FAMINE IN NORTH KOREA:
Causes and Cures

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Abstract

In this paper we start from incomplete data ridden with gross measurement errors to construct the underlying data base for a computable general equilibrium model (CGE) of the North Korean economy using cross-entropy estimation techniques. This model incorporates fragmentary information in a rigorous way and allows us to examine the implications of a number of alternative scenarios. First, we model a production-oriented recovery program as the restoration of flood-affected lands. We then model an external assistance program as the acquisition of all food aid necessary to attain the United Nations organizations' estimates of minimum human needs. The trade-oriented recovery program is modeled as a relaxation of agricultural import quotas and the importation of food on commercial terms. Finally, we model a systemic reform program as the elimination of quantitative restrictions on all external trade.

We find that only the trade- and reform-centered strategies are likely to provide a sustainable solution to North Korea's problems. Because of North Korea's lack of comparative advantage in the production of grains, the production-oriented strategy fails to attain the country's minimum human needs target. The target could be obtained through international assistance, but it appears that this assistance has been motivated by donors' non-famine-related foreign policy goals and may not be sustainable. Higher levels of assistance depress agricultural prices (and domestic production), rural wages, and the wages of the low skill urban workers, contributing to income inequality. In contrast, not only minimum human needs, but also normal human demands are met under the trade-oriented strategy. However, total normal demand is met only through systemic reform. Under both of the trade- and reform-oriented strategies, GDP rises and wages for all labor groups increase, offering the possibility of a recovery strategy where everyone gains.

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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 experiencing a famine of unknown severity. US Congressional staffers who visited the country concluded that from 1995 to 1998 between 900,000 and 2.4 million people had died from starvation or hunger-related illnesses with deaths peaking in 1997 (Kirk 1998). Non-governmental organizations, 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 (1998) 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. If these estimates are accurate, they imply that a double-digit share of the pre-crisis population of roughly 22 million has succumbed.

Table 1 presents the official North Korean figures on the composition of output. What the data suggest is that the economy has collapsed around agriculture—that is, the fall in agricultural output has been actually less dramatic than the decline in output in other sectors. Nevertheless, agriculture has been adversely affected by the decline in the non-agricultural part of the economy. The two primary fertilizers used in North Korea, urea and ammonium sulfate, are both petroleum-based, and shortages of petroleum feedstocks have adversely effected domestic production of fertilizer. A shortage of coal has shut down a coal-fired fertilizer plant. Periodic blights have been worsened by a shortage of agricultural chemicals. Fuel shortages and a lack of spare parts have impeded the use of agricultural machinery, forcing the reintroduction of draught animals. Electrical shortages have interfered with irrigation, which is based heavily on electrically powered water pumps.

Problems in production have been compounded by difficulties in distribution and in the use of output. Shortages of fuel and spare parts for vehicles have hampered distribution. At the same time, some outside observers have questioned the uses to which output has been put: scarce cereals appear to continue to be used to produce luxury products such as noodles, urban areas with high concentrations of Korean Workers Party (KWP) 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, a deterioration in the food balance.

Despite the desperate situation internally, the government maintains the most militarized society on earth, with more than one million men (and increasingly women) under arms, and estimated 25 percent of GDP devoted to military expenditures (US ACDA 1997). This point is 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 reveal anything like this economic 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. This suggests that the non-military part of the economy is being severely squeezed.

In this highly distorted economy, reform could have enormous benefits, 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 changes in the composition of output, involving literally millions of workers changing employment—could be expected to have enormous political implications, and possibly present large, perhaps insurmountable, obstacles to reform under the current regime.

In this paper we start from incomplete data ridden with gross measurement errors to construct the underlying data base for a computable general equilibrium model (CGE) of the North Korean economy using cross-entropy estimation techniques.[1]This 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. First, starting from the post-shock base, we model a production-oriented recovery program as the restoration of flood-affected lands. As an alternative to this production-oriented program, we model an external assistance program as the acquisition of all food aid necessary to attain the United Nations Development Program (UNDP), World Food Programme (WFP), and Food and Agricultural Organisation (FAO) estimates of minimum human needs. The trade-oriented recovery program is modeled as a relaxation of agricultural import quotas and the importation of food on commercial terms. Finally, we model a systemic reform program as the elimination of quantitative restrictions on all external trade, which allows the economy to align domestic production according to comparative advantage. We examine the implications for domestic food availability (as well as other indicators of welfare) with an eye toward the distribution of income between urban and rural residents. 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.

[1] Coles and Hammond (1995) develop a rigorous general equilibrium model of famine and demonstrate that famine is possible even in a perfectly competitive Walrasian economy, and that all of the classical existence and efficiency theorems apply. Our paper is, to our knowledge, the first application of CGE modeling to an actual famine.

To preview our conclusions, we find that only the trade- and reform- centered strategies are likely to provide a sustainable solution to North Korea's problems. Because of North Korea's lack of comparative advantage in the production of grains, the production-oriented strategy fails to attain the country's minimum human needs target. The target could be obtained through international assistance, but it appears that this assistance has been motivated by donors' non-famine-related foreign policy goals. As a consequence, one cannot be confident that this is a sustainable famine-relief strategy. In addition, higher levels of assistance depress agricultural prices (and domestic production), rural wages, and the wages of the low skill urban workers, contributing to income inequality. Higher levels of assistance also crowd out food imported on commercial terms and, in effect, amount to balance of payments support. How that support is used depends on government preferences.

In contrast, not only minimum human needs, but also normal human demands are met under the trade-oriented strategy. However, total normal demand is met only through systemic reform. Under both of the trade- and reform-oriented strategies, GDP rises and wages for all labor groups increase, offering the possibility of a recovery strategy where everyone gains (a Pareto improvement).

THE SLOW-MOTION FAMINE

Prior to the partition of the Korean peninsula in 1948, the colder and more industrialized North imported food from the more fertile South. After the partition, North Korea sought food security through self-sufficiency, encouraging the production of rice in the southern most provinces, while maize, potatoes, and other staples were grown in the northern provinces.[2]

Although as with everything else North Korean, some controversy surrounds the precise timing and magnitude of North Korea's agricultural decline, the consensus is that production peaked around 1989 and has fallen significantly since (table 2).[3]This decline in agricultural production occurred in the context of an economy-wide crisis. By the late 1980s, North Korea had exhausted its possibilities for extensive development and defaulted on its international debts, effectively foreclosing its access to international capital markets. It had fallen out with its primary patron, the Soviet Union, and the value of repayments on past aid exceeded the inflow of new assistance. The subsequent collapse of the Soviet Union and the break-up of the Eastern Bloc precipitated an enormous macroeconomic shock. Eberstadt, Rubin, and Tretyakova

[2] Eventually the goal of complete self-sufficiency was abandoned. Indeed, in recognition of the deteriorating situation, agriculture was identified as one of the oxymoronic "three first" priorities in the 21st Plenary session of the 6-term Party Central Committee in December 1993, which was repeated in Kim Il Sung's 1994 New Year's Day speech and reaffirmed in the *Rodong Sinbum's* 1995 New Year's Day editorial following his death.

[3] See H. S. Lee (1994), Lee, Nakano, and Nobukuni (1995), O (1995), and Smith (1998) for discussions of North Korean agriculture.

(1995) estimate that in 1991 North Korea suffered a trade shock equivalent to 40 percent of total imports due to disengagement with the Newly Independent States, and by 1993 Russian exports had fallen to less than a tenth of their earlier levels.[4]

With regard to agriculture, in 1991, the government launched a "let's eat only two meals a day" campaign which was subsequently intensified; by 1993 persistent, though unconfirmable, reports emerged of food riots (*The Economist,* 18 December 1993). By 1994 North Korean radio broadcasts had admitted the existence of hunger (*The Economist,* 28 May 1994).[5] In May 1995, South Korean President Kim Young Sam made a public offer of unconditional food assistance to the North. Later that month the North Korean government admitted that the country was experiencing a food shortage and asked the government of Japan for assistance. In June, the North Korean government in Pyongyang reached agreements with the governments of Japan and South Korea to procure emergency food aid, and in July, the Pyongyang government announced to its public that it was receiving external assistance, though it failed to mention the South Korean role.

In July and August 1995, North Korea suffered catastrophic floods. The government announced that 5.4 million people had been displaced, 330,000 hectares of agricultural land had been destroyed, and 1.9 million tons of grain had been lost. The government put the total cost of the flood damages at $15 billion.[6] Although outside organizations ultimately formulated far lower estimates of these damages, in December 1995 the FAO and the WFP issued a issued joint statement that 2.1 million children and 500,000 pregnant women were on the verge of starvation, and the WFP mission warned that "starvation could possibly affect millions of people in the summer." In January 1996, the International Committee of the Red Cross (ICRC) issued a statement that 130,000 people were on the brink of starvation, and 500,000 could be affected by the time of the autumn harvest.

The floods of 1995 were followed by more, though less severe, floods in July 1996, and renewed appeals for help. These appeals took the form of statements that North Korea was on the brink of a

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[4] For a more complete description of these shocks see Noland (1996).

[5] For examples of the anecdotal evidence emerging on hunger prior to the 1995 floods, see *The Economist* 16 July 1994 and 22 October 1994. At the same time, it should be noted that eyewitness accounts did not paint a uniformly grim picture of the situation. Reporting on a May 1995 visit to North Korea, *Financial Times* correspondent John Burton described the people he encountered as looking "adequately fed" (*Financial Times,* 8 May 1995).

[6] The most heavily affected areas were the corn growing provinces of Chagang, and North P'yongan in the northwest of the country, and the rice producing area of North Hwanghae, south of Pyongyang. The consensus of outside observers is that the damage, while extensive, was not as severe as the government initially claimed. For example, a UN survey concluded that the flooding displaced 500,000 people, not the 5.4 million the government initially claimed. We make use of information on the geographical incidence of the floods in our modeling work.

famine, though it was not until March 1997 that the WFP provided eyewitness accounts of malnourishment (WFP, 19 March 1997). By April 1997 the WFP was characterizing North Korea as being "on the knife edge of a major famine" (WFP, 18 April 1997). Again, these assessments were disputed by independent observers (Flake 1997). Assessment of the true extent of distress was complicated by the widespread belief that the North Korean government maintains substantial stockpiles of grain.[7]

Given the relative scarcity and low fecundity of North Korean arable land, the drive to maximize output has involved the use of environmentally unsustainable techniques. Continuous cropping has led to soil depletion and the overuse of ammonium sulfate as nitrogen fertilizer has contributed to acidification of the soil and a reduction in yields. The need to bring more and more marginal land into production has caused deforestation which in turn has increased the rapidity of run-off, soil erosion, and river bed silting, and ultimately to flooding.

In addition to these structural problems, North Korean agriculture is beset by organizational problems including overcentralization of decision-making and an emphasis on large state farms. Although there have been anecdotal reports that there has been some introduction of more incentive compatible systems such as fixed-rent tenancies, in response to the crisis, the extent of these changes is unclear.[8]

Although flooding precipitated the food crisis in North Korea, agriculture, like the rest of the

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[7] Estimates of stockpiling range as high as 1-2 years difference between demand and supply (H. S. Lee 1994), and some have questioned the need for external assistance in the presence of government controlled stockpiles. Indeed, South Korean President Kim Young Sam stated that most of the 150,000 tons of rice South Korea donated to North Korea had been distributed to the military (*Korean Newsreview*, 29 June 1996). During the 1996 US presidential campaign, Republican candidate Bob Dole criticized the Clinton Administration's decision to provide aid, claiming that this was "rewarding the enemy" and that the food would go to the military (*Washington Post*, 8 June 1996). Niksch (1996) reports that unnamed US intelligence officials estimate that the North Korean military has enough food stockpiled to sustain offensive military operations for 90 days, while their ROK counterparts estimate that the North Korean military has stockpiled 1.2 million tons—enough for four months during wartime. Military stockpiling has been confirmed by visiting Russian officials, and altogether an estimated 15-20 percent of annual supplies go into military stockpiles.
A slightly higher figure of 1.2-1.5 million tons has been given by an official at the South Korean government's unification think tank (Park, 1996). An unnamed South Korean official put the level of stocks as enough for ten months and South Korean Foreign Minister Gong Ro Myung asserted that these stockpiles were not being counted in estimates of North Korea's shortfall and that the problems in North Korea had been exacerbated by the regimes unwillingness to release these stocks (*Japan Times*, 18 January 1996).

[8] Agricultural operations are organized into state farms and peasant cooperatives. On the state farms, peasants are paid fixed salaries. In the case of the cooperatives, which are theoretically owned by the members, members 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" (H. S. Lee, 1994, p. 511). 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. However, under the stress of the ongoing crisis, reports have emerged of introduction of limited innovations such as family or subteam responsibility systems in which families or subteams are granted responsibilities for particular subplots subject

economy, has been in secular decline since the beginning of the decade. Even without flooding, North Korea would have entered the mid-1990s with a substantial apparent food deficit.

Yet while there has been a decline in food production, famine in North Korea is more due to systemic crisis and a decline in income. It reflects an "entitlement failure" that Sen (1981) argues is characteristic of many famines. Sen identified the problem as a catastrophic decline in incomes or entitlements of vulnerable groups, who then face starvation, rather than a failure to produce or supply enough food.

One could argue that in North Korea vulnerable groups initially lost their entitlement to food due to political decisions regarding rationing through the government-run Public Distribution System (PDS) rather than through market forces. Historically, the PDS, a system through which approximately 13.5 million North Koreans (around 62 percent of the population) receive subsidized food rations, has been the primary mechanism for the distribution of food in North Korea. The main groups outside the PDS are the workers on state farms, who receive only six months' rations through the PDS, and workers on cooperative farms who must depend on on-site production. This latter group appears to have born the brunt of the losses due to flooding, and has been the main recipient of humanitarian assistance (WFP 1996a).

A government decree promulgated in 1952 stipulates a standard ration that all participants in the PDS are to receive. However, it is unclear to what extent this promise was ever fulfilled. Over the years the ration has been reduced ostensively as part of various stockpiling schemes (table 3). In the course of the current crisis, consumption has been compressed further, and according to one source the standard adult grain ration has been reduced to around 450 grams per day (WFP 1996b). All eyewitness accounts (including the personal observations of one of the present authors) indicate that the distribution of hardship is highly uneven, with those outside the PDS in the flood-affected areas bearing the brunt of the burden. Some groups and locales appear to be entirely unaffected by the crisis, while widespread reports of significant famine-related deaths have emerged from other areas. The North Korean government continues to deny or circumscribe access by outside observers (including humanitarian aid workers). As a consequence, it is impossible to ascertain with any degree of certainty the magnitude of hardship currently faced by the population of North Korea.

As the famine has intensified and the PDS mechanism has failed, food is increasingly allocated through informal markets, and the situation has come more closely to resemble past famines in market economies described by Ravallion (1987).

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to a fixed-rent tenancy. It is impossible to determine how widespread these new institutional arrangements are.

The Food Balance

The food balance is a product of the demand for and the supply of food.[9] Demand is a function of the direct, final demand for food by the human population; indirect demand for seed, feed, and industrial uses (including the manufacture of alcohol); and finally, losses and spoilage. Supply consists of production, imports, and any drawdown on accumulated stocks. In the case of North Korea, measures of each of these components are subject to considerable uncertainty.

Consider demand. The major component of demand is direct final consumption by humans. There are no reliable data on this demand for North Korea. Instead, analysts estimate demand by imputing a certain degree of consumption or caloric intake per capita and multiplying by the population to obtain aggregate demand. However, different population groups (children, sedentary adults, manual workers, etc.) need or desire different amounts of food. So not only does one need information on the population size, demographic data are essential as well.

Unfortunately, these data do not exist. The most recent population census data, which were transmitted to the UN in 1997, pertain to 1993. Prior to the release of these data, analysts and relief agencies had based their calculations on the previous census, done in 1989.[10] Two US demographers analyzed these data and prepared population projections on that basis (Eberstadt and Bannister 1992). It is telling to note that the raw population estimates used by the WFP, the South Korean National Unification Board (NUB), and a team of independent researchers, all differ from each other and from the Eberstadt-Bannister projections. The outside world (and perhaps the North Korean government itself) does not know how many North Koreans there are, much less their distribution across different demographic categories.

Suppose for a moment that we did have good information on the North Korean population. The next step would be to estimate caloric intake and assign the sources of caloric intake to different food groups. Again, there are no data. The estimates of the NUB and WFP apparently use South Korean data as a starting point and then make speculative adjustments to fit the North Korean case. In practice, differing assumptions regarding caloric needs and nutritional sources generate significantly different estimates of demand.[11]Smith (1998), for example, argues that "the share of rice and maize in total cereal intake has

[9] This specification of "needs" or "demands" in physical terms without reference to prices or opportunity costs may strike economists as odd. This is the normal methodology used by relief agencies however, and we will subsequently use these figures to calibrate our experiments without further comment.

[10] To cite one example, the WFP cites a population estimate around 500,000 lower than the Bannister-Eberstadt projection. One is left with the impression that either by the mid-1990s North Korea had already experienced serious demographic shocks, or that the only existent demographic model of North Korea is seriously flawed.

[11] See Drèze and Sen (1989) for a general discussion of this issue, and H. S. Lee (1994), Lee, Nakano, and Nobukuni (1995), and Smith (1998) for applications to the specific case of North Korea.

historically been much lower than assumed by international agencies in assessing North Korean per capita grain consumption (p.57).

Likewise there are no data on indirect demand for seed, livestock feed, and industrial uses such as the manufacture of alcohol, so these demands are imputed. To recap, every datum needed to estimate demand—from population to indirect demand for seed—cannot be observed directly and must be constructed.

How about supply? Again, every relevant datum is missing. The biggest single component of supply is domestic production. Since production cannot be measured directly, outside observers impute it by combining estimates of planted acreage and yields. Setting aside the issue of land damaged by flooding, one could expect that experts could come up with tolerably accurate estimates of planted acreage. Yields are a different matter, however. The NUB, for example, estimates yields by operating experimental farms in South Korea and China in which North Korean agricultural techniques are mimicked. The WFP combines data review on estimated planted acreage and selective field sampling to generate estimates of yields (WFP 1996). The potential for gross misestimation is substantial. Likewise, no hard data exist for losses from spoilage, though there are estimates (FAO 1997).

The other major component of supply is imports. In principle one could construct reasonably accurate estimates of North Korean food imports using export statistics of North Korea's trade partners. Unfortunately, this effort faces several difficulties. Most of North Korea's food imports apparently now come from China, which has notoriously inaccurate statistics. Moreover, food aid may be misclassified in the trade statistics of China and other countries. Barter trade is not reported at all, especially barter that may involve arms or military technology. So there is even uncertainty about supply from external sources.

Lastly, North Korea could be adding to, or more likely, running down, accumulated stocks. As previously noted, there is considerable disagreement as to the size of these putative stocks and to the extent to which North Korea may be building or drawing upon inventories.

To conclude, there is fundamental uncertainty about each subcomponent of North Korea's food balance. Widely cited figures unfortunately imply a degree of precision and understanding of the situation wholly unsupported by hard evidence. The outside world does not know how much food North Korea has nor how much it needs (table 2).

Despite this lack of certainty at the aggregate level, the consensus among virtually all observers is that at least some population groups in North Korea are being adversely affected by the shortage.

Food Diplomacy

While the ultimate responsibility for North Korea's predicament lies in Pyongyang, it is abundantly clear

that the outside world has played politics with food. The North Korean crisis has been treated as an opportunity to extract political concessions from the North Koreans. Thus the food crisis, while having a technical component, has also been a diplomatic issue.

By 1994 North Korea had publicly admitted a food shortage, and in February 1995, World Vision International, a California-based Christian relief organization, had secured permission from the US and South Korean governments to raise funds for humanitarian food shipments to the North.[12] North Korea had reportedly concluded an agreement with Thailand to obtain 100,000 tons of rice in 1993, and reached a second agreement at this time to obtain additional rice in exchange for steel.[13]

As the situation worsened, North Korea turned to Japan, its former colonial master, presumably because Japan had substantial reserves in its grain stocks, and it would be less humiliating to accept assistance from Japan (which could be portrayed as a kind of reparations) than from rival South Korea (which had smaller reserves, in any event).[14] This overture was opposed by the Kim Young Sam South Korean administration, whose Deputy Prime Minister Woong Bae Rha warned Japan of "soured relations" if Japan were to provide aid in the absence of South Korean participation—a position not universally held by South Korean National Assembly members.[15]

Eventually agreement was reached that South Korea and Japan would jointly provide assistance to North Korea. According to the plan, South Korea would provide North Korea with 150,000 tons of rice in unmarked bags, while Japan would provide 150,000 tons *gratis* and another 150,000 tons on concessional terms.[16] Observers expected this deal to improve relations between not only among North Korea and the donors, but also between North Korea and the US, which had made improved North-South ties a condition of closer diplomatic relations. South Korean President Kim Young Sam predicted that the rice deal would pave the way for the planned summit meeting which had been shelved by the death of Kim Il Sung the

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[12] *Korea Newsreview*, 11 February 1995.

[13] In the end, the Thais delivered roughly 160,000 tons of rice, but refused to deliver the rest after the North Koreans defaulted on their obligations. North Korean also apparently concluded a rice for cement swap with Vietnam. A zinc for wheat exchange with the US firm Cargill fell through in June 1997.

[14] At the same time, North Korea began accepting donations from United Nations agencies such as UNICEF and the WFP, as well as a wide range of private charities. However the mandate of the UN agencies is fairly narrowly drawn and the volumes of assistance through these channels has been dwarfed by bilateral assistance. Even fate seemed to conspire against the North Koreans: in March 1996, a vessel bearing the second shipment of WFP assistance (including all $2 million of US aid) sank en route to the North. Although the cargo was insured and could be replaced, the mishap delayed the distribution of emergency supplies.

[15] See *Korea Times*, 31 May 1995 and 9 June 1995.

[16] In one of the many strange twists in this strange saga, around this time the government of Japan also began providing assistance to the Palestine Liberation Organization around this time. It was the first time Japan had provided aid to a quasi-governmental entity with which it did not have formal diplomatic relations. Some observers interpreted this as paving the way for aid to North Korea, which, like the PLO, does not enjoy

previous year.[17]

This optimism was soon put to rest with the delivery of the first shipload of South Korean rice. The North Korean authorities, in contravention of the agreement, forced the ship upon entering the harbor to fly a North Korean flag, and later detained the crew of another relief vessel, charging them with spying. The outrage in South Korea was predictable, and the Kim Young Sam administration, which had earlier indicated a willingness to purchase rice on the international market if additional assistance were necessary, now spoke instead of the impossibility of providing additional rice until the government purchase of the domestic crop was completed for the year.[18] The North Koreans quickly apologized for the incident, which was interpreted in at least some quarters as an indication of their state of desperation, but already the damage had been done—the South Koreans began trying to persuade other countries not to provide additional assistance, and conditioned any further assistance to the North on the opening of bilateral talks.[19] Progress was made on this front in the summer of 1997, when South Korea reversed its stance and began providing additional aid as it became apparent that the seriousness of the situation in North Korea was not abating. This approach was intensified following the election of Kim Dae Jung in December 1997, and in 1998, South Korea continued to supply North Korea with food.

A similar evolution was occurring in the United States (table 4). As concern about the situation grew going into 1996, and with no diplomatic breakthroughs in sight, the United States began to adopt a slightly more assertive posture than South Korea. In June, Secretary of State Warren Christopher announced that the United States would make a small ($6.2 million) additional contribution to the WFP appeal.[20] This move was widely interpreted as an attempt to induce North Korean participation in a briefing in preparation for the Four Way Talks, a multilateral diplomatic negotiation on the future of the Korean peninsula, and adherence to the Agreed Framework, a 1994 accord with the United States on the

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diplomatic relations.

[17] See *Korea Times*, 24 June 1995; *Korean Newsreview*, 1 July 1995.

[18] See *Korea Times*, 23 June 1995 and 11 July 1995.

[19] On the first point see John Burton and Edward Luce, *Financial Times*, 4 July 1995. On the latter point see *Wall Street Journal*, 14 December 1995.

[20] The source of these funds was the storied PL-480 ("Food for Peace") account. The ability of the US to make larger bilateral contributions, should it decide to do so, is constrained by North Korea's membership on the list of nations sponsoring international terrorism.

In the midst of the June 1996 WFP call for additional aid, and diplomatic maneuvering regarding the appropriate response, press reports emerged in South Korea that North Korea received $130 million in insurance compensation for crop damage in 1994 (see, for example, *Washington Post*, 13 June 1996 and *Korea Times*, 16 June 1996). If true, this would have dwarfed the amount of the WFP appeal and undercut the case for providing humanitarian assistance. US State Department officials expressed skepticism regarding the magnitude of the insurance payment, and in the end a consensus of sorts seemed to emerge that the North Koreans had only received $13-25 million in compensation (*Washington Post*, 13 June 1996; Reuters, 14 June

North Korean nuclear program. Although the Clinton Administration denied this intention, public statements by Representative Bill Richardson (D-NM), subsequently UN Ambassador and now Energy Secretary, who had a series on contacts with the North Koreans seemed to bolster this interpretation.[21] The decision was publicly lambasted by then Republican Presidential nominee apparent Bob Dole and other prominent Republicans.[22] With the crisis continuing into 1997, the US made another, larger, $25 million donation to the WFP in the spring. In July 1997, former Senator Sam Nunn and former ambassador to Seoul James Laney visited Pyongyang to pave the way for the anticipated August start of preliminary discussions to set the agenda for the Four Way Talks. After the Nunn-Laney trip, the US announced a $27 million (100,000 ton) donation of grain, inaugurating a policy of "food for meetings" that would continue to the present.[23] Under this policy, the US provides food aid in exchange for North Korean participation in a variety of diplomatic negotiations. So, for example, on 10 September 1998, the same day the US and North Korea announced resumption of suspended missile proliferation and Four Party talks, the *New York Times* reported that the US had agreed to send 300,000 tons of grain to North Korea, a report that US officials were forced to publicly confirm that day.

Looming in the background of this maneuvering has been China. When the Soviet Union withdrew support for North Korea, China emerged as its major patron, supplying in the early 1990s nearly three-quarters of its food imports (Flake 1995a; Eberstadt 1995). China had reportedly been providing North Korea 500,000 tons of grain for free and an additional 200,000-300,000 tons on a concessional basis (Y. H. Park 1996). After the Chinese government indicated in 1994 that they would demand payment for future shipments, and exports to North Korea, subsequently dwindled.[24] However, apparently concerned about the worsening situation in the North and growing numbers of North Koreans illegally crossing into

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1996; and *Financial Times*, 27 July 1996).

[21] Similarly, Japanese Foreign Ministry officials denied any linkage between Japan's decision to follow the US lead and offer more aid and the Four Way Talks. Private analysts in Tokyo asserted that this was indeed the case, however (Reuters, 11 June 1996). South Korean officials, on the other hand, were more explicit about the linkage between aid and the four-way talks. See *Korea Times*, 12 June 1996. For its part, North Korea commemorated the 46th anniversary of the beginning of the Korean war by blaming the United States for the war and pledging that the country would "annihilate all potential aggressors."

[22] Former Ambassador to South Korea and to China James R. Lilley characterized the Clinton policy as pouring money into a "black hole" in an opinion piece titled "Underwriting a Dictatorship" (*Washington Post*, 19 July 1996).

[23] Nevertheless, while the US and South Korea were softening their stance towards the North, Japan maintained its distance. In July 1997 North Korea made a diplomatic concession to Japan—allowing the spouses of North Koreans to return to Japan to visit their families, in an apparent attempt to soften the Japanese stance. The Japanese had previously announced that such visits were a precondition to assistance. The Japanese responded by donating approximately 60,000 tons of rice.

[24] Government budget pressures and a declining ability to jawbone state firms into unprofitable operations were given as the official justification for this policy change.

China's Jilin province, in 1996 the Chinese government announced that it would send 100,000 tons of grain, and unconfirmed reports indicated that the Chinese would resume shipping 500,000 tons annually.[25] If these reports are true, this would make China North Korea's prime benefactor. What is known is that food is entering into North Korea from China on concessional, commercial, and barter terms.[26]

North Korea, for its part, responded to the crisis in a variety of ways. The regime tacitly removed some restrictions on mobility to facilitate foraging, and acquiesced in the growth of farmers' markets. Local officials took a more assertive role in procuring food supplies, and there were reports of changes in the organization of agricultural production in some local areas. Increased effort was put into developing high yield varieties, and the North Korean government, ever masters of the grand gesture, invited Norman Borlaug, father of the "Green Revolution," to Pyongyang. Kim Jong Il, the country's putative leader, was reported to have visited a military farming complex and urged that they grow more vegetables "in order to boost combat power" (Reuters, 27 June 1995). The government also appealed to the Group of 7 industrialized countries for assistance prior to the Lyon summit. The rather paltry response elicited from these appeals reportedly undercut reformist technocrats in the government.[27]

MODELING ALTERNATIVE RECOVERY STRATEGIES

As noted earlier, natural disasters have reduced arable land in North Korea, exacerbating the food shortage. Although land recovery could be expected to lead to increased agricultural output and employment, one can easily question whether a production-oriented recovery strategy would be best for a country with North Korea's high ratio of population to arable land, northerly latitude, and short growing seasons. One could imagine alternative famine recovery and food security strategies based on access to

[25] The renewal of aid was announced in July 1996 by the Secretary General of the State Council of China, Luo Gan, during a visit to Pyongyang to commemorate the 35th anniversary of the Sino-North Korean Treaty of Friendship, Cooperation and Mutual Assistance. Observers also pointed to worsening relations between China and South Korea, as evidenced by disputes over the development of a passenger jet and fishing rights in the Yellow Sea. See Reuters, 13 July 1996, and *Financial Times*, 16 July 1996. At the same time, China was announcing the provision of aid, North Korea sent its highest ranking delegation to Taiwan to try and procure assistance from that quarter (Reuters, 25 June 1996). See Snyder (1997) for more discussion of China's relations with North Korea and the food issue.

[26] Multiple eyewitness accounts describe North Korean local officials attempting to secure food supplies in China's Jilin province. Much of this is apparently barter trade, with the North Koreans bartering scrap metal, marine products, and trees for grain. The cutting down of trees has worsened the deforestation problem and may contribute to future flooding. However, the freelancing by local officials could be interpreted as systemic decentralization which could be hard to reverse if and when the crisis abates.

[27] See, for example, *Financial Times*, 12 December 1995. More broadly, the future course of economic policy in North Korea is highly uncertain. See Noland (1998) for discussion.

imports on commercial terms.

The economy-wide repercussions of production-, aid-, trade-, and reform-centered strategies have been analyzed using a CGE model. This model starts from a standard neoclassical specification, but then incorporates disequilibrium in grain markets and severe quantity controls in international trade in all products, 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 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.[28]

The model has eleven 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 which buys consumer goods, government which spends on goods and public administration, and an aggregate capital account which 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.

To account for the current famine conditions, we assume that there is an infinite demand for grains at the base price up to the WFP/FAO/UNDP minimum human needs target of 3.7 million metric tons (Q^* in figure 1). (These organizations put "normal" human demand at 4.8 million metric tons and total demand including seed, livestock, and industrial uses at 7.8 million metric tons.) Beyond this human minimum, demand is elastic and the market-clearing price falls. This approach implies that production up to 3.7 million metric tons could be absorbed by the economy without a fall in prices received by farmers and any possible adverse supply response.[29] This specification also provides us the benchmark for concessional assistance in the aid-oriented scenario.

Primary factors of production are three types of land, capital, agricultural labor, high-skill urban labor, and low-skill urban labor. Aggregate production functions were estimated for aggregate capital and

[28] 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.

[29] Technically we model this as an increase in government (PDS) demand which leaves prices unchanged as the supply curve shifts. In the North Korean context, one could imagine this as simply an increase in PDS

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 (CES) specifications yielded estimates of the aggregate substitutability between capital and labor of around unity. 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 CES functions of the primary factors, to account for lower elasticities of substitution in sectors such as agriculture, mining, and the military. 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 the 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 1980's, rice and maize have been produced on 0.58 million and 0.6 million hectares of land, respectively. The remaining arable land has been used in the production of 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 the UNDP (1998), we estimate land lost in the 1995-96 floods county by county and class by class. About 15 percent of arable land was destroyed, with the incidence of flooding being higher on high quality land (28 percent) than on medium and low quality land (13 percent). 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.[30]

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deliveries back toward some previous survival ration.

[30] 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/or differentiated products, as in the case at hand. Nevertheless, as an empirical

Modeling Quantity Controls in Trade

The major distortion in the economy is assumed to be quantitative controls on both imports and exports.[31] (The calibration of this distortion is summarized in appendix A.) Demanders are assumed to treat imports and domestically produced goods as imperfect substitutes (the Armington assumption), and 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 a gravity model (Noland, Robinson, and Scatasta 1997). Then, we assume the difference between desired

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

imports and observed imports is due to the imposition of quantity rationing by the government. That is: where M is imports, D is domestic supply, qr is the quantity rationing rate, and the subscript I refers to the sector.[32]

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 also parameterized so that the desired sectoral export ratios are consistent with the results from the gravity model. Symmetric with the treatment of imports, quantity controls are specified so that actual sectoral 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.[33] 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.

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matter, one may still obtain the counterintuitive result that at constant prices an increase in an endowment can cause a decrease in an output quantity.

[31] The major source of revenue for the North Korean government is turnover taxes. But since these are assessed on the basis of the legal status of the transacting enterprises (i.e., the tax on an exchange between two state enterprises is different than the tax on an exchange between a state enterprise and a social cooperative) 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.

[32] 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.

DATA

The model utilizes two main databases: macroeconomic national accounts and a microeconomic Social Accounting Matrix (SAM) of North Korea for 1996, the most recent year for which data are available. The SAM, described in appendix 1, 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 enough degrees of freedom to estimate the parameters, even if we were willing to make very strong assumptions about the error generation process—which we are not. However, in contrast to the usual situation in econometrics, 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 from 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 the 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 which serves as a prior in the estimation, and 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 one that also: (1) satisfies all the adding-up constraints inherent in the definition of a SA; (2) includes any other constraints

[33] The degree of sectoral quantity rationing is given in appendix table A.1.

such as knowledge about parts of the SAM (e.g., some of the national accounts or other aggregates); and (3) incorporates stochastic information about constraints involving measurement error. The method is both flexible and powerful in dealing with scattered and inconsistent data.

With respect to the macroeconomic SAM, we retained the assumption that the North Korean government makes all investments, but introduced a more elaborate revenue-generating system consistent with the North Korean data. However, the North Korean data is internally inconsistent and the macro SAM does not balance. We estimate that base GDP is roughly 32 billion won, higher than the officially reported 23 billion won. The reason is two-fold. 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 imply a tremendous decline in output relative to the 1990 SAM constructed by Noland, Robinson, and Scatasta. This result suggests that either there were very big reductions in factor supplies or that much of the economy was operating at 10 to 15 percent of capacity. The simplest way to generate a consistent macro SAM was to assume higher output. While it may well be the case that floods, famine, and the practice of scrapping capital and bartering it for food have 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.[34]

With respect to the microeconomic SAM, the inter-industry relations from the Noland, Robinson, and Scatasta 1990 micro SAM were used as a starting point (or prior), with some adjustments to reflect the apparent reduction in the capacity utilization rate (or, alternatively, decline in the value of the North Korean capital stock) and to obtain aggregate consistency with the macro SAM.[35]

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 is 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

[34] 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.

[35] The input-output coefficients contained in the 1990 prior SAM were in turn derived from a pre-reform (1979) Chinese input-output table compiled by the World Bank. This table was constructed using standard national accounts (SNA) conventions, expanding on the material product accounts (World Bank 1985). The assumption is that a starting point (or prior) for the inter-industry input-output relations in North Korea is pre-reform China, reflecting their common links to 1970s vintage Soviet manufacturing technology. See Noland,

aggregation, the skilled wage premium obtained from the South Korean data is within the dispersion observed in fragmentary data on North Korean wages.

Land is allocated across the three agricultural activities as described in the previous section. The share of land in value-added is initially estimated from cross-country comparisons, yielding reasonable starting estimates of "rental rates" for different types of land.

POLICY EXPERIMENTS

The model is used to run four basic scenarios and the analysis is carried out in ten incremental steps or experiments.[36] In the first scenario, North Korea (costlessly) recovers land and agricultural capital damaged in the 1995-96 floods. In the second, we inject grains into the economy until domestic availability reaches the UNDP/WFP/FAO 3.7 million metric ton minimum human needs target. We then augment aid until the domestic consumption reaches the 4.8 million metric tons "normal human needs" target. In the third scenario, we remove quantity rationing of agricultural imports. In the fourth scenario, we remove the quantity rations of all international trade and the economy experiences the static gains from trade associated with specialization according to comparative advantage.[37] As a final variant on this scenario, we additionally increase agricultural yields to their pre-crisis levels, reflecting the increased availability of intermediate inputs.

In scenario 1, North Korea costlessly rehabilitates flood-affected lands in 10 successive steps. As can be seen in figure 2, the impact on GDP is minimal, increasing it by less than 2 percent. Domestic production of rice and other agricultural commodities increases by around 4 percent and corn production rises by 24 percent. Domestic food availability remains below the WFP/FAO minimum human needs target, however (figure 3). (In terms of figure 1, this is the shift in the supply curve from S to S .) Employment in agriculture rises, as labor is drawn into the agricultural sectors to complement the increase

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Robinson, and Scatasta (1996) for sensitivity analyses.

[36] In the figures these experiments are labeled EXP1 through EXP10. They are alternative static equilibria—they do *not* represent changes over time.

[37] The static reallocation effect would certainly not be the only response of the economy to a relaxation of controls on international trade. Noland, Robinson, and Scatasta (1997) and Noland, Robinson, and Wang (1999) analyze the implications of an "obsolescence shock" when the capital stock accumulated under the central planning regime is exposed to internationally available technologies and world prices. These two studies also investigate the possibility of increases in total factor productivity (TFP) associated with the adoption of new technologies and management techniques. Noland, Robinson, and Liu (1997) examine the possibility of sectorally non-uniform increases in TFP associated with technological convergence between North and South Korea. Quantitatively these studies find that the "obsolescence shock" and TFP effects roughly offset each other, and, in the interests of clarity, these issues are set aside for the purposes at hand.

in the land endowment (figure 4).[38] The agricultural wage rises slightly (and pulls up the urban low-skilled wage), while the urban high-skilled wage actually falls slightly as complementary low-skilled workers are drawn into agriculture (figure 5). There is a modest shift in the distribution of income toward agricultural labor and capital, and away from urban skilled labor.

The UNDP/WFP/FAO target is attained (by construction) in scenario 2, the aid-oriented strategy. (In figure 1 the supply curve shifts to S .) The provision of aid has no direct impact on GDP, though one could imagine a positive indirect impact through enhanced work effort due to better nutrition and higher caloric intake. This aid is also non-fungible, by construction.[39] Aid above the human minimum needs target would put the economy on the downward sloping part of the demand curve and affect both domestic production and the demand for commercial imports.

To investigate this further, we ran an simulation in which we injected aid until domestic consumption reached the UNDP/WFP/FAO "normal human needs" target of 4.8 million metric tons, i.e., so that the supply curve (S) intersects the demand curve on the downward sloping segment to the right of Q^* in figure 1.

In this scenario, producer prices for agricultural products fall, and aid crowds out both domestic production and imports on commercial terms. As a consequence, nearly 4 million metric tons of aid are required to reach the target. As domestic agricultural output declines, rural labor migrates to the cities putting downward pressure on the wages of low skill urban workers. Nominal wages for urban skilled labor rise due to the increased supply of complementary factors of production, and the real wages of high skill workers rises even further due to the decline in the price of food. This result reflects the modeling assumption that rural and urban low skill labor are substitutes and cross-sectoral migration is possible. It is also possible that, with sufficient means of social control, a government that wished to maintain the

[38] 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 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 two percent.

[39] An issue which could be relevant in North Korea is that the local intermediary (the PDS) could act as a rent-extracting monopolist rather than a competitive supplier of aid. Coate (1989) discusses the role of intermediaries in the context of a formal model of famine relief, focusing solely on the efficiency of alternative famine relief policies. In the case of North Korea, concerns have been expressed among donors that the North Korean government might expropriate rents to support additional military expenditure, and this has been used as an argument in favor of in-kind food aid. Also of relevance is McGregor (1998), which analyses both targeted and non-targeted food distribution and public works famine relief strategies in a general equilibrium context without reaching robust analytical conclusion. Donors, who apparently expect targeting, have expressed concern that the North Korean government might divert humanitarian aid to the military and other

sectoral distribution of labor could impede this process.

Imports of all non-agricultural products increase as aid crowds out imports on commercial terms, reflecting the fact that money is fungible and aid is a form of balance of payments support. Again, the specific response reflects the underlying modeling assumptions, in this case that the demand for military services by the government has been held constant. If military demand were allowed to increase (and capture some of the rents associated with aid) this would affect the composition of production and trade.

The minimum human needs target is exceeded in the trade-oriented strategy (scenario 3), despite the fact that agricultural output and employment fall. Indeed, the UNDP/WFP/FAO total demand target of 7.8 million metric tons is nearly met under this strategy, In the trade-oriented strategy, domestic grain production falls to 1.9 million metric tons, but this decline is offset by an increase in imports to 6.0 million metric tons. GDP rises by nearly seven percent, as more than one million workers leave agriculture, primarily for employment in the light manufacturing sector. Wage rates rise for labor groups as well as capital. Within labor there is a modest shift in the income distribution toward the high-skilled as a consequence of the increased supply of complementary low-skilled urban workers.

In scenario 4, all quantitative restrictions on international trade in all products are removed. As indicated previously, this will capture only the static reallocation effect; more subtle impacts of comprehensive trade reform on the value of the capital stock, the level of TFP, and the degree of internal distortions are discussed elsewhere.[40] As shown in figure 2, this systemic reform increases GDP by more than 50 percent, indicating the extraordinarily distorted nature of the North Korean economy.[41] Domestic availability of rice and maize on commercial terms more than doubles relative to the base—an increase far larger than in any of the previous scenarios.

The composition of output changes enormously as light manufacturing, construction, and services expand, while agriculture, industrial intermediates, and capital goods contract. Within agriculture, the output of maize increases, as the highly inefficient production of rice is abandoned and land is increasingly devoted to maize production. Light manufacturing experiences an export explosion, increasing more than 30-fold, and mining exports more than quadruple. Imports rise in all traded goods categories, led by more than 10-fold increases in rice and capital goods imports.

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favored groups.

[40] See Noland, Robinson, and Scatasta (1997), Noland, Robinson, and Liu (1997), and Noland, Robinson, and Wang (1999). The latter paper also analyzes the possible "peace dividend" associated with military demobilization.

[41] In some sense this result is reminiscent of Stewart (1986) who argues that cash relief may be preferable to direct provision of food aid, in that cash relief may have the desirable benefit of sustaining the economic infrastructure of the famine-affected region.

These changes in composition have profound effects on factor usage and returns (figures 4 and 5) . More than two million workers leave the agricultural sector, and most are re-employed in the light manufacturing sector. The real wages of agricultural labor and urban low-skill labor nearly double, and the urban high-skilled wage more than doubles. The rate of return on capital also nearly doubles. The rate of return on land falls, however, as the increased availability of imported agricultural goods reduces domestic scarcity, and with it the implicit returns to land. The distribution of income shifts in favor of the urban high-skilled.

As a final experiment, we estimated the impact of a "complete recovery" scenario in which the opening to international trade and the increased availability of all kinds of produced intermediates such as fertilizer and fuel permits North Korea to reattain pre-crisis agricultural yields. In this scenario North Korean GDP rises more than 70 percent. The main difference between this and the previous "systemic reform" scenario is that, due to the increased yields, rice production in North Korea actually rises, increasing 20 percent from the base. Maize production more than doubles. (The production increase is tilted toward maize, because North Korea's comparative disadvantage is less intense in maize production. Under free trade some land formerly used to grow rice is converted to maize production.) The increase in grain yields boosts the agricultural wage, thus moderating some of the rural-urban migration and reducing the increase in income inequality that arises, though it should be emphasized that this increase in inequality occurs as all three categories of labor more than double their wage rates relative to the base.

These results are speculative and subject to a certain degree of spurious precision. Nevertheless, the modeling work conveys several important points. An aid-oriented strategy could have a variety of unintended consequences from both the standpoint of the donors and recipient. Since high levels of aid crowd out domestic production, it depresses the wages of low skill workers and exacerbates income inequality. And, since high levels of aid also crowd out food imports on commercial terms, this implicit balance of payments support can be used to finance higher levels of other activities, including military activities.

Even defined narrowly in terms of domestic food availability, the pay-offs to reform dwarf the impact of more narrow efforts to raise productivity in agriculture. In other words, far more food could be procured indirectly through systemic reform than could be obtained directly through international assistance. The underlying process that generates these gains—massive shifts in the composition of output, and a tremendous increases in international trade exposure—may or may not be politically acceptable to the current regime.

CONCLUSION

A famine of unknown magnitude is underway in North Korea. In this paper we use a CGE model to analyze the impact of four recovery strategies: production-oriented, aid-oriented, trade-oriented, and reform-oriented. We find that only the trade- and reform-centered strategies are likely to provide a sustainable solution to North Korea's problems. Because of North Korea's lack of comparative advantage in the production of grains, the production-oriented strategy fails to attain the country's minimum human needs target. The target could be obtained through international assistance, but it appears that this assistance has been motivated by donors' non-famine-related foreign policy goals, and as a consequence, one cannot be confident that this is a sustainable famine-relief strategy. Moreover, an aid oriented strategy may have unintended consequences from the standpoints of both the donor and the recipient: high levels of aid could crowd out domestic production with deleterious internal implications, while the same aid could crowd out commercial imports, freeing resources for military activities.

In contrast, not only minimum human needs, but also the more ambitious normal human demand target for grains are met under both the more narrow trade-oriented strategy and the broader reform strategy. However, the normal total demand (human and non-human uses) target is only achieved through systemic reform (though the trade-oriented strategy comes close). In both the trade- and reform-oriented strategies, domestic output of grains actually falls, but this decline is more than offset by increases in imports on commercial terms. In both cases, there are significant changes in the composition of output and employment, and greatly increased exposure to international trade. Sectors such as light manufacturing expand to absorb labor released by the contracting agricultural sector, and wages for both agricultural labor and urban low skilled labor increase. Even larger wage increases are experienced by urban high-skill workers as a result of the increase in the supply of complementary low-skill workers.

The current North Korean regime might regard these changes as potentially politically destabilizing, especially since much of the increase in trade would be with South Korea and Japan, two countries with which North Korea maintains problematic diplomatic relations.[42] As a consequence, the North Korean regime may prefer a mixed strategy in which attempts to boost domestic food production are supplemented by the acquisition of external assistance. Since domestic production alone is unlikely to meet even minimum human needs, such a strategy appears quite limiting. Escape from the famine will almost surely require at least some liberalization of trade policies.

[42] See Noland (1996) for a gravity model analysis of the geographical incidence of trade under reform.

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Table 1. COMPOSITION OF OUTPUT, 1992 - 1996

(Millions of US dollars at US$1 = won 2.15)

	1992	1993	1994	1995	1996
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

Source: North Korean submission to the IMF

Table 2 Food balance estimates (million metric tons)

Source:		1989	1990	1991	1992	1993
NUB[1]	production[2]	5.48 (5.48)	4.81 (4.86)	4.43 (4.42)	4.27 (4.26)	3.88 (3.88)
	demand	6.00	6.50	6.47	6.50	6.58
	imports	0.69	0.86	1.27	0.92	1.09
	uncovered requirement	-0.10	0.14	-0.32	-1.15	-1.22
LNN[1]	production	5.66	5.79	5.72	5.84	5.82
	demand					
	imports	0.66	0.60	1.29	0.83	1.09
	uncovered requirement	0.22	0.29	0.38	-0.58	-0.46
WFP[1]	production					
	demand					
	imports					
	uncovered requirement					
North Korea	production					
	demand					
	imports					
	uncovered requirement					
EDCC	production					
	demand					
	imports[1]		0.52	1.26	0.92	1.35
	uncovered requirement					
USDA/FAS[1]	production	5.08	4.30	3.90	3.72	
	demand					
	imports					
	uncovered requirement					
H. Smith[1]	production	5.21	5.48	4.81	4.43	4.27
	demand[2]	6.00	6.20	6.40	6.50	6.58
	imports[3]	0.69	0.86	1.27	0.92	1.09
	uncovered requirement					
P.W. Lim[1]	production[2]			4.81	4.43	4.27
	demand	460 g per person				
	imports[3]			1.29	0.83	1.09
	uncovered requirement					
Roundtable	production[1]	7.58	7.26	7.27	7.06	7.5
	demand					
	imports[2]					
	uncovered requirement					
FAO	production[1]		4.94	4.55	4.24	3.91
	demand					
	imports					
	uncovered requirement					
IMF[1]	production					
	demand[2]					
	imports					
	uncovered requirement					
FAO/WFP[1]	production					
	demand					
	imports					
	uncovered requirement					

Table 2.
Continued

Source:		1994	1995	1996	1997	
NUB[1]	production[2]	4.13 (4.12)	3.45 (3.45)	3.70 (3.68)	3.48 [3]	
	demand	6.67	6.72			
	imports	0.60	0.89			
	uncovered requirement	-2.19	-1.70			
LNN[1]	production	5.85	5.90	2.84		
	demand					
	imports	0.36	0.75	5.55		
	uncovered requirement	-1.61	-1.02	-1.04		
WFP[1]	production		4.08	2.84		
	demand		5.99	5.55	5.36	
	imports					
	uncovered requirement		-1.91	-1.04	-1.83	
North Korea	production		7.64			
	demand		5.76			
	imports					
	uncovered requirement		3.88			
EDCC	production					
	demand					
	imports[1]	0.40	0.89	0.97		
	uncovered requirement					
USDA/FAS[1]	production	3.42	3.82	3.38	3.18	3.10 (est)
	demand					
	imports					
	uncovered requirement					
H. Smith[1]	production	3.88	4.13 [4]	3.76/3.45/4.08 [5]	2.84/2.87 [6,7]	
	demand[2]	6.67	6.72	7.64/5.78(6.73)/5.55 [5]	5.36/4.97 [6]	
	imports[3]	0.60	0.89 [8]	?/1.02/1.02 [5,9]	0.53/0.75 [6]	
	uncovered requirement					
P.W. Lim[1]	production[2]	3.88	4.13 [4]	3.45	3.69 [5]	
	demand					
	imports[3]	0.49	0.96	1.05	1.44 [6]	
	uncovered requirement					
Roundtable	production[1]	5.73	2.77	1.81	2.11	
	demand					
	imports[2]					
	uncovered requirement					
FAO	production[1]	4.20	3.56	3.74	2.94	
	demand					
	imports					
	uncovered requirement					
IMF[1]	production			2.50		
	demand[2]			7.80		
	imports			0.60		
	uncovered requirement			3.80		
FAO/WFP[1]	production		4.10	2.90	2.66	
	demand					
	imports					
	uncovered requirement					

Table 2.
Continued

Notes:

NUB -
(1) Milled equivalents.
(2) Numbers in parentheses as reported by H. Smith. NUB/RDA estimates include rice, maize, other cereals, beans, and potatoes.
(3) *North Korea Grain Summary* , USDA/FAS (Mar 1998)

LNN -
(1) Milled equivalents. Uses NUB for production data.

WFP -
(1) Milled equivalents. Reports estimated production for one calendar year and demand and uncovered imports for following year.

North Korea -
(1) Milled equivalents.

EDCC -
(1) Grain and flour, including rice, corn, wheat, and barley. Figures for before 1994 in Asia and Pacific Rim Report WRS-94-6, USDA/ERS (1994). Figures for 1994 and beyond from John Dyck at USDA, who was also responsible for construction of data in USDA./ERS report.

USDA/FAS -
(1) Total grains, including rice, corn, and wheat/barley.

Smith -
(1) Table 1, Chun (1996)
(2) Estimates by Rural Development Agency (RDA). Total demand includes demand for food and demand for other uses.
(3) Kim (1995)
(4) Loss of grain stock due to floods is not considered.
(5) *Assessment of Damage and Immediate Relief Requirements Following Floods* , UN Dept of Humanitarian Affairs (12 Sept 95) / NUB/RDA (based on actual food rationing) / *Special Alert 267 and 270* , FAO/WFP (May and Sept 96)
(6) FAO/WFP (Dec) / FAO/WFP (June)
(7) Net of flood losses. Assumes advance consumption of 50% maize and potato crop and grain imports of 500,000 MT.
(8) United Nations (1995)
(9) Adjusted by author on basis of final import data for 95/96.

Lim -
(1) Includes pulses and tubers.
(2) Previous year. *Estimates of North Korea's Grain Output* , RDA.
(3) Current year. *North Korea's Trade in 1996* , KOTRA (1997).
(4) Not accounting for storage losses due to flooding (626,000 tonnage according to Pyongyang).
(5) Not accounting for prematurely consumed maize.
(6) Preliminary: commercial imports of 660,000 tons plus food aid of 780,000 tons.

Roundtable -
(1) Rice (milled equivalent) and corn. DPRK Agricultural Commission.

FAO -
(1) Rice milled equivalents. Includes wheat, rice, barley, maize, rye, oats, millet, and sorghum.

IMF -
(1) As reported by authorities.
(2) Normal demand estimate (human consumption, animal feed, industrial use, see, and other). 4.8 MT for human consumption.

FAO/WFP -
(1) *North Korea Grain Summary* , USDA/FAS (Mar 1998)

Table 3 Standard rations

	Daily Ration (grams)	
	official standard	**net of official reductions**
Children under 6	300	234
Children 7-15	500	390
Adult worker	700	546
Soldier	800	694
Elderly	300	234

Note: WFP reports that standard adult daily ration has been unofficially to 450 grams.

Source: NUB, as reported by Yoo Young Ock, "North Korean Economic Situation, and the Possibilities for South-North Economic Cooperation," *East Asian Review* 8, no. 1: 69.

Table 4 Food for meetings

Date	Amount	Gift	Channel		Source
1995	$225,000	cash	UNICEF	The two pledges of assistance were for a vaccination program and a program to provide nutritional supports to young children and nursing mothers.	Winston Lord, Testimony before the House Committee on International Relations (Mar 19, 96) UN Consolidated Inter-Agency Appeal for Flood Related Emergency Humanitarian Assistance to the DPRK (Jun 96)
Feb-96	$2 million	food	WFP	The gesture could be an attempt to buffer the Agreed Framework from increased tensions building up between the two Koreas.	Glain and Cho, Asian Wall Street Journal (Feb 7, 98) Mann, LA Times (Jun 13, 96)
Jun-96	$6.2 million	food	WFP	"It (the aid package) indicates that there may have been progress in secret talks with North Korea on the four-nation peace talks proposal." Talks were proposed by Clinton and Kim Young-Sam in April 96. "US officials said they hope the emergency food donation will encourage flexibility by Pyongyang" on the proposal for four-party peace talks. Earlier in the month, an end to North Korea's nuclear weapons program had been negotiated.	Nando Times (Jun 11, 96) Asian Wall Street Journal (Jun 16, 96) Asian Wall Street Journal (Jun 16, 96)
Feb-97	$10 million	food	WFP	Corn soy blend for children under age of give and rice and corn for flood victims. Seoul and Washington provided aid, "hailing the peaceful resolution of the case involving top North Korean defector Hwang Jang Yop" (9) "North Korea has made clear its readiness to join the talks in exchange for aid to cover its annual food shortfall." South Korea and the US have maintained that no official aid will be given to North Korea as a precondition for its attendance in the Four-Way Peace Talks. However, the US and SK have left room for continued aid with these pledges. (8)	State Dept Press Release (Feb 19, 97) Newsreview (Mar 29, 97) Newsreview (Apr 5, 97)
Apr-97	$15 million	50,000 MT of food aid	WFP	For children under age of 6. Talks to persuade North Korea to join peace talks broke down April 22 after the US and SK refused to provide additional food assistance. (8) In addition to food assistance, the April talks included discussion about "American remains from the Korean War, the missile non-proliferation issues, and technical problems involved in the establishment of liaison offices between the United States and North Korea."	State Dept Press Release (Apr 15, 97) Newsreview (April 26, 97) State Dept Daily Press Briefing (Apr 22, 97)

				Missile talks will be held between North Korea and the US in New York in May.	State Dept Daily Press Briefing (Apr 22, 97)
Jul-97	$27 million	100,000 MT of food aid	WFP	Targeted to children and the elderly. On June 30, North Korea accepted the proposal by the US and South Korea for Four-Party peace negotiations. Prepatory talks will be held in New York on August 5. Bilateral meetings will be held in NYC in preparation for the Four-Party plenary session in Geneva on Sept 18 and 19. North Korea in its official announcement that it was accepting mentioned some sort of agreement with the US.	State Dept Daily Press Briefing (Jul 14, 97) State Dept Press Release (Jun 30, 97) State Dept Daily Press Briefing (Sep 11, 97)
				"The US decision comes three weeks before a crucial meeting in New York of North Korea, South Korean, Chinese and US officials to decide the timing, location and agenda for future negotiations on a permanent peace treaty ending the 1950-53 Korea War - a negotiation that North Korea has frequently linked to the provision of additional food aid." (A15)	Smith, WP (Jul 15, 97) FT (Jul 15, 97)
Oct-97	$5 million	grant	UNICEF	NK agreed to admit 10 food relief monitors in addition to the seven monitors already there. Earlier, the USAID had warned, "we will not provide assistance unless there is effective monitoring."	AP (Oct 12, 97) State Dept Daily Press Briefing (Oct 14, 97)
Feb-98	$75 million	200,000 MT	WFP	On Feb 6, South and North Korea, the United States and China decided "to open an ad hoc committee meting in Geneva next month in preparation for a four-party dialogue on Korea affairs." (4)	Newsreview (Feb 14, 98) State Dept Daily Press Briefing (Feb 5, 98)
Sep-98		300,000 MT of wheat	WFP	DPRK has agreed to resume missile talks on Oct 1. DPRK has agreed to attend a third plenary of the Four Party Talks in October. DPRK has agreed to continue discussion about US concerns of underground construction in North Korea. DPRK also agreed to restart talks on being removed from US list of state-sponsors of terrorism.	State Dept Press Release (Sept 10, 98)
				"While American officials routinely insist that food aid is decided on humanitarian grounds, and is never used as a bargaining chip, diplomats from other countries monitoring the talks say the containment of the nuclear material was a key condition." (?)	Sanger, NYT (Sept 10, 98) State Dept Press Release (Sept 21, 98) http://www.state.gov/www/regions/eap/korea_north_food_aid_1997.html

Figure 1.

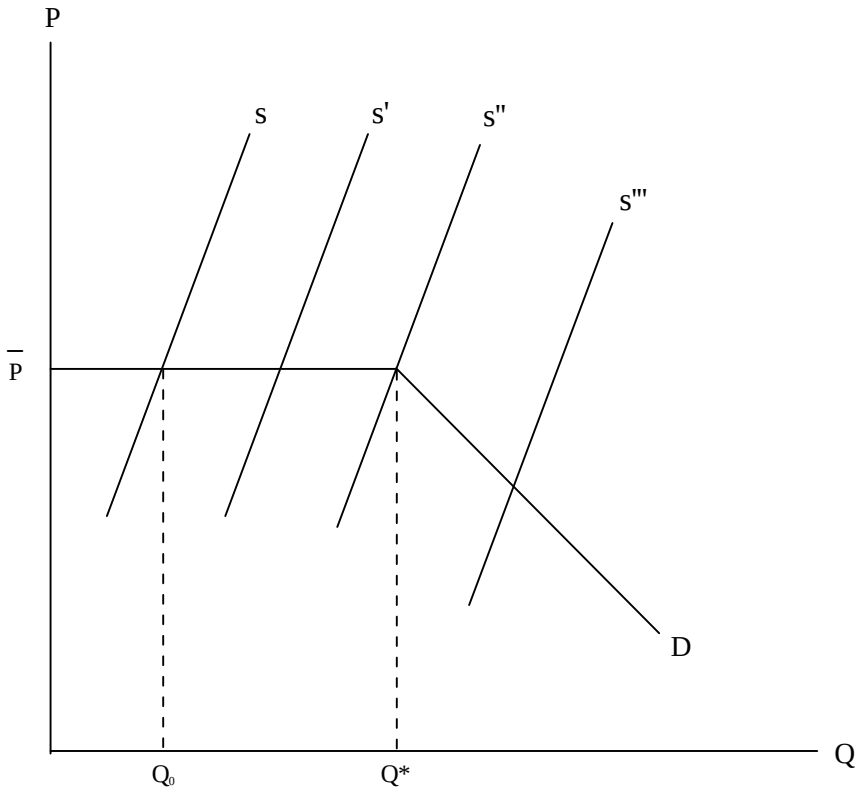


Figure 2. REAL GDP

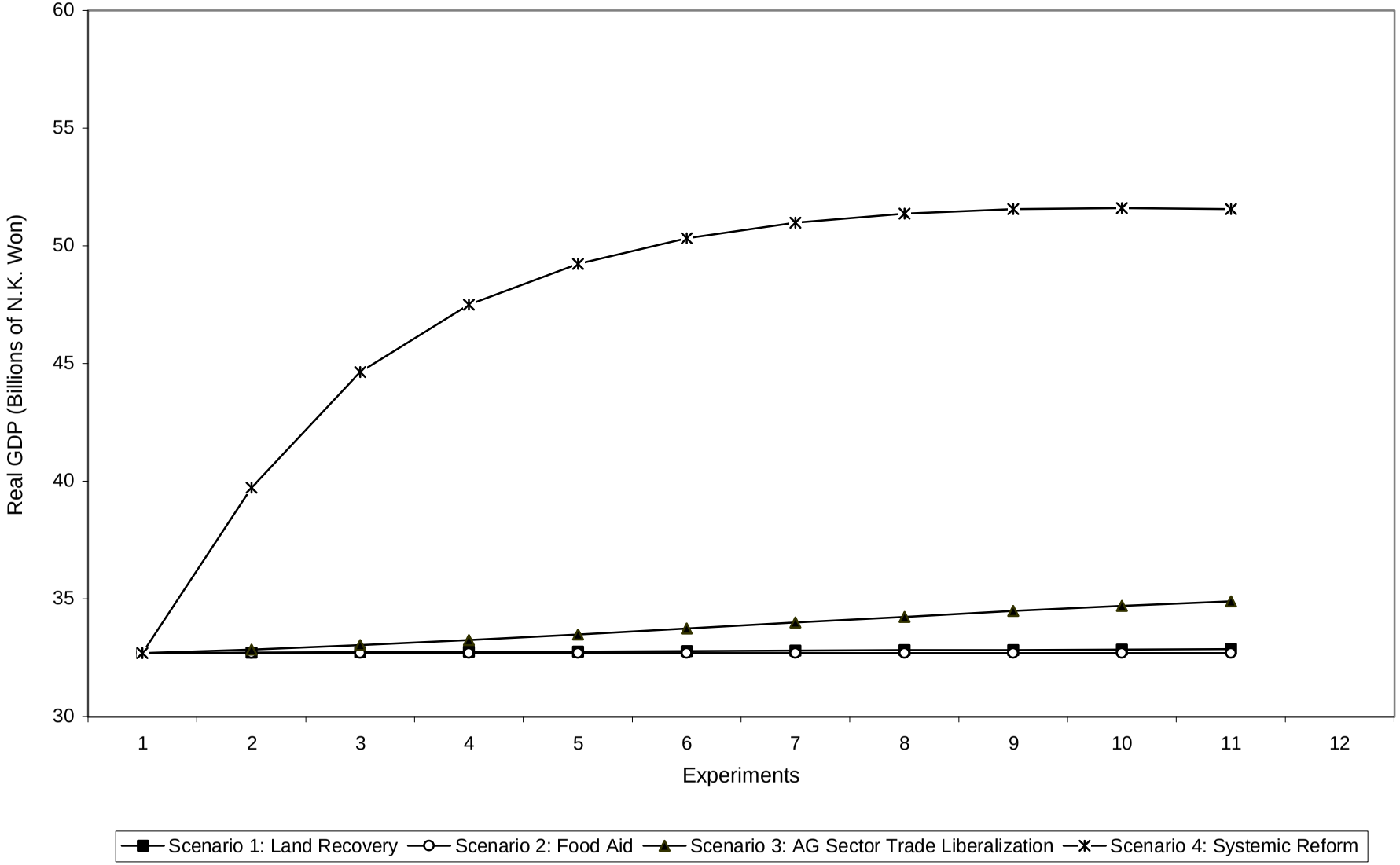


Figure 3. GRAIN AVAILABILITY

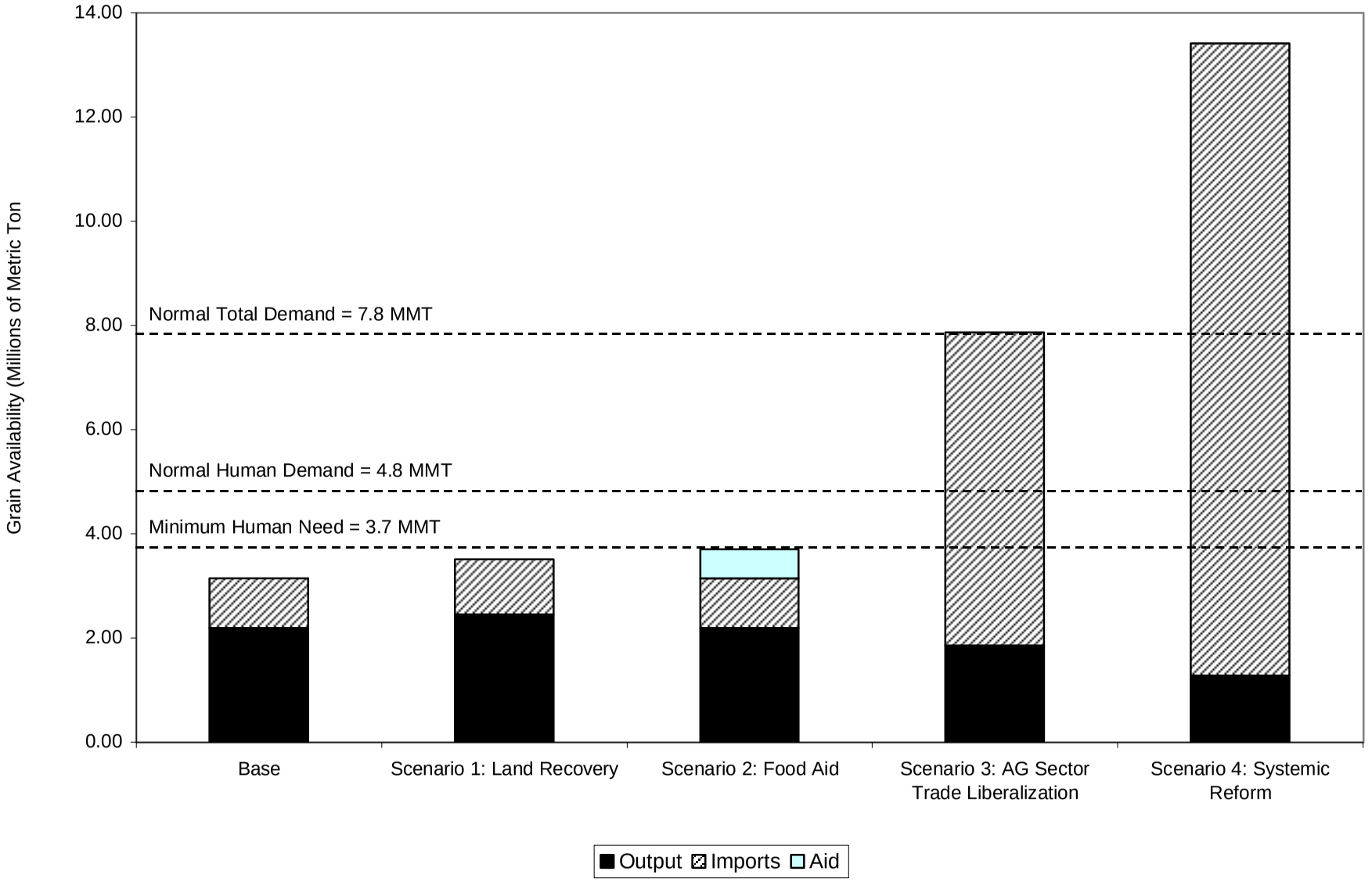


Figure 4.
EMPLOYMENT IN AGRICULTURAL SECTORS
(Millions of People)

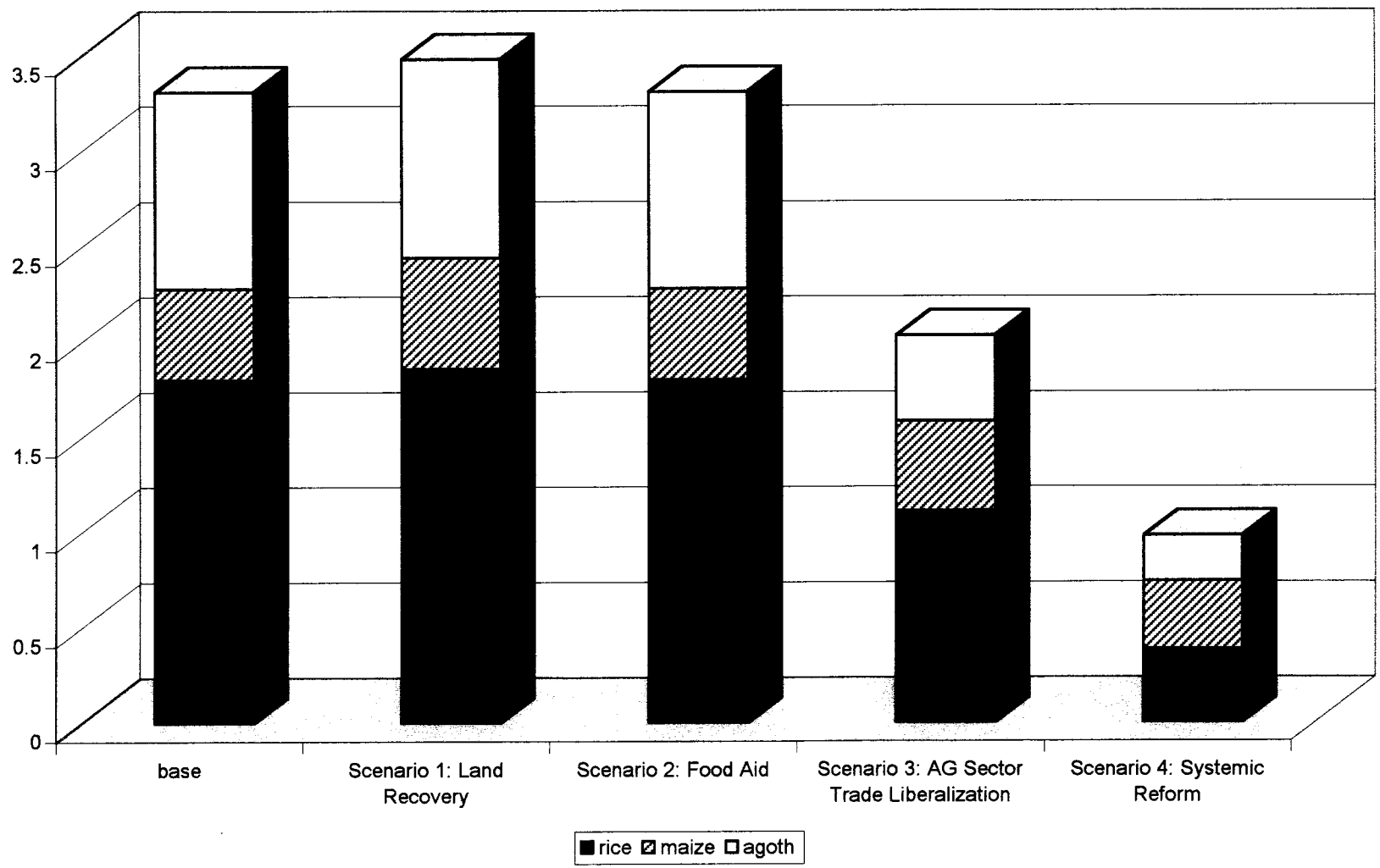
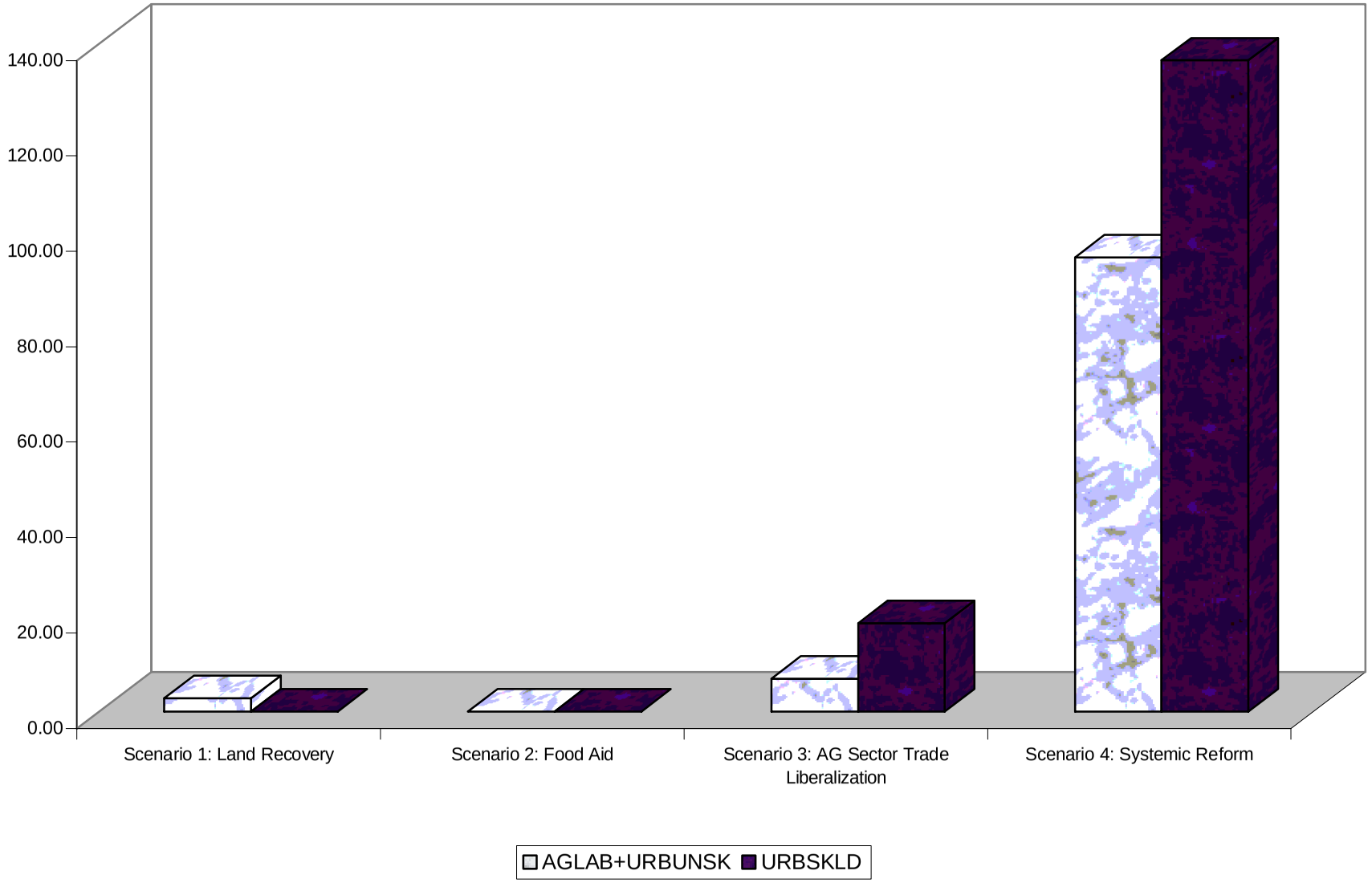


Figure 5. PERCENT CHANGE IN AVERAGE WAGE RATES



Appendix 1

A SAM for North Korea

A Social Accounting Matrix (SAM) provides a tabular snapshot of the economy at one point in time. 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 sum of each column must equal the 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 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.

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

North Korea SAM, 1996

(Billions of N.K. Won)

	ACRICE	ACMAIZE	ACAGOTH	ACMINING	ACLMANUF	ACINTERM	ACKGOODS	ACCONSTR	ACPUBADM	ACARMY	ACSVC	CMRICE	CMMAIZE	CMAGOTH
ACRICE	0	0	0	0	0	0	0	0	0	0	0	5.85	0	0
ACMAIZE	0	0	0	0	0	0	0	0	0	0	0	0	1.21	0
ACAGOTH	0	0	0	0	0	0	0	0	0	0	0	0	0	2.40
ACMINING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACLMANUF	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACINTERM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACKGOODS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACCONSTR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACPUBADM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACARMY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACSVC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMRICE	0.08	0.00	0.23	0.02	1.01	0.05	0.00	0.07	0	0.27	0.20	0	0	0
CMMAIZE	0	0.00	0.04	0.01	0.20	0.01	0.00	0.01	0	0.05	0.04	0	0	0
CMAGOTH	0.08	0.03	0.73	0.01	0.31	0.02	0.00	0.02	0	0.09	0.06	0	0	0
CMMINING	0	0	0.07	0.33	0.80	2.42	0.10	0.03	0	0.21	0.74	0	0	0
CMLMANUF	0.34	0.05	0.02	0.16	2.29	0.23	0.12	0.13	0	0.20	1.17	0	0	0
CMINTERM	0.91	0.12	0.23	0.34	0.74	2.16	1.25	0.87	0	0.22	1.08	0	0	0
CMKGOODS	0.08	0.01	0.02	0.10	0.09	0.09	0.93	0.29	0	0.34	0.38	0	0	0
CMCONSTR	0.01	0.00	0.00	0.07	0.00	0.02	0.03	0.09	0	0.34	0.11	0	0	0
CMPUBADM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMARMY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMSVC	0.14	0.02	0.04	0.13	0.59	0.41	0.35	0.13	0	0.21	0.59	0	0	0
CAPITAL	1.20	0.16	0.31	1.83	0.91	1.29	1.19	0.17	0.28	3.35	1.94	0	0	0
LLAND	0	0.09	0.26	0	0	0	0	0	0	0	0	0	0	0
MLAND	0.37	0.14	0.06	0	0	0	0	0	0	0	0	0	0	0
HLAND	0.31	0.27	0.00	0	0	0	0	0	0	0	0	0	0	0
AGLAB	1.57	0.22	0.42	0	0	0	0	0	0	0	0	0	0	0
URBUNSK	0	0	0	0.71	0.73	0.47	0.59	0.14	0.23	0.56	0.79	0	0	0
URBSKLD	0	0	0	0.30	0.15	0.11	0.15	0.04	0.94	1.06	1.32	0	0	0
HHALL	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DIRTAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INDTX	0.75	0.10	0.20	2.62	0.99	1.09	0.93	0.49	0	0	0.91	0	0	0
TARIFFS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EXPTAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAPACC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROW	0	0	0	0	0	0	0	0	0	0	0	0.85	0.16	0.37
TOTAL	5.85	1.22	2.62	6.61	8.82	8.37	5.65	2.47	1.44	6.89	9.32	6.70	1.37	2.76

	CMMINING	CMLMANUF	CMINTERM	CMKGOODS	CMCONSTR	CMPUBADM	CMARMY	CMSVC	CAPITAL	LLAND	MLAND	HLAND	AGLAB	URBUNSK
ACRICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACMAIZE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACAGOTH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACMINING	6.44	0	0	0	0	0	0	0	0	0	0	0	0	0
ACLMANUF	0	8.20	0	0	0	0	0	0	0	0	0	0	0	0
ACINTERM	0	0	7.83	0	0	0	0	0	0	0	0	0	0	0
ACKGOODS	0	0	0	5.43	0	0	0	0	0	0	0	0	0	0
ACCONSTR	0	0	0	0	2.47	0	0	0	0	0	0	0	0	0
ACPUBADM	0	0	0	0	0	1.44	0	0	0	0	0	0	0	0
ACARMY	0	0	0	0	0	0	6.89	0	0	0	0	0	0	0
ACSVC	0	0	0	0	0	0	0	9.31	0	0	0	0	0	0
CMRICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMMAIZE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMAGOTH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMMINING	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMLMANUF	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMINTERM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMKGOODS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMCONSTR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMPUBADM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMARMY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CMSVC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAPITAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LLAND	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MLAND	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HLAND	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AGLAB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
URBUNSK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
URBSKLD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HHALL	0	0	0	0	0	0	0	0	0	0	0	0	2.21	4.19
ENT	0	0	0	0	0	0	0	0	12.62	0	0	0	0	0
GOV	0	0	0	0	0	0	0	0	0	0.35	0.57	0.58	0	0
DIRTAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INDTX	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TARIFFS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EXPTAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAPACC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROW	0.09	0.51	0.82	0.42	0	0	0	0.07	0	0	0	0	0	0
TOTAL	6.52	8.71	8.65	5.85	2.47	1.44	6.89	9.38	12.62	0.35	0.57	0.58	2.21	4.19

	URBSKLD	HHALL	ENT	GOV	DIRTAX	INDTX	TARIFFS	EXPTAX	CAPACC	ROW	TOTAL
ACRICE	0	0	0	0	0	0	0	0	0	0.00	5.85
ACMAIZE	0	0	0	0	0	0	0	0	0	0.00	1.22
ACAGOTH	0	0	0	0	0	0	0	0	0	0.23	2.62
ACMINING	0	0	0	0	0	0	0	0	0	0.18	6.61
ACLMANUF	0	0	0	0	0	0	0	0	0	0.62	8.82
ACINTERM	0	0	0	0	0	0	0	0	0	0.55	8.37
ACKGOODS	0	0	0	0	0	0	0	0	0	0.22	5.65
ACCONSTR	0	0	0	0	0	0	0	0	0	0	2.47
ACPUBADM	0	0	0	0	0	0	0	0	0	0	1.44
ACARMY	0	0	0	0	0	0	0	0	0	0	6.89
ACSVC	0	0	0	0	0	0	0	0	0	0.01	9.32
CMRICE	0	2.22	0	1.55	0	0	0	0	0.99	0	6.70
CMMAIZE	0	0.46	0	0.35	0	0	0	0	0.20	0	1.37
CMAGOTH	0	0.67	0	0.43	0	0	0	0	0.31	0	2.76
CMMINING	0	1.39	0	0.34	0	0	0	0	0.10	0	6.52
CMLMANUF	0	3.13	0	0.17	0	0	0	0	0.70	0	8.71
CMINTERM	0	0.32	0	0.15	0	0	0	0	0.26	0	8.65
CMKGOODS	0	0.25	0	0.23	0	0	0	0	3.05	0	5.85
CMCONSTR	0	0	0	0.01	0	0	0	0	1.78	0	2.47
CMPUBADM	0	0	0	1.44	0	0	0	0	0	0	1.44
CMARMY	0	0	0	6.89	0	0	0	0	0	0	6.89
CMSVC	0	3.92	0	2.04	0	0	0	0	0.80	0	9.38
CAPITAL	0	0	0	0	0	0	0	0	0	0	12.62
LLAND	0	0	0	0	0	0	0	0	0	0	0.35
MLAND	0	0	0	0	0	0	0	0	0	0	0.57
HLAND	0	0	0	0	0	0	0	0	0	0	0.58
AGLAB	0	0	0	0	0	0	0	0	0	0	2.21
URBUNSK	0	0	0	0	0	0	0	0	0	0	4.19
URBSKLD	0	0	0	0	0	0	0	0	0	0	4.08
HHALL	4.08	0	1.88	0	0	0	0	0	0	0	12.37
ENT	0	0	0	0	0	0	0	0	0	0	12.62
GOV	0	0	0	0	10.74	8.08	0	0	0	1.48	21.80
DIRTAX	0	0	10.74	0	0	0	0	0	0	0	10.74
INDTX	0	0	0	0	0	0	0	0	0	0	8.08
TARIFFS	0	0	0	0	0	0	0	0	0	0	0
EXPTAX	0	0	0	0	0	0	0	0	0	0	0
CAPACC	0	0	0	8.2	0	0	0	0	0	0	8.20
ROW	0	0	0	0	0	0	0	0	0	0	3.28
TOTAL	4.08	12.37	12.62	21.80	10.74	8.08	0	0	8.20	3.28	0

Appendix 2
Model Description

Six equation "blocks" are distinguished.

Price Equations

On the import side the model incorporates the "small-country" assumption: equation 1 gives the domestic price of sectoral imports in terms of exogenous world prices, the exchange rate and tariff rates. North Korea is also assumed to be small on the export side; equation 2 shows that the domestic price of sectoral exports is determined by world prices, exchange rate, and any applicable export subsidy or tax, depending on the sign of parameter *te*. Trade distortions are modeled as quantitative restrictions and affect the quantity equations (see next section). The major form of internal distortion is assumed to be indirect turnover taxes.

Consumers buy a composite consumption good and producers sell a composite production good. Their sectoral prices are the weighted averages of the domestic prices of their components, as shown in equations 3 and 4.

A value added (or net) price is defined in equation 5 as the unit value of output minus the cost of intermediate inputs. These are priced on the basis of *PC*, the consumption price of composite goods, defined in equation 6 as the adjustment of the composite consumption good price by final consumption tax rates.

Finally, in equation 7 a cost of living index, defined as a weighted average of sectoral commodity prices, is fixed as the *numeraire*.[1]

Quantity Equations

Sectoral production technology is represented in equation 8 by a set of constant elasticity of substitution (CES) functions of the primary factors—the three types of land, capital and the three types of labor (rural, urban high skill and urban low skill). Equation 9 shows the sectoral demand for primary factors. Their remuneration is set equal to the value added price (net of both indirect taxes and intermediate input costs) times the partial of the production function with respect to each factor. Equation 9 therefore also represents the first-order conditions for profit maximization. Factor demand equations assume that primary factors are paid the same average rental rate (*WF*) , but the model allows for distortions in

[1] The weights being equal to the share of each sector in total consumption.

factor markets through sector-specific parameter (*wfdist*) which measures the extent to which the sectoral marginal revenue product of the factor deviates from its average return. Equation 10 specifies the Leontief intermediate input demand function, based on fixed input-output coefficients.

Each sector is assumed to produce differentiated goods for the domestic and export markets. Equation 11 shows that producers decide how to subdivide their total sectoral output as a constant elasticity of transformation (CET) function of the amounts sold in the two markets. Subject to this transformation function, producers maximize revenue from sales. The first-order conditions yield equation 12, which expresses the ratio of exports to domestic sales in terms of the ratio of their prices. Similarly, imported and domestic products are differentiated at the sectoral level, equation 13 indicating the composite (consumption) good as a CES aggregate. Consumers minimize the cost of obtaining a given amount of composite good, resulting in a relationship between the ratio of the amounts imported and domestically produced and the ratio of their prices (equation 14). Such product differentiation permits two-way trade and provides some autonomy to the domestic price system not found in models that assume perfect substitutability between domestic products and imports in consumption and between domestic and export markets in production.

Initially, the economy's market equilibrium is computed with parameters which are benchmarked on the basis of the analysis presented earlier. The central planners impose a rationing solution which implicitly puts the economy on a lower transformation function than would be attainable in the absence of rationing.[2] The gravity model results provide an indication of the extent to which rationing reduces aggregate trade. The commodity analysis of North Korea's competitiveness was used to parameterize the measure in which rationing was binding at the sectoral level. Finally, the curvatures of the CET functions were parameterized along the lines of previous studies as to the degree of intrinsic differentiation of the commodity aggregates.

For the specific case of North Korea, equations 12 and 14 are modified to introduce restrictions to free trade in the form of export and import quantity rationing ratios. Such rationing greatly distorts the composition production and demand, but does not involve *direct* spillovers in other markets through wedges in relative prices. Still, the rationing of exports and imports distorts producers' and consumers' decisions on both domestic and external markets. Therefore, this formulation enables us to model economy-wide distortions by introducing quantitative restriction only on the external side of the economy.

[2] See Noland, Robinson, and Scatasta (1997) for more detail and a diagramatic exposition.

Income and Expenditure Equations

Equation 15 combines the incomes, across production sectors, accruing to each of the primary factors.

Equation 16 represents a compact formulation of three equations which simultaneously determine real government expenditure, nominal private consumption, and nominal investment demand. The three expenditure aggregates are derived from the distribution of total factor income to the economy's institutions (households and enterprises) and finally from its allocation to the three expenditure categories. This set of equations simply reproduces the flows which are represented in the macroeconomic Social Accounting Matrix (SAM).

In the closure section of the model—not entirely shown to avoid clutter—non-grain government expenditure is held constant at the base value, while investment and household consumption adjust in response to changes in income induced by the policy experiments. The trade balance is fixed and the real exchange rate is allowed to adjust endogenously.[3]

The next three equations specify the sectoral composition of the expenditure aggregates. Sectoral private consumption is based on a Cobb-Douglas utility function, with constant expenditure shares (equation 17). Government demand by non-grain sectors is given by constant shares of real government non-grain spending (equation 18). Real fixed investment by sector of origin is determined in equation 19. The CGE model is static. Investment is only a category of final demand, with no effect on the capital stock in the period, and so has no role in the supply side of the model.

Market-Clearing Conditions

The remaining equation block presents the market-clearing conditions. Equilibrium in product markets is represented in equation 20, equating supply of the composite good in each sector to the sum of product demands. Equation 21 specifies equilibrium in each factor market; total factor supply is fixed and the equilibrating variable is the average factor price (WF_f). External balance is portrayed in equation 22, which specifies a fixed aggregate balance of trade.

Altogether, the model has 277 endogenous variable and 278 equations. However, the model satisfies Walras' Law, and the number of *independent* equations is equal to the number of endogenous variables.

[3] Alternatively one could fix the real exchange rate and allow the trade balance to adjust. In point of fact, the results of the policy experiments are quite similar under this alternative closure.

Appendix 2
Equations of the North Korea CGE model

Price Equations

1. $PM_i = pwm_i \bullet (1 + tm_i) \bullet EXR$ — Import prices

2. $PE_i = pwe_i \bullet (1 - te_i) \bullet EXR$ — Export prices

3. $PQ_i = \frac{PD_i \bullet D_i + PM_i \bullet M_i}{Q_i}$ — Composite good prices net of cons. taxes

4. $PX_i = \frac{PD_i \bullet D_i + PE_i \bullet E_i}{X_i}$ — Average producer prices

5. $PV_i = PX_i \bullet (1 - tx_i) - \sum_j PC_j \bullet a_{ji}$ — Value added prices net of indirect taxes

6. $PC_i = PQ_i \bullet (1 + tc_i)$ — Consumption prices of composite good

7. $PINDEX = \prod_i (PC_i)^{pwcs_i}$ — Numeraire consumer price index

Quantity Equations

8. $X_i = CESP(FDSC_{i,f})$ — CES Production function

9. $WF_f \bullet wfdist_{i,f} = PV_i \bullet ad_i \bullet [\sum_f (a_{i,f} \bullet FDSC_{i,f}^{-p_i})]^{-1overp_i-1} \bullet a_{i,f} \bullet FDSC_{i,f}^{-p_i-1}$
Demand function for primary factors (First order condition for profit maximiz.)

10. $INT_i = \sum_j a_{ji} \bullet X_j$ — Total intermediate uses

11. $X_i = CET(D_i, E_i)$ — Exports transformation frontier

12. $\frac{E_i}{D_i} = ratex_i \bullet CET^* \left(\frac{PE_i}{PD_i} \right)$ — Export supply

13. $Q_i = CES(D_i, M_i)$ — Imports substitution frontier

14. $\frac{M_i}{D_i} = ratm_i \bullet CES^* \left(\frac{PM_i}{PD_i} \right)$ — Import demand

Income and Expenditure Equations

15. $YFCTR_f = \sum_i WF_f \bullet wfdist_{if} \bullet FDSC_{i,f}$ — Factor income

16. $(GDTOT, INVEST, CONSUM) = F(YFCTR_f)$ — Expenditure aggregates as a function of factor income

17. $PC_i \bullet CD_i = cles_i \bullet CONSUM$ — Private consumption by sector

18. $GD_{ngrain} = gles_{ngrain} \bullet GDTOT$ — Government consumption by sector

19. $PC_i \bullet ID_i = g_i(INVEST)$ — Investment demand by sector of origin

Market Clearing Conditions

20. $Q_i = INT_i + CD_i + GD_i + ID_i + DST_i$ — Goods markets equilibrium

21. $FS_f = \sum_i FDSC_{i,f}$ — Factor markets equilibrium

22. $\sum_i (PWM_i \bullet M_i) = \sum_i (PWE_i \bullet E_i) + FSAV + FBOR + REMIT$ — External balance

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NOTATION

Endogenous variables

PM_i = domestic price of imports
PE_i = domestic price of exports

PC_i	=	composite good price to consumers
PQ_i	=	composite good price net of consumption taxes
PD_i	=	price of domestically produced good for domestic market
PX_i	=	average producer price
PV_i	=	value added (net of indirect taxes) price
EXR	=	foreign exchange rate
X_i	=	gross domestic output
$FDSC_{if}$	=	factor demand by sector
WF_f	=	nominal average factor wages
M_i	=	imports
E_i	=	exports
Q_i	=	demand for composite good
D_i	=	domestic demand for domestically produced good
$YFCTR_f$	=	factor income
$CONSUM$	=	total private consumption
$INVEST$	=	total investment demand
$GDTOT$	=	total government current expenditure excluding military spending
INT_i	=	intermediate demand
CD_i	=	private consumption by sector
GD_{ngrain}	=	government consumption by non-grain sectors
ID_i	=	investment demand by sector of origin

Exogenous variables

$PINDEX$	=	numeraire consumer price index
$REMIT$	=	foreign remittances to households
$FBOR$	=	net foreign borrowing
$FSAV$	=	current account balance (or foreign savings)
FS_f	=	aggregate factor supply

Parameters

pwm_i	=	world prices of imports
pwe_i	=	world prices of exports
$pwcs_i$	=	weights in composite price index
$a_{i,f}$	=	CES production function share parameters
a_{ji}	=	input-output coefficients

ad_i	=	CES production function shift parameters
p_i	=	CES production function exponents
$ratex_i$	=	export rationing ratios by sector
$ratm_i$	=	import rationing ratios by sector
$wfdist_{i,f}$	=	factor price proportionality constant
tm_i	=	import tariff rates
te_i	=	export tax rates
tx_i	=	indirect tax rates
tc_i	=	consumption tax rates
$cles_i$	=	household expenditure shares
$gles_{ngrain}$	=	government expenditure shares

Functions

$CESP$	=	CES production function
CET	=	Constant elasticity of transformation function
CET^*	=	Relation derived from revenue maximization in a CET
CES	=	Constant elasticity of substitution function
CES^*	=	Relation derived from cost minimization in a CES
F	=	Mapping from factor income to expenditure aggregates
g_i	=	Derivation of investment demand by sector of origin

Indexes

i, j	=	production sectors (rice; maize; other agricultural goods, forestry and fisheries; mining; light manufacturing; intermediate products; capital goods; construction; public administration; military; services)
$ngrain$	=	production sectors excluding rice and maize sector
f	=	factors (three types of land; rural labor, urban high sk. labor, urban low sk. labor, capital)

Appendix 3
Parameterization

Sector	Elasticities	
	Import Substitution	**Export Transformation**
Rice	5.0	0.5
Maize	5.0	0.5
Other Ag., For. & Fish.	5.0	0.5
Mining	0.5	5.0
Light Manufacturing	0.5	5.0
Ind. Intermediates	0.5	1.5
Capital Goods	5.0	0.5
Services & Non-traded	1.5	1.5

Sector	Rationing ratios: actual over desired	
	Imports	**Exports**
Rice	0.05	0.90
Maize	0.05	0.90
Other Agr, For. & Fish.	0.05	0.90
Mining	0.20	0.05
Light Manufacturing	0.20	0.05
Ind. Intermediates	0.20	0.50
Capital Goods	0.05	0.90
Services	0.20	0.50
Non-traded	1.00	1.00

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