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Modeling Inter-Korean Economic Integration

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Abstract

We construct the Korean Integration Model (KIM), a two-country computable general equilibrium (CGE) model linking the North and South Korean economies. Using KIM, we simulate the impact of a customs union and a monetary union of the two economies both in the presence and absence of cross-border factor mobility. Factor mobility is of critical importance. If factor markets do not integrate, the macroeconomic impact on South Korea of economic integration with the North is relatively small, while the effects on North Korea are large. With a monetary union and factor market integration, there is a significant impact on the South Korean income and wealth distribution. If investment flows from South to North and labor flows from North to South, there is a shift in the South Korean income distribution toward capital, and within labor

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toward urban high skill labor, suggesting growing income and wealth inequality in the South. (JEL Classification: F15, O53, P33)

I. Introduction

The worsening economic plight of North Korea has been widely documented.[1] In response, the regime has initiated some modest reforms that do not alter the fundamental centrally planned character of the economy, but the policy changes to date are probably inadequate to address the task at hand. In one poll of scholars, 38 percent of the respondents predicted that the current regime would not last a decade Y. S. Lee [1995] . In a more recent poll, the respondents' mean subjective probability of collapse was 26 percent, while the mean estimate of significant reform was 40 percent Noland [1998], Table 1 .

One obvious direction of reform would be to marketize the economy and open it to greater interaction to the outside world – including South Korea. Greater North-South economic integration, either in the context of a reform strategy initiated by the North, or in the context of collapse and absorbtion by the South, potentially could have profound effects on both economies, yet scant effort has been devoted to constructing economic models to analyze this possibility. In this paper we construct the Korean Integration Model (KIM), a two-country computable general equilibrium (CGE) model linking the North and South Korean economies, extending earlier modeling work on the North Korean economy by Noland, Robinson, and Scatasta (NRS) [1997] . That work developed an eight sector, four factor, constant returns to scale computable general equilibrium (CGE) model of the North Korean economy. The single-country NRS model was used to examine three issues associated with economic reform: the static gains to trade liberalization, the increase in total factor productivity induced by the importation of capital goods embodying new technologies, and the "obsolescence shock" reduction in the capital stock as a result of the introduction of new goods and significant changes in the structure of relative prices. The model was calibrated to 1990, the last year before North Korea entered a period of

1. See Noland [1996] for an overview of the North Korean economy and additional referees not cited in this paper.

severe macroeconomic instability.

The main results obtained by NRS are that 1) the static gains from trade liberalization for North Korea are potentially huge – on the order of 25-35 percent depending on specific assumptions about factor market adjustment; 2) total factor productivity could increase by 18 percent, leading to a roughly 50 percent increase in national income in the complete liberalization scenario; and 3) that North Korea could absorb up to an approximately 50 percent "obsolescence shock" reduction in the capital stock before national income fell under successful economic reform.

Sectoral results reported in that paper indicated that there would be an enormous shift in the composition of output and employment towards the light industry sector (and to a lesser extent mining), while agriculture and the capital goods sector would tend to contract as factors were reallocated in a more economically rational way.

The NRS model was then used to calculate the "cost of unification" defined as the addition to the North Korean capital stock necessary to increase North Korean per capita incomes to 60 percent of those of the South, a target thought adequate to choke off incentives for mass migration. In 1990 this "cost of unification" was $319 billion, rising to $754 billion in 1995, and $1,721 billion in 2000 as the gap between North and South Korean incomes grew with delay in the initiation of reform.

In this paper we alter and extend the NRS model to a two-country setting by constructing a similar eight sector, four factor, constant returns to scale model of the South Korean economy and linking it to the North Korean model.[2] The Korean Integration Model (KIM) allows us to examine two issues of major importance – the macroeconomic impact on the North and South Korean economies of different modes of economic integration, and the impact on the distribution of income in and across the two economies.[3] Using KIM we simulate the impact of a North Korea – South Korea customs union, and a monetary union (defined as an exchange rate unification and a fixed

2. The KIM model differs from the NRS model in that the North Korean social accounting matrix (SAM) has been recalibrated and different substitution and transformation elasticities introduced.
3. The underlying sectoral results are similar to those obtained from the NRS model and are omitted here for the sake of brevity.

aggregate trade balance for the two economies) in the both presence and absence of cross-border factor mobility. Our results indicate that this distinction is of critical importance. If factor markets do not integrate, the macroeconomic impact on South Korea of economic integration with the North is relatively small. Far larger macroeconomic results are obtained when we create a monetary union and begin allowing factor market integration. Indeed, factor market integration has a significant impact on the South Korean income and wealth distribution. If investment flows from South to North and labor flows from North to South, there is a shift in the South Korean income distribution toward capital, and within labor toward urban high skill labor, suggesting increased income and wealth inequality in the South.

II. The Korean Integration Model (KIM)

The Korean Integration Model (KIM) is a member of a growing family of trade-focused, multi-country, computable general equilibrium models designed to analyze the impact of trade liberalization and the formation of free trade areas and customs unions. KIM consists of two linked country CGE models, one for North Korea and one for South Korea. The rest of the world is included by means of a simple representation of fixed world prices for North and South Korean exports and imports. The countries are linked by trade flows, and the model solves for all internal prices, including commodity and factor prices, and external prices of all traded goods. Domestically produced and traded goods are specified as imperfect substitutes, which provides for a realistic continuum of “tradability” and allows for two-way intersectoral trade.

KIM has a standard neoclassical specification, except that the model incorporates severe quantity controls in exports and imports, with concomitant distortions in domestic product and factor markets. The markets for goods, factors, and foreign exchange are assumed to respond to changing demand and supply conditions, which, in turn, are affected by government policies, the external environment, and other exogenous influences. The model can be considered medium-to-long run in that all factors are assumed to be intersectorally mobile. It is Walrasian in that only relative prices matter. Sectoral product prices, factor prices, and the exchange rate are determined relative to an aggregate consumer price index, which defines the numeraire.[4]

The model has eight sectors: agriculture/forest/fisheries, mining, light manufacturing, industrial intermediates, capital goods, construction, public administration, and services. There are three “demanders”: a single aggregate household which buys consumer goods, a government which spends on goods and public administration, and an aggregate capital account which purchases investment goods. Primary factors of production are capital, agricultural labor, high-skill urban labor, and low-skill urban labor. Land is not explicitly modeled as a separate factor and can be considered as subsumed in agricultural capital.

Sectoral production technology is represented by a set of Cobb-Douglas functions of the primary factors, while intermediate inputs are demanded according to Leontief, fixed input-output coefficients.[5] On the demand side, import demand functions are specified as AIDS (Almost Ideal Demand System)-translog – which allows substitution elasticities to differ between domestic-, Korean partner-, and rest-of-the-world-produced goods.

KIM focuses on real trade flows, relative prices, and the real exchange rate. The aggregate price level in each country is taken as exogenous, and the model does not include money or other assets. The model includes the basic macro aggregates for each country, including the government deficit, the balance of trade, and the savings-investment balance. The balance of trade for each country is fixed exogenously (except when modeling full integration), so the model does not consider any possible macro feedbacks from trade liberalization to changes in international capital flows. The macro “closure” for each country is simple. Government revenue is determined

4. The exchange rate variable in the model can be seen as a price level deflated (PLD) real exchange rate, deflating by the numeraire cost of living index.

5. In the case of North Korea aggregate production functions were estimated for aggregate capital and labor using data reported in Hwang [1993] and Y. S. Lee [1994]. The results are remarkably robust and plausible given the quality of the underlying data. Constant elasticity of substitution specifications yielded estimates of the substitutability between capital and labor of around unity. The hypothesis that the aggregate production function was Cobb-Douglas could not be rejected. In most specifications, North Korea exhibited slightly negative total factor productivity growth, which is typical of many pre-reform socialist economies.

endogenously, given a variety of fixed tax rates, while government expenditure is fixed endogenously. The government deficit is endogenous. Aggregate investment in each country is assumed to be a fixed share of GDP, and aggregate savings is assumed to adjust to equate total savings and investment.

KIM includes quantity rationing of both exports and imports. North Korea is assumed to have levels of "desired" exports and imports that would be typical for a country of its size and per capita income, but that exports and imports are rationed physically, yielding the low levels observed in the base data.[6] South Korean trade with North Korea is similarly assumed to be rationed in physical terms, and "desired" trade between the two countries is assumed to equal levels that would be predicted from a gravity model. Trade liberalization and integration in the form of a customs union is modeled by removing all quantity rationing and imposing a common external tariff equal to South Korean tariffs.

KIM also includes a facility for modeling monetary union by specifying: (1) a fixed exchange rate between North and South Korea, and (2) a unified, fixed, balance of trade for the two countries together. The result is that, in the various experiments done with this specification, the separate North and South Korean trade balances can vary, but their sum is fixed.

A. Modeling Quantity Controls in Trade

In the case of North Korea, the major distortion in the economy is assumed to be quantitative controls on both imports and exports. Because of data problems, discussed below, we assume no other sources of price distortions such as sectorally differentiated taxes and subsidies, which we treat explicitly in the case of South Korea. Such sectoral distortions undoubtedly exist in North Korea, but are effectively impossible to conceptualize much less measure, so we focus only on trade liberalization. Demanders are

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6. The volume of "desired" trade is obtained through the use of a gravity model of international trade. The sectoral composition of that trade was estimated using detailed sectoral data on North Korean trade, together with hte equivalent data from South Korea and Japan – North Korea's principal "natural" trading partners according to the gravity model. See Noland, Robinson, and Scatasta [1997] for detail.

assumed to treat imports and domestically produced goods as imperfect substitutes (the Armington assumption), and have an AIDS-translog sectoral import demand function that depends on the relative prices of imports and domestically produced goods on the domestic market. These demand functions are parameterized according to the "normal" levels of sectoral imports that one would expect North Korea to have without any rationing, given the results from the gravity model. Then, we assume the difference between desired imports and observed imports is due to the imposition of quantity rationing by the government. That is:

$$\left(\frac{M_i}{D_i}\right)^{rationed} = qr_i \left(\frac{M_i}{D_i}\right)^{desired} \tag{1}$$

where M is imports, D is domestic supply, qr is the quantity rationing rate, and the subscript i refers to the sector.[7]

The model also specifies sectoral export supply functions, where the export supply ratio depends on the ratio of the export price to the price on the domestic market. The supply functions are parameterized so that the desired ratio is consistent with the results from the gravity model. Symmetrically with the treatment of imports, quantity controls are specified so that actual exports are less than desired.

The result is that demanders are forced off their import demand curves and producers are forced off their export supply curves.[9] The distortions are quite large, indicating large potential gains from liberalizing trade and allowing markets to clear. The trade rationing leads to major distortions in the domestic price system as well.

B. Data

The model utilizes four main databases, macroeconomic and microeco-

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7. This approach to modeling import rationing was first used by Dervis, de Melo, and Robinson [1982], who discuss the properties of this approach, including questions of incentive compatibility.
8. The sectoral export transformation functions are specified as constant elasticity of transformation (CET) functions.
9. The degree of sectoral quantity rationing is given in Appendix Table 1.

nomic Social Accounting Matrices (SAMs) of North and South Korea for 1990, the most recent year for which data were relatively unaffected by the severe macroeconomic shocks that North Korea began to suffer in 1989 (see Appendix 1). In the case of South Korea, construction of the SAMs was straightforward. However in the case of North Korea, the approach we adopted was to draw on a variety of data sources and use a matrix balancing technique to ensure consistency that is essentially Bayesian in that it stays "close" to known controls (or Bayesian prior) while imposing all the consistency requirements of the balanced accounts.[10]

Data for the North Korean macroeconomic SAM were primarily derived from North Korean government budget data as reported in Hwang [1993]. One assumption made to build the macro SAM is that the North Korean government makes all investments. Government revenues are treated as being derived solely from direct household and enterprise taxes. Indirect taxes, import tariffs, and export tax rates are set to zero. In reality, revenues are raised from a transaction tax which varies depending on the legal status (state-owned, co-op, etc.) of the transacting parties, thus obviating the whole notion of a sectoral tax rate. In the absence of precise information about tax incidence, this was computed on the basis of a number of assumptions: (i) households' marginal propensity to save is between 30 percent and 40 percent; (ii) private savings are seized by the government via a number of instruments which are here summarized as a direct income tax; (iii) data about government current expenditure and investment are assumed to be reliable; (iv) part of capital/land returns are distributed to households, but capital/land income from public enterprises is appropriated by the government in the form of a enterprise tax.

The input-output coefficients are contained in a microeconomic SAM which was derived from a pre-reform [1979] Chinese input-output table compiled by the World Bank. This table was constructed to SNA standards, expanding on the material product accounts World Bank [1985] . The assumption is that a good starting point (or prior) for inter-industry input-output relations in North Korea is pre-reform China, reflecting their com-

10. The particular technique we used is a "cross entropy" method that is described in Golan, Judge, and Robinson [1994].

mon links to 1970s vintage Soviet manufacturing technology.[11] This does not imply that the sectoral output shares are similar to China's – North Korea is clearly a more industrialized economy – but simply that the use of intermediate inputs to create final output is similar to China's.

In the cross-entropy estimation procedure, we minimize the entropy distance between the new estimates, which are consistent with all of the information we have, and the prior. In general, the better the data, the less important the prior. In our case we experimented with using the South Korean input-output table as our prior. None of the qualitative results changed, and many of the quantitative results scarcely changed either. Given the degree of aggregation of the model this should not be surprising – the results are not being driven in any major way by the particular input-output structure.

Urban workers are divided into high skilled (professional, technical, and managerial) and low skilled (the remainder). The initial starting point for industry employment structure was taken from the Chinese data. The wage premium was calculated on the basis of South Korean data. While one might expect a priori that wage dispersion in the North would be less than in the South, at this level of sectoral aggregation, the skilled wage premium obtained from the South Korean data was within the dispersion observed in fragmentary data on North Korean wages. Sectoral outputs are derived from estimates of North Korean GDP Noland [1996] and output shares reported by the Korea Development Bank [1994]. When these output shares were applied to the labor data they yielded a rural wage that was too high relative to urban wages. The agricultural sector's share was reduced to about 21 percent of value-added which reduced agricultural wages to a level more consistent with the fragmentary North Korean wage data.[12] A real exchange rate was constructed from the GDP estimates reported in Noland [1996]. The real (PPP adjusted) North Korean won-US dollar exchange rate was used to convert export and import data from dollars into won to obtain

11. For a description of the Soviet origins of North Korean industrial technology, see Bazhanova [1992].
12. This highlights the importance of working within a SAM framework which enables the researcher to detect potential discrepancies between the available data sources and to adjust the data sets in a way which is internally consistent.

the domestic resource equivalent of external trade. The model equations and further description are presented in Appendix 2.

III. Policy Experiments

Integration is studied under two main scenarios. The formation of a customs union which involves: (a) the elimination of North Korean quantity rationing of trade, (b) the elimination of intra-Korean barriers to trade, and (c) the adoption of South Korea tariffs as the common external barrier. In this scenario, there is product, but not factor, market integration between North and South Korea. The second main scenario involves the formation of a monetary union in which the real exchange rate between North and South Korea is fixed. Three variants are examined. In the first, capital moves from South to North Korea until North Korean per capita income rises to 60 percent that of the South's.[13] In the second variant, this is achieved by allowing labor to migrate from North to South Korea. In the third variant, the per capita income target is achieved through the movement of both labor and capital. This formulation not only allows us to calculate the macroeconomic impacts of product and factor market integration, but also permits us to calculate income and its distribution with respect to the both the original populations of North and South Korea, and the post factor market integration distribution of population on the Korean peninsula.

A final issue involves the specification of the North Korean economy. As argued in NRS, liberalization of the North Korean economy is likely to involve at least three identifiable effects: static reallocation of factors according to comparative advantage; an increase in total factor productivity (TFP) associated with importation of capital equipment embodying new, superior, technology developed abroad, and an "obsolescence shock" reduction in the value of the existing capital stock.[14]

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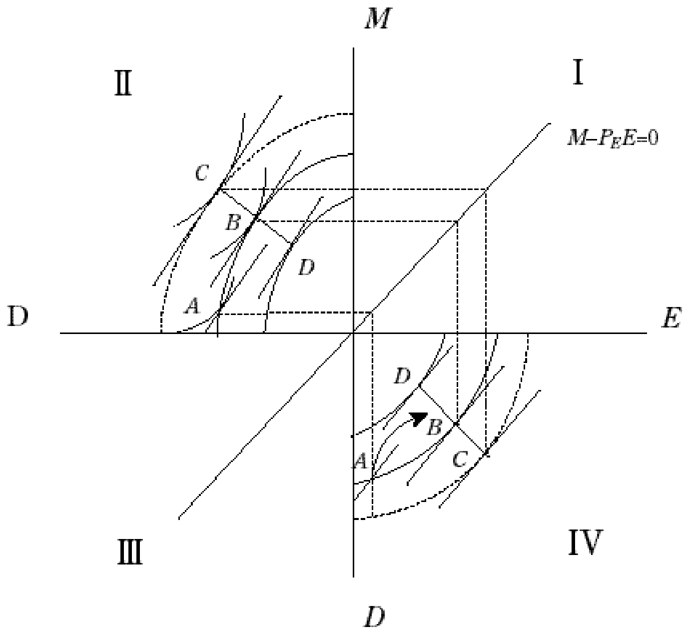
13. This is the figure conventionally thought to choke off incentives for mass migration and was selected to facilitate comparison with previous studies. See Noland [1997] for further discussion and citations.
14. A referee has suggested that North Korea has developed technology that is highly dependent on domestically produced intermediates, and this, rather than quantitative controls on trade, is the real reason that North Korea exhibits such small vol-

Figure 1



This is illustrated graphically in Figure 1, which presents a simplified model with an imported good (*M*), an export (*E*), and a domestic non-traded good (*D*). The country produces two goods, *D* and *E*, and consumes two goods, *D* and *M*. The production possibility frontier is given in quadrant IV (lower right) and the balance-of-trade constraint is given in quadrant I (upper right). The consumption possibility frontier is given in quadrant II (upper left), which indicates supplies to the domestic market of domestically produced goods (*D*) and imports (*M*), with *M* being purchased from

umes of trade. For many final goods (food, for example) this is clearly not the case. Nevertheless, it may well be the case, that North Korea's indigenous technology may affect its response to liberalization. Robinson, Noland, and Liu [1998] report results that assume that North Korea gradually adopts South Korean technology as the two economies integrate and South Korean investment occurs. These results suggest that North Korean final goods production is highly intermediate-input intensive (*i.e.* North Korea wastes a lot of intermediate inputs, as do other socialist economies) and that the process of liberalization could have even bigger pay-offs than described in this paper.

export receipts (quadrant 1).

Figure 1 shows the movement from rationing equilibrium A to free trade equilibrium B in quadrants II and IV. The movement from point A to point B in the fourth (lower right) quadrant changes the structure of production and will yield an increase in real output (GDP) measured in base prices, even though it represents a movement along the same production possibility frontier. In quadrant II, real expenditure (absorption) measured at base prices also increases, as does welfare (measured by the difference between two indifference curves). These three measures all reflect the increase in efficiency arising from the removal of rationing.[15]

Recent research suggests that the world is characterized by international technological spillovers. These are quite important in the case of developing countries which benefit from technological developments abroad transmitted through primarily through international trade interacting with the domestic capacity for absorption. In the case of North Korea, the parameters estimated by Coe, Helpman, and Hoffmaister [1996] indicate that complete liberalization would result in a total factor productivity gain of approximately 18 percent.[16] This is depicted in Figure 1 as the movement from the rationing equilibrium A to the free trade equilibrium C on the new, expanded, production and consumption possibility frontiers.[17]

Finally, an important question involves the value after liberalization of the pre-existing capital stock. There are two points to consider. First, due to the putty-clay nature of technology, the capital stock accumulated under one set of output and factor prices is likely to be sub-optimal for different relative prices. While this is true for all economies, the impact is particularly acute for transition economies, where the relative prices under central planning were wildly at variance with those observed in world markets. Second, economies sheltered from international trade may manufacture products

15. Empirically, these three measures turn out to assume very similar values.
16. This estimate is derived from a regression model relating total factor productivity to imports of capital goods from developed countries, secondary school enrollments, and interaction terms.
17. It is also possible that the North Korean productivity increase could come about through the introduction of South Korean managers (along with South Korean capital) as argued by Dyck [1997].

that are essentially worthless in world markets. (Think of televisions or radios without tuners – both of which are produced in North Korea.) To the extent that capital is product-specific, this capital will be effectively worthless when the economy is opened up to trade. Sinn and Sinn [1992] report that one half to two-thirds of East Germany's capital stock was worthless after unification. If lack of exposure to international trade is taken as a proxy for internal distortion, the North Korean economy is likely to be even more distorted than was the East German economy.[18] This is depicted as equilibrium D on the new, smaller, production and consumption possibility frontiers.[19]

NRS explored these possibilities in some detail. In the interests of parsimony, unless otherwise indicated, we report here only the experiments in which North Korea undergoes complete liberalization, experiences an 18 percent total factor productivity increase, and suffers an "obsolescence shock" reduction of two-thirds of its capital stock.

A. The Results

The key results are that the impact on South Korea of *product* market integration in the customs union scenario is relatively minor: trade with North Korea simply substitutes for trade with other countries and, given the small size of North Korea relative to South Korea, trade creation and diversion have a trivial impact on South Korea (Tables 1 and 2). With regards to

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18. This treatment is obviously a stylized one. One way to think of it is that there are goods with positive prices in autarchy and a world price of zero. When the economy is opened up, product specific capital depreciates instantly.

19. There is a counterargument that the North Korean capital stock might not decline by as much as the East German case. Two reasons are given. First, it is argued that the decline in the value of the East German capital stock was partly a result of West German transfers that facilitated the shift in demand from formerly East German home goods to imports from the West. If the North Koreans received fewer transfers they would be forced to continue buying home goods, maintaining the value of the North Korean capital stock.

    Second, the East Germans lost their major markets in other centrally planned economies, contributing to the decline in the capital stock. It has been asserted that China represents a viable market for cheap, low quality North Korean manufactured goods.

    If one accepts these arguments, then one should focus on the previously described scenarios in which the value of the North Korean capital stock is implicitly maintained.

Table 1
Korean Customs Union

	Trade Liberalization, TFP increase, no obsolescence shock	Trade Liberalization, TFP increase, 2/3 reduction in capital stock
	Percentage changes from base	
GDP Growth		
South Korea	0.1	–0.1
North Korea	29.3	–32.3
Combined	3.8	–4.1
Agricultural Labor Wage		
South Korea	–1.2	–0.6
North Korea	23.1	–29.5
Low-Skill Urban Wage		
South Korea	0.5	0.5
North Korea	43.9	–5.6
High-Skill Urban Wage		
South Korea	0.5	0.4
North Korea	35.2	–6.1
Rental Rate on Capital		
South Korea	0.5	0.3
North Korea	36.6	87.4

North Korea, the results are similar to those obtained under MFN liberalization as reported by NRS, and are completely dominated by the assumed size of the obsolescence shock.[20]

The integration of *factor* markets is a different story, however. With monetary union, it is natural to expect the capital market, if not the labor market,

20. The decline in the agricultural wage while urban wages are rising would presumably lead to rural-urban migration. The model was re-run allowing for migration between the rural and low-skill urban labor. In the baseline case in which the large wage relative difference arose in the customs union model with trade liberalization and TFP growth, when migration was permitted, 540,000 workers in North Korea, and 40,000 workers in South Korea left agriculture for the urban sector. In the customs union model with trade liberalization, TFP increase, and 2/3 capital stock reduction, the rural to urban migration figures are 310,000 for North Korea and 61,000 for South Korea. These results are summarized in Table 2. Results reported in the remainder of the paper allow for rural-urban migration.

Table 2
Korean Customs Union with Rural-Urban Migration

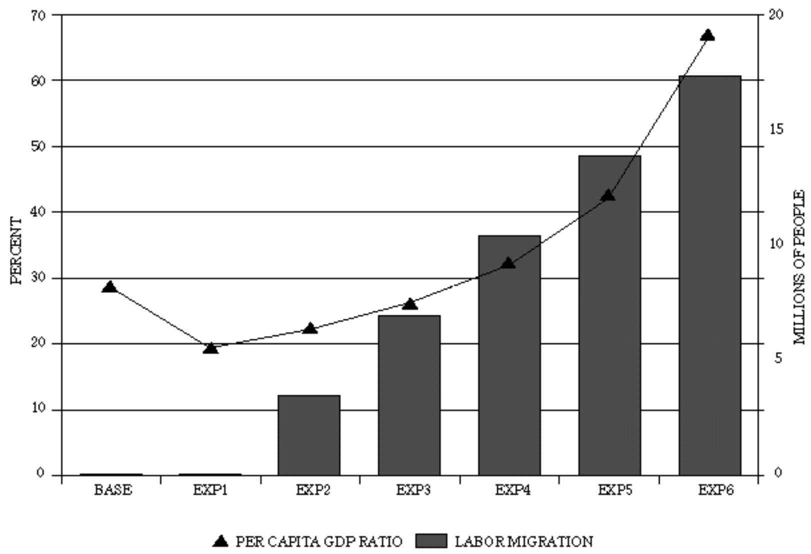
	Trade Liberalization, TFP increase, no obsolescence shock	Trade Liberalization, TFP increase, 2/3 reduction in capital stock
	Percentage changes from base	
GDP Growth		
South Korea	0.24	0.03
North Korea	29.8	–31.7
Combined	3.9	–4.0
Agricultural Labor Wage		
South Korea	0.12	0.2
North Korea	37.5	–12.8
Low-Skill Urban Wage		
South Korea	0.1	0.2
North Korea	37.5	–12.8
High-Skill Urban Wage		
South Korea	0.6	0.4
North Korea	34.9	–6.6
Rental Rate on Capital		
South Korea	0.4	0.3
North Korea	37.0	88.0

to integrate. For heuristic purposes, however, we initially consider the hypothetical case in which the inter-Korean labor market integrates but the inter-Korean capital market does not (that is to say labor flows from North to South, but capital does not flow the other direction). In this case, three-quarters of the population of North Korea would migrate South before the 60 percent per capita income target was attained (Figure 2). This extreme result serves to underscore the critical importance of generating capital inflows into North Korea.[21]

In the more plausible converse case, where capital flows North, but labor

21. We have assumed that this migration solely takes the form of North Korea - South Korea migration. It is quite possible that in reality there might also be emigration to other destinations, in particular China. If this were the case it would obviously effect the precise calculation of migration necessary to achieve the income convergence target.

Figure 2
Per Capita GDP Gap & Labor Migration



is not permitted to move South, around $400 billion of capital (18 percent of the South Korean capital stock) would be required to move in order to attain the per capita income target, underlining the implicit trade-off between capital and labor flows as equilibrating adjustment mechanisms (Figure 3).[22]

Having established the extreme bounds of cross-border factor mobility necessary to achieve the per capita income convergence target, we focus on the intermediate case in which there is a degree of cross-border movement in both labor and capital (Figure 4). Five experiments are run. In EXP1, North Korea experiences income gains from static reallocation of factors and induced total factor productivity increase, but these are not sufficient to maintain income in the face of a two-thirds of the capital stock obsolescence shock. In the succeeding experiments we allow workers to migrate from

22. We have treated the capital movement as a pure grant. It is also possible to calculate the rents and impute them to South Korean national income as remitted profits, as is done in one calculation below.

Figure 3
Per Capita GDP Gap & Capital Migration

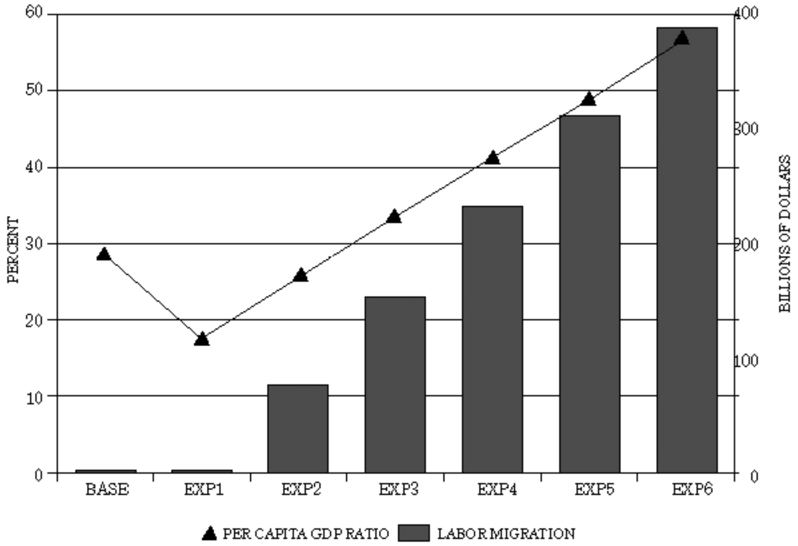
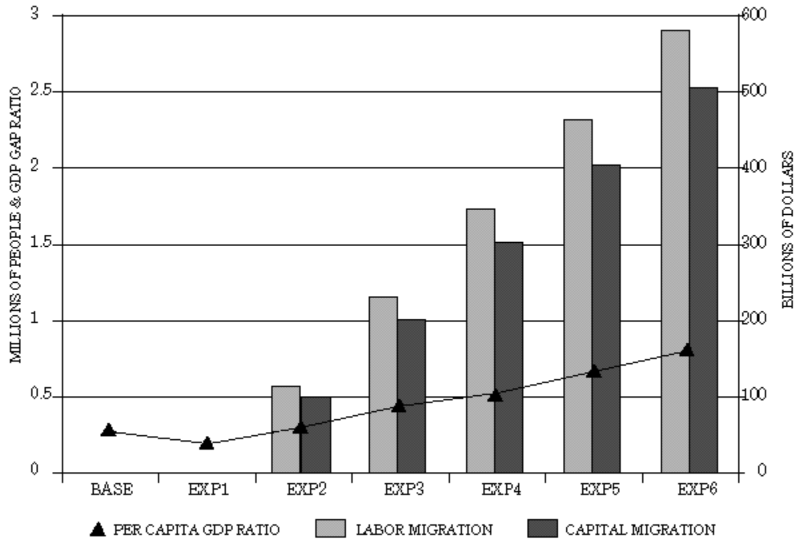


Figure 4
Per Capita GDP Gap & K-L Migration



North Korea to South Korea in increments of three percent of the population (approximately 600,000 people). At the same time we transfer capital from South to North Korea in increments of approximately 30 percent of the North Korean capital stock, or around $100 billion per experiment.

Real GDP rises in North Korea and falls slightly in South Korea in response to these factor movements (Figure 4). Income for the combined Koreas rises as the returns to factors are equalized in the two economies, with combined income exceeding the base by almost seven percent in experiment 6 (EXP6).

The capital-labor ratio and the returns to labor rise in North Korea, which experiences capital inflow and labor outflow. The opposite is true in South Korea. The rate of return on capital rises in both Koreas, however. The capital-labor ratio is falling in South Korea. Due to the obsolescence shock is it has also fallen in North Korea, plus the increase in TPF increases the productivity and returns to all factors, including capital. In EXP4, where approximately $300 billion of capital flows North, and roughly 1.7 million people come South, the 60 percent per capita income target is attained. Further increases in capital transfers and labor migration (EXP5 and EXP6) lead to

Figure 5
GDP Changes with K-L Migration

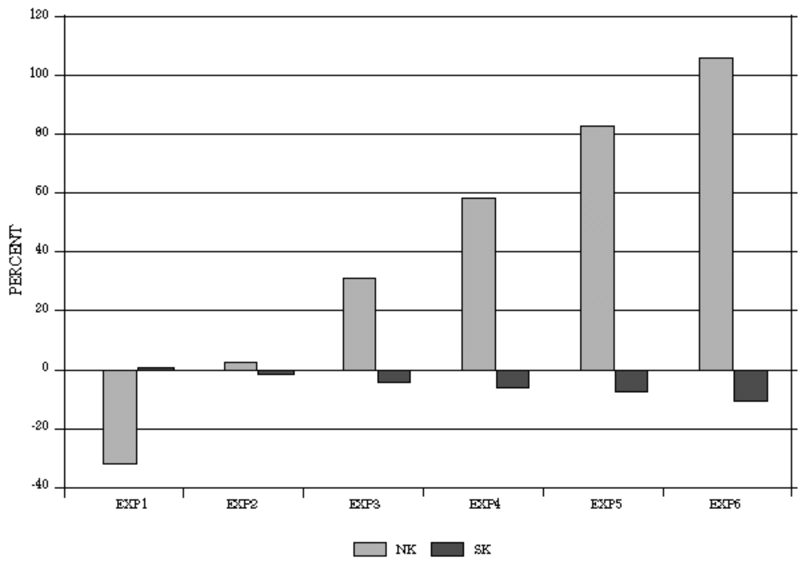
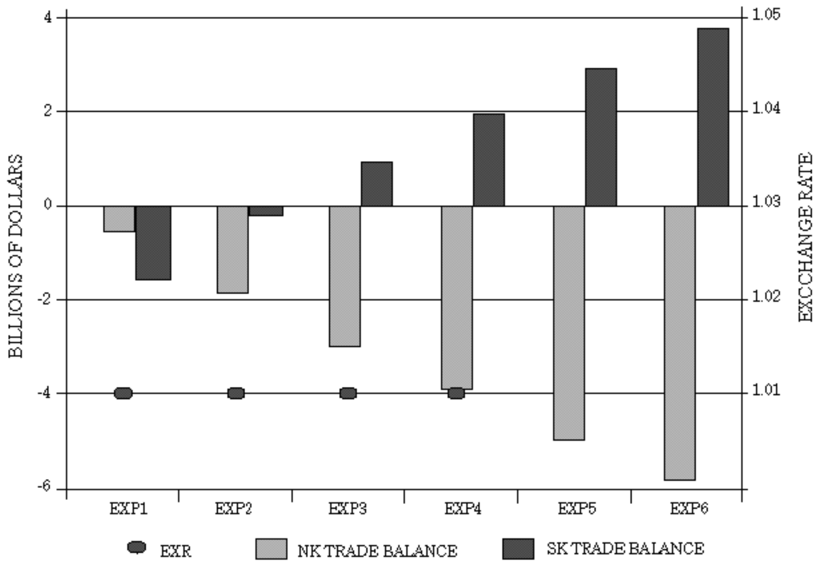


Figure 6
Trade Balance and Exchange Rate



even greater per capita income convergence. As for GDP changes, the North Korean GDP has more than doubled, whereas the South Korean GDP has declined by less than 10 percent. The combined GDP, however, has increase by 7 percent (Figure 5).

Relative to the base case, trade with the rest of the world rises sharply in North Korea and remains roughly constant in South Korea. However, with the aggregate trade balance fixed, the rise in the North Korean deficit is offset by South Korea, which goes from a small deficit to a small surplus with the rest of the world (Figure 6). The unified currency experiences a slight real depreciation.

Inter-Korean trade increases enormously with the elimination of inter-Korean trade barriers, with the small North Korean surplus vis-a-vis the South growing to a surplus on the order of one to one and one half billion dollars, across the six experiments.

The model can also be used to examine the impact of factor market integration on the distribution of income – both among income classes, and

Table 3
South Korean Income Distribution

	Percentage Share of National Income			
	Base	EXP4, capital transfer treated as grant	EXP4, capital transfer treated as remitted profits	EXP4, defined with respect to current residents, capital transfer treated as remitted profits, migrants wages excluded
Factor				
Agricultural Labor	2.8	2.9	2.6	2.4
Low Skill Labor	19.4	20.6	17.9	17.1
High Skill Labor	28.5	28.8	25.1	25.4
Capital	49.4	47.6	54.4	55.1

between capital and labor, both inclusive and exclusive of migrants. We focus exclusively on EXP4, where approximately $300 billion of capital flows from South to North Korea, and around 1.7 million North Koreans migrate South.

In this case, the distribution of income in South Korea shifts away from capital and toward labor when the capital flow is treated as a pure grant and the distribution of income is calculated inclusive of wages earned by immigrants from North Korea (Table 3). Within labor there is a slight shift concentration of income in the high skilled group.

However, if the capital transfer is treated as investment yielding a stream of remitted profits, the income distribution shifts strongly toward capital and away from labor. This outcome is reinforced if the income distribution is calculated with respect to current residents of South Korea – that is to say if immigrants wages are excluded from the calculation. In this case there is both a shift in the income distribution toward capital and within labor a shift in the distribution toward the high skilled group. Ownership of capital is presumably concentrated in the high skilled group, which suggests that economic integration along the lines of EXP4 would result in widening income and wealth inequality among current South Koreans.

IV. Conclusion

The Korea Integration Model (KIM) is, to our knowledge, the first behavioral economic model of economic integration between North and South Korea. We have used it to focus on the macroeconomic impact on the two economies of economic integration and the impact of economic integration on the distribution of income.

From the standpoint of South Korea the results highlight the critical role of cross-border factor mobility. As shown in Tables 1 and 2, if factor markets do not integrate, the macroeconomic impact of economic integration with the North on South Korea is relatively small, regardless of assumptions about the magnitude of the obsolescence shock to the North Korean capital stock. The North Korean economy is small relative to South Korea and inter-Korean trade simply substitutes for trade with third parties. The degree of trade creation and diversion are trivial under a customs union without cross-border factor movements.

However, far more significant results are obtained when we create a monetary union and begin allowing factor market integration. As shown in Figures 2-4, labor and capital movements are in effect substitutes: enormous movements of labor are required to attain the per capita income convergence target in the absence of capital flows from South to North.

Moreover, these capital and labor flows have a significant impact on the distribution of income in both economies, which we calculate with respect to both the pre- and post-migration distribution of the population (Table 3). As might be expected, the results depend critically on whether the capital transfer is treated as a grant or as investment yielding remitted profits. In the latter case, the South Korean distribution of income shifts toward capital and away from labor, and within labor toward urban high skill labor.

Several extensions to this work are obvious. First, the model is calibrated for 1990, the most recent year for which the North Korean data are not contaminated by severe macroeconomic shocks. One possibility would be to update the South Korean part of the model using actual data, and the North

Korean part of the model using conjectured data. If the model were recalibrated in this way, the amounts of labor and capital that would have to move to attain per capita income convergence would increase. Calculations reported by NRS indicate that on current trends the doubling rate of the divergence between North and South Korean per capita income is roughly every five years, so for example, if the model were recalibrated to 1995, roughly twice as much capital or labor would have to move to achieve the same degree of convergence.

Second, an alternative to the approach of modeling TFP growth as a function of imported capital goods would be for North Korea to adopt South Korean technology as a function of the extent of capital transfer.

Third, our closure of the monetary union experiment fixed the combined Korean trade imbalance at its observed level and allowed the unified real exchange rate to adjust endogenously. It is quite plausible instead to assume that the unified Korea would experience additional capital inflows together with a real exchange rate appreciation.

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Appendix 1
Social Accounting Matrices

KIM utilizes two main databases for North Korea, a macroeconomic and a microeconomic Social Accounting Matrix (SAM) of North Korea for 1990, which is the most recent year for which data were relatively unaffected by the severe macroeconomic shocks that began in 1989. A Social Accounting Matrix (SAM) is a consistent array of economic transactions among agents that reconciles the input-output and national accounts.[23] Each non- zero cell in the SAM represents the value of an economic transaction between actors. The accounts of the SAM define the transactions and income flows among five basic actors in the economy: producers/enterprises, households, government, capital account and the rest of the world. The input-output notion of inter-industry linkages is generalized to the idea that each actor's purchase is another actor's sale. Any flow of money from one actor to another is recorded in the SAM as a payment by some actor (the column) to some other actor (the row). The SAM also generalizes the national income accounting notion that income equals expenditure. The SAM must in fact be balanced: the total sum of each column must be equal to the total sum of each row, so that a budget constraint is imposed on each productive sector, labor category, household type and so forth. This means that (1) costs (plus distributed earnings) exhaust revenues for products, (2) expenditure (plus taxes and savings) equals income for each agent, and (3) demand equals supply for each commodity.

The SAM is divided into a number of blocs. The Activities bloc describes the costs and revenues for domestic producers. In the columns the producers buy intermediate inputs, make value added payments to primary factors and transfer indirect, value added and export taxes to (or receive subsidies from) the government. In the rows they sell goods on domestic and foreign markets. The Commodities bloc describes markets for final products. The row describes sales on the domestic market, distinguishing between intermediate, consumption and investment demand. The column identifies

23. For a detailed treatment of Social Accounting Matrices see Pyatt and Round [1985], Stone [1986], or Devarajan, Lewis and Robinson [1994].

absorption, which equals the value of domestic products sold on the domestic markets plus imports (valued at world prices), consumption taxes, value added taxes and tariffs. The Factors bloc describes value added payments to primary factors (in the row) and their distribution to specific institutions (enterprises, households, and government) plus the payment of direct factor taxes (in the column). The remaining blocs describe transfers among institutions.

Appendix 2
Structure of The Kim-CGE Model

Solving the CGE Model

The two-country CGE model presented here has been developed and solved using a package called the General Algebraic Modeling System (or GAMS).[24] To a great extent, the GAMS representation of model equations is easily read as standard algebraic notation. Subscripts indicating countries, sectors, or factors appear in parentheses [X_{ij} becomes $X(i, j)$], and a few special symbols are used to indicate algebraic operations [Σ becomes SUM, Π becomes PROD]. For example, the Cobb-Douglas consumer price index equation:

$$PINDCON = \prod_i PC_i^{pwtc_i}$$

is represented in GAMS as:

$$\text{PINDCON} = \text{PROD}(i, PC(i)^{**}pwtc\,(i, k))$$

where PROD stands for the product operator, the i at the left of the parenthetic expression is the sectoral index over which summation occurs, and

24. GAMS is designed to make complex mathematical models easier to construct and understand. In our case, we are using it to solve a large, fully-determined, non-linear CGE model (where the number of equations and number of variables are equal), although GAMS is suitable for solving linear, non-linear, or mixed integer programming problems as well. For a thorough introduction to model-building in GAMS, see Brooke, Kendrick, and Meeraus [1988].

the two asterisks (**) indicate exponentiation.[25]

Table I lists the countrywide, sectoral, and factor classifications used in the model, as well as identifying the sectoral subsets that are needed in the equations of the model. Table II contains the variable definitions used in the CGE model. Table III contains the parameter definition that appear in the model equations.

Table I: Variables in the KIM-CGE Model

Price Block	
EXR (k)	Exchange rate
PC (i, k)	Consumption price of composite good
PD (i, k)	Domestic prices
PDA (i, k)	Processors actual domestic sales price including subsidy
PE (i, k, cty1)	Domestic price of exports
PEK (i, k)	Average domestic price of exports
PINDCON (k)	Consumer price index
PM (i, k, cty1)	Domestic price of imports
PQ (i, k)	Price of composite goods
PREM (i, k)	Premium income from import rationing
PVA (i, k)	Value added price including subsidies
PVAB (i, k)	Value added price net of subsidies
PWE (i, cty1 , cty2)	World price of exports
PWM (i, cty1, cty2)	World price of imports
PX (i, k)	Average output price
TM2 (i, k, cty1)	Import premium rates
Production Block	
D (i, k)	Domestic sales of domestic output
E (i, cty1, cty2)	Bilateral exports
EK (i, k)	Aggregate sectoral exports
INT (i, k)	Intermediate demand

25. There are a few other syntax rules and conventions that appear in the equations shown below. The "$" introduces a conditional "if" statement in an algebraic statement. For example, $PM(i, k, cty\ 1)$ \$$imi(i, k, cty\ 1)$ = xxx will carry out the expression shown for all $PM(i, k, cty\ 1)$ that belong to the set $imi(i, k, cty\ 1)$; in other words, calculate an import price for all sectors in which there are imports.

M (*i*, *cty*1, *cty*2)	Bilateral imports
Q (*i*, *k*)	Composite goods supply
SMQ (*i*, *k*, *cty*1)	Import value share in total sectoral demand
X (*i*, *k*)	Domestic output

Factor Block

AVWF (*iff*, *k*)	Average wage with current weights
FDSC (*i*, *iff*, *k*)	Factor demand by sector
FS (*iff*, *k*)	Factor supply
WF (*iff*, *k*)	Average factor price
WFDIST (*i*, *iff*, *k*)	Factor differential
YFCTR (*iff*, *k*)	Factor income

Migration Block

WGDFL (*la*, *k*, *lb*, *l*)	Wage differentials
MIGL (*la*, *k*)	Labor migration flows (within category)
MIGRU (*la*, *k*)	Labor migration flows (across category)

Income and Expenditure Block

CDD (*i*, *k*)	Private consumption demand
CONTAX (*k*)	Consumption taxes
ENTSAV (*k*)	Enterprise savings
ENTAX (*k*)	Enterprise taxes
ENTT (*k*)	Government transfers to enterprises
ESR (*k*)	Enterprise savings rate
EXPTAX (*k*)	Export tax revenue
FBAL (*k*)	Overall current account balance
FBOR (*k*)	Foreign borrowing by government
FSAV (*k*, *cly*1)	Bilateral net foreign savings
FTAX (*k*)	Factor taxes
GD (*i*, *k*)	Government demand by sector
GDPVA (*k*)	Nominal expenditure GDP
GDTOT (*k*)	Government real consumption
GOVSAV (*k*)	Government saving
GOVREV (*k*)	Government revenue
HHT (*k*)	Government transfers to households
HSAV (*k*)	Aggregate household savings
HTAX (*k*)	Household taxes

ID (*i*, *k*)	Investment demand (by sector of origin)
INDTAX (*k*)	Indirect tax revenue
MPS (*hh*, *k*)	Savings propensities by households
REMIT (*k*)	Remittance income to households
TARIFF (*k*, *cty*1)	Tariff revenue
VATAX (*k*)	Value added taxes
YH (*hh*, *k*)	Household income
YINST (*ins*, *k*)	Institutional income
ZFIX (*k*)	Fixed aggregate real investment
ZTOT (*k*)	Aggregate nominal investment

Table II: Country, Sectoral and Factor Classifications in the KIM-CGE Model

Countries and Regions			
CTY1, CTY2	Universe	NK	North Korea
		SK	South Korea
		RT	Rest of the world
K (CTY1)	Countries	NK	North Korea
		SK	South Korea
Sectors and Groupings			
I, J	Sectors of production	AGRFSH	Agriculture/Forest/Fishery
		MINING	Mining
		LMANUF	Light Manufactures
		INTERM	Intermediate goods
		KGOODS	Capital goods
		CONSTR	Construction
		PUBADM	Public administration
		SVC	Services
im (*i*, *k*)	Import sectors		
imn (*i*, *k*)	Non-import sectors		
ie (*i*, *k*)	Export sectors		
ien (*i*, *k*)	Non-export sectors		
imi (*i*, *k*, *cty*1)	Bilateral imports in base data		
iei (*i*, *k*, *cty*1)	Bilateral exports in base data		

iel (*i*, *k*)	Aggregate CET export sectors
ied (*i*, *k*)	Downward sloping export demand from rest of world
ik (*i*)	Capital and intermediates goods sectors (INTER, KGOODS)
iag (*i*)	Agricultural sectors (AGRFSH)
iagn (*i*)	Non-agricultural sectors
iserv (*i*)	Service sector (SCV)

Factors and Groupings

iff, f	Factors of production	CAPITAL	Capital stock
		AGLAB	Rural agricultural labor
		URBUNSK	Urban unskilled labor
		URBSKLD	Urban skilled labor

Households and Institutions

hh	Households	HHALL	Single household category
ins	Institutions	LABR	Labor
		ENT	Enterprises

Table III. Parameters in the KIM-CGE Model

Basic model Parameters

CLES (*i, hh, k*)	Household consumption shares
EB (*i, cty*1, *cty*2)	Exports, base data
EKB (*i*, *k*)	Total sectoral exports, all destinations, base data
ENTR (*k*)	Enterprise income tax rate
FS0 (*iff, k*)	Aggregate hctor supply, base data
FT (*k*)	Factor tax rate
GLES (*i*, *k*)	Government expenditure shares
GOVGDP (*k*)	Govermnent expenditure to GDP ratio
HHTR (*hh, k*)	Household income tax rate
INVGDP (*k*)	Investrnent to GDP ratio
IO (*i*, *j*, *k*)	Input output coefficients
LSH (*hh, k*)	Household transfer income shares
PVAB0 (*i*, *k*)	Baseyear value added price
PWEB (*i, cty*1, *cty*2)	World price of exports, base data
PWM0 (*i, cty*1, *cty*2)	World market price of imports, base data
PWTC (*i*, *k*)	Consumer price index weights (PQ)
RHSH (*hh, k*)	Household shares of remitt nce incomc

SINTYH (*hh, ins, k*)	Household distribution of value added income
SPREM (*i, k*)	Share of premium revenuc to the government
TC (*i, k*)	Consumption tax rates
TE (*i, k*)	Tax rates on exports
THSH (*hh, k*)	Household transfer income shares
TM (*i, k, cty*1)	Tariff rates on imports
TX (*i, k*)	Indirect tax rates
VATR (*i, k*)	Value added tax rate
ZSHR (*i, k*)	Investment demand shares
Production and Trade Function Parameters	
AD2 (*i, k*)	CES production function shift parameter
AE (*i, k*)	CET export composition function shift parameter
AT (*i, k*)	CET function shift parameter
ALPHA2 (*i, k*)	Coefficient in CES production function
GAMMA (*i, k, cty*1)	CET export composition function share parameters
GAMMAK (*i, k*)	CET function share parameter
RHOE (*i, k*)	CET export composition function exponent
RHOT (*i, k*)	CET function exponent
Parameters for AIDS Import Demand Functions	
SMQ0 (*i, k, cty*1)	Base year import value share
AQS (*i, k*)	Constant in Stone price index
AMQ (*i, k, cty*1)	Share parameter in AIDS function
AQ (*i, k*)	Constant in translog price index
BETAQ (*i, k, cty*1)	Coefficient in AIDS function
GAMMAQ (*i, k, cty*1, *cty*2)	Price psrsmeter in AIDS function

Table IV: Quantity Equations

(1) *X* (*i, k*) = AD2(*i, k*)*(SUM (*iff* $FDSC0 (*i, iff, k*), ALPHA2 (*i, iff, k*)*FDSC (*i, iff, k*)** (−RHOP(*i, k*))))** (−1/RHOP (*i, k*));

(2) (1 − *ft*(*k*))*WF(*iff, k*)*WFDIST(*i, iff, k*) = SCALE(*i, k*)*(1 − vatr(*i, k*))*pva (*i, k*)* AD2 (*i, k*)*(SUM(*f* $FDSC0(*i, f, k*), ALPHA2(*i, f, k*)*FDSC(*i, f, k*)** (−RHOP(*i, k*))))**((−1/RHOP(*i, k*))−1)*ALPHA2(*i, iff, k*)**FDSC(*i, iff, k*)** (−RHOP(*i, k*)−1);

(3) INT (*i, k*) = SUM(*j*, IO(*i, j, k*)*X(*j, k*));

Model Specification

In addition to eight sectors for each country model, the model has four factors of production (agriculture labor, unskilled urban labor, skilled urban labor, and capital), as identified in Table I. The output-supply and input-demand equations are shown in Table IV. Output is produced according to a CES function of the primary factors (equation 1), with intermediate inputs demanded in fixed proportions (equation 3). Producers are assumed to maximize profits, implying that each factor is demanded so that marginal product equals marginal cost (equation 2). In each economy, factors are not assumed to receive a uniform wage or “rental” (in the case of capital) across sectors; “factor market distortion” parameters (the WFDIST that appears in equation 2) are imposed that fix the ratio of the sectoral return to a factor relative to the economywide average return for that factor.

Table V: Price Equations

(4) PM(imi, k, cty1)	=	PWM(imi, k, cty1)*EXR(k)*(1 + TM(imi, k, cty1) + tm2(imi, k, cty1));
(5) PE(iei, k, cty1)	=	PWE(iei, k, cty1)*(1−te(iei, k))*EXR(k);
(6) PEK(ie, k)	=	SUM(cty1$pt(k, cty1), PE(i, k, cty1)*E(i, k, cty1))/EK(i, k);
(7) PDA(i, k)	=	(1 − TX(i, k))*PD(i, k);
(8) PQ(i, k)*Q(i, k)	=	PD(i, k)*D(i, k) + SUM(cty1$imi(i, k, cty1),(PM(i, k, cty1)* M(i, k, cty1)));
(9) PX(i, k)*X(i, k)	=	PDA(i, k)*D(i, k) + SUM(cty1$iei(i, k, cty1),(PE(i, k, cty1)));
(10) PC(i, k)	=	PQ(i, k)*(1 + TC(i, k));
(11) PINDCON(k)	=	PROD(i, PC(i, k)**pwtc(i, k));
(12) PVA(i, k)	=	PX(i, k) − SUM(j, IO(j, i, k)*PC(j, k));
(13) PWE(i, cty1, cty2)	=	PWM(i, cty2, cty1);

The price equations are shown in Table V. In equations 4 and 5, world prices are converted into domestic currency, including any tax or tariff components. Equation 13 guarantees cross-trade price consistency, so that the world price of country A’s exports to country B are the same as the world price of country B’s imports from country A. Equation 6 defines the aggregate export price as the weighted sum of the export price to each destination. Equation 7 calculates the domestic price, net of indirect tax. Equations 8 and 9 describe the prices for the composite commodities Q and X. Q represents the aggregation of sectoral imports (M) and domestic goods supplied to the domestic market (D). X is total sectoral output, which is a CET aggregation of total supply to export markets (E) and goods sold on the domestic market (D). Equation 10 defines the consumption price of composite goods from the composite good price (PQ) and consumption taxes (tc). Equation 12 defines the sectoral price of value added, or "net" price (PVA), as the output price minus the unit cost of intermediate inputs (from the input-output coefficients).

In the KIM-CGE model, the aggregate consumer price index in each region is set exogenously (PINDCON in equation 11), defining the numeraire. The advantage of this choice is that solution wages and incomes are in real terms; moreover, since our Cobb-Douglas price index is consistent with the underlying Cobb-Douglas utility function, the changes in consumption levels generated by the model are exactly equal to the equivalent variation. The solution exchange rates in the sub-regions are also in real terms, and can be seen as equilibrium price-level-deflated (PLD) exchange rates, using the country consumer price indices as deflators. The exchange rate for the rest of the world is fixed, thereby defining the international *numeraire*.

Table VI: Income and Expenditure Equations

(14) YFCTR(*iff, k*)	=	SUM(*i*,(1−*ft*(*k*))*WF(*iff, k*)*WFDIST(*i, iff, k*)*FDSC(*i, iff, k*));
(15) TARIFF(*k, cty*1)	=	SUM(*i*\$*imi*(*i, k, cty*1), TM(*i, k, cty*1)*M(*i, k, cty*1)*PWM (*i, k, cty*1))*EXR(*k*);
(16) PREM(*i, k*)	=	SUM(*cty*1\$*imi*(*i, k, cty*1), TM2(*i, k, cty*1)*M(*i, k, cty*1)*PWM (*i, k, cty*1))*EXR(*k*);
(17) INDTAX(*k*)	=	SUM(*i*, TX(*i, k*)*PD(*i, k*)*D(*i, k*));
(18) EXPTAX(*k*)	=	SUM((*i, cty*1), te(*i, k*)*PWE(*i, k, cty*1)*E(*i, k, cty*1)*EXR(*k*));
(19) YINST("labr", *k*)	=	SUM(*la*, YFCTR(*la, k*));
(20) YINST("ent", k)	=	YFCTR("capital", *k*) + EXR(*k*)*FKAP(*k*) − ENTSAV(*k*) − ENTAX(*k*) + ENTT(*k*) + SUM(*i*,(1-sprem(*i, k*))* PREM(*i, k*));
(21) YINST("prop", *k*)	=	YFCTR("land", *k*);

(22) YH(hh, k)	=	SUM(ins, sintyh(hh, ins, k)*YINST(ins, k)) + rhsh(hh, k)* EXR(k)*REMIT(k) + HHT(k)*thsh(hh, k);
(23) ENTAX(k)	=	ENTR(k)*(YFCTR("capital", k) + ENTT(k));
(24) FTAX(k)	=	SUM((iff, i), ft(k)*WF(iff, k)*WPDIST(i, iff, k)*FDSC(i, iff, k));
(25) HTAX(k)	=	SUM(hh, $hhtr$(hh, k)*YH(hh, k));
(26) VATAX(k)	=	SUM(i, vatr(i, k)*PVA(i, k)*X(i, k));
(27) CONTAX(k)	=	SUM(i, TC(i, k)*PO(i, k)*Q(i, k));
(28) GOVREV(k)	=	SUM(cty1, TARIFF(k, cty1)) + INDTAX(k) + EXPTAX(k) + FTAX(k) + HTAX(k) + CONTAX(k) + SUM(i, sprem(i, k) *PREM(i, k)) + ENTAX(k) + VATAX(k) + FBOR(k)*EXR(k);
(29) GOVSAV(k)	=	GOVREV(k) − SUM(i, GD(i, k)*PC(i, k)) − HHT(k) − ENTT(k);
(30) HSAV(k)	=	SUM(hh, MPS(hh, k)*((1.0-hhtr(hh, k))*YH(hh, k)));
(31) ENTSAV(k)	=	esr(k)*YFCTR("capital", k);
(32) ZTOT(k)	=	GOVSAV(k) + HSAV(k) + ENTSAV(k) + EXR(k)* FSAVE(k);
(33) FSAVE(k)	=	FBAL(k) − FBOR(k) − REMIT(k);
(34) CDD(i, k)	=	SUM(hh, CLES(i, hh, k)*YH(hh, k)*(1.0-hhtr(hh, k))* (1.0-mps(hh, k)))/PC(i, k);
(35) GD(i, k)	=	gles(i, k)*GDTOT(k);
(36) ID(i, k)	=	zshr(i, k)*ZFIX(k);
(37) ZTOT(k)	=	SUM(i, PC(i, k)*ID(i, k));
(38) GOVGDP(k)	=	SUM(i, pc(i, k)*gd(i, k))/gdpva(k);
(39) INVGDP(k)	=	SUM(i, pc(i, k)*id(i, k))/gdpva(k);
(40) GDPVA(k)	=	SUM(i, PC(i, k)*(CDD(i, k) + GD(i, k) + ID(i, k))) + SUM((i, cty1), PWE(i, k, cty1)*E(i, k, cty1))*EXR(k) − SUM((i, cty1), PWM(i, k, cty1)*M(i, k, cty1))*EXR(k)

The circular flow of income from producers, through factor payments, to households, government, and investors, and finally back to demand for goods in product markets is shown in the equations in Table VI. The country models incorporate official tariff revenue (TARIFF in equation 15) which flows to the government, and the tariff equivalent of non-tariff barriers (PREM in equation 16) which accrues as rents to the private sector. Each economy is modeled as having a number of domestic market distortions, including sectorally differentiated indirect, consumption, and value-added taxes as well as factor, household, and corporate income taxes (equations 17-18 and 23-27). The single household category in each economy has a

Cobb-Douglas expenditure functions (equation 34). Real investment and government consumption are set in equations 35 and 36, while aggregate government consumption and investment are set to fixed shares of GDP in equations 38 and 39.

Table VII: Export Equations

(41) X(*ie*1, *k*)	=	AT(*ie*1, *k*)*(GAMMAK(*ie*1, *k*)*EK(*ie*1, *k*)**(−RHOT(*ie*1, *k*)) + (1 − GAMMAK(*ie*1, *k*))*D(*ie*1, *k*)**(−RHOT(*ie*1, *k*)))** (−1/RHOT(*ie*1, *k*));
(42) X(*ien*, *k*)	=	D(*ien*, *k*):
(43) EK(*ie*1, *k*)	=	D(*ie*1, *k*)*(PDA(*ie*1, *k*)/PEK(*ie*1, *k*)*GAMMAK(*ie*1, *k*)/ (I−GAMMAK(*ie*1, *k*)))**(1/(1+RHOT(*ie*1, *k*)));
(44) E(*iec*, *k*, *cty*1)	=	EK(*iec*, *k*)*(((gamma(*iec*, *k*, *cty*1)*PEK(*iec*, *k*))/(ae(*iec*, *k*) **rhoe(*iec*, *k*)*pe(*iec*, *k*, *cty*1))) **(1/(1 +rhoe(*iec*, *k*))));
(45) M(*i*, *cty*1, *cty*2)	=	E(*i*, *cty*2, *cty*1);
(46) EKPII.(*k*)	=	SUM((*cty*1, *i*), PWE(*i*, *k*, *cty*1)*E(*i*, *k*, *cty*1));
(47) MKPTL(*k*)	=	SUM((*cty*1, *ik*), PWM0(*ik*, *k*, *cty*1)*M(*ik*, *k*, *cty*1));

Export-related functions are shown in Table VII. Exports are supplied according to a CET function between domestic sales and total exports (equation 41), and allocation between export and domestic markets occurs in order to maximize revenue from total sales (equation 43). The rest of the world is modeled as a large supplier of imports to each country at fixed world prices. Rest of world demand for the North and South Korean exports is modeled as occurring at fixed world prices. The world prices for North and South Korea are assumed to be exogenous, a typical small country assumption.

Table VIII: AIDS Import Demand Equations

(48) PM(*i*, *k*, *k*)	=	PD(*i*, *k*);
(49) LOG(PQ(*i*, *k*))	=	LOG(AQS(*i*, *k*)) + SUM(*cty*2, SMQ0(*i*, *k*, *cty*2)* LOG(PM(*i*, *k*, *cty*2)));
(50) SMQ(*imi*, *k*, *cty*1)	=	AMQ(*imi*, *k*, *cty*1)+PETAQ(*imi*, *k*, *cty*1)*LOG(Q(*imi*, *k*))+ SUM(*cty*2, GAMMAQ(*imi*, *k*, *cty*1, *cty*2)*

		LOG(PM($imi, k, cty2$)));
(51) SMQ(i, k, k)	=	1 − SUM(ctyl, SMQ(i, k, ctyl));
(52) M($i, k, cty1$)	=	SMQ($i, k, cty1$)*PQ(i, k)*Q(i, k)/PM($i, k, cty1$);
(53) PD(i, k)*D(i, k)	=	SMQ(i, k, k)*Q(i, k)*PQ(i, k);

The specification of the almost ideal demand system (or AIDS) for imports is shown in Table VIII. The expenditure shares SMQ are given by equation 50, where subscript imi refers to sectors, subscript k refers to the importing country, and subscript cty1 refers to the source of the imports (another region or the rest of the world). We adopt the notation convention that when $k = cty1$, we are describing the domestic component of composite demand (D). Hence in equation 48 the "own" price of imports is simply the domestic price, and in equation 53, D is determined by the SMQ(i, k, k) share, while the import demands are determined in equation 52. The composite price index, PQ, is defined in equation 49 as a Stone price index Deaton and Muellbauer (1980) .

Table IX: Migration Relations

(54)(AVWF(la, k)/EXR(k))	=	wgdfl(la, k, la, l)*(AVWF(la, l)/EXR(l));
(55) FS(i, k)	=	FSO(h, k) + MIGL(la, k) + MIGRU(la, k);
(56) SUM(k, MIGL(la, k))	=	0;
(57) SUM(la, MIGRU(la, k))	=	0;

Table IX outlines the labor and capital migration relations in the model (which are in the simulations reported in this paper), Capital and labor migrations in this paper are determined by the per capita GDP differentials between North and South Korea. The 60 percent per capita income differential is used as the criteria to decide how much capital from South Korea and how many people from North Korea need to be moved in opposite direction across the border. Internal migration in each country maintains a specified ratio of average real wages between the rural and unskilled urban markets (the EXR terms become irrelevant). Domestic labor and capital supply in each country is then adjusted by the capital and labor movements (equation 55), while the other two equations insure that workers do not "disappear" or get "created" in the migration process.

Table X: Market-Clearing Equations

(58) $Q(i, k)$	=	$INT(i, k) + CDD(i, k) + GD(i, k) + ID(i, k)$;
(59) $FS(iff, k)$	=	$SUM(i, FDSC(i, ffl, k))$;
(60) $AVWF(iff, k)$	=	$SUM(i,(1\text{-}ft(k))*wfdist(i, ffl, k)*wf(iff, k)*fdsc(i, iff, k))$ / $SUM(j, fdsc(j, iff, k))$;
(61) $FSAV(k, cty1)$	=	$SUM(i, PWM(i, k, cty1)*M(i, k, cty1)) - SUM(i, PWE(i, k, cty1)*E(i, k, cty1))$;
(62) $FBAL(k)$	=	$SUM(cty1, FSAV(k, cty1))$;

To complete the model, there are a number of additional “market-clearing” or equilibrium conditions that must be satisfied, as shown in Table X. Equation 58 is the material balance equation for each sector, requiring that total composite supply (Q) equal the sum of composite demands. Equation 59 provides equilibrium in each factor market; Equation 61 is the balance condition in the foreign exchange market, requiring that import expenditures equal the sum of export earnings and net foreign capital inflows; equation 62 is the overall trade balance equation, summing up the bilateral trade balances.

Model Closure

The KIM model permits a number of different “closure” choices that affect the macroeconomic relationships in the model. In all simulations reported in this paper, we have assumed that the aggregate trade balance (FBAL) is fixed for both countries, and that the exchange rate (EXR) varies to achieve external balance in the customs union part of model. However, in monetary union part of model, the exchange rate is fixed between the North and South and in addition, the balance of trade for the two countries are also fixed and unified.The separate North and South Korean trade balances can vary, though their sum is fixed. Government revenue is determined endogenously, given a variety of fixed tax rates, while government expenditure is fixed exogenously. Aggregate Investment in each country is assumed to be a fixed share of GDP, and aggregate saving is assumed to adjust to equate total savings and investment.

Appendix Table 1 (a)

Import Rationing Rates (Actual over Desired)

Sector	North Korea	South Korea	Rest of the World
AGRFSH.NK	1.0	0.899	0.036
AGRFSH.SK	0.566	1.0	1.0
MINING.NK	1.0	0.245	0.368
MINING.SK	0.05	1.0	1.024
LMANUF.NK	1.0	0.072	0.353
LMANUF.SK	0.01	1.0	1.488
INTERM.NK	1.0	0.075	0.942
INTERM.SK	0.289	1.0	1.004
KGOODS.NK	1.0	0.02	0.312
KGOODS.SK	0.717	1.0	1.0
CONSTR.NK	1.0	1.0	1.0
CONSTR.SK	1.0	1.0	1.0
PUBADM.NK	1.0	1.0	1.0
PUBADM.SK	1.0	1.0	1.0
SVC.NK	1.0	0.024	0.619
SVC.SK	0.023	1.0	1.006

Note: The smaller the ratio, the larger the distortion.

Appendix Table 1 (b)

Export Rationing Rates (Actual over Desired)

Sector	North Korea	South Korea	Rest of the World
AGRFSH.NK	1.0	0.566	5.094
AGRFSH.SK	0.899	1.0	0.924
MINING.NK	1.0	0.05	0.314
MINING.SK	0.245	1.0	1.106
LMANUF.NK	1.0	0.01	0.071
LMANUF.SK	0.072	1.0	1.197
INTERM.NK	1.0	0.289	1.401
INTERM.SK	0.075	1.0	0.991
KGOODS.NK	1.0	0.717	2.581
KGOODS.SK	0.02	1.0	0.997
CONSTR.NK	1.0	1.0	1.0
CONSTR.SK	1.0	1.0	1.0
PUBADM.NK	1.0	1.0	1.0
PUBADM.SK	1.0	1.0	1.0
SVC.NK	1.0	0.023	0.204
SVC.SK	0.036	1.0	1.002

Note: The smaller the ration the larger the distortion.

Appendix Table 2
Elasticities

Sector	SK Import Substitution	SK Export Transformation	ROW Import Substitution	ROW Export Transformation
AGRFSH.NK	2.0	2.0	2.0	2.0
MINING.NK	1.0	2.0	1.0	2.0
LMANUF.NK	4.0	2.0	4.0	2.0
INTERM.NK	2.0	2.0	2.0	2.0
KGOODS.NK	2.0	2.0	2.0	2.0
CONSTR.NK	0.6	2.0	0.6	2.0
PUBADM.NK	0.6	2.0	0.6	2.0
SVC.NK	1.4	2.0	1.4	2.0

Sector	NK Import Substitution	NK Export Transformation	ROW Import Substitution	ROW Export Transformation
AGRFSH.SK	2.0	2.0	2.0	2.0
MINING.SK	1.0	2.0	1.0	2.0
LMANUF.SK	4.0	2.0	2.0	2.0
INTERM.SK	2.0	2.0	2.0	2.0
KGOODS.SK	2.0	2.0	2.0	2.0
CONSTR.SK	0.6	2.0	0.6	2.0
PUBADM.SK	0.6	2.0	0.6	2.0
SVC.SK	1.4	2.0	1.4	1.4