Rigorous Speculation: The Collapse and Revival of the North Korean Economy

MARCUS NOLAND
Institute of International Economics, Washington, DC, USA

SHERMAN ROBINSON
International Food Policy Research Institute, Washington, DC, USA

and

TAO WANG *
Florida International University, Miami, FL, USA

Summary. — In this paper, we use cross-entropy estimation techniques to construct the underlying data base for a computable general equilibrium model (CGE) of the North Korean economy, starting from incomplete data, ridden with gross measurement errors. The cross-entropy estimation approach is powerful and flexible, allowing us to make full use of what information we have in whatever form. CGE modeling forces internal consistency. The end product is a model that incorporates fragmentary information in a rigorous way and allows us to examine the implications of a number of alternative scenarios including rehabilitation of flood-affected lands, liberalization of the international trade regime, and military demobilization.

North Korea has been experiencing a famine. Its economy is characterized by systemic distortions and comparative disadvantage in the production of grains. As a consequence, the potential payoffs to economy-wide reforms, even defined narrowly in terms of domestic food availability, dwarf more targeted attempts to raise agricultural productivity. To many, this finding—that a famine might be better addressed by the export of manufactures than the recovery of flood-damaged lands—is a striking and counterintuitive result. Moreover, we find that if reforms were to be undertaken, the country could generate a significant additional “peace dividend” by partially demobilizing its enormous military.

Key words — Asia, North Korea, CGE models, reform, transitional economies

1. INTRODUCTION

As well as can be ascertained, North Korea is now into its eighth year of economic decline. It has been facing food shortages at least since the early 1990s and is well into a famine of unknown magnitude. ¹ Despite its desperate internal situation, the government maintains the most militarized society on earth, with more than one million men (and increasingly women) under arms and an estimated 25% of gross domestic product (GDP) devoted to military expenditures (US ACDA, 1997). Economic reform could have enormous benefits in this highly distorted economy, especially in light of the country’s dire situation. Yet, at the same time, the effects of reform—a significant increase in exposure to international trade and investment (much of this with South Korea and Japan, two countries with which North Korea maintains problematic relations) and huge

¹ We would like to thank seminar participants at Hitotsubashi University, the Institute for Global Economics, the Korea Institute for International Economic Policy, and Korea University, and an anonymous referee for helpful comments on earlier presentations of this material. Mina Kim provided research assistance. Final revision accepted: 28 March 2000.
changes in the composition of output, involving literally millions of workers changing employment—could be expected to have enormous political implications, possibly presenting large, perhaps insurmountable, obstacles to reform under the current regime.

The paucity of reliable statistical information about North Korea has bedeviled researchers, and, as a consequence, studies of the North Korean economy have tended toward either uncritical recitations of official statistics or compendia of anecdotes. In this paper, we use cross-entropy estimation techniques to construct the underlying data base for a computable general equilibrium model (CGE) of the North Korean economy, starting from incomplete data ridded with gross measurement errors. The cross-entropy estimation approach is powerful and flexible, allowing us to make full use of what information we have in whatever form. CGE modeling forces internal consistency. The end product is a model that incorporates fragmentary information in a rigorous way and allows us to examine the implications of a number of alternative scenarios including rehabilitation of flood-affected lands, liberalization of the international trade regime, and military demobilization. We do not consider the likelihood of the current regime undertaking any of these actions, or, indeed, any significant policy changes at all. Rather, we simply examine the possible implications of various alternative actions. Although we apply this approach to a reclusive Stalinist regime, in principle the same techniques can be applied to other situations in which economic data are fragmentary and/or of questionable reliability—a situation frequently encountered in developing countries.

To preview the results, we confirm that the North Korean economy is extraordinarily distorted. Due to the large, systemic nature of these distortions and North Korea’s comparative disadvantage in the production of grains, the potential payoffs to economy-wide reforms, even defined narrowly in terms of domestic food availability, dwarf more targeted attempts to raise agricultural productivity. Under reform, domestic production of food declines, but human survival requirements are easily met through imports. In contrast, flood rehabilitation leads to an increase in domestic food production, but this increase falls short of human survival requirements. To many, this finding—that a famine might be better addressed by the export of manufactures than the recovery of flood-damaged lands—is a striking and counterintuitive result. Moreover, we find that if reforms were to be undertaken, the country could generate a significant additional “peace dividend” by partially demobilizing its armed forces and redeploying its soldiers to more economically productive uses.

2. ORGANIZATION OF THE NORTH KOREAN ECONOMY

Since North Korea’s inception, property rights have resided primarily with the state and resource allocation has largely been carried out through central planning, not markets. The roles of money, prices, and other familiar institutional features of market economies are still severely circumscribed. The distinguishing feature of North Korea has been the extremes to which central planning has been taken.

The organizing principle of the North Korean economy is the ideology of *juche* or national self-reliance. The result has been the development of the world’s most autarkic economy. The international trade share (exports plus imports) is around 12% of GDP, which is well below the 50–55% observed in South Korea and a fraction of the trade share that North Korea would exhibit if it were a “normal” country of its size and structure. The emphasis on self-reliance has been so great that North Korea never joined its communist brethren in the Council for Mutual Economic Assistance (CMEA), and its own central plans have been timed to frustrate any linkages with those of the other planned economies (Hwang, 1993).

In North Korea, economic assets are predominantly in state hands. The Constitution establishes two basic categories of economic organization (state-owned enterprises and social cooperatives) and appears to establish the goal of nationalizing the co-ops. The state retains ultimate property rights while the co-ops are granted usage rights. 2 A Constitutional revision promulgated in August 1998 mentions “private property” (Article 24), “material incentives” (Article 32), and “cost, price, and profit” (Article 33) in an otherwise thoroughly orthodox elaboration of a planned, socialist, self-reliant, *juche* economy. Whether the mention of market concepts in the Constitutional revision signals any move toward reform is unclear. 3
The central plan, specified in physical terms, is formed iteratively by the State Planning Commission (the central authority), the Office of State Affairs, and local committees from each plant and enterprise. Prices, set by the central planners to reflect the cost of labor inputs, play an accounting, not a resource allocation, role. There are three sets of prices, roughly corresponding to three types of markets—state-run, co-op, and farmers. These prices are applied depending on the type of transaction. For example, state-run markets, which handle mostly industrial goods, transact at “wholesale prices.” A transaction between a state enterprise and a co-op would be at “industrial wholesale prices,” which is the “wholesale price” plus a transactions revenue tax wedge. The third price category is the retail price charged at commercial outlets, where queuing is apparently the norm. In addition, there are limited farmers’ and citizens’ markets in which prices presumably reflect scarcity values, as well as a black market in consumer goods.

All financial transactions through the plan are intermediated by designated state-owned banks as a method of control. In any event, money is basically only a means of exchange since prices are irrational and resource allocation is bureaucratic. Limited interest-bearing accounts exist, with rates set by the planners, but these play no real role in determining the rate of capital accumulation, which is determined by the planners. Likewise, interest rates play no allocation role, as capital is allocated by the central planners through the government-controlled financial institutions in the form of investment grants (Hwang, 1993). Monetary policy has been erratic: the government has been through two currency reforms in the past decade, foreign exchange certificates have been circulating in parallel to domestic North Korean won notes, and recently the government has established a dual exchange rate system under which inside the Rajin-Sonbong free-trade zone the won is worth approximately 1% of its official value outside the zone.

A second, parallel, military economy exists outside the central plan. Its origins lie in a military modernization program adopted at the fifth plenary session of the Fourth Central Committee of the Korean Workers’ Party in 1966 following the intensification of the Sino-Soviet split (Koo, 1992; Namkoong & Yoo, 1994). This parallel economy is highly secretive, even internally. According to Eberstadt (1994), the State Planning Commission reportedly was deprived of access to information on it in the early 1970s, and meetings with outsiders are not held in the usual government ministries, but rather in unofficial locations such as hotels, etc. (DKIH, 1991). This parallel economy amounts to autarky-within-autarky: the military maintains a completely integrated economic system from farms and mines on up through facilities that manufacture uniforms and weapons, with separate administrative structures, including foreign trade firms. DKIH (1991) estimates that half of the army is engaged in what elsewhere would be civilian economic activities—an estimate that has also been supported by a former high-ranking US intelligence official.

3. STATISTICAL OVERVIEW

At the time of the division of the peninsula, North Korea had relatively more physical and human capital than South Korea, was relatively more industrialized, and had higher per capita income. Much of the physical capital stock was destroyed during the Korean War, which was accompanied by mass population movements as well. Nevertheless, the conventional wisdom is that per capita income in North Korea exceeded that of South Korea well into the 1970s.

In all likelihood, the North Korean economy was already encountering significant difficulties in making the transition from extensive to intensive development by this time. In the aftermath of the first oil crisis, North Korea, among others, borrowed significantly from foreign banks recycling their petrodollar receipts. North Korea was unable (or unwilling) to pay off these loans and defaulted, effectively foreclosing its access to international capital markets. Eberstadt (1998b) points out that North Korean capital goods imports never reattained their mid-1970s values.

Kim Il-Sung’s decision to default on his Western creditors left North Korea highly reliant on the USSR as its sole significant source of economic support. But by the mid-1980s, the Soviets had become disenchanted and began pressuring the North Koreans to begin repaying their accumulated debts. In 1985, the USSR and North Korea agreed on a repayment schedule, and, according to the US Central Intelligence Agency, by 1987 net flows had turned negative—that is, North Korean
repayments exceeded the value of new Soviet assistance.

These events were followed in short-order by the breakup of the Soviet Union and the collapse of the Eastern Bloc. In 1990, Russia announced that it would no longer supply North Korea with subsidized oil, and the North responded by suspending repayments. Ebers-tadt, Rubin and Tretyakova (1995) estimates that in 1991 North Korea suffered a trade shock equivalent to 40% of total imports due to disengagement with the Newly Independent States, and by 1993 imports from Russia had fallen to less than a tenth of their earlier levels.

These external shocks were compounded by a series of natural disasters. Although as with everything else North Korean, controversy surrounds the precise timing and magnitude, the consensus is that agricultural production peaked around 1989 and has fallen significantly since.11

As early as 1991, publicly available evidence suggested a worsening food availability problem in North Korea, and by 1994 North Korean radio broadcasts had admitted the existence of hunger.12 In July and August 1995—after North Korea had asked for and had begun receiving international food assistance—the country suffered catastrophic floods.13 The floods of 1995 were followed by more, though less severe, floods in July 1996, and in the following year the country was hit with a drought. Although these natural disasters exacerbated the food crisis, agriculture had been in secular decline since the beginning of the decade. Even without the disasters, North Korea would have entered the mid-1990s with a substantial food deficit.

Historically, output has been measured on a material product basis, which is basically incompatible with the system of national accounts (SNA) used in market economies. Net material product covers value-added in the material product sectors (manufacturing, agriculture, construction, commodity transportation, productive communication, productive commerce, and a few others). The sum of sectoral material products multiplied by prices yields the gross output value of social production.14

The South Korean central bank data indicate that 1990 was the most recent year that the North Korean economy registered positive growth (Figure 1).15 Recently the United National Development Program (UNDP) has been working with the government of North Korea to construct standard national accounts. Some data were released to an International

Figure 1. North Korean GDP growth.
Monetary Fund (IMF) mission that visited North Korea in October 1997 (IMF, 1997). These data appear to reflect the economy under the control of the central planners (that is, they exclude the military and activities in the informal sector), and indicate that the fall in output began in 1994. Although the quantitative estimates contained in these two sets of figures differ markedly, they are qualitatively consistent—the North Korean economy is shrinking.

Table 1 presents the official North Korean figures on the composition of output. The data suggest that the economy has collapsed around agriculture—that is, the drop in agricultural output has actually been less dramatic than the output decline in other sectors. According to these figures, industrial output fell by nearly two-thirds during 1992–96, and construction activity declined by almost as much. Taking construction as a proxy for investment, investment may well have fallen below replacement level and the capital stock may have been shrinking. This notion is supported by the government expenditure data reported in Table 2. Taking the economic development category as a proxy, investment has fallen by more than half from the values the North Korean government announced in the early 1990s. This point is further reinforced if one believes that certain military or military-related expenditures are hidden in the economic development budget. Estimates of North Korean military manpower and equipment do not show anything like this decline over the relevant period. Indeed, US and South Korean defense ministry figures show a slight increase in North Korean military deployment during this period. These figures imply that the nonmilitary part of the economy is being severely squeezed.

Two other things stand out in Table 2. First, for 1993, the government reports expenditures and receipts far larger than GDP. This would appear to violate the basic precepts of national income accounting. Second, it reports expenditures on defense that are far smaller than normally cited. Indeed, data on labor force participation provided by the North Korean authorities appear to omit the military entirely. All in all, these figures should probably be taken with very large grains of salt.

Data on government revenues are reported in Table 3. The largest single source of revenue is turnover taxes, which is typical in centrally planned economies (CPEs). Profits from state enterprises is the next largest source of government revenue. Excluding the problematic data for 1993, it appears that the government sector accounts for roughly 90% of national income, an extraordinarily high figure even by CPE standards.

| Table 1. Composition of output, 1992–96 (millions of US dollars at US$1 = won 2.15)* |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Total                           | 20,875                          | 20,935                          | 15,421                          | 12,802                          | 10,588                          |
| Agriculture                     | 7,807                           | 8,227                           | 6,431                           | 5,223                           | 4,775                           |
| Industry                        | 4,551                           | 4,689                           | 3,223                           | 2,228                           | 1,556                           |
| Construction                    | 1,315                           | 1,256                           | 910                             | 819                             | 508                             |
| Other                           | 7,160                           | 6,762                           | 4,858                           | 4,532                           | 6,748                           |


| Table 2. Government budget balance, 1994–96 (billions of won)* |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Revenues                        | 41.6                            | 24.3                            | 20.3                            | na                              | na                              | na                              |
| Expenditures                    | 41.4                            | 24.2                            | 20.6                            | na                              | na                              | 20.4                            |
| Economic development            | na                              | na                              | 12.4                            | na                              | na                              | na                              |
| Social and cultural             | na                              | na                              | 5.0                             | na                              | na                              | na                              |
| Defense                         | na                              | na                              | 3.0                             | na                              | na                              | 3.0                             |
| General administration          | na                              | na                              | 0.2                             | na                              | na                              | na                              |
| Balance                         | 0.2                             | 0.1                             | -0.3                            | na                              | na                              | na                              |
| Memorandum item: GDP            | 33.2                            | 27.4                            | 22.7                            | na                              | na                              | na                              |

4. INTERNATIONAL ECONOMIC RELATIONS

Although the North Korean government has released budget figures in the past, external trade statistics have been considered a state secret. In principle, “mirror statistics” reported by North Korea’s trade and investment partners can be used to deduce North Korea’s external transactions. North Korea’s largest export sectors are apparel and marine products, with other exports tending to be concentrated in light manufacturing, some natural resources, and iron and steel. The largest import categories are petroleum, cereals, and textile yarn. Broadly speaking, it appears that North Korea imports energy, food, and capital goods. The US Arms Control and Disarmament Agency (ACDA) reports a small volume of arms trade, though it is unclear whether this trade is omitted from the GATT (General Agreement on Tariffs and Trade) statistics or is misclassified therein.

Aggregate trade figures derived from the IMF’s Direction of Trade Statistics and other sources indicate that China is by far North Korea’s main trade partner, and has allowed the North Koreans to run annual bilateral deficits of approximately one half billion dollars (Figure 2). The prominence of China in North Korea’s trade would be even larger if aid, smuggling, and barter transactions were included in the calculations, though quantity, value, and concessional components of Chinese trade are unclear. Following China, North Korea’s other largest trade partners are Japan, South Korea, Russia, and Germany. Most of the trade between North and South Korea consists of apparel manufactured on consignment and then transshipped through China. Noticeably absent from the list of trade partners is the United States, which effectively maintains an embargo against North Korea.

![Figure 2. North Korean trade.](image-url)
Two points stand out from the aggregate trade figures. First, reported trade volumes have not been growing, reinforcing the impression of an economy in secular decline. Second, North Korea has been running chronic trade deficits. These deficits must be financed in some way, but since a series of loan defaults in the 1970s, North Korea has been effectively cut off from international capital markets. If North Korea’s trade with South Korea and China (which has permitted North Korea to accumulate large arrears in its trade account) is interpreted as politically determined, then these two countries would appear to finance nearly two-thirds of North Korea’s trade deficit. Much of the rest may be financed by illicit activities such as drug and ivory trafficking and counterfeiting, (North Korean diplomats have been expelled from host countries for all of these offenses) as well as private remittances, particularly from Japan.

Recently, North Korea has obtained significant international assistance to deal with its food shortage: bilaterally from China and multilaterally through the World Food Program from other countries. Similarly, North Korea has been receiving energy assistance in the form of oil imports and assistance with nuclear reactor construction through the Korea Energy Development Organization (KEDO), a multinational consortium established as part of a 1994 nuclear agreement with the United States.

A question naturally arises: what would the North Korean economy look like if it were to undergo successful reform? It is plausible to anticipate that there would be a reallocation of factors according to comparative advantage and, were reforms accompanied by a reduction of political hostilities with the South, there could be a significant demobilization of the military followed by redeployment of productive factors to alternative uses. Based on the experience of other transitional economies, one would expect a significant reorientation of international trade flows away from socialist allies, and toward natural trading partners. One way to get a sense of how North Korea might look as a “normal” country is to use a standard “gravity” model of bilateral trade to simulate its post-reform trade pattern. Frankel and Wei (1995) report such a model for 1990 which characterizes the volume of trade as a function of country size, income level, proximity, and other factors. North Korean values of these explanatory figures were then substituted into the gravity model regression to generate North Korea’s “natural” pattern and volume of trade.

According to the results reported in Table 4, North Korea’s natural trade partners would be South Korea, Japan, China, and the United States, in that order. South Korea and Japan alone would account for nearly two-thirds of North Korea’s trade. Moreover, the share of international trade in national income would roughly quadruple.

Noland (1996) analyzed North Korea’s prospective comparative advantage using disaggregated trade and investment data for North Korea and its two largest prospective trade partners, South Korea and Japan. First, using North and South Korean trade data, 465 sectors were put through a series of five filters. Twenty-five of the original 465 sectors, largely in primary products such as fish and minerals, as well as manufactured goods such as textiles and apparel, met all five criteria for prospective comparative advantage (Noland, 1996, Table 16). A second calculation, this time using North Korea and Japanese data and a similar set of criteria, yielded an additional 12 sectors, mostly natural resource-based (Noland, 1996, Table 17).

### Table 4. Actual and “natural” North Korean trade shares* b

<table>
<thead>
<tr>
<th>Actual trade share</th>
<th>“Natural” trade share</th>
</tr>
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<tbody>
<tr>
<td>China 23</td>
<td>South Korea 35</td>
</tr>
<tr>
<td>Japan 21</td>
<td>Japan 30</td>
</tr>
<tr>
<td>South Korea 10</td>
<td>China 13</td>
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<tr>
<td>Russia 4</td>
<td>United States 7</td>
</tr>
<tr>
<td>Rest of the world 42</td>
<td>Rest of the world 15</td>
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<tr>
<td>Memorandum:</td>
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<td>Share of total trade in GDP 12</td>
<td>71</td>
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*Source: Bank of Korea.

Intra-Korean trade counted as international trade; GDP in current dollars.
Finally to address the issue of North Korea's current exports not providing a useful signal of its future exports, the data were re-analyzed focusing exclusively on the South Korean and Japanese data. An additional 14 sectors, nearly all light manufacturing industries, met these criteria (Noland, 1996, Table 18). In summary, an analysis of the North Korean, South Korean, and Japanese trade and investment data suggest that North Korea's sectors of prospective comparative advantage would largely be in primary products where North Korea's natural resources convey a comparative advantage, and light manufacturing industries which have been declining in Japan and South Korea, but could be competitive in lower-wage North Korea.

5. A GENERAL EQUILIBRIUM PERSPECTIVE ON REFORM

As noted earlier, natural disasters have reduced arable land in North Korea, exacerbating the food shortage. Land recovery could be expected to lead to increased agricultural output and employment. From the results obtained with the gravity model, one would expect trade reform to result in a large increase in trade flows in North Korea and a significant shift in the composition of output away from heavy and toward light industry. This shift would imply major adjustments for many North Korean workers and enterprises. At the same time, expansion would be expected to take place mainly in labor intensive industries, which could facilitate the transition by absorbing displaced workers. This labor absorption would be of paramount importance if military demobilization was to release large number of workers for nonmilitary activities.

The economy-wide repercussions of land recovery, trade liberalization, and military demobilization have been analyzed using a CGE model which 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.

The model has 11 sectors: rice, maize, other agriculture/forest/fisheries, mining, light manufacturing, industrial intermediates, capital goods, construction, public administration, the military, and services. There are three "demanders": a single aggregate household that buys consumer goods, a government that spends on goods and public administration, and an aggregate capital account that purchases investment goods. The government is the sole, and completely price inelastic, demander of military services. All goods and services are traded internationally with the exceptions of construction, public administration, and the military. 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.

Primary factors of production are three types of land, capital, agricultural labor, high-skilled urban labor, and low-skilled urban labor. Aggregate production functions were estimated for aggregate capital and labor using data reported in Hwang (1993) and Lee (1994b). 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. In the CGE model, sectoral production technology is represented by a set of Cobb-Douglas functions of the primary factors, with the exception of the mining and military sectors which use constant elasticity of substitution (CES) functions with lower substitution elasticities. Intermediate inputs are demanded according to Leontief, fixed input–output coefficients. Labor and capital are intersectorally mobile; land is specific to agriculture but mobile within the three agricultural sectors. Migration is permitted between rural and urban low-skill labor markets.
The loss and recovery of arable land

Total arable land in North Korea is 1.85 million hectares. Following FAO (1997) and UNDP (1998), we distinguish three types of land: high quality land (0.4 million hectares) that is permanently irrigated, medium quality land (0.65 million hectares) that is not permanently irrigated but capable of supporting rice production, and non-irrigated lower quality land (0.8 million hectares) suitable only for the production of other cereals. Since the late 1980s, rice and maize have been produced on 0.58 million and 0.6 million hectares of land, respectively. The remaining arable land is used in producing other agricultural produce. All rice production occurs on irrigated, high-quality or medium-quality land. Of the 0.6 million hectares allocated for maize, only one-third is irrigated. Most of the rest is grown on medium-quality or low-quality land that does not have permanent irrigation.

By using the county data from UNDP (1998), we estimate land lost in the 1995–96 floods county by county and class by class. About 15% of arable land was destroyed, with the incidence of flooding being higher on high-quality land (28%) than on medium and low-quality land (13%). We use the post-flood land distribution as the base in our simulation, then costlessly restore land in the “land recovery” scenario. It should be noted that the land recovery is not evenly distributed across the three types, and, to the extent that different crops use the three types of land in differing intensities, the Rybczynski effects on the three types of crops will also be unequal.

Quantity controls in trade

The major distortion in the economy is assumed to be quantitative controls on both imports and exports. Demanders are assumed to treat imports and domestically produced goods as imperfect substitutes (the Armington assumption). They have a 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 that the difference between desired imports and observed imports is due to the imposition of quantity rationing by the government. That is:

\[
\left( \frac{M^*_i}{D^*_i} \right) \text{rationed} = qr \left( \frac{M^*_i}{D^*_i} \right) \text{desired},
\]

where \( M \) is the imports, \( D \) the domestic supply, \( qr \) is the quantity rationing rate, and the subscript \( i \) refers to the sector.

The model also specifies sectoral export supply functions in which the export supply ratio depends on the ratio of the export price to the price on the domestic market. The supply functions are also parameterized such that the desired ratio is consistent with the results from the gravity model. Symmetrically with the treatment of imports, quantity controls are specified such 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. We can measure the impact of the relaxation of these quantity constraints in terms of its Hicksian equivalent variation expressed as a share of base GDP (that is we measure it as a movement along the production possibility frontier—not as a change in the production possibility frontier). The distortions are quite large, indicating large potential gains from liberalizing trade and allowing markets to clear. The trade rationing contributes to major distortions in the domestic price system on top of explicit internal taxes.

Military demobilization

North Korea is probably the most militarized society on earth, devoting an estimated 25% of GDP to military activities and maintaining more than one million men under arms. As noted earlier these stylized facts may be a bit misleading: probably half of North Korea’s armed forces are engaged in non-warfighting activities that would be performed by the civilian sector in most other countries. In our model, we allocate half of the army to non-military activities, leaving a sizable share of the economy’s resources tied up in military activities.

Assuming that trade and other reforms were undertaken, military demobilization could generate additional welfare gains as resources previously devoted to the military were released into higher productivity activities. To illustrate the potential gains, we consider a scenario where we reduce the size of the military to the
roughly 3.5% of GDP devoted to military activities in South Korea in 1995, and then measure the “peace dividend” increase in GDP associated with this reallocation of resources.

6. DATA

The model utilizes two main databases: a macroeconomic and a microeconomic Social Accounting Matrix (SAM) of North Korea for 1996, the most recent year for which data are available. The SAM is a consistent array of economic transactions among agents that reconciles the input–output and national accounts. In estimating the SAM, we had to draw on a variety of sources, including incomplete national accounts, sectoral production and trade data, and estimates of government accounts. These data are not only incomplete, but also probably replete with serious measurement errors.

For the modeling exercise, we need various share coefficients from the SAM, such as sectoral intermediate-input and value-added shares (for production functions) and expenditure shares (for consumption functions). Our problem is to estimate these coefficients, which requires estimating a consistent SAM for the base-year of the model, using scarce data measured with unknown error. Using standard econometric methods, the problem is essentially hopeless—there are not enough data to provide the degrees of freedom necessary in estimating the parameters, even if we were willing to make very strong assumptions about the error generation process—which we are not. In contrast to the usual situation in econometrics, however, we have a great deal of prior information about the parameters to be estimated. The structure of the SAM imposes powerful adding-up constraints, and we have information about the likely values of the various coefficients from a variety of sources, including comparative data from past periods and other similar countries. The issue is how to use this information efficiently.

In this situation, we use an estimation approach, which Golan, Judge and Miller (1996) call “maximum entropy econometrics,” that draws on information theory. The estimation philosophy is to use all the information available, including information about the coefficients to be estimated, but not to assume any information that is unavailable. Our particular estimation approach applied to SAMs is described in Golan, Judge and Robinson (1994) and Robinson, Cattaneo and El-Said (1998) and incorporates assumptions of estimation error (errors in variables) and prior knowledge about parts of the SAM (such as various macro aggregates). We incorporate prior information about the structure of the SAM by specifying an initial SAM that reflects all the information we have (even if inconsistent). We then estimate a new SAM that is not only “close” to the old SAM—minimizing a “cross entropy” measure of the deviation between the two—but also: (a) satisfies all the adding-up constraints inherent in the definition of a SAM; (b) includes any other constraints such as knowledge about parts of the SAM (e.g., some of the national accounts or other aggregates); and (c) incorporates stochastic information about constraints involving measurement error. The method is both flexible and powerful when dealing with scattered and inconsistent data.

So, for example, with respect to the macroeconomic SAM, we retained the assumption that the North Korean government makes all investments but at the same time introduced a more elaborate revenue-generating system consistent with the North Korean data. The North Korean data were internally inconsistent however and the macroeconomic SAM would not balance. Base GDP is calculated to be roughly 32 billion won, higher than the officially reported 23 billion won figure shown in Table 1. The reason is twofold. First, the officially reported figure appears to exclude the military. Second, the officially reported data do not appear to be internally consistent when entered into a consistent SAM. Even assuming that little investment has occurred and that the capital stock has actually shrunk, the 1996 figures would imply a tremendous decline in output relative to the 1990 SAM constructed by Noland, Robinson, and Scatasta. This result implies that there were very big reductions in factor supplies or that much of the economy was operating at 10–15% of capacity. The simplest way to generate a consistent SAM was to raise output. While it may well be the case that floods, famine, and the practice of scrapping capital and bartering it for food has reduced factor supplies, and utilization of remaining capacity is low, there are also reasons to believe that the actual output is higher than reported by the authorities.35

With respect to the microeconomic SAM, the interindustry relations from the Noland,
Robinson, and Scatasta 1990 microeconomic SAM were used as the proto-SAM, updating it to reflect the apparent reduction in the capacity utilization rate (or, alternatively, decline in the value of the North Korean capital stock) and obtain consistency with the macroeconomic SAM. 36

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 pre-reform 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.

Land is allocated across the three agricultural activities as described in Section 6. The share of land in value-added was initially estimated from crosscountry comparisons, yielding reasonable starting estimates of “rental rates” for different types of land.

7. POLICY EXPERIMENTS

The model was used to run five basic scenarios and the analysis is carried out in 10 incremental steps or experiments. 37 In the first scenario, North Korea costlessly recovers land damaged in the 1995–96 floods. In the second, quantity rationing of international trade is removed and the economy experiences the static gains from trade associated with specialization according to comparative advantage.

The next three scenarios are extensions of the second. 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 international trade. 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 (TFP) gain of approximately 18% as a result of its economic opening and importation of capital equipment embodying new technologies from abroad. (Indeed, the results reported in Noland, Robinson and Liu, 1999, and Noland, Robinson and Wang, 2000a, imply that this is a conservative estimate.) 38 The third scenario therefore assumes that the static reallocation effects of trade liberalization are accompanied by a 18% sectorally uniform increase in TFP.

The fourth scenario concerns the value of the post-liberalization 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 suboptimal 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 different from those observed in world markets. Second, economies sheltered from international trade may manufacture products 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. 39 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. On the basis of the East German experience this shock was calibrated as one-half to two-thirds of the value of the 1990 pre-opening capital stock in Noland, Robinson and Scatasta (1997). In the current model, calibrated to 1996, the capital stock has already shrunk, and the obsolescence shock is assumed to be smaller at 25%. 40

In the fifth and final scenario we examine the issue of military demobilization and the “peace dividend.” In this scenario, the North Korean military is demobilized by 70% until the share of the military in national income approximates the 3.5% exhibited in South Korea. 41

These five scenarios are implemented in 10 experiments, or steps, that indicate a range of possible results and also show the impact of partial reforms.

The simulations suggest that North Korea is indeed an extraordinarily distorted economy. In scenario 1, North Korea costlessly rehabilitates flood-affected lands in 10 successive steps. As can be seen in Figure 3, the impact on GDP is minimal, increasing it by less than 2%. Domestic production of rice and other agricultural commodities increases by around 4% and corn production rises by 12%,
leaving domestic consumption below the Food and Agriculture Organization’s (FAO’s) human survival target. At first glance, this result might seem odd—increasing the arable land endowment of a famine-afflicted country should have a bigger macroeconomic impact. These results reflect two important underlying facts: first, North Korea was already experiencing a famine prior to the floods that commenced in July 1995, second, only around 15% of the arable land was affected by the floods. So, while natural disasters may have exacerbated the food availability problem, the famine is not a product of bad weather. Rather, systemic mismanagement and lack of intermediate inputs such as fuel and fertilizer are its proximate cause. The latter, in turn, are due to severe balance of payments constraints and policy decisions about the use of foreign exchange—which are fundamentally outside the agricultural sector. Nevertheless, this result underlines a critical issue: if only a relatively modest component of the decline in output can be attributed to flood-related declines in agriculture, then what explains the rest?

Scenario 2 addresses the main distortion in the model, the severe repression of international trade. The gravity model results reported in Noland (1996) suggest that, in 1990, the total share of imports and exports in North Korean GDP would have been roughly 70% if North Korea had exhibited the economic behavior of a “normal” country of its economic size. With the economy now smaller, the expected trade share should be even higher. In scenario 2, the quantitative restrictions on trade are relaxed in 10 steps, and the impact on GDP is shown in Figure 3. It should be emphasized that these steps have no time dimension. As might be expected on the basis of microeconomic theory, the impact of the relaxation of the constraint is greatest at the beginning and declines thereafter. A complete freeing of this constraint increases GDP by approximately 60% due to static reallocation of factors alone. Domestic availability of rice and maize on commercial terms increases by more than 80% and 90%, respectively—far more than in the land recovery scenario—and unlike the land recovery scenario, in excess of the FAO’s human survival needs target.

This static reallocation effect would not be the only affect of liberalizing trade. Increased importation of capital equipment from abroad could increase TFP substantially. As shown in Figure 3, these gains are almost exactly offset by the negative impact of an assumed obsolescence shock to the capital stock of 25%. Obvi-
ously one should not attach too much weight to the exact figures derived from this modeling exercise. Rather, these results are probably best interpreted as an indication that, in an economy as distorted as North Korea’s, an increase in the economy’s openness to international trade could have enormous macroeconomic effects, dwarfing the impact of a flood.

The final scenario is a 70% military demobilization, which reduces North Korea’s expenditure on the military to a share of GDP similar to the South’s. Obviously there would have to be major diplomatic breakthroughs for this to occur, but the experiment is presented as a heuristic exercise to illustrate how large the potential payoffs might be. This experiment is probably dependent on the trade liberalization experiment. Without liberalization, it is unclear where the demobilized resources would be redeployed; however, with liberalization, they could be redeployed to their highest efficiency uses.

As shown in Figure 3, redeployment of resources on this scale could add another 18% to GDP, with the five scenarios undertaken together increasing real GDP by nearly 79% from the base. Domestic consumption of rice and maize more than triples. Holding non-defense government spending constant in nominal terms, the other components of GDP rise. Real consumption nearly triples, while investment nearly doubles. International trade expands enormously. Holding the trade balance constant, the real exchange rate experiences a modest appreciation; if the real exchange rate is held constant, the trade deficit expands somewhat.

The composition of output changes enormously (Figure 4) as light manufacturing, mining, construction, and services expand, while industrial intermediates, capital goods, and the army contract in response to changes in the relative price structure and the decline in government demand for military services (Figure 5). Within agriculture, maize output falls, then expands, as the highly inefficient production of rice is abandoned and land is increasingly devoted to the production of maize. Light manufacturing experiences an export explosion, with exports increasing 40-fold, and mining exports more than triple. Imports rise in all traded goods categories, led by a 15-fold growth in capital goods imports.

These changes in composition have profound effects on factor usage and returns (Figure 6). Two and one-half million workers leave the agricultural sector and another 350,000 leave the army, the bulk of which are re-employed in...
Figure 5. Relative price of output by sector.

Figure 6. Percentage change in average factor price.
the light manufacturing sector. Even in the agricultural sector, the employment and wage changes are greater under economic reform than under land recovery. Employment also increases in the mining, construction, and service sectors. The real wages of all three classes of labor more than triple, with the largest increases experienced by the highly skilled. The rate of return on capital also more than triples. The rate of return on land falls, however, as the increased availability of imported agricultural goods reduces food scarcity, and with it the implicit scarcity returns to land. The distribution of income shifts slightly in favor of the urban high-skilled.

These results are speculative and subject to a degree of spurious precision. Nevertheless, the modeling work conveys several important points. First, even when defined narrowly in terms of domestic food availability, the payoffs to reform dwarf the impact of more narrowly conceived policies focused on agricultural recovery. Even when defined narrowly in terms of the domestic food availability, the payoffs to systemic reform are multiples of even costless recovery of flood-affected lands and the replacement of the flood-damaged agricultural capital stock. Potential increases in GDP from reform are on the order of 60%, with an additional 18% obtainable as a "peace dividend" if North Korea were to substantially demobilize its enormous military. With reform, domestic output of food declines, but domestic food consumption easily exceeds human survival requirements because of the availability of imports. In contrast, flood rehabilitation leads to an increase in domestic food production, but this increase falls short of the human survival target.

Ultimately, this paper could be considered an example of rigorous speculation in that we have attempted to bring to bear rigorous technical methods to an important issue where the existing data are fragmentary and in all likelihood error-ridden. We have attempted to avoid spurious precision. The robustness of the results is obviously an issue in any such exercise, and through the design of our experiments and scenarios, we have attempted to convey a sense of which results are likely to be more robust and which are likely to be less so. The neoclassical nature of the model generates relatively frictionless adjustment, especially in the reallocation of factors across sectors, and the experience of the past decade with other transitional economies suggests that considerable institutional and policy reform are required to support successful adjustment. In this sense the model results are probably overoptimistic. They should be interpreted as what a competent government might be able to achieve—not as predictions of what the current North Korean regime will actually accomplish.

8. CONCLUSION

In this paper, we have used cross-entropy estimation to construct the data base for a CGE model of the North Korean economy. The modeling work extends the literature on the North Korean economy in a number of important ways. The model we construct is, to our knowledge, the first behavioral economic model to explicitly address the issue of North Korea's famine and the potential gains to the economy from military demobilization.

Because the North Korean economy is so distorted, we find that the returns to systemic reform dwarf those associated with more narrowly conceived policies focused on agricultural recovery. Even when defined narrowly in terms of the domestic food availability, the payoffs to systemic reform are multiples of even costless recovery of flood-affected lands and the replacement of the flood-damaged agricultural capital stock. Potential increases in GDP from reform are on the order of 60%, with an additional 18% obtainable as a "peace dividend" if North Korea were to substantially demobilize its enormous military. With reform, domestic output of food declines, but domestic food consumption easily exceeds human survival requirements because of the availability of imports. In contrast, flood rehabilitation leads to an increase in domestic food production, but this increase falls short of the human survival target.

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NOTES

1. US Congressional staffers who visited the country in 1998 concluded that 300,000–800,000 people were dying annually from starvation or hunger-related illnesses (Washington Post, August 20, 1998; Economist, August 22, 1998). Nongovernmental organizations (NGOs), extrapolating from interviews with refugees in China and observations on the ground, have produced estimates of famine-related deaths on the order of 2.8–3.5 million. Eberstadt (1998a) observes that the number of delegates at the 1998 Supreme People’s Assembly implied a mid-1998 population more than three million fewer than demographic projections made on the basis of the 1989 census. Given a pre-crisis population of roughly 22 million, these estimates would
2. Enterprises are classified as state-owned or worker cooperatives. They are further classified by size and, for administrative control purposes, as central or local. Larger plants are under the control of the central party and the Economic Bureau of the Office of State Affairs. Local plants are under the control and guidance of local party and economic guidance committees at the provincial level (Hwang, 1993). A new incentive system for enterprises (the “Independent Accounting System”) was introduced in 1984 and recently a greater degree of multiplant integration under a common management structure with an associated domestic trading firm (similar to the East German Kombinat or South Korean chaebol) has been permitted. Worker remuneration is set on the basis of job classification and seniority among other factors, and there exists a material incentive system.

Similarly agricultural operations are organized into state farms and peasant cooperatives, the County Farm Management Committee and the Central State Agriculture Committee providing economic management and party organs providing management guidance. The recent tendency has been to increase the importance of state farms (which are considered ideologically more advanced) and to integrate the agricultural sector more firmly into the central plan. On the state farms, peasants are paid fixed salaries. In the case of the cooperatives, which are theoretically owned by the members, the latter receive equal shares paid in cash and in kind, with bonuses going to work units overfulfilling targets. “In reality, the peasants are reduced to employees in either case” (Lee, 1994a, p. 511).

3. Some prominent “reformers” within the leadership appear to have been purged. Soon after the constitutional revision was announced the daily newspaper and theoretical magazine of the Korean Workers Party published a joint editorial excoriating economic reform and opening, describing it as “honey-coated poison,” and reiterating the intention of maintaining a planned, self-reliant economy. The signals coming out of North Korea are mixed, to say the least.

4. One implication of taxing enterprises differentially by ownership type (in addition to violating horizontal equity) is that it makes calculating sectoral tax burdens effectively impossible.

5. For a description of the formal pricing structure and black markets, see Hwang (1993) and Suh and Kim (1994), respectively.

6. For more on the North Korean financial system, see Kim (1995).

7. On the conventional wisdom see Eberstadt (1994) and Kim (1994). The conventional view would be consistent with the econometric evidence of Easterly and Fischer (1994) which found that centrally planned economics (CPEs) typically exhibit stronger than average performance in the initial stages of industrialization and then deteriorate into weaker than average performance as allocative efficiencies become more and more costly. According to Hwang (1993), South Korean per capita income did not exceed the North’s until 1986.

8. See Noland (1996) for quantitative material on the debt (non-)burden. In this and other regards, comparisons between North Korea and Romania are striking (Noland, 1997).

9. This debt trades in an (admittedly thin) secondary market at a considerable discount, with recent quotes in the range of 12–15 cents on the dollar (International Financing Review, August 29, 1998). The discount narrowed in late 1996 reaching roughly 50% and remained there through early 1998 when it began widening. Market participants indicate that the discount is an inverse indicator of regime viability: as conditions in North Korea worsen, the likelihood of collapse and absorption by the South increases and with it the prospect of debt holders being paid by the government of the unified peninsula. According to this logic, the market has been signalling an enhanced expectation of regime survivability.

10. Soviet assistance took a variety of forms including provision of key commodities at “friendship prices,” technology transfer, and provision of significant trade credits and other forms of concessional economic exchange. See Noland (1996) for quantitative estimates and further discussion.


12. See Noland (2000) and Smith (1998) for more detailed assessments of the food situation and the diplomacy of food aid.

13. The most heavily affected areas were the corn growing provinces of Chagang, and North P’yongan in the northwest region of the country and the rice producing area of North Hwanghae, south of Pyongyang. We use this information on geographical incidence of the flooding in our subsequent modeling effort.

14. There are three major problems with this definition. First, produced intermediates are doubled-counted.
Second, nonmaterial sectors (which include housing, health and welfare expenditures, education, science, art, personal services, state administration, etc.) are ignored. Third, the prices, which are calculated to reflect the labor theory of value, do not reflect true scarcity values. As a consequence, even under the best of circumstances (such as having a cooperative government), it is difficult to reconcile material product accounts with the system of national accounts. Given the secrecy of the North Korean government, concordance is virtually impossible. Hwang (1993) makes a valiant effort, but the results are not fully convincing.

15. These data are of questionable accuracy. They are apparently calculated by taking measures of physical output and then calculating income using South Korean value-added weights. These figures are then subject to interagency bargaining within the South Korean government prior to public release. Given the collection methods, there is no way to verify the estimates of physical output. Furthermore, it is far from obvious that the South Korean value-added schema is the most appropriate. In other countries where such methods have been applied, the resulting estimates appear to overestimate the volatility of output, as industrial output exhibits greater variance than service activities.

16. The collapse of the industrial economy has adversely affected agriculture. The two primary fertilizers used in North Korea, urea and ammonium sulfate, are both petroleum-based, and shortages of petroleum feedstocks have adversely affected domestic production of fertilizer. Likewise, periodic blights have been worsened by a shortage of agricultural chemicals. Fuel shortages have impeded the use of agricultural machinery, forcing the reintroduction of draught animals.

Problems in production have been compounded by difficulties in distribution and the use of output. Fuel shortages have hampered distribution. At the same time, some outside observers have questioned the use to which output has been put: scarce cereals continue to be used to produce luxury products such as noodles, urban areas with high concentrations of Korea Workers Party members and government officials have received preferential allocations, and it has been claimed that military stockpiling continues. The end result of these difficulties has been a secular deterioration in food production, and in the absence of additional imports, in the food balance.

17. Data on capital goods imports from an earlier period reported by Eberstadt (1998c) suggest that the decline in investment may be a secular phenomenon going back decades.

18. These taxes present special problems for analysis because they are levied at differential rates depending on the legal status of the transacting parties. (For example, the tax wedge imposed on an exchange between two state enterprises is different than the wedge imposed on a transaction between a state enterprise and a cooperative.)

19. These statements are based on partner country reports to the General Agreement on Tariffs and Trade (GATT), supplemented by data from the Korea Trade-Investment Promotion Agency in the case of countries such as Iran which do not report the commodity structure of their trade with North Korea to the GATT. See Noland (1996) for details.

20. The ACDA figures for the North Korean arms trade are consistent with the statistics on DPRK-Russian trade reported by Eberstadt et al. (1995).


22. Even here one must be careful. Partner coverage may be incomplete. In addition, there is a venerable history of trade ministry clerks around the world mistaking North and South Korea. Such errors have occurred in the past decade in Mexico, Austria, and most recently Lebanon. Moreover, the IMF reporting convention counts transport and insurance as part of imports; when one calculates the “mirror statistics” one has to adjust the constructed North Korean figures for this accounting convention. Lastly, these figures ignore barter trade. Although the existence of barter transactions would presumably not bias trade balance estimates in any particular way, barter could significantly distort analysis of trade volumes and composition. See Noland (1998) for a more complete discussion of these issues.

23. The latter are sometimes reported to be in the billions of dollars, though recent research (e.g., Ebers-tadt, 1996; Noland, 1996, 1998) indicates that these private aid flows are probably considerably smaller than claimed.


25. See Noland (1996) for details of this calculation.

26. The filters were: (a) sectors in which North Korea had a “revealed” comparative advantage, defined as the ratio of North Korea’s share of world exports of a particular commodity category to its share of world exports as a whole; (b) sectors in which “revealed” comparative advantage had increased during 1980–92;
(c) sectors in which South Korea has declining “revealed” comparative advantage; (d) sectors in which South Korean export shares were forecasted to fall in Noland (1991); and lastly (e) sectors in which the growth of South Korean outward foreign direct investment has exceeded that of the economy. The list is debatable—one might not expect North Korea’s current exports, in essence the residual of the plan, necessarily to be the exports in a reformed, market economy. Nonetheless, this seems like a reasonable place to start.

27. Although South Korea had been the rice bowl in the past, if trade were opened today North Korea might end up being a net exporter of agricultural goods to the South, especially if capital markets were relatively unified and labor markets were not. O (1995) asserts that a reformed North Korea could have a comparative advantage in fruits, vegetables, dairy products, and meats (including beef, chicken, and pork). Both countries would undoubtedly remain global net importers of food.

28. The criteria were: (a) sectors in which North Korea had a “revealed” comparative advantage; (b) sectors in which North Korea’s “revealed” comparative advantage had increased during 1980–92; (c) sectors in which Japan has declining “revealed” comparative advantage; (d) sectors in which Noland (1990) projected Japanese net exports to drop; and (e) sectors in which the growth rate of Japanese outward foreign direct investment has exceeded that of the economy.

29. A similar set of criteria were employed: (a) sectors in which North Korea had a “revealed” comparative advantage; (b) sectors in which this “revealed” comparative advantage has declined over time; (c) both countries were forecast to lose competitiveness in these sectors; and (d) the rate of outward foreign direct investment has been in both countries is higher than national income.

30. This analysis was done partly on the basis of historical experience. It is possible that with changes in real exchange rates (such as an appreciation of the yen) industries of greater capital intensity (auto parts, for example) than those reported in Noland (1996) could be future candidates for relocation to North Korea. General Motors, for example, has expressed interest in constructing an auto parts plant in the Rajin-Sonbong special economic zone (Financial Times, June 17, 1995).

31. 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.

32. The Rybczynski effects refer to the impact of a change in a factor endowment on output quantities. In an “even” international trade model where the number of goods equals the numbers of factors, an increase in a factor endowment will lead to an increase in the production of at least one good and a decrease in the production of at least one other. This simple version of the theorem breaks down when the model is “uneven,” includes nontradables, and differentiated products, as is the case at hand. Nevertheless, as an empirical matter, one may still obtain the counterintuitive result that an increase in an endowment can cause a decrease in an output quantity.

33. Data on aggregate revenue from turnover taxes are reported in Table 3. But since these taxes are assessed on the basis of the legal status of the transacting enterprises, sectoral tax rates per se do not exist. In our modeling work, we have allocated these receipts more or less evenly across the industrial sector with a mild degree of escalation by degree of processing, as typically has been the case in other CPEs.

34. This approach to modeling import rationing was first used by Dervis, de Melo and Robinson (1982). See their paper for a discussion of the properties of this approach, including questions of incentive compatibility.

35. First, they have an incentive to understate output to increase international aid flows. Second, as mentioned in the text, the official data appear to refer only to output or resources controlled by the central planners. Evidence indicates that the military economy and economic activity outside the plan have increased, or at least have not decreased as rapidly as formal activity under the plan. Finally, aid flows which account for a considerable share of food consumption, do not appear to be included in the official figures.

36. The input–output coefficients contained in the 1990 proto-SAM were in turn 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 (The World Bank, 1985). The assumption is that a starting point (or prior) for the interindustry input–output relations in North Korea is pre-reform China, reflecting their common links to 1970s vintage Soviet manufacturing technology. This does not imply that the structure of the two economies are similar—China was, and remains, a far more agrarian economy than North Korea—simply that the pattern of factor usage in manufacturing is similar. See Noland et al. (1997) for sensitivity analyses.

37. In the figures, these experiments are labeled EXP1 through EXP10. They are alternative static equilibria; they do not represent changes over time.
38. See Noland et al. (1999) and Noland et al. (2000a) for further discussion as well as an analysis of sectorally nonuniform changes in TFP. In all likelihood, importation of capital equipment would not be the only avenue of TFP enhancement associated with opening. Dyck (1997) argues that introduction of new management practices was critical in the East German case.

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

40. 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.

41. As indicated earlier, we assume that half of the army is engaged in activities (construction, manufacturing etc.) that normally would be performed in the civilian sector of the economy, and that half of the army is engaged in “warfighting” activities. Demobilization is modeled as a reduction of resources devoted to strictly military activities.

42. One can think of at least two possible channels by which the impact of the floods could be underestimated. First, if one assumes high substitutability among primary inputs, labor and capital could simply substitute for land. Second, some of the capital stock in the agricultural sector was destroyed in the floods. As a mental experiment and a check on robustness, a variant of the first experiment was run in which the agricultural capital stock was augmented as land was recovered. The addition of capital along with land did indeed increase the output response, but the impact on GDP was still only around 2%.

43. A “J-curve” adjustment path in which output initially falls and then rises can be obtained by subjecting the North Korean economy to an instantaneous obsolescence shock to its capital stock while phasing in the trade reform and technological upgrading (cf. Noland, Robinson & Liu, 1998). Frankly, we do not have a good sense of the relative dynamics of these effects and have not pursued this issue in this application.

44. Noland, Robinson and Wang (2000b) report an additional scenario in which agricultural yields are restored to their pre-crisis levels through the increased availability of produced intermediates such as fertilizer as a result of the trade liberalization. Rice production increases about 20% relative to the base, and maize production actually doubles. Through increased domestic production and increased imports, North Korea attains the FAO’s normal total demand target.

45. For the sake of brevity the remaining discussion refers to experiment 10 of scenario 5.

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