully integrated economy starting in period 31. We note that the permanent sizes of the South and North will depend on the sizes of their respective capital stocks in this period. This can be seen by reexamining (4.4) when the capital to infrastructure ratio is the same in both regions.

$$\mu = \frac{(K^S / K^N)}{1+(K^S / K^N)} \tag{4.5}$$

In our simulation this leads to large amounts of migration. This migration pressure could be relieved by waiting longer to allow labor mobility which would lower the K^S / K^N ratio. Also, the government could introduce taxes and subsidies in prior periods designed to encourage larger capital buildup in the North and less capital buildup in the South.

Figures 1 though 7 show the time path of various macroeconomic variables in the North and South under this scenario.

Average skilled wages in the two regions equalize when skilled labor is allowed to migrate. There is a large jump in skilled wages in the North when this happens. Skilled wages in the South change little, however. They drop much more dramatically with the opening of the free trade area. Figure 2 shows that the movements on specific skilled wages are very different from the averages. For non-traded foods and natural resources (categories 1 & 2) the most dramatic movements come with the free trade area, but skilled wages in the South remain higher than those in the North until skilled labor migration is allowed. For utilities and non-traded services, the drop in skilled wages associated with the free trade area occurs in the North, driving them from levels above those in the South to levels well below those in the South. They rise dramatically again when skilled labor migration is allowed. For all other industries (those where there is significant trade with the rest of the world) skilled wages in the South respond very little. In the North, they tend to rise with the implementation of the free trade area and again with migration of skilled labor.

Figure 3 shows that unskilled wages rise in the South when skilled labor is allowed to migrate. This is due to an influx of skilled workers into the South from the North which raises the marginal product of unskilled labor. Equalization of unskilled wages due to migration of unskilled labor then drives this wage down in the South and up dramatically in the North.

Figures 4 through 6 show that the movements in unskilled wages are driven primarily by movements in levels of technology which are, in turn, driven by infrastructure congestion. When unskilled labor is free to migrate, large numbers of unskilled workers migrate from the North to the South, causing a drop in unskilled wages in the South and a rise in unskilled wages in the North. This migration leads to infrastructure congestion in the South, lowering aggregate productivity. The reverse is true in the North and aggregate productivity rises dramatically.

We assume in the scenario illustrated that there is no adjustment of the level of infrastructure across regions. Instead, infrastructure per unskilled worker adjusts solely via unskilled labor migration. The implied movements in unskilled labor are huge; more than two-thirds of the North's unskilled labor force moves to the South. This result is somewhat arbitrary. Since both regions are simply scaled versions of each other, the government could just as easily choose to invest more in the North's infrastructure at the expense of the South's. The amount of unskilled labor migration needed to equalize unskilled wages would be smaller in this case.

Finally, table 7 shows that output per capita drops in the South and rises dramatically in the North when unskilled labor is free to migrate. Again, this is due to technology jumps.

5 Conclusions

Our simulations indicate that the potential gains to North Korea from economic integration with the South are huge, while the South remains relatively unaffected. Nonetheless, there is a great deal of uncertainty associated with our simulations. First, the parameterization of our model (for North Korea in particular) is based on educated guess and assumption rather than hard data. There is little that can be done about this other than to note the problem and perform sensitivity analysis. Secondly, the timing of various reforms is speculative. We have no way of knowing how much time would elapse between the North opening to international trade and defense reductions, for example. They could well happen simultaneously. Policy makers are not debating specific policies on infrastructure investment by the South in the North. Even the most basic reforms we model seem unlikely in the near future.

With this important caveat, there is still a great deal of interesting behavior in the simulations. We concentrate our attention on a few of the most important results.

First, adjustments to complete integration are likely to be large even with preparatory stages. As we show, if there is no attempt made to equalize the levels of infrastructure per unskilled worker, a majority of the North's workers will want to migrate to the South. Undoubtedly much of this is due to the simplicity of our model. There is no cost of migrating and the level of technology depends strongly on the level of infrastructure per unskilled worker. Nonetheless, it seems likely that unless the costs of migration were very high or technology was only very weakly dependent on infrastructure per worker the amount of labor migration would still be very high.

Second, the biggest long-run effects on output in the North come from changing government policies. While movements in the direction of freer trade raise output per capita in the steady state, the biggest gains come from raising infrastructure investment and lowering the defense burden.

Third, the biggest effects on both skilled and unskilled wages in the North and South come from allowing freer trade. This is either in the form of trade in goods or in the form of labor migration. Hence, while overall welfare in the North is most strongly influenced by government tax and spending policies, the biggest effects on owners of particular factors comes from the degree of openness to trade.

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Table 1

Total Trade as a Fraction of Sectoral Output, South Korea

Our Industries		GTAP industries		
1	Non-traded Foods	1	Paddy Rice	0%
	2%	2	Wheat	3%
		3	Cereal Grains	0%
		4	Vegetables, Fruits & Nuts	3%
		5	Oil Seeds	2%
		6	Sugar Cane & Beets	0%
		9	Livestock	1%
		11	Raw Milk	0%
		19	Beef	7%
		22	Dairy	5%
2	Natural Resources	12	Wool	3%
	5%	13	Forestry	3%
		14	Coal	0%
		18	Other Minerals	5%
3	Traded Foods	7	Plant Fibers	172%
	61%	8	Other Crops	15%
		10	Other Animal Products	22%
		14	Fishing	35%
		20	Other Meat Products	159%
		21	Vegetable Oils & Fats	25%
		23	Processed Rice	17%
		24	Processed Sugar	192%
		25	Other Foods	108%
		26	Beverages & Tobacco	22%
4	Processing	27	Textiles	505%
	191%	28	Apparel	187%
		29	Leather Products	363%
		30	Lumber	72%
		31	Paper Products	59%
		32	Refined Oil & Coal Products	270%
		33	Chemical, Rubber & Plastic	181%
		34	Other Mineral Products	34%
		35	Ferrous Metals	143%
		36	Other Metals	508%
		37	Metal Products	109%
5	Manufacturing	38	Motor Vehicles & Parts	258%
	310%	39	Other Transport Equipment	416%
		40	Electronics	907%
		41	Other Machinery & Equipment	135%
		42	Other Manufactured Goods	163%
6	Utilities	43	Electricity	0%
	0%	44	Gas Distribution	0%
		45	Water Distribution	2%
7	Non-traded Services	46	Construction	0%
	3%	52	Financial Services	2%
		56	Public Adminstration	6%
		57	Dwellings	0%
8	Traded Services	16	Petroleum	N/A
	26%	17	Natural Gas	N/A
		47	Trade	12%
		48	Other Transport	22%
		49	Water Transport	57%
		50	Air Transport	210%
		51	Communications	16%
		53	Insurance	20%
		54	Other Business Services	40%
		55	Recreation & Other Consumer Services	18%

Table 2

Parameterizations & Steady State for Baseline Model

Parameters

	South	**North**	**ratio**
a_1:	0.045	0.045	1.000
a_2:	0.008	0.008	1.000
a_3:	0.027	0.027	1.000
a_4:	0.154	0.154	1.000
a_5:	0.129	0.129	1.000
a_6:	0.024	0.024	1.000
a_7:	0.264	0.264	1.000
a_8:	0.349	0.349	1.000
L_1:	0.252	1.089	0.231
L_2:	0.172	0.726	0.237
L_3:	1.374	5.775	0.238
L_4:	10.759	4.692	2.293
L_5:	10.616	4.692	2.262
L_6:	0.465	0.032	14.615
L_7:	50.325	3.443	14.615
L_8:	26.037	2.049	12.705
b:	0.441	0.441	1.000
c:	0.394	0.394	1.000
h:	0.5	0.5	1.000
g_z:	0.015	0.015	1.000
β:	0.95	0.95	1.000
δ:	0.1	0.1	1.000
σ:	0.087	0.087	1.000
N:	300	157.5	2.222
f:	0.0418	0.124	0.337
m:	0.0245	0.25	0.098
i:	0.0221	0.01105	
			2.000

Steady State Values

	South	**North**	**ratio**
ξ:	1.000	0.335	8.5
$\bar{K}$:	69.608	8.228	16.9
$\bar{I}$:	4.671	0.276	8.5
$\bar{Y}$:	24.307	2.873	3.8
$\bar{Y}/W$:	0.061	0.016	0.8
$\bar{M}$:	5.178	6.246	1.3
$\bar{D}$:	8.490	6.415	1.0
$\bar{r}$:	0.154	0.154	4.1
$\bar{v}$:	0.033	0.008	36.6
$\bar{w}_1$:	0.716	0.020	35.7
$\bar{w}_2$:	0.187	0.005	32.4
$\bar{w}_3$:	0.072	0.002	3.2
$\bar{w}_4$:	0.049	0.016	3.3
$\bar{w}_5$:	0.043	0.013	0.6
$\bar{w}_6$:	0.207	0.358	0.6
$\bar{w}_7$:	0.021	0.036	0.7
$\bar{w}_8$:	0.060	0.081	1.7
P_1:	0.303	0.177	1.7
P_2:	0.242	0.142	1.7
P_3:	0.207	0.124	1.1
P_4:	0.195	0.171	1.1
P_5:	0.190	0.166	0.9
P_6:	0.247	0.286	0.9
P_7:	0.169	0.196	0.9
P_8:	0.201	0.224	8.5

Table 3

Steady State values for Scenario 2 - North Opens to International Trade

	South	%Δ baseline	North	%Δ baseline	ratio	%Δ baseline
$\overline{K}$:	69.61	0%	10.58	29%	6.6	-22%
$\overline{I}$:	4.67	0%	0.36	29%	13.2	-22%
$\overline{Y}$:	24.31	0%	3.70	29%	6.6	-22%
$\overline{Y}/W$	0.06	0%	0.02	29%	3.0	-22%
$\overline{M}$:	5.18	0%	8.03	29%	0.6	-22%
$\overline{D}$:	8.49	0%	7.69	20%	1.1	-17%
$\overline{v}$:	0.03	0%	0.01	29%	3.2	-22%
$\overline{w}$:	0.08	0%	0.04	-23%	2.0	-50%
ξ:	1	0%	0.38	13%	2.6	-12%

Table 4

Steady State values for Scenario 3 - Both North & South Lower Defense

	South	%Δ baseline	North	%Δ baseline	ratio	%Δ baseline
$\overline{K}$:	70.68	2%	11.48	39%	6.2	-27%
$\overline{I}$:	4.74	2%	0.39	39%	12.3	-27%
$\overline{Y}$:	24.68	2%	4.01	39%	6.2	-27%
$\overline{Y}/W$	0.06	2%	0.02	39%	2.8	-27%
$\overline{M}$:	2.63	-49%	4.36	-30%	0.6	-27%
$\overline{D}$:	4.27	-50%	4.06	-37%	1.1	-20%
$\overline{v}$:	0.03	-1%	0.01	30%	3.1	-24%
$\overline{w}$:	0.08	2%	0.04	-17%	1.9	-53%
ξ:	1	0%	0.39	17%	2.5	-15%

Table 5

Steady State values for Scenario 4 – North-South Free Trade Area

	South	%Δ baseline	North	%Δ baseline	ratio	%Δ baseline
$\overline{K}$:	71.34	2%	13.68	66%	5.2	-38%
$\bar{I}$:	4.78	2%	0.46	66%	10.4	-38%
$\overline{Y}$:	24.89	2%	4.77	66%	5.2	-38%
$\overline{Y}/W$	0.06	2%	0.03	66%	2.3	-38%
$\overline{M}$:	2.65	-49%	5.19	-17%	0.5	-38%
$\overline{D}$:	4.29	-49%	4.59	-28%	0.9	-29%
$\bar{v}$:	0.03	0%	0.01	55%	2.6	-35%
$\overline{w}$:	0.06	-25%	0.03	-34%	1.8	-56%
ξ:	1	0%	0.43	27%	2.3	-21%

Table 6

Steady State values for Scenario 5 - Free Trade Area with Common Policies

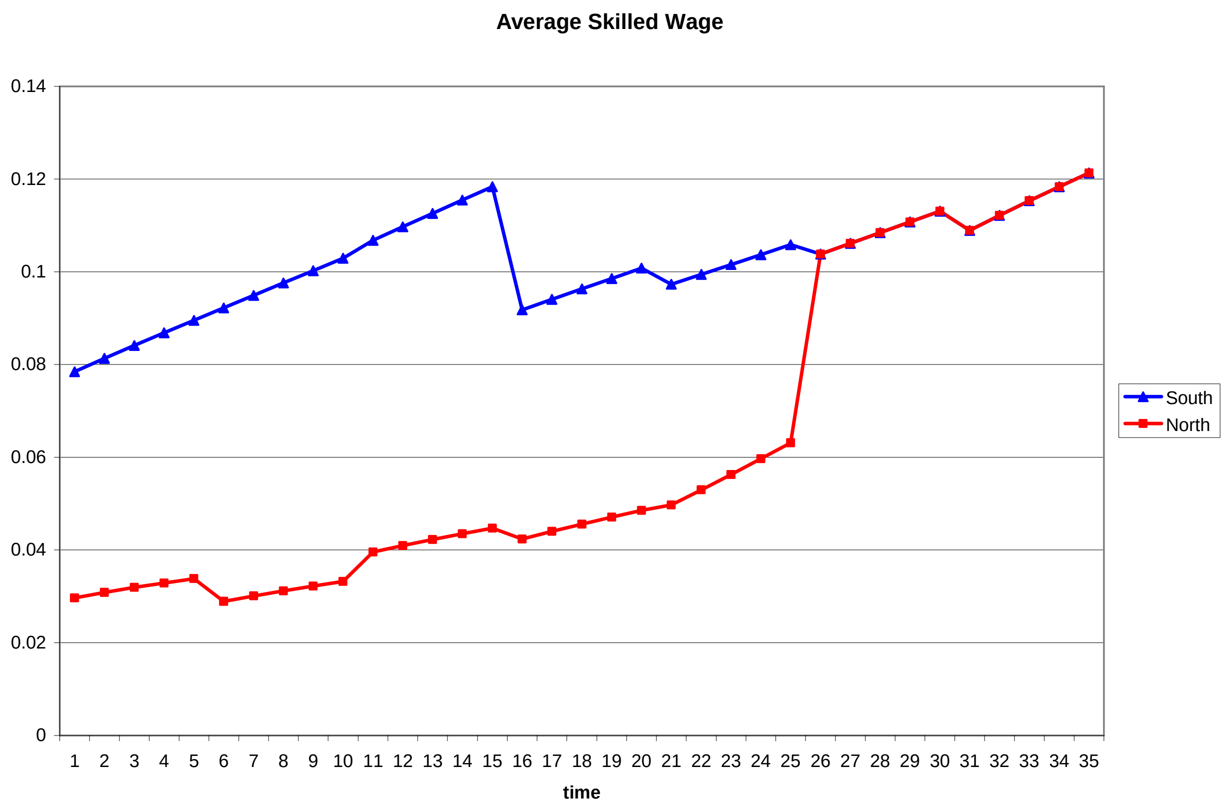
	South	%Δ baseline	North	%Δ baseline	ratio	%Δ baseline
$\overline{K}$:	71.88	3%	27.30	232%	2.6	-69%
$\bar{I}$:	4.82	3%	1.83	563%	2.6	-84%
$\overline{Y}$:	25.08	3%	9.52	231%	2.6	-69%
$\overline{Y}/W$	0.06	3%	0.05	231%	1.2	-69%
$\overline{M}$:	2.67	-48%	1.01	-84%	2.6	218%
$\overline{D}$:	4.30	-49%	1.79	-72%	2.4	82%
$\bar{v}$:	0.03	1%	0.02	197%	1.4	-66%
$\overline{w}$:	0.06	-30%	0.07	37%	0.8	-80%
ξ:	1	0%	0.85	153%	1.2	-61%

Table 7

Steady State values for Scenario 6 - Mobile Skilled Labor or Fully Integrated Economy

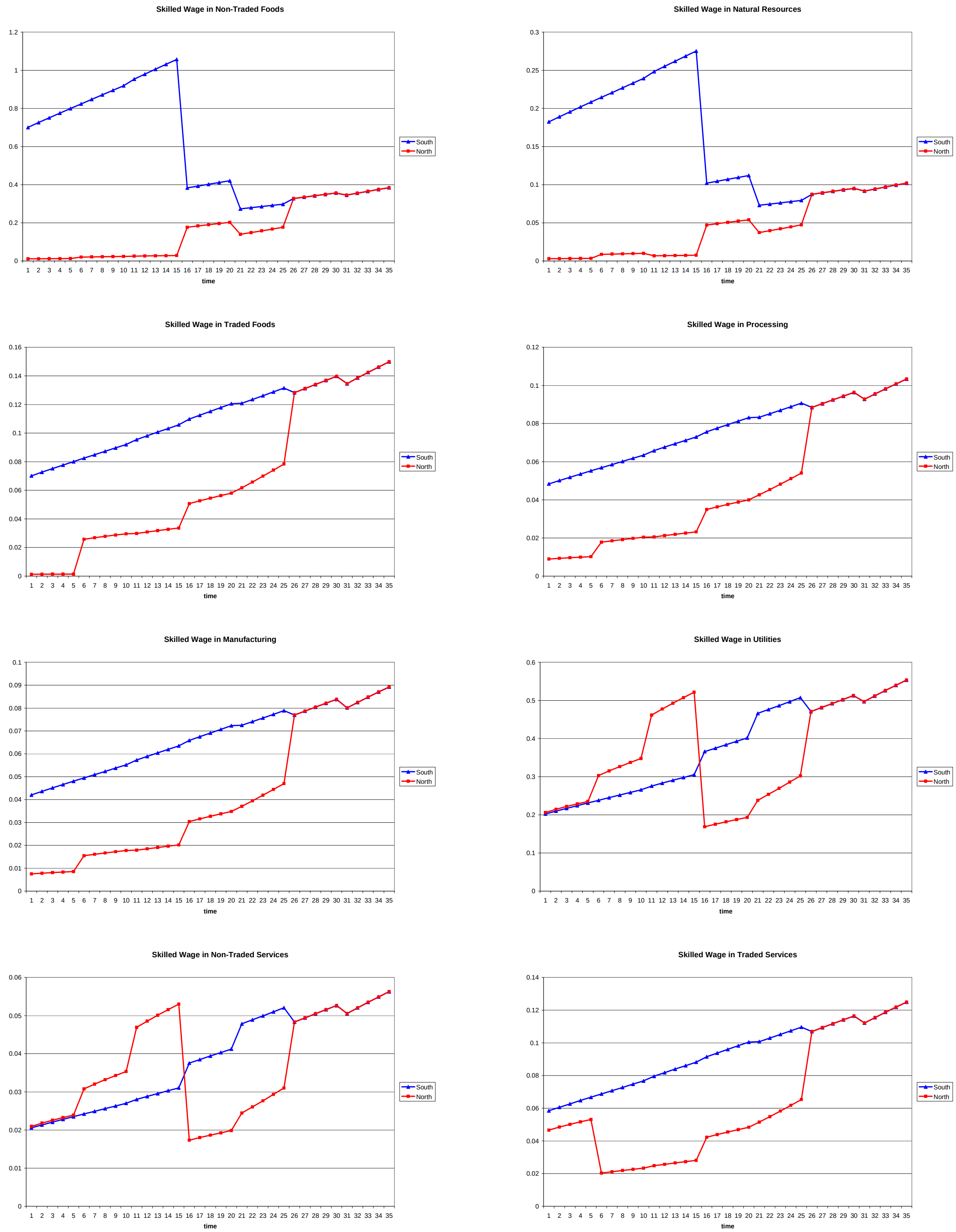
	South	%Δ baseline	North	%Δ baseline	ratio	%Δ baseline
$\overline{K}$:	68.61	-1%	36.01	338%	1.9	-77%
$\bar{I}$:	4.60	-2%	2.41	774%	1.9	-89%
$\overline{Y}$:	23.94	-2%	12.56	337%	1.9	-77%
$\overline{Y}/W$	0.06	-2%	0.07	337%	0.9	-77%
$\overline{M}$:	2.55	-51%	1.34	-79%	1.9	130%
$\overline{D}$:	4.22	-50%	2.21	-66%	1.9	44%
$\overline{v}$:	0.03	-4%	0.03	291%	1.0	-75%
$\overline{w}$:	0.06	-21%	0.06	24%	1.0	-75%
ξ:	1	0%	1.00	198%	1.0	-66%

Figure 1



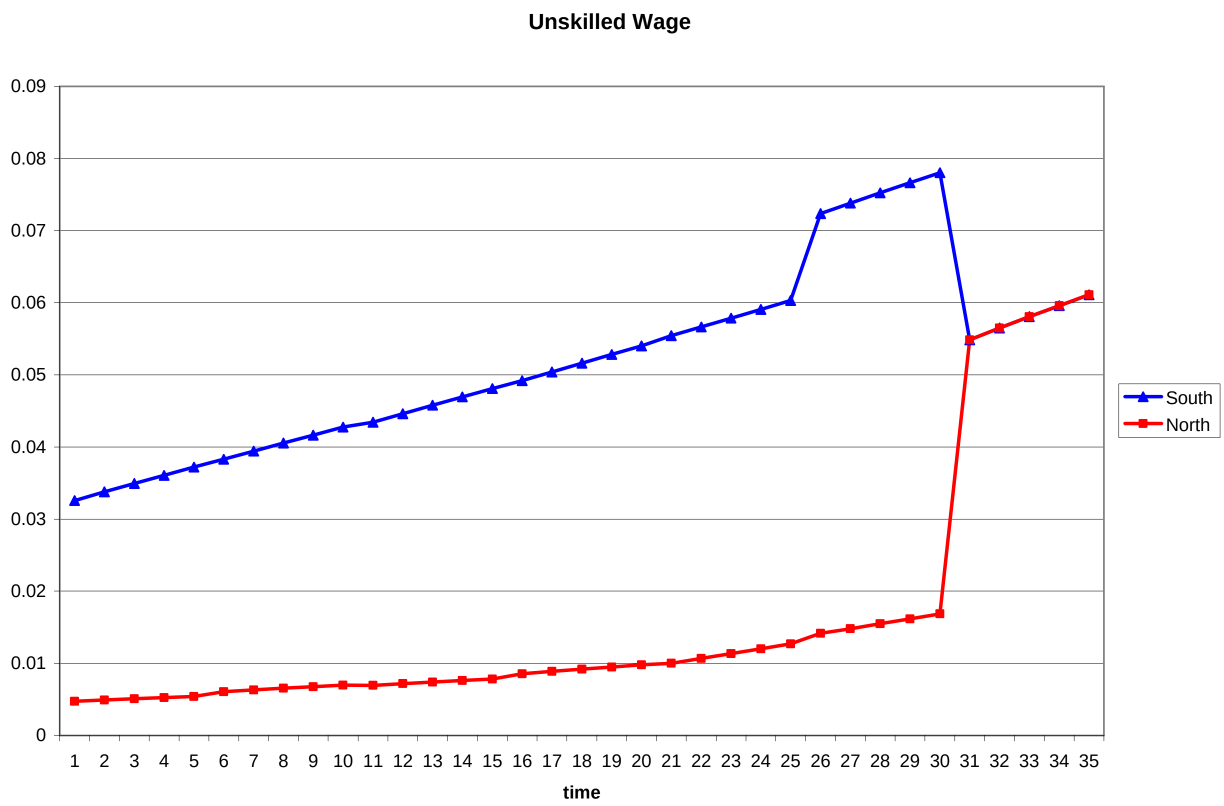
Average Skilled Wage
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
time
South
North

Figure 2



Skilled Wage in Non-Traded Foods
South
North
time
Skilled Wage in Natural Resources
South
North
time
Skilled Wage in Traded Foods
South
North
time
Skilled Wage in Processing
South
North
time
Skilled Wage in Manufacturing
South
North
time
Skilled Wage in Utilities
South
North
time
Skilled Wage in Non-Traded Services
South
North
time
Skilled Wage in Traded Services
South
North
time

Figure 3



Unskilled Wage
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
time
South
North

Figure 4


Skilled Workers
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
time
South
North

Figure 5

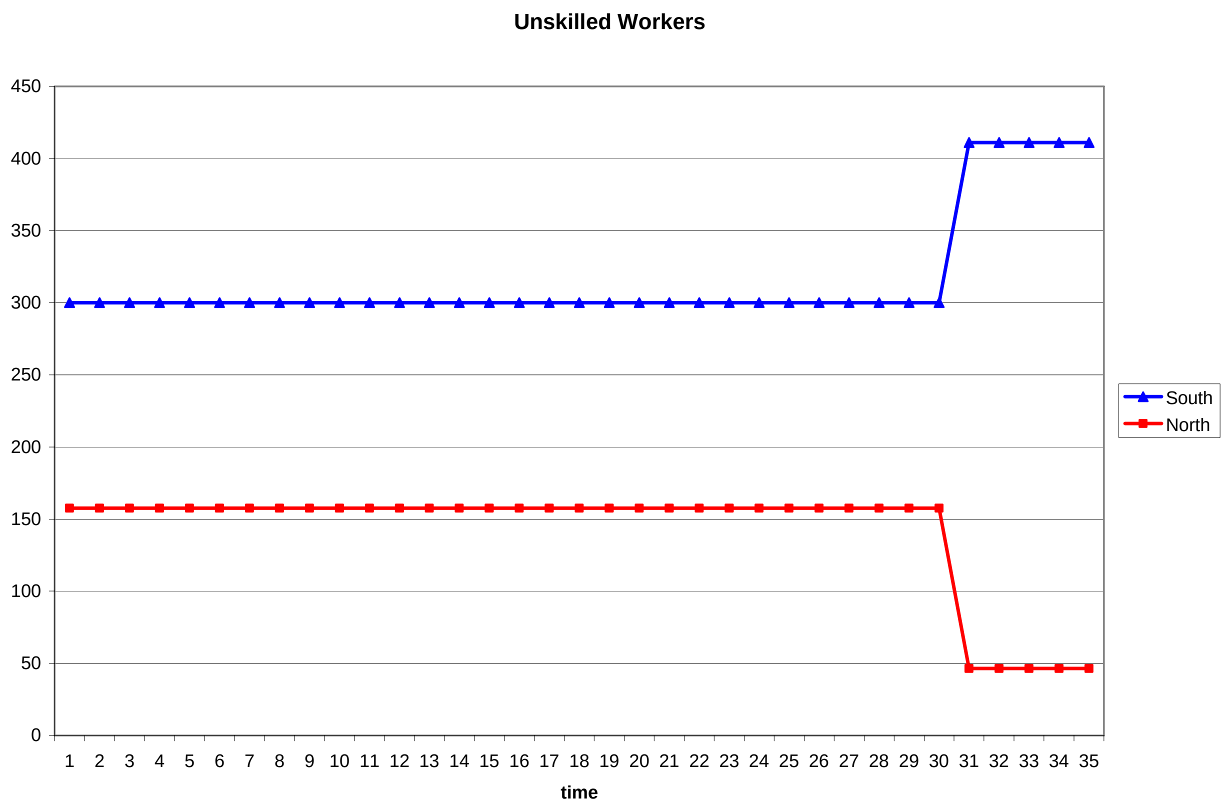
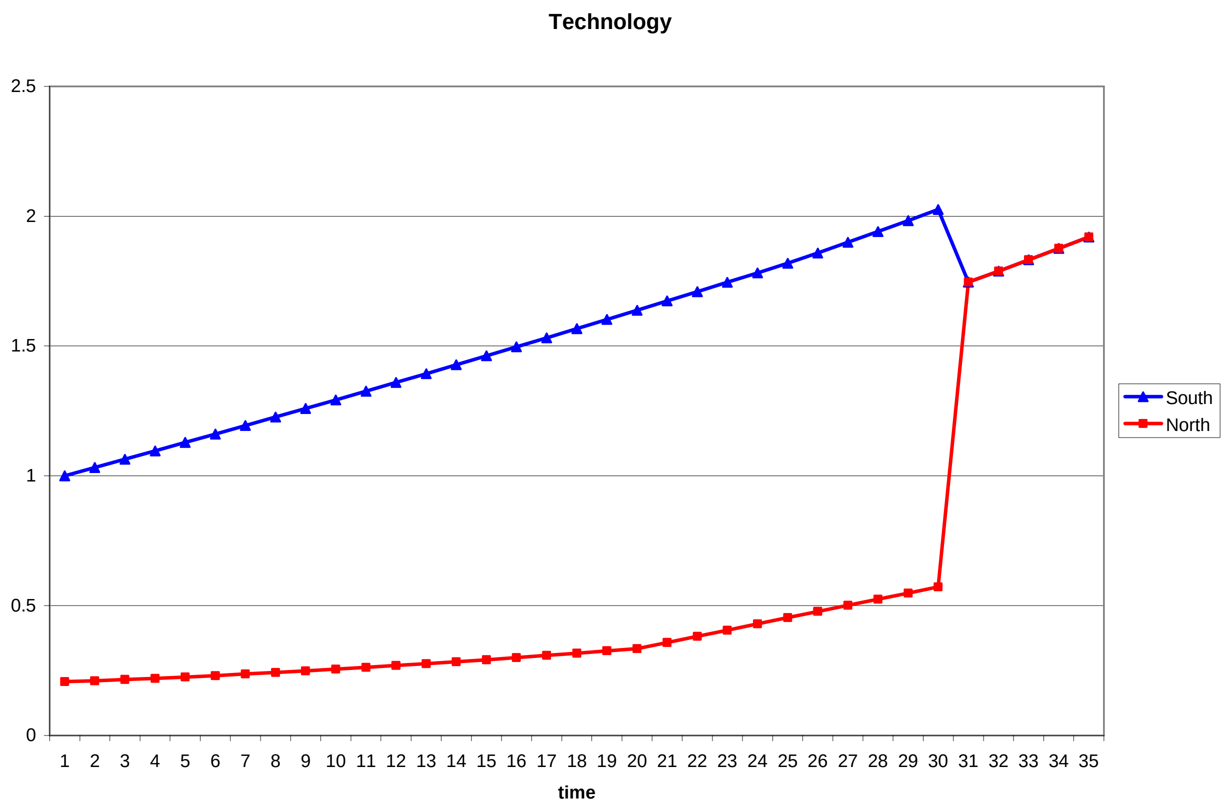
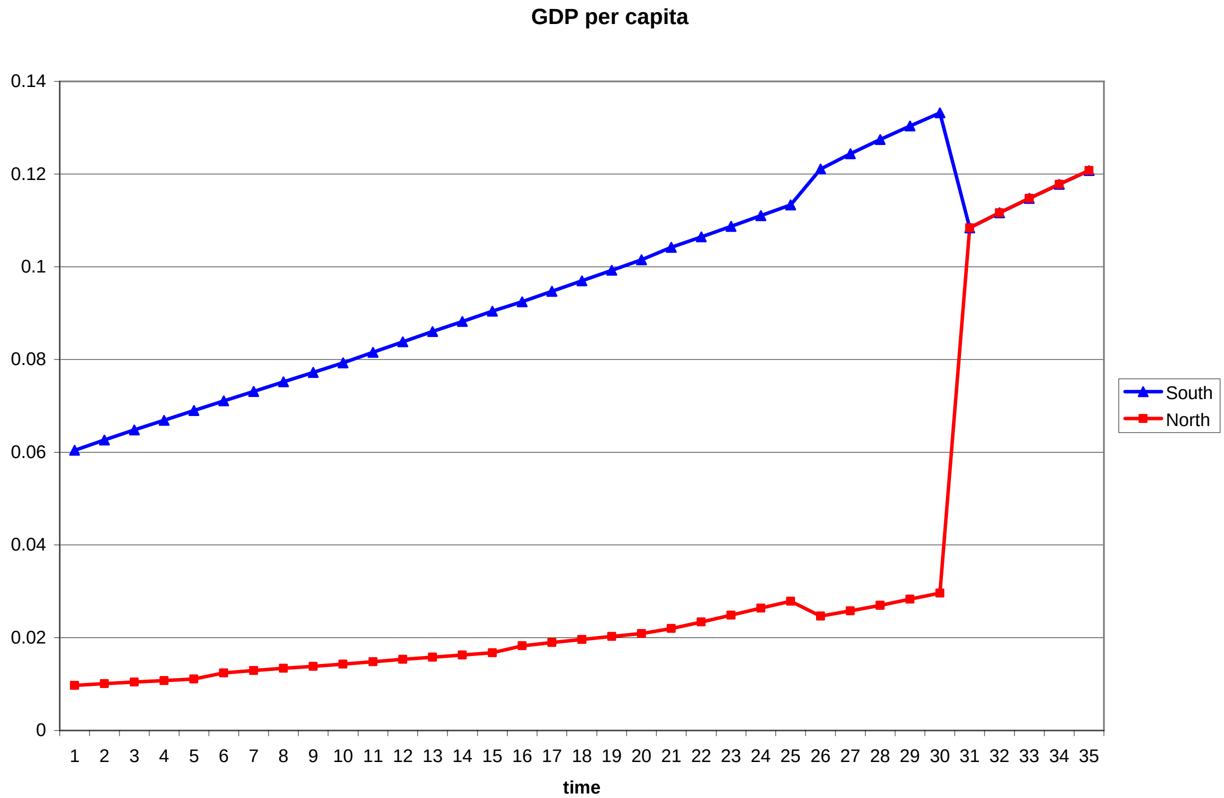

Unskilled Workers
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
time
South
North

Figure 6



Technology
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
time
South
North

Figure 7


GDP per capita
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
time
South
North