Achieving Food Security in North Korea*

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Abstract

The North Korean economy has been in steep decline for several years. This decline has been most visible in the agricultural sector with a severe food crisis during the 1990s thought to have resulted in the deaths of between 2-3 million people. Three factors are put forth as having precipitated the crisis—the loss of socialist trading partners in the late 1980s; a series of natural disasters in the mid-1990s; and constraints imposed by North Korea's autarkic economic system leading to the growing divergence in food supply and demand. In this paper, we estimate a production function for North Korean agriculture and then test for the relative significance of these factors in explaining changes in grain output and yield for the period 1961-98 and for the sub-period 1988-97. We argue that the dominant triggering factor of this crisis was the sharp loss of supplies of agricultural inputs following the disruption of the trade ties with the socialist block from the late 1980s. We also find the institutional failure of collective farming responsible not only for a persistent deterioration of technology but also the key constraint on production potential. The contribution of climatic factors to the agricultural crisis, was at most only a secondary cause. We conclude that to revitalize the agricultural sector and achieve food security, North Korea will need to introduce a household farming system and increase its interaction with international markets.

I. Introduction

North Korea does not have a comparative advantage in agriculture. Yet, like most other centrally planned economies, North Korea has pursued a policy of self-sufficiency in grain production. In practice, this has seen the adoption of a series of policy programs affecting the organisation and management of agricultural production and the structure of land ownership and utilization (Moon 1995). Despite an obvious comparative disadvantage in agriculture,[2] North Korea achieved steady expansion of grain production for several decades with grain output more than doubling between 1961 and 1988.[3] Though some studies argue that the grain deficit in North Korea could be sizable even in a normal year (Kim et al 1998), excesses of grain production over controlled consumption were experienced prior to 1988 (Lee 1994). Since then, food conditions have deteriorated sharply.

After 1989, the public grain distribution system came under strain due to a combination of factors, the most devastating of which was the disruption of trade with major input suppliers. The adverse consequences of these factors extended well beyond the supply of agricultural inputs. The loss of socialist trading partners severely affected farm operations by reducing imports of petroleum, fertilizers and machinery spare parts

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[2] Only around 20 per cent of land in North Korea is arable, with some 1.4-1.7 million hectares suitable for cereal production, and approximately 80 per cent of the land requiring irrigation.

[3] Numbers cited in this paper, unless otherwise indicated, are based on the data set compiled for this study.

needed for irrigation, for agricultural chemical plants, for power supply, and for North Korea's electrified railway service.

Initially North Korea was able to cope with the shortfalls by importing grain on a barter system, by exporting good-quality rice in exchange for cheaper grain, by drawing heavily on the stockpile and by public campaigns advising the consumption of 'two meals a day'.[4] In an attempt to adhere to its obligations under the rationing system, the government in the years thereafter drew heavily on the stockpile to make up the shortfall from domestic production. However, the decline in North Korea's capacity to earn foreign exchange since the early 1990s, has meant the regime has been unable to replenish stocks through imports and the volume of stock has continually declined. By 1992 grain demand was estimated as exceeding supply by more than 1 million tons, with an increased reliance on imports and food aid (Figure 1). By 1997, grain output had fallen to half of the 1988 level. The famine that followed from the mid-1990s is considered on some estimates to have claimed as many as 2-3 million lives, or about 10 per cent of the total population (Natsios 1999).[5]

The causes of famine are the subject of a literature largely pioneered by Amartya Sen. Sen (1981), in observing that a shock to food availability is never evenly distributed over the affected population, formulated the 'entitlement approach' for the analysis of famines that pays special attention to access to food. This was subsequently extended by Devereux (1988) and Ravallion (1996) to encompass both 'supply-side' (food availability) and 'demand-side' (access to food) theories of famine.

The entitlement approach has important analytical implications for understanding the recent famine in North Korea. The available evidence suggests North Korea's population has been unevenly affected, attributable mainly to the urban-biased policy[6] and exacerbated by poor functioning of the transportation system due to shortages of energy.[7] Closer examination of this issue, however, is difficult without access to more detailed information. In this study, we focus more on the factors responsible for agricultural crisis in the 1990s, the so-called 'supply-side' theory of entitlement approach (Lee 1994; Kim et al. 1998).

One obvious difficulty for any rigorous empirical analysis of the North Korean economy is access to reliable data. As the first step, we construct a consistent data set (including output, planting areas, labor, tractors and fertilizers) for the grain sector for the period 1961-98. We then update and adjust the data from information made available by international aid organizations (based on information collected during their fieldtrips to North Korea) as well as from published and unpublished documents.

Three factors have been put forth as having precipitated the agricultural crisis in North Korea: (1) the loss of socialist trading partners in the late 1980s which severely curtailed inputs (Lee 1994); (2) constraints imposed by North Korea's autarkic economic system (Eberstadt 1999; Noland 1995); and (3) a series of natural disasters in the mid-1990s (Kim et al. 1998). To date, none of these factors has been verified empirically. In this paper,

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[4] According to FAO/WFP (1995), North Korea was reportedly holding some 4 million tons in food grain stocks at the beginning of the 1990s.

[5] During the agricultural crisis in China in 1958-61, the number of deaths was estimated at 30 million (Ashton et al 1984). This was equivalent to about 5 per cent of the total population.

[6] The disparity between access to food between the privileged and underprivileged and between the urban and rural population is substantial. Urban centers, which house the bulk of the North Korean population, are accorded higher consumption standards, as are members of privileged classes in the government and party bureaucracy, the military and the families of workers employed in priority industries. Together this group is likely to encompass around one-third of the non-agricultural population. Those groups expected to be suffering the greatest nutritional stress would include the rural nonagricultural population and inhabitants of second-or third-tier urban centers without access to such priority professions as military industries or those that generate hard currency (Eberstadt 1999:67).

[7] The on-going debate about the agricultural crisis and famine in China in 1958-61 offers a useful reference to this study (Ashton et al. 1984; Chang and Wen 1997; Lin 1990; Lin and Yang 2000). In an analysis of China's famine in 1958-61, Lin and Yang (2000) argue that urban-biased policy, along with the policy shift from voluntary to compulsory collectivization, was an important determinant of rural-concentrated famine.

we argue that the agricultural crisis was mainly caused by the sharp decline of agricultural inputs following the loss of socialist trading partners. This triggering effect, in turn, had its root in the distorted pattern in the application of agricultural technology that evolved during the Cold War that relied excessively on inputs from the socialist bloc (Hayami and Ruttan 1970). But while North Korea's autarkic system might be responsible for the famine because of implied constraints on importing grain and inputs, it cannot completely explain the sudden collapse of domestic production. In this regard, we argue that North Korea's agricultural crisis, like other centrally planned economies, can also be related to the institutional failure of collective farming (Lin 1990). The contribution of climatic factors was at most only secondary. These conclusions emerge from our growth accounting exercise based on the production function approach.

This paper is organized as follows. The next section offers a brief review of North Korea's agricultural development. Section III presents the three alternative hypotheses thought to account for the decline of grain production. Section IV outlines data sources and the methods applied to compile the data set for this study. Section V discusses the quantitative methodology employed and presents the tested results, followed by a discussion of the policy implications in the final section.

II. Agricultural development in North Korea

North Korea's agricultural policy was directed personally by Kim Il Sung until his death in 1994. The basic system underlying agricultural management was cultivated from Kim Il Sung's personal visits to sites in North Korea whereby Kim is said to have provided 'on the spot guidance' of farm management techniques and on how to solve administrative and managerial problems. The result was the emergence of the mass mobilization technique known as the *Chongsanri* method, named after the cooperative farm Kim visited, which emphasized communal cooperation as well as political conditioning of the masses (Koo and Jo 1995). The more significant articulation is set out in Kim's so-called 'Rural Thesis' that puts forth the task of increasing food production and developing rural areas in the lofty ideological terms of preparing for the transition to communism by eliminating the differences between town and country and between the peasants and workers (Lee 1994). Collective farming and technological revolution constituted the means by which Kim Il Sung believed North Korea would attain self-sufficiency in grain.

Between 1954-58, some one million farm households were transformed into collectivized farms, most designated as cooperative farms, and a smaller number of designated state farms.[8] Cooperative farms have remained the dominant form of farm organization whereby everything including land, farm facilities, and implements are owned collectively and members are paid incomes in shares of what they produce. Decisions concerning the output mix, allocation of inputs and their prices, planting and harvesting dates, the distribution and prices of farm product, are made on the basis of specific central government directives (Moon 1995). Fulfilling the government set target is the basic tenet of life for collective farm workers.[9]

In collective farms, remuneration for individual members is paid on the basis of the number of workday points accumulated for a given period of time, with the degree of loyalty to the party also taken into account (Chung 1974). Under this system, a subteam was assigned a specific number of workday points for performing a planned task on an allotted area of land. Depending on whether the subteam over fulfills or under fulfills the planned target, the workday points were adjusted upward or downward. Once the workday points earned by the

[8] As of 1987 the number of cooperative farms was estimated at 3,700 and that of state farms at 220, with the state farm share of total cultivated land estimated at 20 per cent and accounting for 30 per cent of total agricultural output (Moon 1995). More recent reports suggest there are currently some 3,000 cooperatives, 300 state farms and 240 farms of various types (Quinones 1999).

[9] Since income and status depend considerably on achieving targets determined by higher units, there is a tendency for the lower levels of administration and farm managers to embellish positive achievements in reporting to superiors (Smith 1998).

subteam as a group are determined, they are divided among individual members according to their contribution (Moon 1995:84-85).[10]

Technological revolution of irrigation, electrification, mechanization and chemicalization sat at the center of the post-collectivization agricultural policy. By 1970, the basic irrigation system was in place, largely in response to the North Korean climatic conditions whereby the dry spring necessitates irrigation and the heavy rainfall in the summer results in flooding.

However, implementation of programs of rapid mechanization and chemicalization, though quite successful in the 1970s and early 1980s, gave rise to a peculiar pattern in the application of agricultural technology. According to the theory of 'induced technical innovation', labor abundant countries (such as Japan) pursue land-saving (fertilizer-using) technology while land abundant countries (such as the United States) develop labor-saving (machinery-using) technology (Hayami and Ruttan 1970, 1985). Compared to the world average, North Korea is an arable land-scarce country. However, the use of tractors was quite intensive. On the basis of FAO data, the growth rate of the number of tractors was a steady 7 per cent per annum in 1961-77, but jumped to 14 per cent per annum in 1977-84 as the mechanization program intensified.

Fertilizer usage also increased significantly, recording an annual growth rate of 12 per cent between 1961-78. After that, the level of fertilizer application remained relatively stable until 1989. Fertilizer consumption then fell dramatically, from between 700,000-800,000 tons in the late 1980s to 110,000 by 1998 (FAO/WFP 1999).[11] A historical comparison of North Korea's fertilizer consumption with that of other Northeast Asian economies as well as Vietnam suggests that North Korean consumption of fertilizers has probably been excessive (Table 1). According to the FAO statistics, in 1972, fertilizer use was 194 kilograms per hectare of agricultural land, which was lower than that of Japan and South Korea but much higher than China and Vietnam. In 1990, however, North Korea was already at similar levels to South Korea. It is important to recall that both South Korea and Japan not only had very high levels of agricultural protection but also were much more advanced economies. In other words, if the levels of agricultural protection and income were lower, South Korea and Japan would have consumed much less fertilizer. In comparing the composition of fertilizer consumption in North and South Korea, North Korea has applied much smaller proportions of phosphate and potash fertilizers, pointing to a further source of inefficiency.

The seemingly excessive use of fertilizers and, perhaps, tractors, were likely induced by two factors. On the one hand, the availability of fertilizer and oil imports on concessional terms from the socialist trading partners encouraged North Korea to increase the levels of application at marginal costs lower than that for other East Asian economies. On the other hand, as self-sufficiency in grain was a primary policy goal, North Korea was forced to increase yields through massive use of inputs regardless of efficiency and costs.[12] This peculiar pattern of technology, in relying heavily on modern inputs, in effect laid the basis for an agricultural crisis when the supply of fertilizers and oil were suddenly curtailed.

As a result of massive inputs, grain production expanded steadily, at 2.8 per cent per annum between 1961 and 1988. This was obviously much lower than input growth. In the following ten years, however, grain production collapsed, recording an annual growth rate of -5.6 per cent in 1988-98 (Figures 2-4). It was this sharp decline that resulted in the food crisis in the mid-1990s.

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[10] The incomes of state farms are not linked to the amount of output they produce; the entire output is turned over to the state, and workers are paid fixed wages set by the state like workers in industrial enterprises.

[11] If North Korea's three fertilizer manufacturing plants were running to capacity some 410,000 tons of nitrogen equivalent could be produced (FAO/WFP 1998).

[12] Once food conditions improved in the mid-1970s, the government apparently gave a relatively lower priority to grain production and eased its push for further farm mechanization and chemicalization (Lee 1994). High yielding varieties require sufficient amounts of fertilizers, and North Korean agriculture failed to receive crucial support in the form of sustained progress in chemical fertilization and farm mechanization. For an economy geared for self-sufficiency, North Korea has never developed domestic sources of potassium and has thus remained dependent on the availability of foreign exchange for its imports.

III. Hypotheses

Three hypotheses are commonly put forth in the literature as having contributed to North Korea's agricultural crisis — exogenous shocks in the form of disruptions in trade with former socialist trading partners from the late 1980s; the institutional constraints embodied in North Korea's agricultural system; and three years of natural disasters from 1995-97.

First, the disruption in trading ties with former communist allies in the late 1980s and early 1990s has been stressed by the North Korean government as the main factor explaining the decline in agricultural output (Smith 1997). Before that, aid and trade conducted on either barter or concessional terms enabled North Korea to obtain critical energy supplies while avoiding balance of payment difficulties. The former Soviet Union ceased providing economic aid from 1987. More devastatingly, the former Soviet Union in 1990 and China in 1993 requested that North Korea pay the standard international price and that it pay in hard currency rather than through barter trade. As North Korea lacked the hard currency needed to meet these terms, the level of its imports from the former Soviet Union dropped sharply with total trade volume between North Korea and the Soviet Union falling from US$3.2 billion in 1990 to US$360 million in 1991. The drop of petroleum imports was dramatic, from 506,000 tons in 1989 to 30,000 tons in 1992 (Lee 1994:544). Although 1993 officially marked the advent of hard-currency settlement terms in Chinese-North Korean trade, China has continued to serve as a de facto concessional supplier of grain, oil and coal[13] (Table 2).

The sharp declines of imports from the socialist block meant reduction in supplies of agricultural inputs, as a large proportion of former imports were either agricultural inputs or raw materials necessary for production of agricultural inputs. As a result, North Korea's three domestic fertilizer plants ran at far below capacity, with tractors and other related transportation equipment becoming increasingly idle. By 1998, on the basis of the data set constructed for our analysis, the actual usage of tractors and fertilizers only reached 21 per cent and 14 per cent of their respective 1988 levels. Given this, a sharp decrease of grain output was inevitable.

Second, most outside observers emphasize North Korea's economic system as the main underlying cause the decline in agricultural output (Eberstadt 1999; Noland 1995; Smith 1998). Since 1956, North Korea has managed its economy according to the ideology of self-reliance, in effect an economic strategy synonymous with the inward-oriented economics of an autarkic state.

While North Korea's autarkic system was responsible for the country's inability to avoid famine once the shocks were triggered, what needs to be explained here is not so much the widening gap between grain demand and supply, but rather, what precipitated the collapse of grain production. An underlying element, hypothesized here as a key factor, was the failure of collective farming. As Lin (1988) has pointed out in the Chinese case, a major problem with collective farming lay in the trade-offs between the benefit of scale economies and the costs of monitoring. Agricultural production sites were often scattered and the result of efforts by individuals cannot be measured directly in a collective. Because it was costly, there was virtually no monitoring. This led to the scenario that Chinn (1980) has termed 'universal laziness' — team members presented themselves in the field, accrued the working points, but made no serious effort to work. This could lead to losses of grain production in two ways — technical inefficiency and technological deterioration. In the case of China, the introduction of the commune system in the late 1950s resulted in more than 20 per cent productivity decline, whilst the household responsibility system reform in the late 1970s brought about a surge in both productivity and output (McMillan et al. 1989; Lin 1992; Wen 1993).

[13] Several unconfirmed reports emerged in mid-1996 that China had budgeted in its current Six-Year Plan for a revival of its concessionary pricing practice or 'friendship price system' with North Korea. Between 1996-2000, China reportedly agreed to provide North Korea with 500,000 tons of grain, 1.3 million tons of crude oil and 2.5 million tons of coal. China has since officially announced that it donated 100,000 tons of grain to North Korea in 1995, 500,000 tons in 1996, 150,000 tons in 1997 and 100,000 tons in 1998; along with 1 million tons of oil between 1989-96 (Shin 1999). Other estimates of border trade suggest than more than 500,000 tons of food grain has flowed annually from China to North Korea in recent years (Shin 1999).

A third explanation for the cause of the food crisis is adverse weather conditions from 1995-97 (Kim et al. 1998). In 1995, heavy rains caused severe flooding. The rains, which came at a critical time in the crop cycle, were up to three to five times above normal for the July-August period, during which the country usually receives some 60 to 65 per cent of its annual precipitation. In July 1996, the country was again affected by floods (though the severity was not comparable to that of the previous year), and then by drought in the run up to the 1997 harvest season in October. The flood damage was estimated by North Korea as having reduced arable land by 19 per cent in 1995 and 16 per cent in 1996 (UNDP 1998).

While admitting some impacts of adverse weather on grain production, we are doubtful of the significance of this factor. In other cases, such as in China during 1958-61, climatic change was also used as an excuse by policy-makers to cover up policy failures (Lin 1990). If adverse weather was the dominant factor explaining North Korea's agricultural crisis, this would still not explain why grain output had begun to show steady declines from the beginning of the 1990s. It would also not explain why in 1998 and 1999, when weather conditions had improved, output still remained at around 1997 levels but below 1995 and 1996 levels. There were years during 1961-88 when weather conditions were adverse, but grain shortfalls often stayed within 5 per cent.

IV. Data

The data compiled for this study are time series data on grain production for the period 1961-98. The variables include grain output,[14] planting areas, labor, tractor, fertilizer and weather condition.

North Korea ceased publishing regular statistics in 1965. Those statistics that have been made available by the government since then are often discontinuous and fragmentary, with questions surrounding their reliability. Since gaining membership in the United Nations, North Korea has been providing data to UN related agencies. Studies applying this data suggest it may not, generally speaking, be erroneous or inflated (Eberstadt and Banister 1992). Nonetheless, any analysis must be tempered by the knowledge that there are considerable gaps in the information available from which to draw conclusions with any degree of certainty. The absence of reliable statistical information means that indirect estimates have to be extensively employed.

North Korea has in the past reported agricultural production data to the Food and Agricultural Organization (FAO), although it is unclear to what extent the FAO supplements this data with its own estimates. With North Korea's increased dependence on food aid, more data has become available following access by the FAO/WFP and following the provision of data by North Korea's Agricultural Commission. South Korean agricultural institutions also estimate North Korean grain production (Smith 1997).

There are reasonable grounds for assuming that the FAO grain production series, at least up until the late 1980s, is broadly reflective of North Korean agricultural trends (see Smith 1997). The most comprehensive benchmark from which to compare the FAO data against is Lee's (1994) study of constructed estimates of North Korean demand and supply of grain. Drawing on both production figures cited by Kim Il Sung in speeches, announced results of mobilization programs, and internal documents of discussions between Kim Il Sung and agricultural officials, Lee constructs estimates of North Korea's supply and demand of grain for the year 1966 and for the period 1973-93, discounted for inflated reporting.

Grain production data for the period 1994-1998 can also regarded as a reasonable representation of North Korea's agricultural production trends on the basis of information provided by North Korea's Agricultural Commission and from FAO/WFP estimates following their discussions with North Korean agricultural officials, field visits and analysis of regions where the principle effects of the natural disasters have been felt since they gained access in the mid-1990s. The big gap in our knowledge is the period 1989-1993, where the FAO data series for rice in particular looks too high. Total grain production is shown as increasing gradually from 7.76 million tons to 9.27 million tons, with paddy rice production increasing gradually from 3.5 million tons in 1989 to 4.78 million tons in 1993. This is unlikely to have been the case given what is known about the input

[14] Grain includes paddy rice, maize, barley, rye, oats, millet, sorghum and potatoes. Potatoes have been converted to cereal equivalent using a 4 to 1 conversion rate.

structure to agriculture at this time. Even during the period 1984-88, before external conditions turned sharply adverse, it is difficult to find internal factors pertaining to grain production undergoing favorable changes (Lee 1994).

To overcome this inconsistency, we deflate the FAO series to accord with Lee's estimates of North Korean agricultural production for the period of concern. This requires reducing the FAO rice and maize series by 3.9 per cent in 1989, 3 per cent in 1990, 3.1 per cent in 1991 and 3.1 per cent in 1992. The estimate for grain production in 1993 is especially problematic. In 1993, a severe cold front visited Northeast Asia, causing yield damage of 10-30 per cent in northeast China, South Korea and Japan. This unseasonally cool summer affecting North Korea was factually reported in the North Korean press. However, Lee estimates production as having increased by 2 per cent in 1993 on reports of figures released by the North Korean government in the process of celebrating the 30th anniversary of the Rural Theses, and on reports of a bumper harvest based on an unusual availability of chemical fertilizers. Although we use Lee's 1993 figure, caution is warranted when directly applying the output data for 1989-93.

Labor input refers to economically active population in agriculture as reported by the FAO. The decline of agricultural employment in North Korea has been relatively slow, from 40 per cent to 25 per cent between 1960-90 (Eberstadt and Bannister 1992). Official North Korean figures reported to the FAO put the share of the labor force in agriculture by 1990 at 34 per cent. North Korea's 1993 Population Census, released by the Central Bureau of Statistics, puts the share of labor on state farms and in the farming sector at 3.28 million or 31 per cent of the labor force. There is a debate amongst North Korea analysts about whether this series is too high, although there has most likely been population movement back into the rural sector in the 1990s as conditions in the industrial sector have deteriorated.

Land area is the actual planting area for grain. Another option is to use harvested area. We chose not to use this series for two reasons. First, the data quality of harvested area is usually lower, especially for the earlier years, given the quantitative difficulties in defining the loss of harvested areas. Second, if the reduction in harvested area was the result of drastic climate changes, its impact should be captured by the weather variable.

Capital input is simply the number of tractors in use. Ideally we would wish to construct a series to include irrigation equipment, oxen and cattle. However, the only available data on a consistent basis are tractors in use. The FAO series has the number of tractors rising to peak at 75,000 in 1992 and then remaining constant at 75,000 from 1992-96. This is unlikely to be the case given the fuel and spare parts shortages that had began to impact the agricultural sector. Based on field visits, the FAO/WFP estimates North Korea tractor capacity of 20 per cent by 1998. Given this, and the absence of alternative estimates, we have assumed the series as declining from 1989 (when imports of crucial inputs began to fall) with a yearly decline of 5,600 tractors, reaching 15,000 tractors by 1998.

Fertilizer input is measured by the physical weights of total fertilizer application. Data on fertilizer usage for 1961-88 is from the FAO, with data thereafter from North Korea's Agricultural Commission.

A proxy variable for *weather* conditions is constructed to capture the possible impacts of weather changes on grain production. Because a consistent time series on weather conditions are not available for North Korea, we instead use data from China's Jilin province as a proxy.[15] Two series are constructed. The first is the annual rainfall in Jilin province. The second is defined as the proportion of farming area affected by climatic factors as a share of total cultivated area, with the area 'affected' defined as yields having fallen by 20 per cent. The first series is expressed in numbers of centimeters and the second in percentage terms.

V. Accounting for the contributing factors

We first estimated a normal production function, with total output as the dependent variable and land, labor, tractor and fertilizer as inputs. The results were unsatisfactory — most estimates were either insignificant or

[15] Jilin province is adjacent to North Korea's North Pyongan province located in the southwest of the country. The southwest of the country produces roughly 60 percent of North Korea's food grain (predominately rice) with the remainder coming principally from the northwest.

with the wrong signs. Given we are unable to improve on the data set, we instead estimate the yield production function in which all the output and input variables are deflated by planting areas. Given the limited sample size, we only apply the Cobb-Douglas function form

$$Y = AL^{\alpha} K^{\beta} F^{\gamma} e^{\varepsilon}$$

where Y is grain yield, L is number of workers per hectare, K is number of tractors per hectare, F is fertilizer application per hectare and ε is the statistical residual. To capture the impact of climate change and technological change over time, two proxy variables, D (weather condition) and T (time trend) are added to the above function

$$Y = AL^{\alpha} K^{\beta} F^{\gamma} e^{\delta D + \varphi T + \varepsilon}$$

It can be linearized by taking logarithm on both sides of the equation

$$\ln(Y) = \theta + \alpha \ln(L) + \beta \ln(K) + \gamma \ln(F) + \delta D + \varphi T + \varepsilon$$

The above yield production function is then empirically estimated applying the data set for North Korea's grain production described above. The OLS approach was first applied and first-order auto-correlation was detected. This was adjusted for by applying the Pagan (1974) method and the results are reported in Table 3. Both annual rainfall and areas affected by floods/drought were used as proxy variables for the weather conditions in separate regressions. Table 3 reports only the results using the affected area series, which have more reasonable estimates but are still insignificant. There might be two reasons for the insignificant results for the weather variable (columns 2 and 3). On the one hand, the proxy weather variable was constructed using data on areas affected by floods and drought in Jilin province of China, so that the series may not accurately reflect changes in climate conditions in North Korea during that period. On the other hand, it may also be an indication that, over that whole period, the impact of weather conditions on grain yield was insignificant.

Three different models are estimated, the first model contains only three primary factors as the explanatory variables (column 1), the second model includes the weather proxy variable (column 2) and the third model is further added with the time trend (column 3). Whilst recognizing the results may be sensitive to the way in which the data is constructed, they are in general satisfactory as most coefficient estimates for primary factors are positive and significant. The estimate for the time trend variable is negative and significant (column 3), which implies persistent technological deterioration during the period of agricultural collectivism.

The production function results are then applied to decompose the growth of grain output. Because total grain output (O) equals planting area (N) multiplied by yield (Y)

$$O = N * Y$$

We have

$$\dot{O} = \dot{N} + \dot{Y}$$

where variables with a dot on the head refer to their growth rates. And from the production function, we have

$$\dot{Y} = \alpha\dot{L} + \beta\dot{K} + \gamma\dot{F} + \dot{\Phi}$$

where $\dot{\Phi}$ is total factor productivity growth. This implies that

$$\dot{O} = \dot{N} + \alpha\dot{L} + \beta\dot{K} + \gamma\dot{F} + \dot{\Phi}$$

Table 4 gives the decomposition results for the periods 1961-88 and 1988-97. The first period represents a phase of steady growth of grain production. Total grain output grew at 2.8 per cent per annum, of which 23 per cent was contributed by enlargement of the planting area and 77 per cent was due to increases in yield. The results also reveal that the driving force behind the rising yield was increased inputs of factors. Productivity change was strongly negative, at an astonishing –1.2 per cent per annum. Grain production in North Korea, even though it was expanding steadily before 1988, exhibited a clear pattern of extensive growth relying exclusively on increased inputs. Such a growth pattern is unsustainable over time.

The decomposition exercise for the second period 1988-97 is designed to account for factors responsible for the agricultural crisis. The starting and ending years were selected because of our reservation about the quality of the 1989-93 data and because grain output falls to its lowest level in 1997. During this period, output declined by –7.3 per cent per annum, which was clearly driven by changes in yield as the planting areas stayed largely unchanged. Of the total contributions to changes in yield, changes in factor inputs, especially fertilizer and tractors, accounted for 69 per cent and changes in productivity accounted for 32 per cent. In other words, of the total -50 per cent decline in grain output during this period, -35 percentage points were due to reduction of inputs and –16 percentage points were due to deterioration of productivity.

These findings clearly confirm the first hypothesis that drastic fall in supply of key inputs, following the disruption of trade ties with socialist trading partners from the late 1980s, is the dominant trigger of the agricultural crisis. This factor was responsible for more than two-thirds of reduction in grain production.

To gauge the likely effects of both adverse weather and institutional failure, we further decompose the total factor productivity component into a trend element and a residual element for the period 1988-97. We argue that, because the agricultural institutions remained largely the same during 1961-98, the trend element of 1988-97 was significantly attributable to the failure of the collective system. The unexplained residual element was contributed by other factors, including weather change. This element only represents the maximum estimate of contributions by adverse weather. The decomposition was carried out in two ways. First, we assume the trend element during this period was the same as the average of the whole period (-1.06 per cent obtained in production function estimation), this gives the residual element of –1.28 per cent per annum (Calculation I). Second, we assume that forces associated with long term factors over the earlier period (1961-88) continued in this period, so the long term element was also –1.15 per cent leaving the residual term at –1.19 per cent (Calculation II).

These simple calculations have strong implications for the causes of agricultural crisis. The failure of the collective system likely resulted in technological deterioration of between –1.06 and –1.15 per cent per annum (or between 14.5-15.7 per cent of output decline during 1988-97). Although the magnitude of this contribution might not be particularly remarkable, it is important to remember that this deterioration has persisted ever since farms were collectivized in the late 1950s. This effect can be seen more clearly by constructing a yield total factor productivity index following the approach adopted by Wen (1993) (Figure 5).[16] In other words, if North Korea's input levels remained unchanged, by 1998, the yield would have dropped to about 65 per cent of its 1961 level, simply because of technological deterioration associated with collective farming.

However, this was only part of the damage caused by the collective system to grain production. Another cost was the loss of productive efficiency. Even given the input levels, North Korea was likely to produce much more grain with a household farming system. To illustrate this, we simulate North Korea's grain output by using production function parameters from Lin's (1992) authoritative study of Chinese agriculture, but with

[16] Note that we also employ the coefficient estimates of the primary inputs to estimate the predicted yield total factor productivity index for the period 1989-93. These results show a continuous declining trend in yield productivity over the 5 year period.

North Korea's input levels of primary factors.[17] In Figure 6, the bottom line is North Korea's actual grain output, and the top line is the simulated output that North Korea would otherwise be able to produce by applying the Chinese parameters. Assuming that the natural environment is the same in the two countries, the areas between the two lines indicate the losses of output in North Korea due to institutional failure. On average, the losses represent about 60 per cent of North Korea's actual output. Although the simulated output also declined in the 1990s because of sharp reduction in inputs, the lowest output in 1997 was still at around 7 million tons, 80 per cent higher than the actual level. This would enable North Korea to comfortably maintain food security. It is important to note that the gap estimates depicted here may be an underestimate as they do not incorporate possible productivity growth over time under the household farming system. On the other hand, others have speculated that North Korea may not achieve the same sustained productivity gains that followed in the wake of Chinese reform, because its natural conditions and workforce structure are not conducive to large-scale agricultural production (McMillan 1997).

The exact significance of adverse weather is difficult to determine. In the yield production function, the proxy variable for weather was insignificant, possibly suggesting weather as an unimportant determinants of yield change over the whole period. This, however, does not rule out the possibility of significant impacts during the 1990s. As shown earlier, the residual element of productivity change during 1988-97 ranged between –1.2 and –1.3 per cent per annum, or about 16 per cent of total output decline. Without detailed information for further decomposition, we take this as the maximum boundary of the contribution by adverse weather conditions. Even this possibly over-estimated number suggests that the contribution by adverse weather was at most only secondary and far less important than North Korean commentary has suggested.

VI. Policy implications

The above analysis suggests that North Korea's agricultural system is now laboring under the inherent bottlenecks that come with an extremely centralized system. Despite a slightly improved harvest in 1999,[18] North Korea will continue to experience annual deficits in grain production. Grain production could be stabilized between 5-6 million tons, leaving an annual shortfall (in food, feed and seed) of around 1-1.5 million tons. Meeting this deficit though requires a significant reorganization of the agrarian incentive structure conducive to raising farm productivity and foreign exchange to pay for the food and inputs needed to sustain agricultural functions (Smith 1997).

To date, North Korea has responded to the agricultural crisis by adopting several measures. These have included the reported implementation during 1996 of the subteam contract farm system[19], an official sanctioning of farmers markets, introduction of a double-cropping system, requests for international technology and capital to conduct a revitalization policy, and requests for food aid. The double-cropping program, initiated in 1996 jointly by UN agencies and the North Korean government, aims to utilize agricultural land available between October to June for additional cereal (wheat and barley) production to be followed by rice and maize cultivation. While considered a success, the program remains dependent on ongoing donor support for seeds and fertilizers. More recently, government priorities have stressed 'seed revolution' through reform in seed breeding; the breeding of grass eating animals such as goats, rabbits and sheep; and the shifting to organic from non-organic

[17] Lin's study for the period 1970-87 obtained the following elasticities—for land 0.67, for labor 0.13, for capital 0.07 and for fertilizer 0.2. He also found that the implementation of the household responsibility system increased farming productivity by 19.8 per cent (during 1979-84).

[18] The FAO/WFP estimate cereal production (maize and rice) of 3.5 million tons in 1999, compared to 2.7 million tons in 1998.

[19] The adoption of the a 'sub-work team subcontracting system' in 1996—whereby work teams lease land from the cooperative farm and are given output in excess of a specified targets—parallels the team production contracting system that China implemented temporarily before introducing the reward based family responsibility system. Under the system, the number of members in some cooperatives have reportedly been reduced from 10-25 to 7-8 (Chun 1997:14). There are reports for example that production targets have been set too high and the shortages of fertilizers and other inputs will make it difficult to produce more than the targeted amount.

fertilizers in an attempt to overcome the sever shortages of fertilizers, with two of North Korea's three fertilizer factories no longer operating.

Implementation of the Agricultural Recovery and Environmental Protection Program (AREP) following the UNDP-led Round Table in Geneva in May and November 1998 is a key step towards a more comprehensive approach to rural reconstruction by moving from humanitarian to developmental assistance. The program is aimed at restoring the production to 6 million tons of cereals within 3 to 4 years through the provision of agricultural inputs, rehabilitation works, environmental protection and capacity building for supporting agricultural production through food-for-work programs and small-scale development projects (FAO/WFP 1999). At an estimated cost of US$300 million, the AREP remains the most cost-effective means to improve the food situation and reduce North Korea's dependence on foreign aid. Yet, despite being a more cost-effective option, the response of the international community to date has been limited. The establishment of diplomatic relations with countries possessing a comparative advantage in agriculture, such as Australia, means North Korea is now eligible to receive technical and developmental assistance in agriculture and environmental management.

But while North Korea is currently giving greater priority to agriculture development planning, many of the adopted measures remain piecemeal in their impact. The government's increased ideological emphasis on potatoes as an alternative staple is also suggestive that North Korea is pursuing a 'low risk' strategy. However, in the absence of grain imports, on-going food aid, or productivity enhancing reforms, the longer-term effects of potatoes as a substitute staple would seem to imply a further lowering of the nutritional levels of the population.

The results of our study suggest that revitalizing North Korea's agriculture through 'low risk' strategy is not a viable policy solution in the long-term. This is because North Korea's agricultural crisis has been mainly driven by factors that will be difficult to reverse in the absence of substantial systemic change. Massive imports of fertilizers and oil on free or concessional terms is unsustainable in the longer term. International aid in forms of grains and fertilizers whilst easing immediate burdens will also not solve the more fundamental problems.

An important and necessary step to revitalize agriculture is de-collectivization. In China, the introduction of the household responsibility system from the late 1970s increased grain output by about 50 per cent within a couple of years (Huang 1998). The simulation exercise of this study also suggests a possible gain of 60-80 per cent of the current output. This should at least enable North Korea to achieve low-level food security in the short term, even at the current low levels of inputs.

Although it would take sometime before a free market can be easily introduced, permitting market exchange of agricultural products at the margin can also be a significant factor for rural development. In the case of China, gradually lifting the long depressed state prices for agricultural products played an important role in increasing incentives during the early years of reform. Of course, this policy would be more effective if a household farming system was in place.

While our results do not explicitly recognize North Korea's autarkic system as the direct trigger of agricultural crisis, it is nonetheless an important factor in the crisis because it induced the peculiar technical innovations North Korea adopted in the years preceding the crisis, and it prevented North Korea from importing grain and agricultural inputs from international markets when the Soviet block collapsed. In this respect, North Korea's famine represents a classic case of food insecurity arising from a strategy of self-reliance.

To achieve food security over the longer term, North Korea must start to adjust its economic structure in light of its own comparative advantages and increase its interactions with the international markets. Imports of large amounts of fertilizers and oil are possible only with access to hard currency. North Korea therefore needs to export. But even if North Korea's ability to earn foreign exchange improves significantly, it is doubtful that it would be necessary for fertilizer consumption to return to the levels of the late 1980s in order to attain much higher levels of agricultural output. Higher levels of agricultural output would also be consistent with food imports, since given North Korea's current level of development it would be much more efficient to purchase grain directly from the international market.

Table 1. Fertilizer use in North Korea and other East Asian economies (kg/hectare agricultural land)

	Year	N	P	K	Total
Japan	1972	138	135	113	386
China	1972	39	13	1	53
	1990	208	63	18	289
Vietnam	1972	28	13	4	45
	1990	78	19	4	101
South Korea	1972	166	76	46	288
	1990	211	103	101	415
North Korea	1972	121	56	17	194
	1990	319	77	9	405
	1994	146	10	1.5	157
	1996	35	10	0.3	45

Notes: N denotes Nitrogenous fertilizers, P Phosphate fertilizers, and K Potash fertilizers. It should also be noted that these numbers are not necessarily consistent with the data constructed in this study. The denominator here is the total agricultural land rather than grain planting areas.
Source: FAO Production Yearbooks (various years).

Table 2: Reported quantity of China's exports of oil, coal and grain to North Korea (million tons)

	Grain	Coal	Crude oil
1988	0.16	1.52	1.20
1989	0.39	1.64	1.07
1990	0.20	1.79	1.06
1991	0.09	1.51	1.10
1992	1.21	1.44	1.02
1993	0.09	1.75	1.03
1994	0.09	0.91	1.05
1995	0.00	0.99	1.04
1996	0.37	0.10	0.00
1997	0.38	0.05	0.24

Source: FAO and Almanac of China's Foreign Economic Relations and Trade (various years).

Table 3. Estimation results of the yield production function

	(1)	(2)	(3)
Constant	-4.1292*	-4.2102*	-14.141***
	(1.7)	(1.7)	(4.7)
Ln(labor)	1.5949***	1.6161***	3.7677***
	(2.8)	(2.8)	(5.7)
Ln(tractor)	0.1033	0.1034	0.2127***
	(1.5)	(1.5)	(3.4)
Ln(fertilizer)	0.1834***	0.1823***	0.1051**
	(3.5)	(3.5)	(2.3)
Weather		-0.0596	-0.1391
		(0.4)	(1.2)
Time trend			-0.0106***
			(4.5)
Adjusted R^2	0.90	0.89	0.93

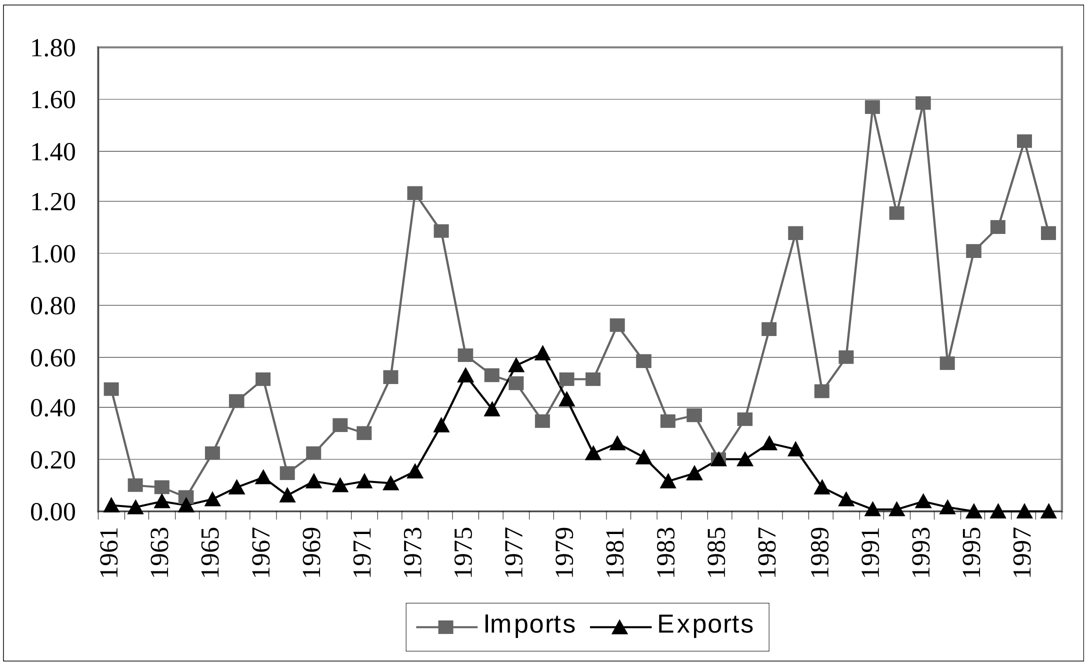
Notes: Numbers in parentheses under the estimated coefficients are related *t*-ratios. Coefficient estimates with *** are significant at 1% level, ** at 5% level and * at 10% level. The estimation results are adjusted for first-order auto-correlation applying the Pagan approach (Pagan 1974).

Table 4. Contributing factors to grain output change, 1961-88 and 1988-97 (%)

	1961-88		1988-97	
	% points	Share(%)	% points	Share(%)
Change in total output	2.77	100.0	-7.33	100.0
= due to change in land areas	0.65	23.4	0.06	-0.9
+ due to change in yield	2.12	76.6	-7.39	100.9
Change in yield	2.12	76.6	-7.39	100.9
= due to change in labor input	1.00	36.1	-0.25	3.4
+ due to change in tractor use	1.54	55.7	-2.75	37.5
+ due to change in fertilizer use	0.75	26.3	-2.05	28.0
+ due to change in productivity	-1.15	-41.6	-2.34	32.0
Change in productivity			-2.34	32.0
(calculation I)				
= time trend (from production function)			-1.06	14.5
+ residual I			-1.28	17.5
(calculation II)				
= continuation of 1961-88 average			-1.15	15.7
+ residual II			-1.19	16.3

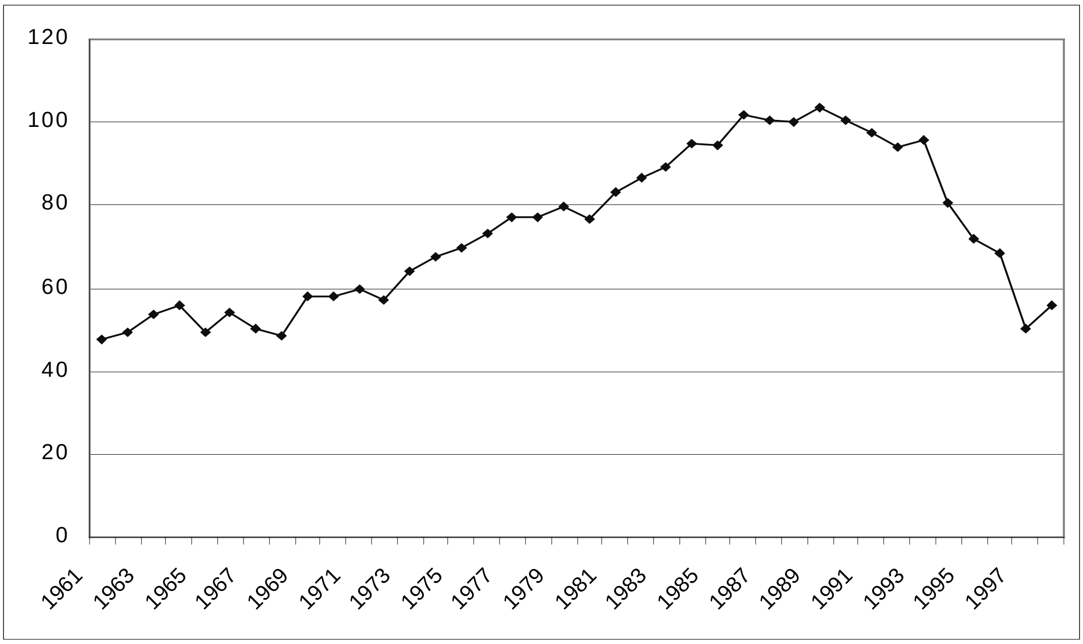
Notes: Decomposition exercises are carried out applying the production function results and the variable values. The growth rates calculated are in percentage per annum.

Figure 1: Imports and exports of grain, North Korean, 1961-98



Note: Imports include commercial trade, food aid granted on specific terms, donated quantities and estimates of unrecorded trade.
Source: FAO Database.

Figure 2: Grain production 1961-1998 (1988=100)



Note: Grain includes paddy rice, maize, barley, rye, oats, millet, sorghum and potatoes.

Figure 3: Tractor and fertilizer application (1988=100)

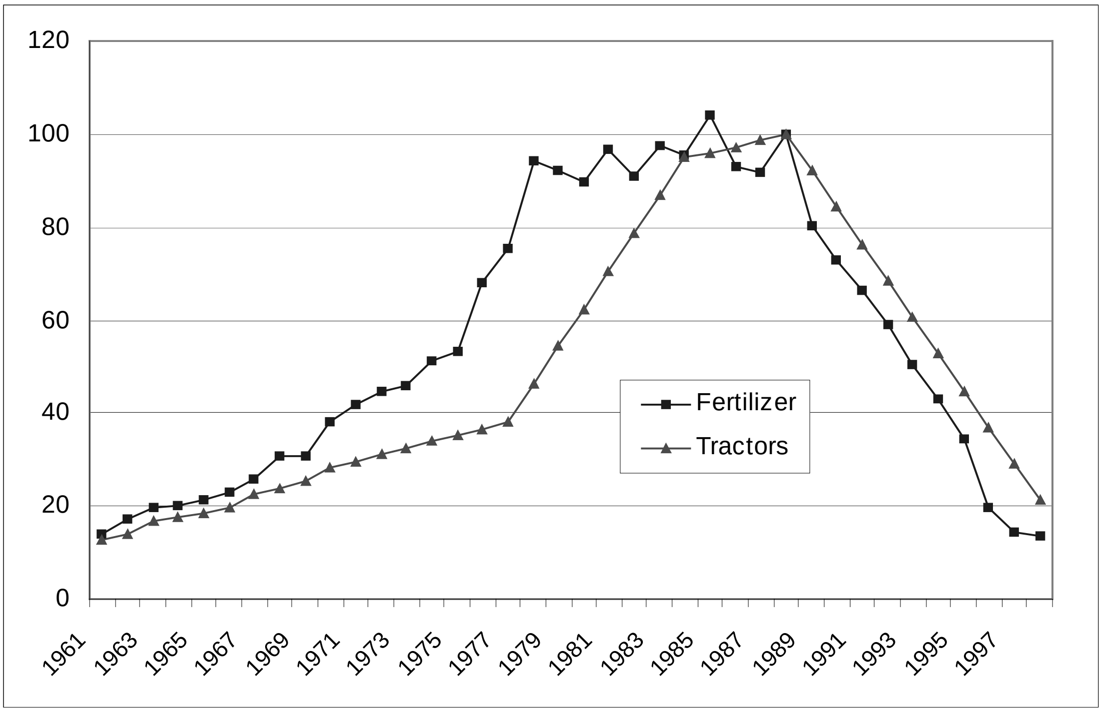


Figure 4: Land and labor application (1988=100)

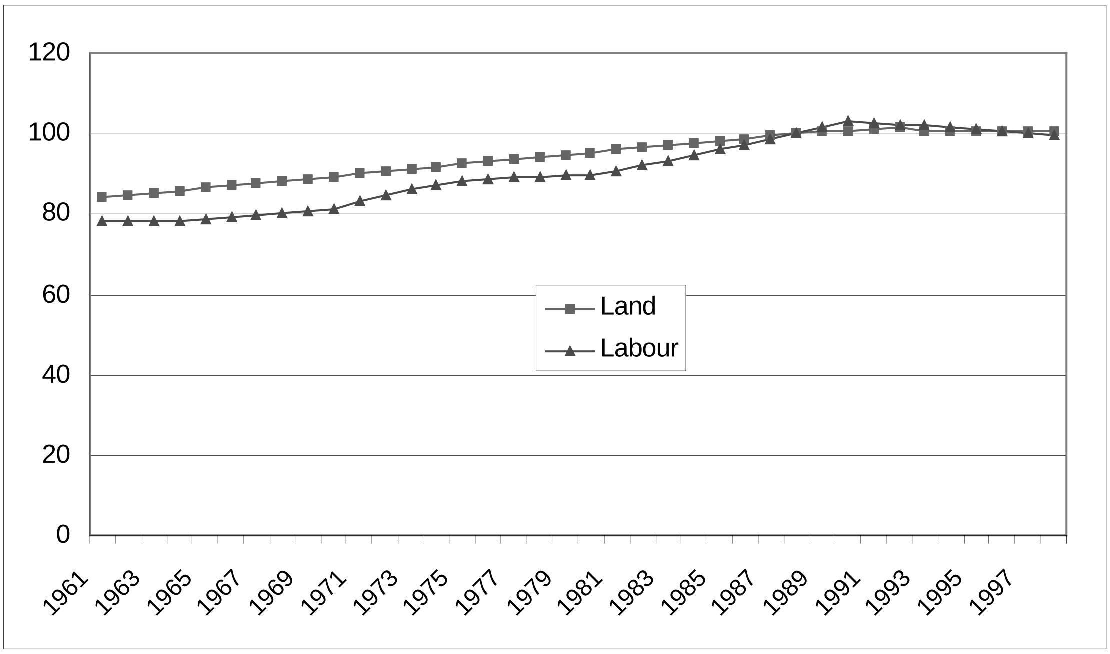
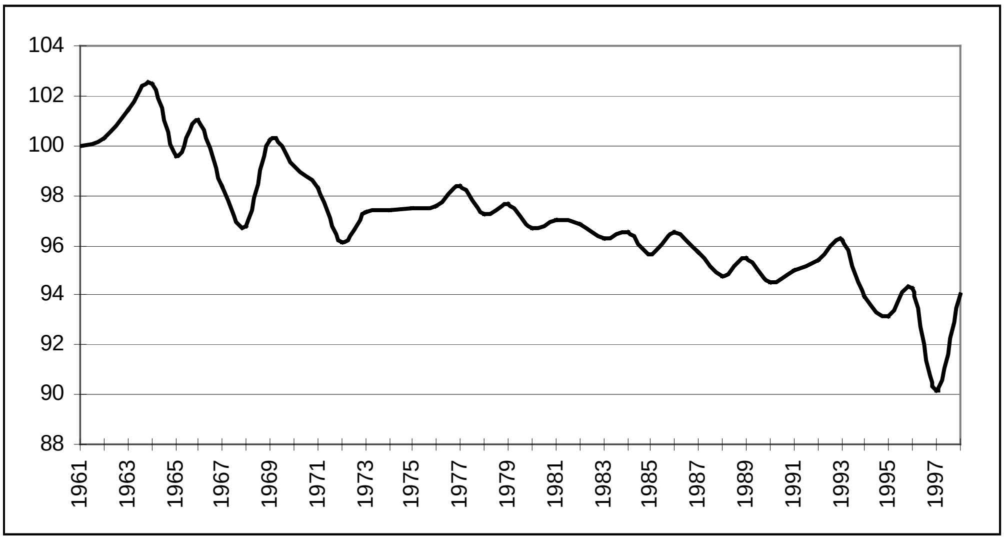
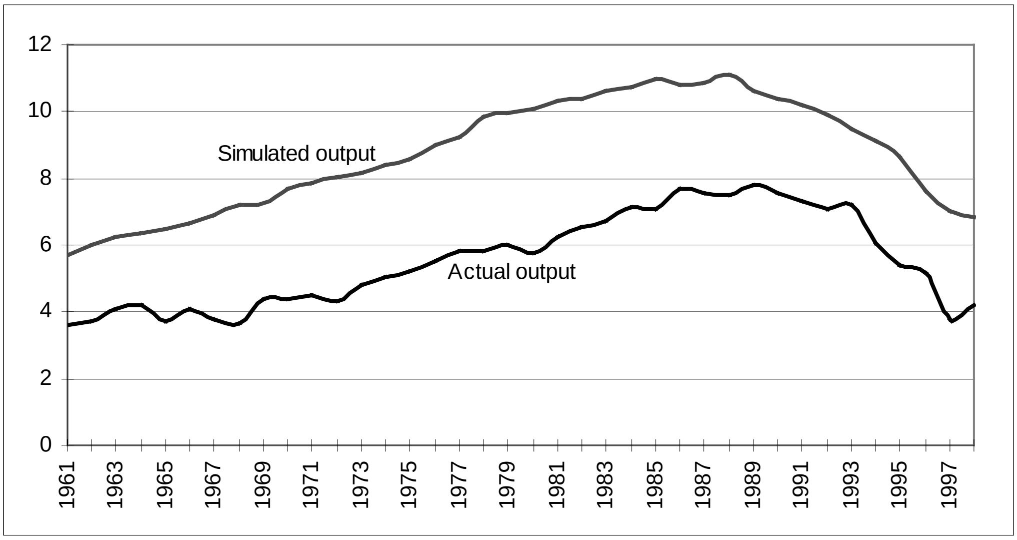


Figure 5: Productivity index for North Korea's grain production, 1961-98 (1961=100)



Note: Yield total productivity index is calculated applying the yield production function estimates following Wen (1993).

Figure 6: Actual and simulated grain outputs (million tons)



Note: The bottom line is North Korea's actual grain output, and the top line is the simulated output using the actual input levels for North Korea and production function parameters for China (Lin 1992).

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