1.0

2.8　　2.5

3.2

1.1　　2.2

3.6

2.0

1.8

1.25　1.4　1.6

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

A RAND NOTE

ESTIMATES OF TOTAL NONMILITARY
CONSUMPTION FOR NORTH KOREA

Bruce W. Don

N-1811-NA

February 1982

Prepared For

The Director of Net Assessment,
Office of the Secretary of Defense

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This Note supports the Korea Institute for
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physical production data. As a part of
this effort, this Note estimates how large
a share of North Korean GNP is accounted
for by non-military consumption. Since the
North Korean economy had only limited
external trade relationships during the
1970s, these estimates are made by
inferring the value of food consumption
from the value of agricultural output.
Given the value of food consumption, it is
then possible to determine the value of
total non-military consumption. The
subject matter would be of interest to
specialists concerned with the North Korea
national accounts. The methodology used
would be of interest to those concerned
with the economics of centrally planned
economies. 47 pp. Ref. (Author)

A RAND NOTE

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PREFACE

The Korea Institute for Defense Analyses (KIDA) and The Rand Corporation have undertaken a collaborative study to evaluate the ability of North Korea to sustain a high level of military effort over the next decade. Rand's participation in the study was supported by the Directorate of Net Assessment, Office of the Secretary of Defense.

As a result of extensive discussions in The Republic of Korea between KIDA and Rand, an agreement was reached at the end of September 1980 that divided the study into the following six component tasks:

 I. National Accounts (KIDA/Rand)

 II. Relationships between Civil and Military Development (Rand)

 III. Sectoral Issues and Bottlenecks (KIDA).

 IV. Foreign Trade and Finance (KIDA/Rand).

 V. Management and Decisionmaking (Rand/KIDA).

 VI. South Korean Defense Economics (KIDA).

The first institution shown in parentheses assumed principal responsibility for the adjacent task, with additional work and inputs provided by the second institution.

A series of meetings between Rand and KIDA was conducted at the Rand offices in Santa Monica in the middle of February 1981, in Seoul at the end of June, and again in Santa Monica through the month of September to coordinate the effort and discuss the progress and findings of both research teams.

A report now in preparation summarizes Rand's work on these tasks and presents the conclusions of its research team. The present Note reports on work that has been done in support of Task I. Using the general approach outlined in the forthcoming reports, it presents estimates of total nonmilitary consumption for North Korea and describes the methodology used to develop those estimates.

ACKNOWLEDGMENTS

I am indebted to Charles Wolf, Jr. of The Rand Corporation, who suggested the overall approach for this analysis and provided advice and encouragement throughout the research effort. I also wish to thank Rand consultant Michael Kennedy of The University of Texas at Austin for his insightful comments on the initial draft of this work. Where I have failed to take good advice or have mistakenly applied it, fairness argues that they bear no responsibility.

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I. SUMMARY AND CONCLUSIONS

This Note supports the Korea Institute for Defense Analyses (KIDA)/Rand Corporation study of the ability of North Korea (NK) to sustain a high level of military effort over the next decade.

The study assesses the ability of North Korea to sustain high levels of military expenditure by using a building-block approach to estimate certain parts of the national accounts from physical production data. As a part of this effort, this Note estimates how large a share of North Korean GNP is accounted for by nonmilitary consumption. Since the North Korean economy had only limited external trade relationships during the 1970s, these estimates are made by inferring the value of food consumption from the value of agricultural output. Given the value of food consumption, it is then possible to determine the value of total nonmilitary consumption. Such an approach embodies some significant assumptions:

- The data we have on North Korean grain production represent some of the most reliable information we have on North Korea.

- Food production within the country is approximately equal to food consumption. This assumption is most realistic when food imports are nearly equal to food exports, and both are small, as in North Korea.

- The value of total consumption can be projected from the value of consumption of food (grain) through the use of an economic behavioral relationship, specifically Engel's law.

This Note first estimates the food budget share for grains (γ), and the budget share attributable to food (δ) for NK.* It then uses these proportions, γ and δ, in conjunction with estimates of the value of NK agricultural output (V_g), to estimate consumption (C), using a relationship of the form:

$$\{1\} \qquad\qquad\qquad C = V_g/\gamma\delta$$

The bases for the estimates of γ, δ and V_g are:

- V_g is calculated by using information on NK crop production made available by KIDA [1] and using United Nations figures for 1975 prices [9].

- γ is calculated by using projections of food consumption for NK for the years 1975 and 1980 and using United Nations figures for 1975 prices. The food quantity projections are derived from the demand model developed by the Food and Agricultural Organization of the United Nations (FAO) [2 and 3], which uses 1964-1966 survey data [8] as its inputs.

- δ is projected from countries with similar income levels and cultures, using estimates of the income elasticity for food (η_{fe}) that have been made by Houthakker [4, p.

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* Appendix A provides definitions of the symbols used throughout this Note. The budget share for grains is grain expenditures (G) divided by total food expenditures (F):

$$\gamma = G/F$$

The budget share attributable to food is food expenditures (F) divided by total expenditures (E) or:

$$\delta = F/E$$

550] and corroborated by Lluch [5, p. 286] and estimates
for δ for the People's Republic of China (PRC) made at
Rand [13] and for the ROK made by the Republic of Korea
Economic Planning Board [12, p. 59, 62].*

The derivation of the consumption function in {1} follows from our

second major assumption and the definitions of Υ and Γ.

Let

C	=	dollar value of non-military consumption	C_f	=	value of NK food consumption
α	=	proportion of husked grain in O_g	β	=	share of rice in O_g
O_g	=	total NK grain crop production	P_r	=	U.S. dollar price of rice
V_g	=	value of NK grain crop	P_c	=	U.S. dollar price of corn
C_g	=	value of NK grain consumption			

---

* The term "income elasticity for food" will be used to
refer to that elasticity estimated by both Houthakker and
Lluch, which is more correctly termed "the elasticity of food
expenditures with respect to total expenditures". This is de-
fined as:

$$\eta_{fe} = \frac{\partial F}{\partial E} \frac{E}{F}$$

By our second assumption

$$\{2\} \qquad C_g = V_g$$

Food consumption is then related to grain consumption by

$$\{3\} \qquad C_f \approx V_g / \gamma$$

and thus total consumption is related to grain consumption by

$$\{4\} \qquad C = V_g / \gamma \delta$$

If we make the simplifying assumption that NK grain production is wholly accounted for by rice and corn, then

$$\{5\} \qquad V_g = \alpha \, O_g \, (\beta \, P_r + [1 - \beta] \, P_c)$$

This results in

$$\{6\} \qquad C = \frac{\alpha \, O_g \, (\beta \, P_r + [1 - \beta] \, P_c)}{\gamma \delta}$$

The estimates of δ and thus C (and C/GNP) are dependent on the income level (GNP per capita) of NK relative to the two countries used as the basis for estimating δ: the PRC and the ROK. This relationship is troubled by the considerable ambiguity in the NK income level. Over a two-year period, these estimates have ranged from $279.37 [6, p. 16] to $670.00 [7, p. 127]. Because of this ambiguity, the income level has been parameterized for our estimates of consumption. Therefore, estimates of NK consumption (and C/GNP) are displayed as a function of

both GNP per capita and the country from which the projections of δ were made. These estimates are illustrated in Figures I-1 to I-4.* They are based on 1975 prices and 1978 levels of crop production and population.** The data from which the plots were generated are provided in Table I-1 for ease of extraction.

Some words of caution concerning the use of the estimates are in order. Although the estimates are plotted as a function of estimated NK GNP per capita (or GNP), these estimates cannot be used with the same confidence in addressing all questions concerning differences in the NK income level. This is because γ and δ may change with actual changes in income level.

The consumption function we use in this Note is appropriate for addressing the level of total nonmilitary consumption that is implied by various estimates of the present NK income level. The changes in γ and δ that can result when the income level does in fact change limit the model's accuracy when it is used to address certain other types of questions concerning differences in the NK income level, such as questions about income level growth. For this type of ques-

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* The figures present the estimates in four different ways in order to allow different relationships to be addressed with ease:

$$C/GNP = f(GNP \text{ per capita}) \qquad C = f(GNP \text{ per capita})$$

$$C/GNP = f(GNP) \qquad C = f(GNP)$$

In the latter two estimates, GNP has also been parameterized, since it is calculated directly from GNP per capita and assumes a constant 1978 population of 16.64 million as estimated by the United Nations [3, p. 278].

** There is a trade-off between the completeness and currency of data on the NK economy. Because of this we have elected to use 1978 as our "present" year.

tion, it would be desirable to use the parameterized variable, GNP per capita (or GNP), to determine what will happen to NK total nonmilitary consumption as the personal (or national) income level grows over time. When the model is used in this way, some growth conditions lead to estimates that are best viewed as lower bounds.

If the model is to be used correctly, it is important to understand the nature of these limitations and the conditions under which they arise. These considerations are detailed in Appendix C. In summary, to use the model presented in this Note within its capability, the following guidelines should be observed. To address issues concerning the impact that various estimates of the present NK income level will have on estimates of total nonmilitary consumption, the estimates of consumption presented in this Note may be used directly. To address the implications of income level growth over a limited range, the model must be used in conjunction with information on population growth to produce proper estimates; these estimates may represent a lower bound on consumption in certain situations. To address more general questions concerning the impact of income level growth, the consumption model developed in this Note should be used as part of a larger model of the NK economy. Such a model should consider agricultural output, net agricultural exports, and population growth in an explicit manner.

NK CONSUMPTION AS PERCENT OF GNP
(1975 prices, 1978 agricultural output)

$$\frac{c}{GNP} = \frac{2.98 \times 10^3}{16.64\ e^{\lambda} + .6\ \ln\ [Y]}$$

$\lambda_{PRC} = 1.789$

$\lambda_{ROK} = 1.885$
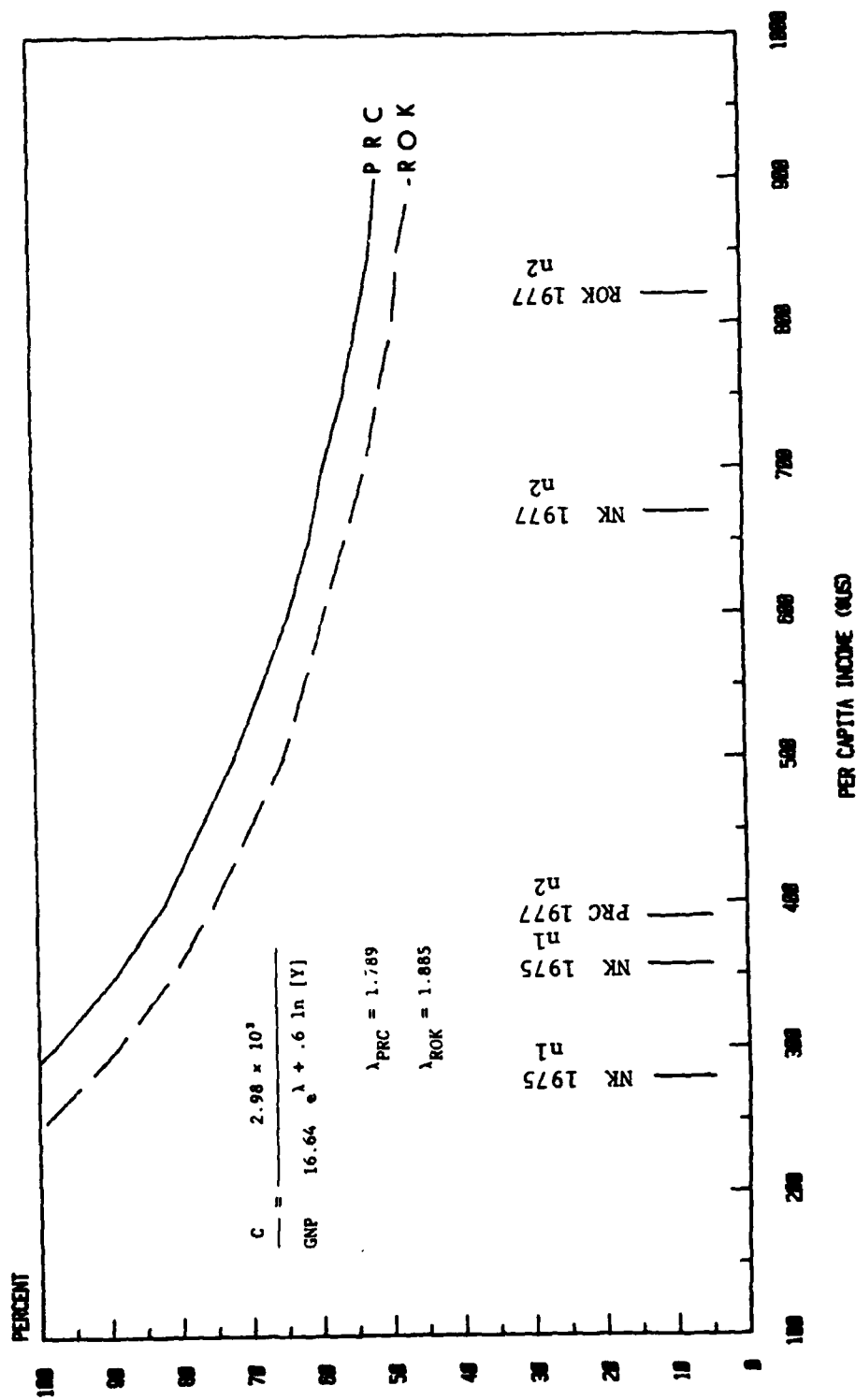
Fig. I-1--CONSUMPTION/GNP = f(PER CAPITA GNP)

ESTIMATES OF NK CONSUMPTION
(1975 prices, 1978 agricultural output)

CONSUMPTION (millions $US)

$$C = \frac{2.98}{e^{\lambda - .4 \ln [Y]}}$$

$\lambda_{PRC} = 1.789$

$\lambda_{ROK} = 1.885$

PER CAPITA INCOME ($US)
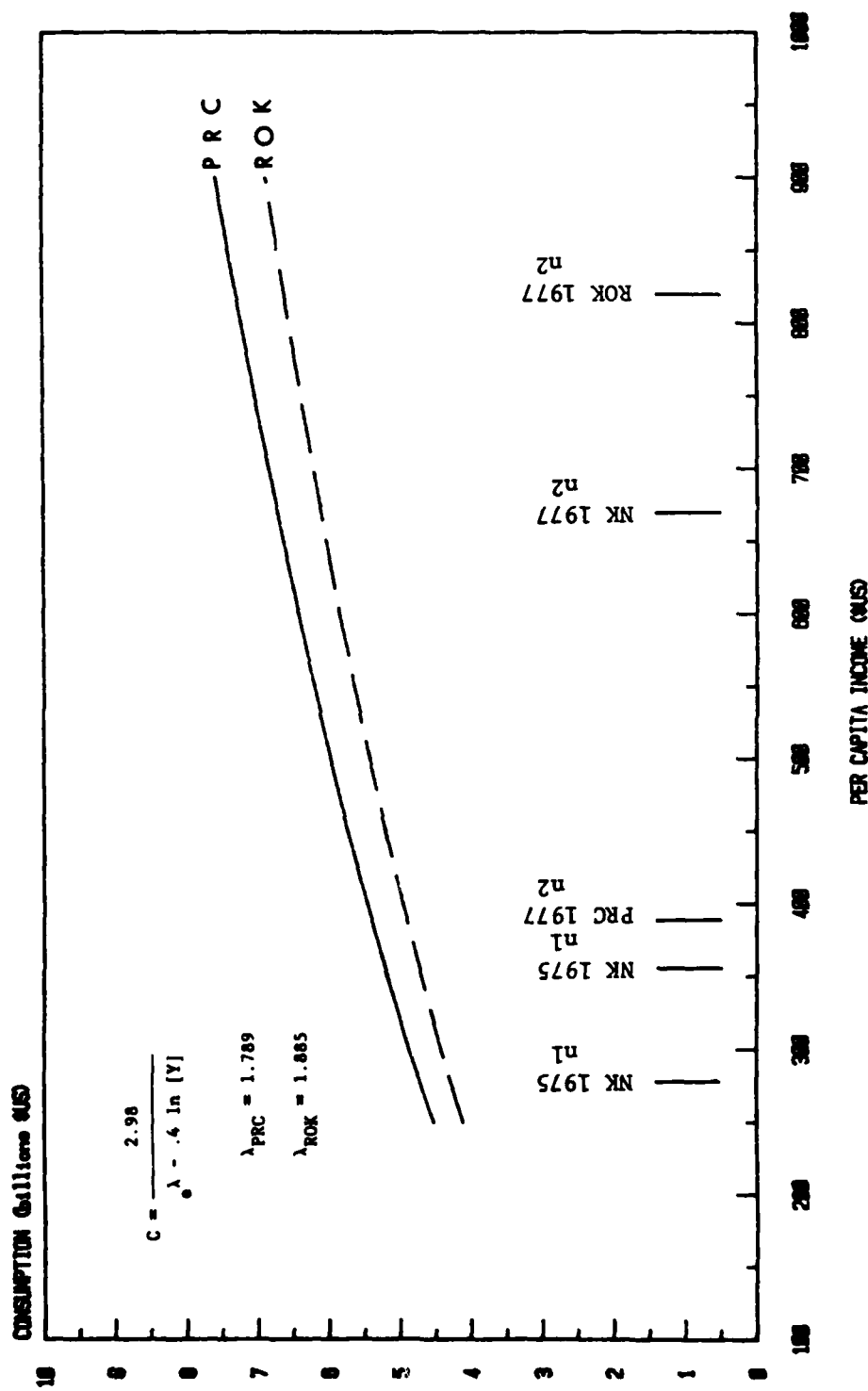
Fig. I-2--CONSUMPTION = f(GNP PER CAPITA)

-9-

NK CONSUMPTION AS PERCENT OF GNP

(1975 prices, 1978 agricultural output)

$$\frac{C}{GNP} = \frac{2.98 \times 10^3}{16.64 \ e^\lambda + .6 \ \ln \ [Y]}$$

$Y = GNP/(16.64 \times 10^6)$

$\lambda_{PRC} = 1.789$

$\lambda_{ROK} = 1.885$

PRC

ROK

Bank of Korea 1975 n1

Bank of Korea 1975 n1

World Bank 1977 n2

NK GNP (billions $US)
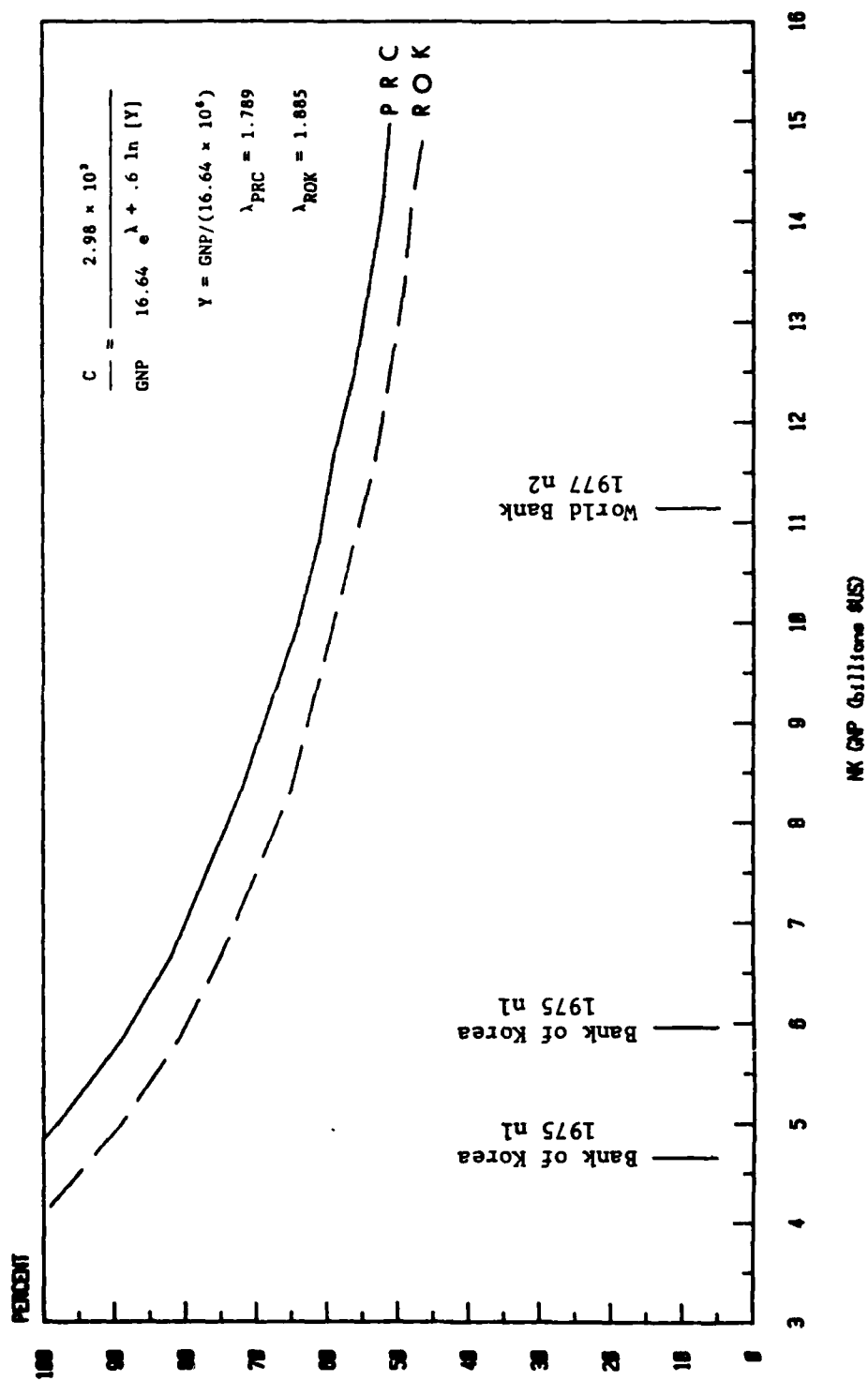
Fig. I-3—CONSUMPTION/GNP = f(GNP)

ESTIMATES OF NK CONSUMPTION

(1975 prices, 1978 agricultural output)

$$C = \frac{2.98}{e^{\lambda} - .4 \ln [Y]}$$

$Y = GNP/(16.64 \times 10^6)$

$\lambda_{PRC} = 1.789$

$\lambda_{ROK} = 1.885$

CONSUMPTION (billions $US)

PRC

ROK

World Bank
1977 n2

Bank of Korea
1975 n1

Bank of Korea
1975 n1

NK GNP (billions $US)
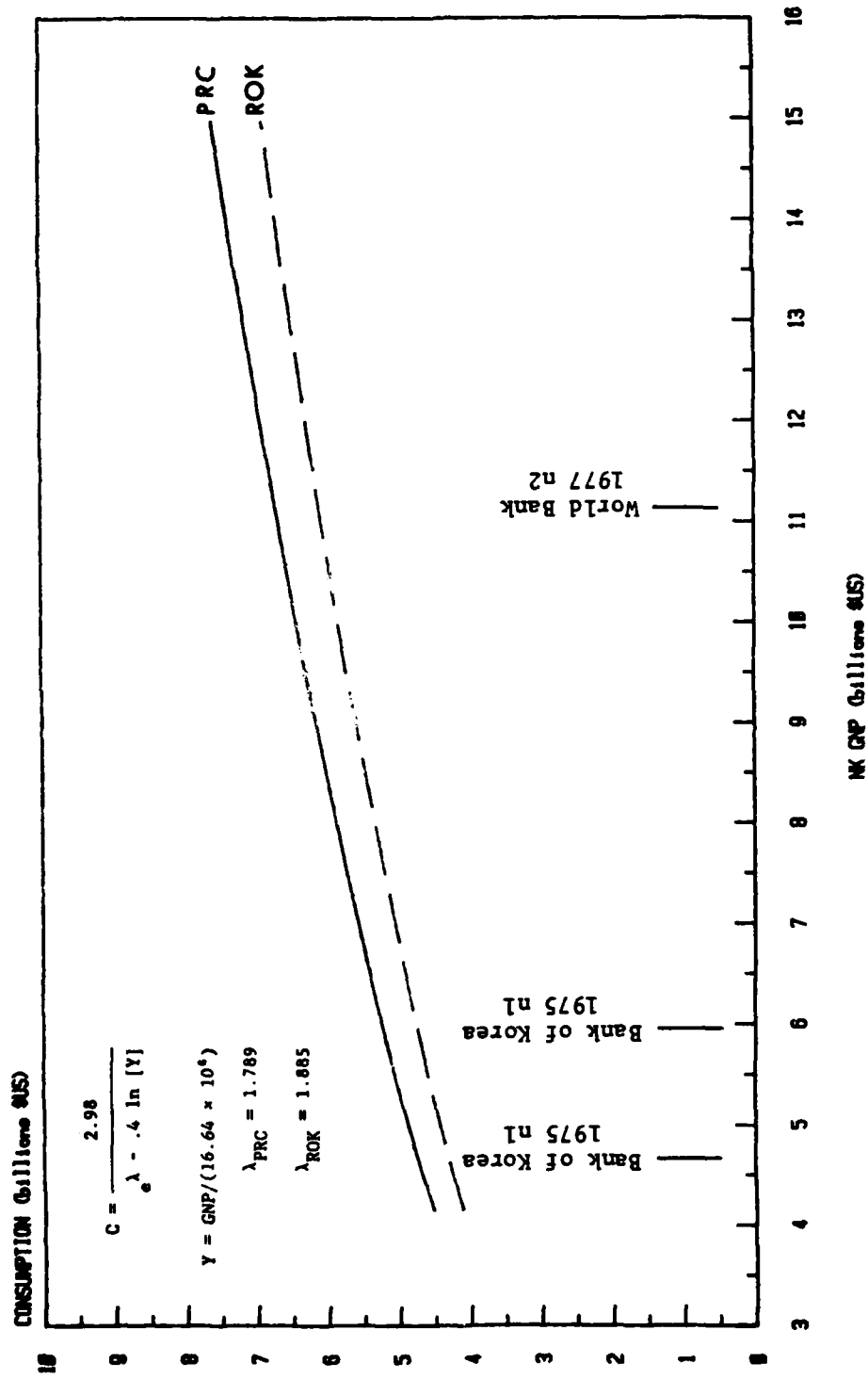
Fig. I-4—CONSUMPTION = f(GNP)

Table I-1

ESTIMATES IN TABULAR FORM

GNP PER CAPITA ($)	GNP ($10⁹)	δ		CONSUMPTION		CONSUMPTION / GNP	
		fr:PRC	fr:ROK	fr:PRC	fr:ROK	fr:PRC	fr:ROK
250	4.16	.66	.72	4.53	4.12	109	99
300	4.99	.61	.67	4.88	4.43	98	89
350	5.82	.57	.63	5.19	4.71	89	81
400	6.65	.54	.60	5.47	4.97	82	75
450	7.49	.52	.57	5.74	5.21	77	70
500	8.32	.50	.55	5.98	5.43	72	65
550	9.15	.48	.53	6.21	5.65	68	62
600	9.98	.46	.51	6.43	5.85	64	59
650	10.81	.45	.49	6.64	6.04	61	56
700	11.64	.44	.48	6.84	6.22	59	53
750	12.48	.42	.47	7.04	6.39	56	51
800	13.31	.41	.45	7.22	6.56	54	49
850	14.14	.40	.44	7.40	6.72	52	48
900	14.97	.39	.43	7.57	6.87	51	46

NOTES ON CONSUMPTION ESTIMATE FIGURES

n1   Estimates of NK GNP per capita made by Choi Joowhan, deputy director of the Bank of Korea. Lower figure assumes a conversion rate of $1 = 3.03 NK won; the higher figure represents a conversion rate of $1 = 2.37 [6, p. 16].

n2   Estimates of NK GNP per capita made by the World Bank in its World Development Report, 1979 [7, pp. 126-127].

n3   For the translation from GNP per capita to GNP, NK population was assumed to be that projected by the FAO for 1978: 16.64 million [2, p. 278].

II. ESTIMATES OF THE GRAIN SHARE OF FOOD BUDGET

To estimate the food budget share attributable to grain consumption (γ = G/F) it is necessary to evaluate the following expression for NK:

$$\{7\} \qquad \gamma = \frac{P_g Q_g}{P_g Q_g + \sum_i P_i Q_i}$$

where

P_g = price of grain

Q_g = quantity of grain

i = index of other (non-grain) food commodity categories

P_i = price of non-grain commodity

Q_i = quantity of non-grain commodity

The prices used to value the quantities are given in Table II-1. Since these are estimates of free market prices, the allocation of resources implied by γ reflects an allocation that would be made by a "shadow consumer" in the centrally planned economy in question. While this is not the allocation that an individual would necessarily make under the policies of the NK government, we assume that it is represen-

tative of the allocation that will be made by the NK economy as a whole.

Table II-1

AGRICULTURAL COMMODITY PRICES

	PRICE	UNITS	CONVERSION	$/kg	GRAIN RELATIVE PRICE
Cereals					
Rice	364.2	$/MT	.001 kg/MT	.364	100
Starchy Roots					
Potatoes	101.16	$/MT	.001 kg/MT	.101	28
Sugar					
Sugar	.205	$/lb	2.204 lb/kg	.452	124
Pulses					
Soybeans	232.6	$/MT	.001 kg/MT	.233	64
Vegetables					
Onions	.4537	DM/kg	2.622 DM/$	.173	48
Fish					
Unspec.					
	196.6	YN/kg	305.15 YN/$	.644	177
Fruits					
Apples	.8764	DM/kg	2.622 DM/$	.334	92
Meat					
Pork	3.87	DM/kg	2.622 DM/$	1.476	
	10.18	KR/kg	6.177 KR/$	1.648	
			avg:	1.562	429

NOTES:
Prices for all but potatoes and conversion rates are from [9, pp. 164-168]. Prices for potatoes are wheat-relative based on [9, pp. 164-168 and 2, p. 33]. All prices are for 1975.

Data on the quantities of the various types of food consumed in NK were generated by the food demand model developed by the FAO for use in its agricultural commodity projections. Since the model is covered in detail in references [2] and [3], only points of significance to our present concern are emphasized here.

The model uses data on food consumption, collected by the FAO for 132 countries, to fit food commodity demand functions for each of the forty food commodities within each of the countries.* The model then uses estimates of population and Gross Domestic Product (GDP) growth to project commodity demands for 1975 and 1980 as a function of income level. As an added control, these projections are checked for nutritional consistency. The NK population and GDP growth used in the model are shown in Table II-2; this information is also provided for the PRC and ROK, and will be used for comparisons [2, p. 9 and 3, pp. 264-276].

Because it is used in calculating the values of Q_g in Equation {7}, the form of Engel Curve that produced the best fit for grain consumption is of particular interest to the present effort. This form has been determined by the FAO to be a log-log-inverse function for

---

* The food consumption data are based on cross-sectional household surveys. The data are collected at ten-year intervals. The data used to make the FAO projections used in this Note were collected during the 1964-1966 (nominally 1965) time period. In some cases, data for the nominal year 1975 were available. In these cases, actual 1975 consumption was used in place of the 1975 estimates of consumption, and the 1975 consumption figures (vice 1965 figures) were used in developing the estimates of 1980 consumption. The data are published in references [8] and [3].

Table II-2

POPULATION AND GDP GROWTH USED IN FAO MODEL

	POPULATION (millions)				GDP GROWTH (annual percentage rate)			
					1970-1975		1975-1980	
	1965	1970	1975	1980	TREND	HIGH	TREND	HIGH
PRC	764.10	847.70	935.90	1033.40	3.6	4.6	3.6	4.6
NK	12.10	13.67	15.47	17.42	3.6	4.6	3.6	4.6
ROK	28.38	32.43	36.87	41.72	5.3	6.5	5.4	6.9

the PRC, NK and the ROK. An Engel Curve of this form is illustrated in Figure II-1 [3, pp. XLVII and 264-276].

The FAO has chosen the log-log-inverse function from several possible forms to model the evolution of per capita demand for staple foods in most developing countries. This is because of the somewhat unusual pattern that data on staple consumption follow. Starting at very low income and nutritional levels, the staple represents a source of calories (and often protein) that is more desirable than the coarser foods. Consumption grows rapidly through this stage in which the staple is consumed as a luxury. As income levels increase, the staple transitions to a necessity and then, rather sharply, to an inferior good because of the progressive substitution of expensive calories for cheap calories [2, p. XXVI].

LOG-LOG-INVERSE (c > 0):

$$\log Q_g = a - b/E - c(\log E)$$
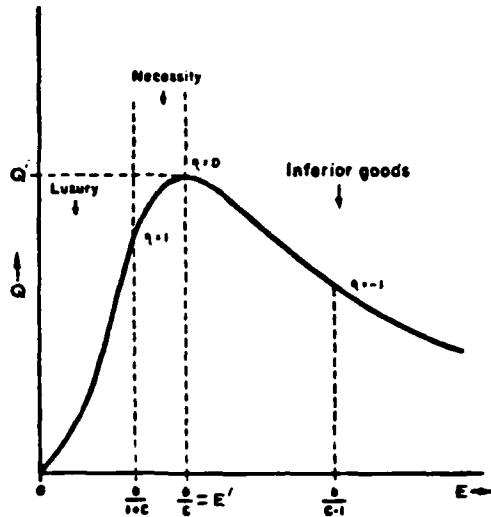
E = total per capita consumption
     expenditure

E' = level of expenditure
     at which the maximum level of
     consumption (Q_g') is reached

Q_g = per capita consumption quantity
       for the good in question

Q_g' = maximum level of consumption
        for the good in question

Fig. II-1 ENGEL CURVE FOR THE LOG-LOG-INVERSE FUNCTION

In specifying the model for each country, the position of the tran-
sition point is determined exogenously. This is done by specifying Q_g'
for each country on the basis of nutritional considerations and com-
parisons with the history of consumption growth in countries that have
already passed through similar economic conditions. Thus each country's
transition point is unique. For the three countries in question the
income elasticities for grain (η_{gq}) in the base period (1965) indicate
that this staple was then considered a necessity.* However, in most

---

* The "income elasticity for grain" would be more accurately
termed "elasticity for grain quantity with respect to total expen-
ditures." This is defined as:

$$\eta_{gq} = \frac{\partial Q_g}{\partial E} \cdot \frac{E}{Q_g}$$

countries the threshold for transition to an inferior good appears to be relatively close to the GNP per capita levels for the ROK.* The FAO estimates of Q_g' for the countries of concern imply that they will reach the transition point at GNP per capita levels of $500 for the PRC and $780 for NK (1975 $US). FAO estimates of Q_g' imply that the ROK reached the transition point in 1969.

With the prices from Table II-1 and the quantities projected by the FAO model, we are able to calculate γ for 1978 by using Equation {7}. These calculations for NK, as well as similar calculations for the PRC and ROK, are shown in Tables II-3 through II-6. Because of the unique Q_g' estimated for each country, the values of γ increase as the income level increases across these three particular countries. Cross-country comparisons must be made with care because of this country specific location of the transition point. The values of q for NK that result from each of the FAO growth rates are similar in both the 1975 and 1980 projections. As a result, the value for γ (.499),

---

* There are several nations with income levels at the upper range of those under consideration that have sli$_\ell$tly negative η_{gq}, indicating that the threshold has been crossed:

	η_{gq}	GNP per capita
Albania	-.03	630
Mongolia	-.09	830
Uruguay	-.07	1430

Although the country-to-country variation in the transition point is fairly wide, it is centered on GNP per capita levels that indicate that the PRC, NK, and the ROK are not atypical.

which will be used in the estimates of total nonmilitary consumption for

NK, is a linear interpolation (for 1978) between the two average values

for γ (for 1975 and 1980) that result from each of the two FAO growth

rate estimates.*

---

* Our calculation of γ assumes that "grain" consists of only cereals. There is a possibility that our figures for total grain crop (O_g) may include the unhusked grain equivalent of starchy roots. Including starchy roots in the "grain" category results in a γ of .553 vice .499. This would require our estimates of C and C/GNP to be adjusted (multiplied) by a factor of .90.

Table II-3

GRAIN SHARE OF TOTAL FOOD BUDGET: NORTH KOREA
(GNP growth at trend rate)

	1975		1980	
	kg/yr	$/yr	kg/yr	$/yr
Cereals	196	71	199	72
Starchy Roots	80	8	81	8
Sugar	6	3	7	3
Pulses	29	7	31	7
Vegetables	99	17	104	18
Fruit	13	4	14	5
Meat	10	16	11	17
Fish	20	13	23	15
Total Food Budget		$138.86		$145 67
Grain Share (%)		51.4%		49.7%

NOTES:

Kg/yr from [3, p. 278]

$/yr calculated from prices in Table II-1.

Table II-4

GRAIN SHARE OF TOTAL FOOD BUDGET: NORTH KOREA
(GNP growth at high rate)

	1975		1980	
	kg/yr	$/yr	kg/yr	$/yr
Cereals	197	71	200	73
Starchy Roots	80	8	82	8
Sugar	7	3	7	3
Pulses	30	7	31	7
Vegetables	101	17	107	19
Fruit	13	4	15	5
Meat	10	16	12	19
Fish	21	14	26	17
Total Food Budget		$140.54		$150.47
Grain Share (%)		51.0%		48.4%

NOTES:

Kg/yr from [3, p. 278]

$/yr calculated from prices in Table II-1.

Table II-5

GRAIN SHARE OF TOTAL FOOD BUDGET: PEOPLE'S REPUBLIC OF CHINA
(GNP growth at trend rate)

	1975		1980	
	kg/yr	$/yr	kg/yr	$/yr
Cereals	144	52	147	54
Starchy Roots	92	9	93	9
Sugar	4	2	5	2
Pulses	15	3	15	3
Vegetables	58	10	60	10
Fruit	6	2	7	2
Meat	19	30	21	33
Fish	9	6	9	6
Total Food Budget		$114.52		$119.97
Grain Share (%)		45.8%		44.6%

NOTES:

Kg/yr from [3, p. 276]

$/yr calculated from prices in Table II-1.

Table II-6

GRAIN SHARE OF TOTAL FOOD BUDGET: REPUBLIC OF KOREA
(GNP growth at trend rate)

	1975		1980	
	kg/yr	$/yr	kg/yr	$/yr
Cereals	213.4	78	204.2	74
Starchy Roots	85.4	9	82.1	8
Sugar	7.7	3	9.1	4
Pulses	7.7	2	8.4	2
Vegetables	99.6	17	104.3	18
Fruit	13.4	4	15.2	5
Meat	10.5	16	13.5	21
Fish	26.6	17	30.1	19
Total Food Budget	$146.82		$152.28	
Grain Share (%)	52.9%		48.8%	

NOTES:

Kg/yr from [3, p. 264]

$/yr calculated from prices in Table II-1.

III. ESTIMATES OF THE FOOD SHARE OF TOTAL BUDGET

Total consumption data for NK are not available. In order to esti-
mate the food share of the total budget (δ = F/E), it will be necessary
to project from countries with similar cultures and income levels, such
as the PRC and ROK. There is theoretical and empirical evidence that
this approach is valid. In particular, Houthakker [4] has made esti-
mates of the elasticities for expenditures on food, clothing, housing,
and other items. In a cross-sectional regression analysis of some 40
surveys covering about 30 countries, he found Engel's Law to be con-
firmed by all surveys.   Also, while the elasticities were not
equal, there were strong similarities. This is particularly true of the
elasticity for food, within a reasonable range of total expenditures.
Additional work in the area, using time-series data, has been done by
Lluch [5]. His findings strongly support those of Houthakker.

In the absence of country specific data, Houthakker suggests that
for food expenditures, a partial elasticity with respect to total
expenditures (η_{fe}) of .6 would be an appropriate estimate.   Lluch
estimated η_{fe} to be .644. There is, however, a significant range
for this elasticity on a country-by-country basis. Houthakker esti-
mates the highest (for Poland) at .731 and the lowest (for UK middle-
class families) at .344. There are two possible explanations for this:

- These are at vastly different ends of the total expendi-
  ture range, and the elasticity, although assumed con-
  stant, appears to change somewhat with total expendi-
  ture.

- It is likely that real relative price differences exist between some countries.

There are some considerations that will limit the accuracy of our estimates when this method is used. A brief outline of the major limitations follows:

- Lluch has estimated the price elasticity for food expenditures to be .493 and notes that relative prices are significant in determining differences in consumption patterns. Meaningful data on relative price differences between the countries in question are not readily available. Making estimates without this factor is equivalent to assuming that relative prices have remained constant. While, in general, this is not desirable as per the comments above, for our specific application it may not be an unreasonable assumption.

- Food expenditures appear to be a function of family size. Houthakker has estimated the elasticity for food expenditures with respect to this variable (the number of persons in the family without any weighting by age or sex). It is about one-half that for total expenditures. Because relevant data on family size in the PRC, NK and the ROK are not available, our estimates will embody the assumption that average family size is the same in all three countries.

- The data on which the estimates are based apply to urban households in the 1945-1957 period. While there is no reason to believe that the food expenditures would change over time except as explained by increases in total expenditures caused by increases in income, family size and prices, the urban households surveyed may not be representative of our problem.

- Engel's Law, strictly speaking, applies to income elasticities. Because data on total income are of questionable quality, the elasticities that are available have been estimated from total expenditures and are thus more appropriately termed total expenditure elasticities. Since the elasticity of total expenditure with respect to income is normally less than 1.0, the income elasticities will actually be smaller than those

we use. While this will result in an overestimation of food expenditures when the PRC is used as the basis for comparison, and an underestimation when the ROK is used, our estimates of δ are not affected, as shown below.

- As Perthel has pointed out [10], estimates such as those that we will be working with are applicable only over a certain range of incomes. By estimating from one country with a greater income and another with a lower income, neither greatly different from that of North Korea, we hope to minimize this problem.

The method for estimating δ follows from Houthakker's model, which was of the form:

{8} $$\ln[F] = \phi + \eta_{fe} \ln[E]$$

He did not report the constant term (ϕ) for any of the countries in his analysis. In order to use the model, we will need to calculate a constant term. This will locate the curve $\delta = f(Y)$ for each of the base countries. To calculate the appropriate constant for our purposes, we:

- Assume $\eta_{fe} = .6$.

- Use the known value for $\delta = F/E$.

- Use the known value for Y.

Beginning with the model above, we can further show that

{9} $$\ln[F] - \ln[E] = \phi + \eta_{fe} \ln[E] - \ln[E]$$

or that

$$\{10\} \qquad \ln[F/E] = \phi + (\eta_{fe} - 1)\ \ln[E];$$

thus

$$\{11\} \qquad \phi = \ln[F/E] + (1 - \eta_{fe})\ \ln[E]$$

If $E = kY$, where $k = APC = MPC$, then

$$\{12\} \qquad \phi = \ln[F/E] + (1 - \eta_{fe})\ \ln[kY]$$

Rearranging

$$\{13\} \qquad \phi = \ln[F/E] + (1 - \eta_{fe})\ (\ln[k] + \ln[Y])$$

$$\{14\} \qquad \phi - (1 - \eta_{fe})\ \ln[k] = \ln[F/E] + (1 - \eta_{fe})\ \ln[Y]$$

and finally letting $\lambda = \phi - (1 - \eta_{fe})\ \ln[k]$, results in

$$\{15\} \qquad \lambda = \ln[F/E] + (1 - \eta_{fe})\ \ln[Y]$$

Using the known quantities shown below, the following results:

<table>
<tr><td colspan="2"><u>for</u> <u>PRC</u></td><td></td><td><u>for</u> <u>ROK</u></td></tr>
<tr><td colspan="2">Y = 390</td><td></td><td>Y = 820</td></tr>
<tr><td colspan="2">δ = F/E = .55</td><td></td><td>δ = F/E = .45</td></tr>
<tr><td>λ</td><td>η_{fe}</td><td></td><td>λ</td></tr>
<tr><td>2.385</td><td>.5</td><td></td><td>2.556</td></tr>
<tr><td>1.789</td><td>.6</td><td></td><td>1.885</td></tr>
<tr><td>1.192</td><td>.7</td><td></td><td>1.214</td></tr>
</table>

Our estimates will be made using η_{fe} = .6; the other values will be used for sensitivity tests.

With values for λ and η_{fe}, it is possible to solve for δ for other income levels. Since

$$\{16\} \qquad\qquad \delta = e^{\ln[F/E]}$$

we can use {15} and {16} to express δ as a function of income level (Y):

$$\{17\} \qquad\qquad \delta = e^{\lambda + (\eta_{fe} - 1)\ln[Y]}$$

The values of δ for NK projected from PRC and ROK using Equation {17} are displayed as a function of income level and base cou::.ry in Figure III-1.

ESTIMATES OF FOOD SHARE OF TOTAL BUDGET

(1975 prices)

fraction of total budget

$\delta = e^{\lambda} - .4 \ln [Y]$

$\lambda_{PRC} = 1.789$

$\lambda_{ROK} = 1.885$

ROK
PRC

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

100   200   300   400   500   600   700   800   900   1000

PER CAPITA INCOME (US)
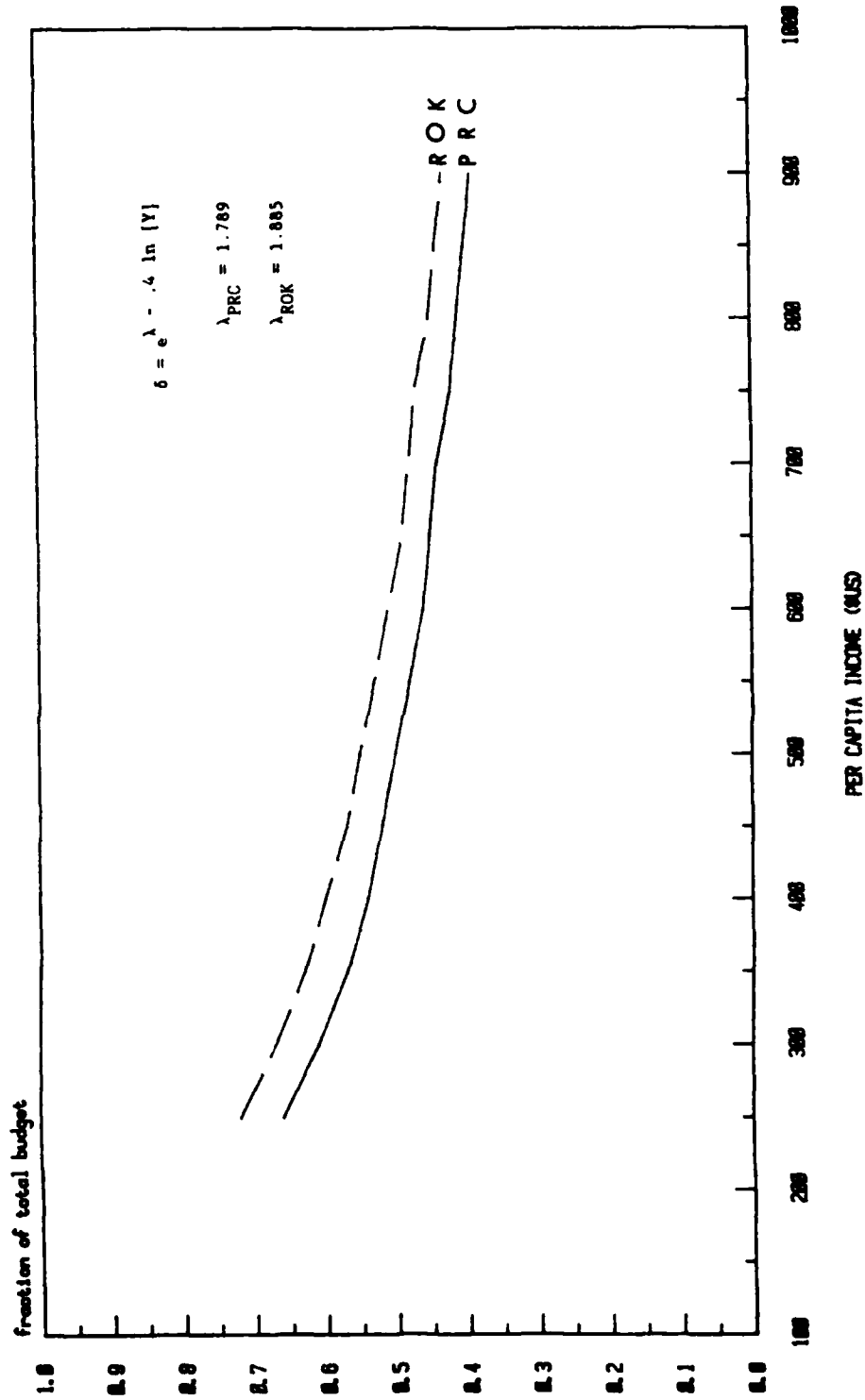
Fig. III-1--ESTIMATES OF FOOD SHARE OF TOTAL BUDGET FOR NK

IV. ESTIMATES OF TOTAL CONSUMPTION

The method chosen to estimate NK nonmilitary spending assumes

{18} $$C = f(Y, \ldots)$$

where Y will be parameterized because of the ambiguity associated with determining the GNP for NK.

As outlined in Section I, total nonmilitary consumption in NK can be estimated using the relationship

{19} $$C = \frac{\alpha\ O_g\ (\beta\ P_r + [1 - \beta]\ P_c)}{\gamma \delta}$$

where

$\quad\quad$ C $\;=\;$ dollar value of nonmilitary consumption

$\quad\quad$ α $\;=\;$ proportion of husked grain in O_g

$\quad\quad$ O_g $\;=\;$ total NK grain crop production

$\quad\quad$ β $\;=\;$ share of rice in O_g

$\quad\quad$ P_r $\;=\;$ U. S. dollar price of rice

$\quad\quad$ P_c $\;=\;$ U.S. dollar price of corn

Using the work in Sections II and III, this becomes

{20}
$$C = \frac{\alpha\, O_g\, (\beta\, P_r + [1 - \beta]\, P_c)}{\gamma\, e^{\lambda + (\eta_{fe} - 1)\, \ln[Y]}}$$

Substituting values for the parameters and consolidating terms results in the following expressions.

For the estimate from PRC:

{21}
$$C \approx \frac{2.98}{e^{1.789 - .4\, \ln[Y]}}$$

For the estimate from ROK:

{22}
$$C \approx \frac{2.98}{e^{1.885 - .4\, \ln[Y]}}$$

in billions

In Equation {19}, γ (the grain share of the food budget) is independent of our prior assumptions about GNP per capita for NK, and is a constant in the function. The parameter δ (the food share of the total budget) is dependent on our assumptions about GNP per capita and thus is a function of Y. This is reflected in Equation {20}.

The values of the parameters used to estimate C are listed in Appendix A. The estimates themselves have already been presented in Figures I-1 through I-4 and Table I-1. As an indication of how sensitive the estimates are to the assumption that $\eta_{fe} = .6$, estimates of NK

C/GNP using η_{fe} = .5 to .7 are shown in Figure IV-1. As a further check on the model, estimates for NK C/GNP used by the FAO are plotted in the same figure. These estimates are from unspecified United Nations sources; the growth rate and price index conditions to which they apply are outlined in Appendix B. Additionally, estimates based on a very small sample taken inside NK indicate that consumption ranges from 52 to 100 percent of gross income [1]. Such estimates are not inconsistent with the estimates made in this Note.

SENSITIVITY TO ASSUMPTIONS

(1975 prices, 1978 agricultural output)

CONSUMPTION AS % OF GNP

ROK .6

.5

.7

PRC

.5
.6
.7

$$\frac{C}{GNP} = \frac{2.98 \times 10^3}{16.64 \ e^\lambda + \eta_{fe} \ \ln [Y]}$$

η_{fe} = .5, .6, .7

Y = GNP/(16.64 × 10⁶)

λ_{PRC} = 1.789

λ_{ROK} = 1.885

UNITED NATION'S ESTIMATES:

x high GNP growth rate, Consumer Price Index deflator
+ high GNP growth rate, Commodity Price Index deflator
o trend GNP growth rate, Consumer Price Index deflator
* trend GNP growth rate, Commodity Price Index deflator

For trend and high growth rates, see Table II-2.
For more information on UN estimates, see Appendix B.
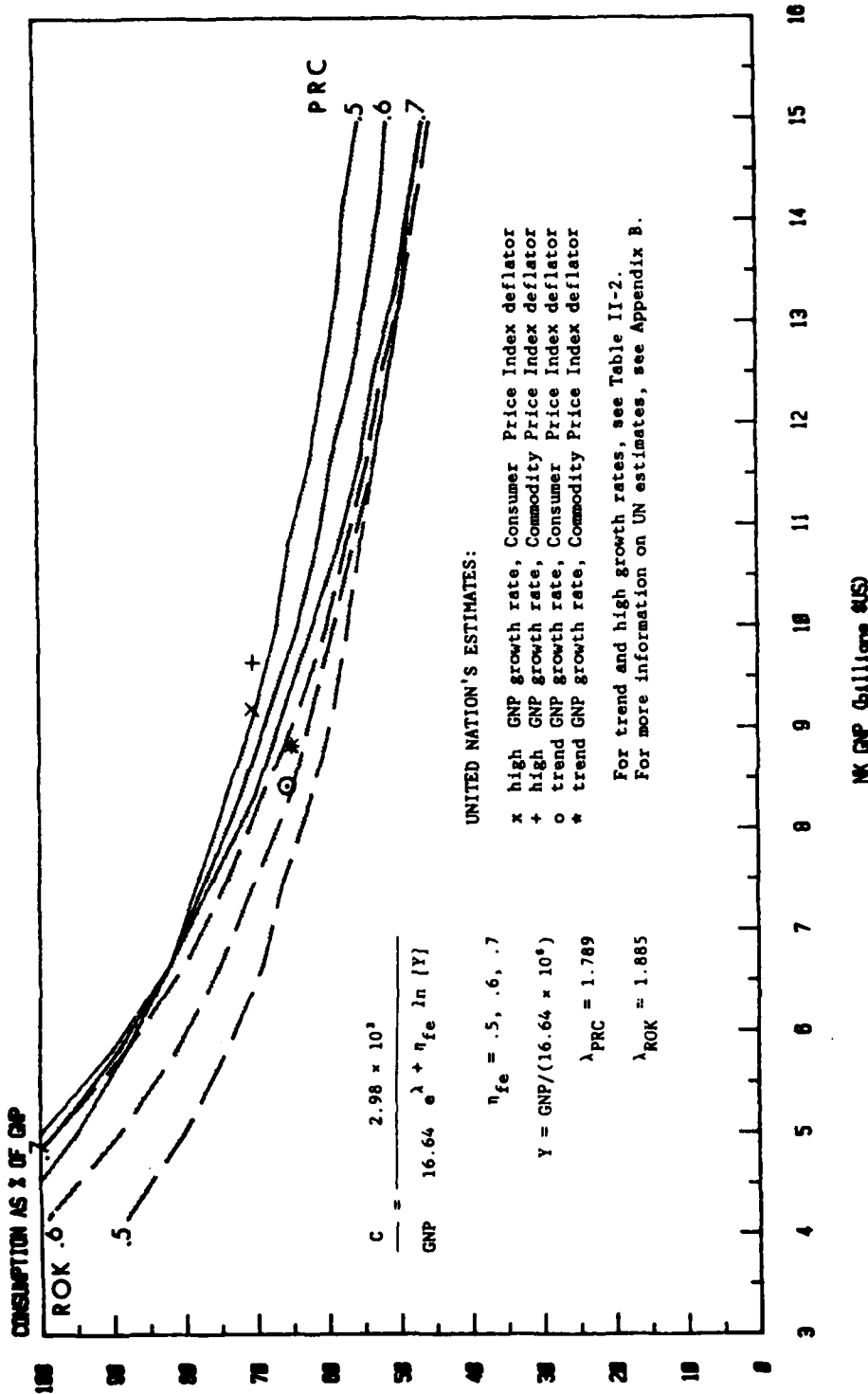
NK GNP (billions $US)

Fig. IV-1--Sensitivity of C/GNP to η_{fe} assumptions

APPENDIX A
DEFINITIONS AND VALUES FOR PARAMETERS

1978 Values/1975 Prices

PARAMETER	DEFINITION	VALUE	REFERENCE
C	Dollar Value of Non-Military Consumption	Dependent Variable	
α	Proportion of Husked Grain in O_g	.77	[1]
O_g	Total Grain Crop Production in NK (Metric Tons)	8.5×10^6	[1]
V_g	Value of NK Grain Crop ($US)		
C_g	Value of NK Grain Consumption		
C_f	Value of NK Food Consumption		
β	Share of Rice in O_g	.42	[1]
P_r	Price of Rice ($US per Kg)	364	[9]
P_c	Price of Corn ($US per Kg)	128	[9]

PARAMETER	DEFINITION	VALUE			REFERENCE
G	Per Capita Expenditures on Grain				
F	Per Capita Expenditures on Food				
E	Per Capita Total Expenditures				
E'	Level of Expenditure at which the Maximum Level of Per Capita Grain Consumption (Q_g') is Reached				
γ	Share of Grain Consumption in Total Food Consumption $$G/F$$	NK .4992			[calculated]
δ	Share of Food Consumption in Total Consumption $$F/E$$	PRC .55	ROK .45		[13] [11]
Y	GNP per capita ($US)	PRC[1] 390	ROK[1] 820		[7]
η_{fe}	Elasticity for Food Expenditures w.r.t. Total Expenditures $$\frac{\partial F}{\partial E}\frac{E}{F}$$	.6			[2]
η_{gq}	Elasticity for Grain Quantity w.r.t. Total Expenditures $$\frac{\partial Q_g}{\partial E}\frac{E}{Q_g}$$	PRC .36	NK .31	ROK .28	[3]

PARAMETER	DEFINITION	VALUE			REFERENCE
P_g	Price of Grain				
Q_g	Per Capita Quantity of Grain Consumed				
Q_g'	Level of Maximum	PRC[2]	NK[3]	ROK[3]	
	Per Capita Grain Consumption (Kg)	144	137	116	[3]
i	Index of Other (Non-Grain) Food Commodity Categories				
P_g	Price of Non-Grain Commodity				
Q_g	Per Capita Quantity of Non-Grain Commodity Consumed				
MPC	Marginal Propensity to Consume				
APC	Average Propensity to Consume				
ϕ	Constant Term in Houthakker's Model (Independent Variable: E)				
λ	Constant Term in Houthakker's Model (Independent Variable: Y)				

NOTES:
1. 1977 Values
2. Rice and Sweet Potatos
3. Rice

APPENDIX B
UNITED NATIONS ESTIMATES OF NORTH KOREAN TOTAL NONMILITARY CONSUMPTION

1975-1980 VALUES IN 1970 US $

GNP GROWTH	1975		1978		1980	
	TREND	HIGH	TREND	HIGH	TREND	HIGH
GNP/CAPITA	269	282	{290}	{314}	304	335
CONSUMPTION (billions)	2.91	3.05	{3.15}	{3.67}	3.71	4.08

ref [3, p. 19,22]

1978 VALUES IN 1975 US $

GNP GROWTH	CONSUMER PRICE INDEX 54.0		COMMODITY PRICE INDEX 57.5	
	TREND	HIGH	TREND	HIGH
GNP/CAPITA	537	581	504	546
CONSUMPTION (billions)	5.83	6.80	5.48	6.38
C/Y (percent)	65	70	65	70

ref [13, p. 61,79]

NOTES:
For trend and high growth rates, see Table II-2.

Interpolated values are shown in brackets { }.

APPENDIX C
LIMITATIONS ON THE USE OF THE MODEL FOR GROWTH PROJECTIONS

As pointed out in Section I, there are certain conditions that affect the validity of the estimates produced by the consumption model developed in this Note. In order to make growth projections, it is desirable to use the parameterized variable, GNP per capita (or GNP), to determine what will happen to NK total nonmilitary consumption as the personal (or national) income level grows over time. Such a use of the model can entail limitations on the validity of the estimates that result. It is important to understand the nature of these limitations and the situations in which they arise if the model is to be used correctly.

These limitations arise because income level has been incorporated in the model in a manner that is primarily designed to handle ambiguity in the estimates of the NK income level in light of the data we have on the edible portion of the grain crop (O_g'), grain prices (P_g), and the fraction of the food budget that is attributable to grain consumption (γ). As a simplified form of the model we have used, Equation {5} from Section I could be written:

$$\text{\{C.1\}} \qquad C = \frac{O_g' \, P_g}{\gamma \, \delta[Y]}$$

In this form, it is perhaps most apparent that for our estimates of C for 1978, O_g' and γ are constants based on the information we have on NK

grain production and consumption in 1978, and that P_g is a constant based on 1975 prices. The fraction of total consumption attributable to food consumption (δ) is a function of the income level (Y). Given that O_g' and γ remain at the 1978 levels, as they do when we address questions concerning the effect of ambiguity in the 1978 NK income level on estimates of consumption, correct estimates are produced by the model. When we address questions concerning the effect of growth in income level on consumption, the model, in some situations, may only produce estimates that are a lower bound on consumption.

As illustrated in Section II, the consumption pattern of grain in most economies argues that γ is a function of personal income level. Thus it would be most correct to represent the relationship shown in Equation {C.1} as

{C.2}
$$C = \frac{O_g' \; P_g}{\gamma[Y] \; \delta[Y]}$$

When the personal income level grows, both $\gamma[Y]$ and $\delta[Y]$ are affected. Since, the growth may have resulted from increases in the productivity of the agricultural sector, O_g' would also have changed. It is necessary to consider the changes in each of these three variables to understand the change in C that results.

CHANGES IN THE BUDGET SHARE FOR GRAINS AND THE BUDGET SHARE FOR FOOD

As the estimate of γ developed in Section II is based on 1978 pro-
jections of 1965 FAO survey data, it is assumed to have incorporated the
effect of the actual 1978 NK income level. Because of this, we have
established an estimate for γ on the basis of these data. Thus, γ (for
1978) is a constant in the consumption function {C.1} used for the esti-
mates reported in this Note; it is not affected by the various estimates
of the present NK income level. This constant is valid only for a lim-
ited range around the present (1978) NK income level because, as
explained in Section II, grain appears to change from a luxury to a
necessity and finally to an inferior good as the income level changes.
When we address questions concerning the level of nonmilitary consump-
tion in NK in 1978, this constant is appropriate; when we address ques-
tions concerning changes from that level, γ will change. Food consump-
tion data indicate that, in NK, grain is now a necessity. As
shown below, this implies that γ would decrease if the NK income level
were to grow from the 1978 level associated with our estimate of γ:

If $G = f(E, \ldots)$; $F = f(E, \ldots)$ and $E = f(Y, \ldots)$ where

G = per capita expenditures on grain

F = per capita expenditures on food

E = per capita total expenditures

Y = per capita income (GNP per capita will be used)

then

$$\{C.3\} \qquad d\left(\frac{G}{F}\right) = \frac{F\,\frac{\partial G}{\partial E}\,dE - G\,\frac{\partial F}{\partial E}\,dE}{F^2}$$

where

$$\{C.4\} \qquad \frac{\partial F}{\partial E} = \eta_{fe}\;\frac{F}{E}$$

Since $G = Q_g P_g$

$$\{C.5\} \qquad \frac{\partial G}{\partial E} = P_g\,\frac{\partial Q_g}{\partial E} + Q_g\,\frac{\partial P_g}{\partial E};$$

and if we assume the price does not change with E, then

$$\{C.6\} \qquad \frac{\partial G}{\partial E} = P_g\,\frac{\partial Q_g}{\partial E}$$

Since

$$\{C.7\} \qquad \frac{\partial Q_g}{\partial E} = \eta_{gq}\,\frac{Q_g}{E}$$

we can express the partial derivative as

$$\{C.8\} \qquad \frac{\partial G}{\partial E} = \frac{P_g Q_g}{E}\,\eta_{gq}$$

Our expression for the change in γ then becomes

$$\{C.9\} \qquad d\left(\frac{G}{F}\right) = \frac{F \frac{P_g Q_g}{E} \eta_{gq} \, dE - G \, \eta_{fe} \frac{F}{E} \, dE}{F^2}$$

which can be expressed in terms of γ as

$$\{C.10\} \qquad d\left(\frac{G}{F}\right) = \frac{\gamma}{E} \, dE \left(\eta_{gq} - \eta_{fe}\right)$$

If $E = kY$, where $k = APC = MPC$, then

$$\{C.11\} \qquad d\left(\frac{G}{F}\right) = \frac{\gamma}{Y} \, dY \left(\eta_{gq} - \eta_{fe}\right)$$

If we denote the new value for the grain share of the total food budget by

$$\{C.12\} \qquad \gamma' = \gamma + d\gamma$$

and we let the new income level be

$$\{C.13\} \qquad Y' = Y + dY$$

the following expression for γ' results

$$\{C.14\} \qquad \gamma' = \gamma \left[1 + \frac{Y'-Y}{Y} \left(\eta_{gq} - \eta_{fe}\right)\right]$$

Equation {C.14} indicates that the new value for γ (γ'), which results from a change in the income level from Y to Y', is dependent not only on the change in Y (i.e., Y' - Y) but also on the difference between the income elasticity for grain (η_{gq}) and that for food (η_{fe}).

As explained in Section III, we believe η_{fe} to be constant over the range of incomes with which we are dealing. In the log-log-inverse function (Figure II-1), η_{gq} is not constant as income changes but is related by

{C.15}
$$\eta_{gq} = b/E - c$$

or, if we assume k = APC = MPC,

{C.16}
$$\eta_{gq} = b'/Y - c$$

Thus, as Y increases, η_{gq} changes from greater than +1 to less than -1, reflecting grain's transition from a luxury to an inferior good. In situations in which η_{gq} is less than η_{fe}, positive changes in Y will result in a decrease in γ. Houthakker [4] has estimated η_{fe} to be about .6. The 1965 FAO survey data indicate that η_{gq} for NK was .31. Assuming an increase in the income level since that time, we would expect η_{gq} now to be a small positive number. As a result, we would expect γ to respond to future (beyond 1978) growth in the income level by decreasing. When attempting to estimate nonmilitary consumption in NK

for situations in which the income level is different from the 1978 level, adjustments to γ must be made or the consumption estimates must be viewed as lower bound estimates.

The response of $\delta[Y]$ to changes in the income level have already been developed in Section III; that is, we expect $\delta[Y]$ to be related to Y through

{C.17} $$\delta = e^{\lambda + (\eta_{fe} - 1) \ln[Y]}$$

This relationship is appropriate when addressing the relation between income level and $\delta[Y]$ for questions concerning both the ambiguity in the present NK income level and growth from that level. Besides the changes in $\gamma[Y]$ and $\delta[Y]$, there is one further aspect of income level growth which must be considered when we are concerned with the effect that such growth has on consumption. This deals with changes in agricultural output. The effects of these changes are discussed below.

CHANGES IN AGRICULTURAL OUTPUT

The effect that changes in Y have on C is determined not only by the effect of Y on $\gamma[Y]$ and $\delta[Y]$, but also by which of the sectors of the NK economy experience the growth. If the growth in Y is confined to sectors other than agriculture, then only $\gamma[Y]$ and $\delta[Y]$ change in equation {C.2} of this Appendix. However, if there is any growth in the agricultural sector, then O_g' increases in addition to $\gamma[Y]$ and $\delta[Y]$. This would have the effect of shifting the curves presented in Figures I-1 through I-4 upward as Y increases. In this situation the curves (and hence the estimates from the model), which are based on the 1978 level of O_g', could only be viewed as a lower bound on consumption.

In the absence of exogenous controls, we would expect consumption (and hence production under our net food exports assumption) to grow in proportion to the income elasticity of the good involved. This would argue that there will be some growth in O_g' if the income level increases in the future. As shown in Section II, however, there are indications that NK is approaching a phase of development in which the income elasticity for grain will be small. This will result in little or no growth in O_g' and implies that even if the estimates of consumption are a lower bound, actual consumption will not be greatly different.

OTHER ASPECTS OF THE GROWTH OF INCOME LEVEL

Other aspects of the growth of Y also impact the use of the model to project the resultant consumption. In Equation {C.1}, Y is the income of the individual decisionmaker; we use GNP/population as a surrogate for this variable. Those estimates in this Note that are presented as a function of GNP assume that the population is constant at a 1978 level of 16.64 million. Growth in NK GNP alone is not sufficient to determine new estimates of consumption. GNP growth must be considered in conjunction with population growth, because it is possible to experience a growth in GNP and population that results in a personal income level that is the same (or even lower) than the previous level. The most direct result of this limitation is that Figures I-3 and I-4, which are presented in perhaps the most convenient form, are valid only for a

population fixed at the 1978 level. To address questions of concurrent population and GNP growth, GNP per capita must be calculated and used with Figures I-1 and I-2.

These considerations result in the following three guidelines for the model's use. To address issues concerning the impact that various estimates of the present NK income level will have on total non-military consumption, the estimates of consumption presented in this Note may be used directly. To address the implications of income level growth over a limited range, the model must be used in conjunction with estimates of population growth to produce proper estimates, and these estimates may represent a lower bound on consumption in certain situations. To address more general questions concerning the impact of income level growth, the consumption model should be used as part of a larger model of the NK economy. Such a model must consider agricultural output, net agricultural exports, and population growth explicitly.

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7-8