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Food Security Policy in a Stochastic  
World

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Food security may be increased by variance-reducing strategies, by food aid, or by development strategies. This paper uses a Korea CGE model, subjected to random fluctuation in world-prices and domestic food productivity, to evaluate these policies. We find that poverty-reducing development strategies are the most effective food-security strategies.

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FOOD SECURITY POLICY IN A STOCHASTIC WORLD

by

Irma Adelman and Peter Berck

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## Abstract

Food security may be increased by variance-reducing strategies, by food aid, or by development strategies. This paper uses a Korea CGE model, subjected to random fluctuation in world-prices and domestic food productivity, to evaluate these policies. We find that poverty-reducing development strategies are the most effective food-security strategies.

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# FOOD SECURITY POLICY IN A STOCHASTIC WORLD

Irma Adelman and Peter Berck

## 1. Introduction

Malnutrition in developing countries is a serious policy concern in international agencies and within developing countries themselves. There is agreement that malnutrition is widespread but little agreement where the best cures might lie. Some analysts and policymakers advocate variance-reducing policies and focus on decreasing international price instability or export-receipt instability. Others see the remedies as lying in reducing national food-supply shortages and advocate some form of food-aid or food-staple R&D. Still others view malnutrition as an acute manifestation of a poverty problem and hold that malnutrition is best tackled by choosing poverty-reducing development strategies.

Which view is most correct? In the present paper we "implement" variants of all these diverse approaches in a common model representing a poor, food-deficit country that is very dependent on international trade. We expose the model-economy to a common set of stochastic shocks arising from fluctuations in domestic food supplies and international prices, implement each policy or strategy in turn, and compare the food security, household welfare, and macroeconomic results. Our results support the poverty-reduction approach to tackling malnutrition, although they indicate that the choice among approaches depends on the country's risk aversion. International interventions we find least effective and sometimes downright harmful. Our results thus in part support current orthodoxy and in part conflict with it.

There is no agreed-upon definition of the term "food-security" even though much has been written on the subject and many different policy proposals have been made to address the issue. While all authors view food security as a condition in which there is less world hunger, some authors implicitly define it as stability in world grain prices; others, as availability of ample world grain supplies; others, as self-sufficiency in food; and still others as availability of foreign exchange to meet food-import requirements. We accept the definition of food-security offered by Reutlinger (1980)--that it represents a condition in which the probability of a country's citizens falling below a minimal level of food consumption is quite low. Aside from the conceptual problems inherent in defining minimal nutritional standards, common to all food-security analyses, this approach requires evaluating the probability of below-subsistence food consumption for all population groups in the economy as a function of international and domestic conditions. For each population group, this probability is clearly related to both the group's mean food consumption and to the variance of its food consumption.

The major current policy proposals for attaining food-security fall into several categories, which can be viewed as affecting either the variance in food prices or the mean real incomes of consumers in developing countries. More specifically, the proposals are: (1) the accumulation of buffer stocks aimed at stabilizing the world price of wheat [Reutlinger (1976), Cochrane and Danin (1976)]. Critics have pointed out that price stabilization policies benefit producers at the expense of consumers [Waugh (1944), Oi (1961), Turnovsky (1978), Turnovsky, Shalit and Schmitz (1980), and Dunn and Heien (1982)]; that trade policies with respect to agricultural products [Bigman and Reutlinger (1979)] or improved market information

services [Scandizzo, Hazell and Anderson (1983)] are more potent than buffer stock policies in stabilizing countries' food supplies; and that stabilization schemes which take up existing supplies will generate a transfer from producers to consumers and have small overall benefits, if any [Newbery and Stiglitz (1981)]. (2) the accumulation of stocks aimed at ensuring supply availability [Bailey, Kurish and Rojko (1974), Eaton, Steel, Coho and Revelle (1976), Johnson and Sumner (1976), and Sarris, Abbot and Taylor (1977)]. Critics have pointed out that commodity storage schemes actually accentuate variability in production and are most effective in eliminating the incidence of high consumption rather than in reducing shortfalls in consumption [Wright and Williams (1982)]. (3) an international insurance scheme to cover higher-than-trend food-import bills [Johnson (1978), Konandreas, Huddleston and Ramangkura (1978) and the Brandt Commission (1980)]. Critics have pointed out that import-expenditure data may provide a wholly misleading picture of a country's need for assistance and that as a consequence the program is likely to fail in the objective of stabilizing food consumption levels [Green and Kirkpatrick (1982)]. (4) food-aid by developed countries [Mellor (1980) and Lane (1980)]. Critics point out that food-aid does not tend to reach the neediest [Lele (1971)], that the income of the poor needs to be raised so that they can benefit from food aid [Berg (1980)] and that it tends to generate negative production incentives which need to be countered by specific policies [Hall (1980), Gavan and Chandrasekar (1979), Rodgers, Srivastava and Heady (1972), Lane (1980) and Mellor (1980)] if food-aid is not to result in worse rather than better nutrition for the neediest. (5) price-subsidy schemes to consumers [Reutlinger and Selowsky (1976), Ahmed (1979), Kumar (1979), George (1979), Perrin and Scobie (1981)] or production



subsidy schemes to producers [Barker and Hayami (1976), and Hayami (1977)]. Critics point out that this policy is expensive if not limited to well defined target groups [Berg (1980)] and administratively demanding and open to evasion if limited to well defined target groups [Lele (1971)], and that it leads to a decrease in the competitiveness of export industries when financed through inflation [Schneider (1985)]. (6) self-sufficiency in food [Lappe (1978)]. Critics point out that this policy may result in higher food-prices than can be obtained by specializing according to comparative advantage and importing food [Falcon (1984)] and that the degree of optimality of food-self-sufficiency policies depends on the country's degree of risk aversion [Sarris (1985)]. (7) agricultural development [Mellor (1976) and Adelman (1984)]. Critics indicate that this policy requires a high rate of return to investment in agriculture to be effective, and that the inelasticity of demand for agricultural products implies that there are definite limits beyond which this policy cannot be pursued without reducing the incomes of farmers, who constitute a large share of the poor. And (8) raising the income of the poor [Berg (1980), Pinststrup-Andersen and Caicedo (1978), Streeten (1985), and Sen (1981)]. Critics indicate that, when achieved through income transfers, this is expensive and needs to be maintained forever and that, when achieved through productivity and through patterns of growth which enhance demand for unskilled labor, this approach requires changes in development strategies which may generate political opposition and take time to implement.

Thus, the proposals for achieving food security are numerous, and cogent criticisms have been advanced against each and every proposal. With rare exceptions, the empirical evaluations of these policy proposals have been carried out in a partial equilibrium framework and analyze the

effectiveness of food-security programs only at the national level. They do not trace out how the interaction of demand and supply responses within the economy mediates the impacts of shocks at the national level upon the incomes of the various groups within the country and upon the prices of the commodities they consume. This paper implements a model that describes how this mediation occurs for a poor, chronic food-deficit country.

Our analysis adds several elements to previous models: (1) in previous models, shocks in production and/or international prices affect consumer-demand only through the prices consumers face, not their incomes; (2) in most previous models, the shocks to food prices are independent of other shocks to the economy (i.e., there is no correlation among shocks); (3) we use an interdependent model with a great many substitution possibilities to translate shocks in international prices and domestic production into shocks on the food-consumptions and real incomes of consumers; and (4) we disaggregate consumers into eight socioeconomic classes distinguished by ownership and access to factors of production and by whether they are net suppliers or demanders of food. Within each class we further disaggregate households by income levels.

The next section describes the methodology of our study. Section 3 presents the results of six simulated food-security policies for the South Korea of 1968.

The Korea of 1968 was a rapidly growing but very poor country. Its per capita income was around 170 1968 dollars, converted at the official exchange rate. It was an open economy with a very large trade deficit; exports were 15 percent of gross domestic product (GDP), and the trade deficit accounted for 10 percent of GDP. About half of its labor force was employed in agriculture, only 15 percent in manufacturing, and the rest in

services. It was a consistent food-deficit country; in 1968 its cereal imports accounted for about 11 percent of its total consumption. Thus, in static terms, the Korea of our study is a typical small, poor, open, negative balance-of-trade, large food-deficit country.

## 2. The Methodology

Agricultural output, internal and international terms of trade, oil prices, and the world-price of food are all subject to random fluctuations. Random shocks to international markets or agricultural production in turn affect consumers through their effects on consumer-incomes and consumption-prices. We describe the shocks at a national level in terms of a multivariate probability distribution. The probability distribution of international prices and domestic food production is then transformed into a probability distribution of incomes and prices for each of several groups of consumers by means of a computable general equilibrium (CGE) model. Finally, food-security and welfare-measures are computed for each consumer-group from the distribution of incomes and prices and used to evaluate the policies.

The remainder of this section describes: (1) the choice of international shocks and the construction of their variance-covariance matrix; (2) the use of the CGE model to transform the probability distribution of these shocks into a probability distribution of prices and incomes; and (3) the indicators used to evaluate food-security and welfare.

### The Shocks

In this model we analyze shocks to food-security arising from four different sources: variations in domestic production of cereals due to

factors such as weather; changes in the international price of cereal imports; changes in the prices of domestic exports, which affect the economy's ability to import food; and changes in energy-prices, which affect both the economy's ability to import food and its ability to import inputs, like fertilizer, used to grow food. This section describes the derivation of the shocks in these variables.

For food-security analysis, the systematic changes in time series (from, for instance, growth) need to be separated from the changes induced by random shocks that a food-security program might reduce. Our method of modeling the shocks was to consider the values of the variables that could be predicted two years ahead and treat the difference between the predictions and the actual values as the shocks. We chose two-years ahead rather than one-year ahead because food stocks have a major impact on food prices, and food stocks adjust slowly. As a result, the random variations from changes in the food system do not fully work themselves out within a single year, and one-year-ahead forecasts badly underestimate the variability to which shocks expose the economy.

The four variables (food production, international cereal prices, domestic export prices, and oil prices) are each normalized so that their 1968 value is unity. The normalized values are then regressed (using Zellner's seemingly unrelated regressions technique) over the period 1963 to 1978 on their own twice-lagged value, a constant term, the year squared, and the year. All equations except the grain equation fit with an  $R^2$  of better than 90 percent and have significant coefficients on all but the lagged variables. The grain-equation has no significant coefficients and an  $R^2$  of only 7 percent. Thus, most of the actual variability in oil prices, export prices, and agricultural production appears systemic while most of the

variability in world-grain-prices appears random. The variance-covariance matrix of residuals from these equations is taken as the true variance-covariance matrix of the shocks.

Table 1 gives the correlation matrix and standard errors of the shocks. World-grain-prices have the largest standard error, about one-third of its trend value. Export prices and food-production have the least variation, about 8 percent of trend. The off-diagonal elements indicate that the correlations among shocks are important: the correlation between export prices and the price of oil is .88 so that high (low) foreign-exchange earnings are likely to offset a high (low) energy-import bill. On the other hand, domestic food production and world-food-prices are negatively correlated (-.61) so that bad harvests coincide with high world-prices, clearly reinforcing any food-shortfall. The other correlations are of much lower magnitude and are positive with one exception--an  $R^2$  of -.20 between domestic food-production and world-grain-prices.

The shocks themselves are constructed by drawing 100 quadruples of price-shocks from a multivariate  $t$  distribution with five degrees of freedom and the estimated variance-covariance matrix. A  $t$  distribution was used because it has relatively fat tails, and our sample period (1963-1978) included many observations, such as the formation of an OPEC cartel, that would have been poorly represented by a normal distribution. A check of the histograms of the shocks shows significant probability of shocks as great as a doubling or halving of oil or grain-prices and reasonable agreement with the historical data. Since our reported results are averaged over the 100 trials, our reported statistics are subject to the central limit theorem, and increasing the number of replications to, say, 1,000

Table 1  
Correlations and standard errors of shocks

	Correlations			
	World grain prices	Export prices	Oil prices	Food production
World grain prices	1.00	-0.20	0.04	-0.61
Export prices	-0.20	1.00	0.88	0.30
Oil prices	0.04	0.88	1.00	0.35
Food production	-0.61	0.30	0.35	1.00
	Standard errors			
	0.33	0.08	0.24	0.08

Source: Computed. Standard errors are percent of mean.

would increase accuracy by only a factor of three while it would impose impossible computational burden.

### Mapping the External Shocks into Domestic Income and Price Variations

These 100 quadruples of shocks were then applied to a CGE model one at a time. The CGE model was used to translate the shocks into the means and variances of group-incomes and of consumer-goods prices. This model is well suited to the analysis of food-security issues since it translates shortfalls in domestic food production or rises in the price of food imports into changes in food-consumption by each class of consuming households, especially the poor. In our model, a rise in the price of food-imports affects not only domestic food-prices and domestic food-production but also the real incomes of all consumers. It also changes the exchange rate and, therefore, other imports and exports. This chain links international and domestic food-security policies to each class' food-consumption and enables us to trace through precisely how food-security policies affect the nutritional status of the poor and near poor in each class. By contrast, most other food-security analyses evaluate food-security policies solely by their effects on the overall supply of grain at the national level and do not consider how these policies affect the ability of the poor to partake of the national supply of food.

The CGE model we use consists of an economywide, simultaneous, multisectoral model that solves endogenously not only for quantities but also for prices [for detailed descriptions of the model, see Adelman and Robinson (1978) and Dervis, de Melo and Robinson (1982). We use the stripped-down version of the CGE model contained in Dervis, de Melo and Robinson, but with many consumers.] The core of the model consists of the

reconciliation of potential demand and supply imbalances in factor and commodity markets by price adjustments, which simulate the workings of labor, commodities, and foreign-exchange markets. The model solves for: wages, profits, product-prices, and the exchange rate; sectoral production, import, export, employment, consumption, and investment; and the flow of funds, gross national product, and balance-of-payments accounts as well as the functional distribution and the size distributions of income to households. The model is pretty neoclassical in that all prices except for world prices are flexible and the equilibrium is a full-employment equilibrium of all factors.

The technological and behavioral functions in the model incorporate substitution possibilities among factors in production and among commodities in final demand. Production technology is represented by fixed input-output coefficients for intermediate goods and constant elasticity of substitution (CES) functions for labor and capital. In the factor markets, labor-demand arises from the profit-maximizing behavior of producers. The supply of labor is disaggregated by skill type. It is assumed fixed within a given period, and only its sectoral allocation is allowed to vary. Farmers and service workers are immobile within each period though mobile between periods. Small farmers in "our" Korea are both land and income poor, but not destitute. They average less than 3/4-acre plots and devote about 50 percent of their expenditures to food purchases. Agricultural proprietors are owner-operators with less than 2-acre plots. On the average, their incomes are only 25 percent higher than those of small farmers. Hired farm-labor is mobile between rural and urban employment as marginal workers. The model determines market-clearing wages and the sectoral allocation of skilled and unskilled workers.



The demand for commodities is responsive to relative price and income variations. The price-responsiveness arises because of the use of linear expenditure system (LES) consumption functions and because of the trade specification which induces price-sensitive substitution among imports and domestic production. The incomes of consumers are determined in the factor markets after subtracting taxes. The demand for commodities by sector is evaluated from these incomes and the exogenously specified savings rates and government consumption functions. Output-prices that clear commodity-markets are then calculated by comparing demand and supply. They determine relative prices. To fix absolute prices we set the wholesale price level as numeraire and use a Cambridge-K money demand equation together with a fixed money supply to calculate the wholesale price level.

Imports and domestic production in a given sector are not considered to be either perfect substitutes or complete complements; rather, there is an elasticity of substitution among them which lies between zero and unity. The balance of trade determines the net demand for foreign exchange. The exchange rate adjusts so as to maintain a predetermined level of foreign capital inflow.

Several closure rules are possible for the model. The one we chose is the one which gives maximum intermediate-run sensitivity to balance-of-payments fluctuations arising in international markets. In it, investment absorbs the full brunt of the adjustment since investment is forced to adjust directly to the enlarged or diminished supply of domestic plus foreign savings.

To provide the counterfactual for the evaluation of the policy alternatives proposed to achieve food-security, this CGE model was run 100

times, once for each of the previously computed combinations of shocks. The factor-incomes for each group, their food-consumptions, and the prices of consumption-goods were then used to determine the welfare and degree of food-security enjoyed by each decile in each group in the base solution. For this purpose, distributions of income within each consumer group were applied to calculate the distributions of consumption in each household-category and to compute the percent of households in each group falling below a specific nutritional intake.

The base-solution indicates that the mapping of external shocks on internal price-fluctuations is contractionary. Substitution effects through international trade and through changes in domestic production and consumption result in a standard error of domestic grain-prices which is only 36 percent of the standard error of world grain-prices and in a variance in manufactured food-prices which is only about 5 percent of the standard error of world grain-prices. On the other hand, the variance in the world-prices of Korean exports is reflected in the variance of domestic-prices of the export sector, manufactured consumer-goods; the standard error of domestic manufactured consumer-good prices is 72 percent of that of Korean export prices on world markets. And shocks in the world price of oil are almost fully reflected in the domestic price of intermediates (the standard error of intermediate-good prices is 93 percent of that in the world price of oil) since substitution possibilities for intermediate goods are more limited: the trade-substitution elasticities are smaller, and the input-output nature of intermediate-input technology limits substitution effects for intermediates to changes in the composition of output. In addition, the variance in world-prices is also transmitted to sectors not directly affected

by shocks; the standard error in their prices is about the same as that of export prices.

### The Evaluation of Food Security Policies

The food-security policies are evaluated by their effects on nutritional status as well as by their effects on overall welfare. The measures of nutritional status we have chosen are the percent of households in each household group that are below their recommended caloric intake and the group's per capita calorie deficit. The deficit is the average number of calories by which the malnourished fall short of their minimal caloric need. Since one of the purposes of stabilization policies is to eliminate extreme outcomes, we also evaluated these policies by calculating the percent of time a severe food shortfall could be expected. Bigman (1982) provides a nice discussion of the merits of these food-security indicators as welfare measures.

The welfare measure we have chosen for each group is the expected equivalent variation for the consumer with the mean income of his group. Consider an initial allocation called "the base" and a proposed food security policy called "the policy." The equivalent variation is the amount of money one would have to pay a consumer in the base to make him as well off as he would be if the policy were implemented. The CGE model uses a linear-expenditure system (LES) to represent consumers. Let  $v(y, p)$  be the ordinal indirect utility function associated with that demand system. For an LES,  $v(y, p)$  can be written as:  $v = (y - m'p) \prod p_i^{\alpha_i}$  where  $y$  is income,  $p$  is the vector of  $p_i$  prices,  $m$  is the "subsistence bundle" vector, and  $\alpha_i$ 's are the marginal shares of income spent on goods  $i$ . Of course, any monotone

transformation of  $v$  will also give the same demands but will have a different coefficient of risk aversion. Let expected utility be

$$EU = E \left[ \frac{v^{1-\beta}}{1-\beta} \right] \quad (1)$$

where the expectation is taken over the 100 replicates. Then, the coefficient of absolute risk aversion to income change is  $\beta/v$  and  $R$ , the coefficient of relative risk aversion, is  $\beta y/v$ . Thus,  $EU$  has decreasing absolute risk aversion and increasing, and asymptotically constant, relative risk aversion. For the cases we will consider, the value of the subsistence bundle is approximately half of mean group-income, and the product of the prices to the powers  $\alpha_i$  in the base is nearly one. Thus,  $\beta$  is approximately  $1/2 R$ . In what follows we chose  $R$  as four and  $\beta$  as two.

### 3. Food-Security Policies

The policies selected for evaluation are: a price stabilization policy; a food import bill insurance scheme; food aid; a food price subsidy scheme; a food self-sufficiency policy implemented by productivity-enhancing investments in agriculture; and a standard development strategy--export expansion. These six policies break into three natural groupings: (1) insurance schemes to reduce variance in food prices, (2) lowering food prices, and (3) development strategies to raise income.

To maintain comparability among food-security programs, we calibrate the experiments so that the increase in the budget deficit incurred for each food-security policy is the same (\$20 million) and that deficit is financed by foreign donations. The two variance-reducing policies required only this amount of financing and little other commitment from domestic

policymakers. Thus these would be the easiest policies to implement. The next set of food security policies, the food-price reducing experiments (food-aid and a food-price subsidy), both require a domestic policy action costing \$20 million. In food aid, that sum is used to import food while in the two-price scheme, it is used to finance the difference between producer and consumer prices. The final programs, development strategies, change investment and trade incentives and are most committing of all. Again they have budget costs of \$20 million. Twenty million dollars is 180 won per capita which is .4 percent of GDP. We compare the results of the implementation of each food-security policy with the base, which contains no food-security program. To see whether the relative and absolute effectiveness of food-security policies depends on the magnitude we chose for the program, we also implemented the policies with each component (tariff rates changes, growth rates changes, tax changes, etc.) increased by 50 percent. These enhanced policies increase the country's aid-compensated budget deficit to \$30 million. We report the expenditure-multipliers for each program in a final table.

For each of these six policies, we compute the calories consumed by each decile of each class of consumers and identify the percentage of consumers in each class whose average daily caloric intake over the year is less than 90 percent of the FAO norm for Korea of 2,200 [United Nations (1973)]. For shorthand purposes, we refer to the percentage of households whose annual average daily calorie intake falls below 90 percent of the norm as the percent malnourished, though we recognize that daily variations in intake and adaptations in activity levels probably result in better nutritional and health status than this average would suggest. The percentages we calculate are higher than those one would get by looking at

the mean per capita food supply available to the country or at the average calorie intake of an average member of each class of consumers. But we believe that our calculations offer a more valid picture of the likelihood of below-norm food intake in each population group and in the country as a whole. In any case, the ranking of the policies by their effects on food security is unaffected by the choice of cutoff point.

Table 2 summarizes the macro variables for the six policy alternatives considered as a percent of the base in the absence of shocks. The import-price stabilization and the trade-balance stabilization policies affect only the variances of the shocks and are, therefore, omitted from this table since they leave the means under these policies the same as in the base. Tables 3-5 summarize the food-security implications of these policies.

The first point to emerge from these calculations is that none of the policies considered achieve very much in terms of cutting the percentage malnourished. The differences among policies in their effects on the average expected food-deficit (defined as the average food-deficit over all 100 shocks) is somewhat more pronounced, but the maximum effect is only 6 percent above the least effective policy. The least effective policies are those that operate only on the variances of the shocks; the most effective are those that raise the mean-incomes of the poverty-groups by appropriate changes in development strategy. We now turn to detailed analyses of each policy.

Import Price Stabilization Policy: The first experiment we consider is an import-price stabilization scheme. Grain is purchased and stored in years when grain prices are cheap and released when grain prices reach a preset release price. The benefits of the buffer-stock are a lessening of the variability in grain-prices, while the costs are the operating costs (less

Table 2

## Macroeconomic indicators for food security

	GDP*	Consumption*	Investment*	Exchange rate	Price level	Wages*	Capital rental rate*	International terms of trade	Agricultural output*	Agricultural consumption*	Agricultural net imports*	Agricultural prices	Agricultural terms of trade
Base	1,620	1,406	408	0.277	100.2	105.7	9.61	100	668	379	60.4	1.04	1.066
	<u>percent of base</u>												
Food aid	100.0	100.1	96.1	101.8	100.3	100.0	101.9	103.8	100.0	101.8	111.9	97.5	95.7
Grain price subsidies	99.9	100.0	94.6	101.4	99.8	100.2	100.2	103.9	100.0	101.0	111.1	99.3	99.0
Agricultural development	104.3	103.3	100.7	108.7	99.8	105.5	96.7	103.8	105.1	104.3	95.2	101.3	99.5
Export-led growth	101.9	103.8	97.6	107.9	99.8	104.8	93.1	103.7	101.6	99.8	110.2	107.0	109.2

\*Denotes constant prices, billions of won.

Source: Computed.

Table 3

## Measures of food security

	Base	World price stabilization	Food import insurance	Food aid	Grain price subsidy	Agricultural development	Export-led growth
<u>Percent malnourished</u>							
Small farmers	55.88	55.76	55.91	58.13	56.08	53.23	52.48
Marginal laborers	84.56	85.24	84.51	84.09	85.4	82.12	84.60
Organized labor	13.71	13.56	13.69	12.03	12.6	12.40	15.79
Service labor	20.40	20.42	20.07	18.99	20.4	18.46	20.83
Total population	36.88	36.81	36.81	37.34	36.86	34.79	35.70
<u>Average daily calorie deficit per malnourished person<sup>a</sup></u>							
Small farmers	340	338	341	352	340	327	322
Marginal laborers	525	527	524	523	528	495	518
Organized labor	143	143	143	143	138	128	138
Service labor	200	199	199	200	198	188	193

<sup>a</sup>The deficit is measured from 1,930 calories; which is already 10 percent below the norm of 2,200; averages over the 100 replicates.



Table 4

Mean and variance of real above subsistence income for seven institutions and seven policies

Institution	Small farmers		Marginal labor		Organized labor		Service labor		Agricultural proprietors		Agricultural capitalists		Industrial capitalists	
	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
Base	4.40	1.11	3.27	0.09	8.63	17.30	7.93	2.69	5.40	1.67	19.78	9.19	50.56	119.00
World price stabilization	4.41	0.70	3.25	0.04	8.28	6.79	7.86	1.87	5.43	1.06	19.75	6.48	50.80	96.79
Food import insurance	4.38	1.12	3.27	0.08	8.51	14.63	8.03	2.73	5.38	1.70	19.75	7.94	51.34	130.89
Food aid	4.07	0.84	3.26	0.10	9.20	17.24	8.32	2.36	5.00	1.26	19.63	10.37	53.79	117.44
Grain price subsidies	4.34	0.30	3.24	0.12	8.50	8.81	7.74	0.78	5.37	0.44	19.80	10.04	50.46	36.90
Agricultural development	4.78	1.11	3.66	0.27	9.90	29.51	8.97	3.23	5.90	1.69	21.94	13.81	52.80	130.82
Export-led growth	5.13	1.03	3.55	0.11	8.34	18.46	8.29	3.15	6.32	1.59	22.05	10.11	51.06	161.60

Source: Computed. Income is average for each group across the 100 replicates, and the variance is also across the 100 replicates.

Table 5

Expected equivalent variation for seven policies  
(percentage of income)

Institution	Small farmers	Marginal laborers	Organized laborers	Service laborers	Agricultural proprietors	Agricultural capitalists	Industrial capitalists
Policy							
World price stabilization	4.08	-0.25	0.48	0.21	4.09	0.50	1.55
Food import insurance	-0.77	-0.05	-0.03	0.67	-0.75	0.07	0.95
Food aid	-2.41	-0.34	4.63	3.02	-2.40	-0.69	4.00
Grain price subsidies	4.05	-0.76	3.04	0.24	4.05	0.03	2.38
Agricultural development	5.08	6.24	5.73	7.09	5.13	8.19	3.43
Export-led growth	11.04	4.66	-3.24	2.09	12.00	9.3	0.41

Source: Computed; average across the 100 replicates of equivalent variation.

operating revenues) of the buffer stock. In a very different model, Reutlinger (1980) performed a similar stabilization experiment, which he summarized in the form of a table. The table gives the frequency of food-shortfalls as a function of the amount of grain in storage. Reutlinger also stated the storage costs so, by assuming a log-normal distribution, we were able to convert his numbers to a table giving the cost of the program as a function of the percent-reduction in the variance. An expenditure of \$20 million reduces the variance in world grain-prices by 56.7 percent.

In our experiment, the buffer-stock policy is modeled by approximately halving the variance in world food prices by a mean-preserving spread. Although the variance in world prices was reduced by somewhat more than one-half, the variance in domestic food prices predicted by the CGE was reduced by only 31.2 percent. Similarly, the experiment reduced the covariances between food prices and other prices and incomes. These reductions in the variance of domestic prices were not as great as the reduction in the variance of world prices because of the supply and demand responses of the model.

World-price stabilization policies change mean real incomes very little (see table 4). Producers gain a very small amount in expected real income, while consumers lose between 1 and 4 percent. But the effects on the variances of real incomes are quite marked. The variances of farmer incomes are reduced by about 40 percent, and urban groups have their income-variances cut by anywhere from 30 percent for service workers to 60 percent for organized labor and 56 percent for marginal workers. Nevertheless, the expected food-security of the economy, as viewed from the perspective of the malnourished, changes very little as a result of the price stabilization. Averaging over the shocks, there is virtually no change in the

expected food-deficit, or the expected percentage malnourished. The basic point is that, when the group means are close to subsistence, and one averages over the shocks, reducing the variance around the mean changes the probability of below-norm food intake very little.

Another way of viewing the effects of stabilizing prices would be to ask about the probability that a group's food-intake deficit is 25 percent greater than its mean value. For small farmers, for example, the price stabilization policy reduces the probability of such an extreme food shortfall from 7 to 2 percent. As a result, the small farmers are willing to pay about 4 percent of their income for the reduced variance in their food-intake (see table 5, which lists the equivalent variations for all the experiments and socioeconomic groups) even though their expected food-deficit is virtually unchanged.

Consumers benefit less than producers from the stabilization--a familiar result; they trade off small losses in mean income for substantial reductions in income variance. Indeed, marginal workers would actually have to be compensated for the existence of a stabilization program to the tune of .25 percent of their income. Other urban groups still feel somewhat better off: They would be willing to pay between .21 percent of their income (service workers) to 1.5 percent (industrial capitalists) for world-price stabilization. If the cost of the price stabilization program were to be passed on to the households in the form of increased taxes, it would amount to four-tenths of a percent of their incomes; everyone except for marginal and service-workers would be willing to pay this insurance cost.

Food-Import Insurance: The second policy we consider is a food-import-bill insurance program. In this program a foreign guarantor pays the Korean government 55 percent of the amount of foreign exchange by

which the food import bill exceeds its trend value at a cost of \$20 million in our experiments. This is a version of the International Monetary Fund (IMF) food facility. The current IMF program is based on an average of export receipts and food-import-bill variations, but it has been argued [Green and Kirkpatrick (1982)] that a pure food-import-bill insurance scheme would be superior to the existing program. The insurance policy paid off in 50 percent of our Monte Carlo replicates.

A policy of this sort has several problems. Since governments can most certainly influence the food-import bill by their agricultural policies and the foreign guarantor can only imperfectly estimate the country's expected insurance payments, the government has an incentive to increase its food-import bill. This moral hazard exists in all import-bill insurance schemes. Similarly, imperfect ability to rate risk will result in adverse selection of countries to participate in the program. Finally, on the national level, the program has the problem of not paying off precisely when the extra income would be most useful for averting starvation: a high food-import bill happens in our replicates much more frequently as an outcome of high national income and high demand than it does as a consequence of crop-failure. The first two problems are not captured in this model while the third is.

The experiments indicate that this is not a good policy due to the inverse correlation of insurance payouts with situations of low food consumption and due to the relatively high price of insurance were it to be charged at its fair actuarial value. Table 4 indicates that the food-import-bill insurance policy is dominated by the price stabilization policy for food producers: it generates a higher variance and a lower mean for them. It is not dominated for urban consumer groups since for them it has a slightly

higher mean and a much higher variance. However, the poor lose in expectation terms from food-import-bill insurance, as indicated by the fact (see table 5) that they would have to be compensated for participating in the scheme anywhere from .77 percent of their income for small farmers to .05 percent for marginal workers, even in the absence of increased taxes to pay for the insurance scheme. No wonder there are very few countries that make use of the IMF food-financing facility in practice!

Food Aid: The next experiment is a food-aid program, such as was available under PL 480. The policy was implemented in the model by increasing the net imports of food by 10 percent (or \$20 million) and simultaneously raising the foreign capital inflow by \$20 million. The net result is to give the country \$20 million worth of imports for free. This is a policy of direct appeal to farmers in developed countries, and one that has great intuitive appeal, but it is a food-security disaster. The total expected food-deficit is the highest of any policy, 3 percent higher than in the base. Food aid makes all farmers (both small farmers and other farmers) very much poorer. Agricultural prices fall about 3 percent. Agricultural terms of trade are about 11 percent lower and expected overall farmer incomes are 9 percent lower. The expected percent of small farmers that are malnourished is 4 percent higher than the base percentage, and they would require a compensation of about 2.5 percent of their income in order to be as well off in expectation terms as they were in the base. Overall food grain consumption in the economy does go up, but only by 1 percent. Urban workers other than marginal workers were better off than in the base since they have both a higher mean and a lower variance in incomes.

Grain Price Subsidies: Most developing-country governments that are concerned with poverty tend to subsidize the price of grain to

consumers, maintaining a dual-price policy. Korea instituted such a policy in 1972. We modeled this dual-price policy by fixing the consumption price of grain below its equilibrium price and placing a value-added tax rebate on grain. The value of the rebate was \$20 million. Price was fixed .8 percent below equilibrium, an amount calculated so that the sum of the effects of fixed price and tax rebate leaves farm income at nearly its level in the base policy and costs \$20 million. Since at least \$20 million worth of food is imported in all the random replicates,<sup>1</sup> this policy could be financed by a gift in food rather than money. Therefore, one can interpret this policy as food aid plus compensation to the farm sector. Scaling the policy to cost only \$20 million makes the variance reducing effects of the policy its most prominent part. Below, we will comment on a much more ambitious policy along these lines.

This experiment has two main macro effects. It raises the consumption of grains somewhat (by 1 percent) and it increases the domestic supply of grains through imports, even though the relative price in domestic currency of imported grain has risen substantially. The import-increase (of 11 percent) is required to satisfy the increase in domestic demand in the face of a virtually fixed domestic supply and is financed by decreasing other imports, through a devaluation (of 1.5 percent). There is no discernible change in GDP.

The program's effects on real incomes are slight; most groups experience a small decline in their incomes, ranging from .2 percent for industrial capitalists to 2.4 percent for service labor. But there is a very substantial decrease in the variance of all real incomes (the variance is cut by between a factor of 3.85 for agricultural proprietors to a factor of 2 for organized labor), except for marginal workers and agricultural capitalists,

who find their variance increased by 33 and 9 percent, respectively. The result is that, except for marginal workers, all groups benefit under this policy. The largest welfare increase is to small farmers and agricultural proprietors (by about 4 percent). In the urban sector, the poor benefit less than the rich not only in absolute terms but also in proportion to their incomes. Indeed, the poorest urban workers actually lose. This is ironic since these policies are usually instituted to benefit the urban poor. By contrast, in the rural sectors, the poorer farmers benefit proportionately more than agricultural capitalists. As a food security policy, the grain-price subsidy scheme accomplishes very little (see Table 3). The overall percent malnourished and the overall calorie deficit are virtually the same as in the base. There is some slight reshuffling of the incidence of poverty: small farmers and organized labor are a relatively smaller proportion of the malnourished population while marginal labor is a larger percentage.

The trivial scale of this two-price policy leads us to experiment with two-price policies of much larger scale. The experiment was to drop consumer prices to 95 percent of their value in the base and, as before, to use a value-added tax rebate to leave farmers with nearly their base real-mean incomes. The cost above the \$20 million of aid, \$173 million, was financed by a value-added tax on all nonfood sectors. Thus, comparing this experiment to the other experiments is an exercise in balanced budget rather than differential incidence. At this scale, a two-price policy leaves only 34.92 percent of the population malnourished, which is the best performance of any of the policies examined in this study.

Changes in Development Strategies: The last two food-security policies consist of changes in development strategy. They are modeled by reallocations of the economy's capital stock, induced changes in sectoral



productivities, and changes in the tariff structure. Unlike the stabilization and insurance policies, these trade and investment policies affect mean incomes as well as affecting variances.

In modeling these experiments, we always reallocated 6 percentage points of total investment away from the service sector. In the base, service-sector investment absorbed 70 percent of total investment and had the lowest rate of return. (Its rate of return was about 40 percent of that in agriculture, 46 percent of that in intermediate manufacturing, and a third of that in consumer-goods and machinery production.) As a result, any reallocation of investment away from services improves the total factor productivity of the economy and sets up the potential for large welfare gains. The different development strategies have larger distributional effects than do the food-security policies discussed earlier. They distribute the welfare gains and losses differently and represent different mean-variance trade-offs for different groups in the economy.

Agricultural Development: The first reallocation of the economy's capital stock represents an agricultural-development-led-industrialization strategy in which agricultural productivity is increased by increased investment in agriculture [ADLI, see Adelman (1984)]. The increase investment could take the form of increased infrastructure such as irrigation programs or land consolidation or terracing. A policy of rural development implemented by increased agricultural investment was followed by Korea between 1972 and 1978. In the experiment we reallocated 6 percentage points more of total investment to agriculture, bringing its share of total investment up to 13 percent; increased productivity in agriculture by 2.5 percent; and reduced all tariffs and subsidies in the economy by two-thirds. The extent of reduction in trade incentive

distortions was set by the requirement that the loss in tariff revenues plus the reduction in subsidy payments cost exactly \$20 million. This reduction in tariffs and subsidies brought trade incentives very close to neutral: the ratio of the effective protection rate on imports to the effective protection rate on exports dropped from 1.08 to 1.03.

We calculated the increase in agricultural productivity induced by the increase in investment in agriculture assumed for this experiment by fitting an agricultural production function to Korean data for 1962 to 1978. To estimate the productivity-enhancement effect of investment in the agricultural sector, it is necessary to disentangle the output-increase due to more capital from the productivity-enhancing effects of infrastructure investment. This requires fitting a production function of the form

$$X_{at} = A^{p(K_t)} K_t^{\alpha_1} M_t^{\alpha_2} L_t^{\alpha_3} G_t^{\alpha_4}$$

where

$X_{at}$  = gross agricultural output,

$A^{p(K_t)}$  = technical progress that is agricultural capital-stock related,

$K_t$  = agricultural capital stock,

$M_t$  = intermediate inputs, mostly fertilizer,

$L_t$  = agricultural labor,

$G_t$  = agricultural land,

and

$t$  = a time subscript.

It was impossible to estimate this production function econometrically because of multicollinearity problems between the two

forms in which capital enters the production function. Instead, we estimated a double log production function of the form

$$\begin{aligned} \log X_{at} = & -19.6 + .06 \log M_t + 3.52 \log L_t + .55 \log K_t \\ & (21.4) \quad (.07) \quad (4.15) \quad (.26) \\ & + .85 \log G_t; \quad R^2 = .87. \\ & (1.05) \end{aligned}$$

We then decomposed the coefficient of .55 on the capital stock into two components as follows: we set the output-increase due to more capital being used in production equal to the CGE-exponent of capital in the production function of the primary sector (.17) estimated from the share of capital in value added in the base year. We then attributed the difference between this CGE-exponent and .55 (i.e., .38) to the productivity-enhancement effect. Finally, to get the increase in productivity due to the agricultural-development program, we multiplied .38 by the percentage increase in agricultural capital stock due to the program (6.58 percent). This yielded the assumed productivity-increase of 2.5 percent.

Comparing the results of the agricultural-development strategy with the base, we find substantial differences in consumption, GNP and reductions in the percentage malnourished (tables 2 and 3). The strategy improves the domestic production of grain (by 5 percent). Farmers gain from the improvement in agricultural productivity (total real value added in agriculture rises by 4.8 percent); and the urban groups, especially the urban poor, gain as well. The expected mean income of marginal workers is about 12 percent higher, and the mean incomes of organized labor and service workers are 15 to 13 percent higher. This is a wage-goods strategy.

Furthermore, real wages rise by 5.5 percent, while the real rate of return on capital drops by 7 percent.

This policy achieves the most in terms of food-security of all policies considered. The food-security of the economy as a whole goes up the most--the percent malnourished in the overall economy decreases by 6 percent, the total food deficit is reduced by 10 percent, and both urban and rural groups experience an increase in their food security. The equivalent variation (see table 5) is about 5 percent for farmers, 8 percent for agricultural capitalists, 7 percent for urban service workers, 6 percent for organized labor, and 3 percent for industrial capitalists. Table 5 indicates that agricultural development is the preferred food-security policy for all urban groups, even organized labor, but that rural groups prefer export-led growth.

Export-Led Growth: The export-expansion strategy was modeled in an analogous fashion to agricultural development. For the export-promotion program, the investment shares in food-processing and in light consumer-goods were increased by 6 percentage points each, with corresponding reductions in the share of investment in services. Tariffs and subsidies were cut by two-thirds, at a fiscal cost of \$20 million, as in the agricultural development experiment. At the same time, the productivity of capital in these sectors was increased by 3 percent to simulate the effects of international competition on efficiency.

This increase in productivity was estimated from sectoral regression equations for Korea reported in Chenery, Robinson, and Syrquin (1986, p. 304) for 1960 to 1977. In these regressions, they decomposed sectoral total factor-productivity increases into productivity change due to import substitution and productivity change due to increases in the share of

sectoral output exported. We aggregated their sectors to correspond to our sectors by using shares in value added, looked at the increase in the share of output of consumer goods and processed foods exported under initial versions of the export-led growth experiment, and then multiplied the aggregated regression coefficients relating to export shares by the change in the share of exports occurring in our export-led growth experiment to obtain an initial estimate of the export-induced change in total factor productivity. We then looked at the change in the share of exports produced by the experiment to check whether the share assumed for the calculation and the share yielded by the experiment were the same and then repeated the procedure until the two numbers converged (only two iterations were required). This procedure yielded a rate of export-induced increase in total factor productivity of approximately 3 percent in both the processed food and light consumer goods sectors.

The export-promotion strategy is both a good growth-strategy and a good food-security strategy for the economy (tables 2, 3, and 4). But it is not as good on either count as agricultural development. In macroeconomic terms, export-led growth achieves less GDP growth and less investment than agricultural development. Real wages and real capital rental rates are both lower. Overall consumption is the same but food consumption is significantly less than with agricultural development, and food imports are substantially higher and food production smaller. The price level is the same, but food prices are very significantly higher. Export-led growth therefore also achieves less overall food security than does agricultural development. In terms of overall food security, agricultural development is a superior strategy since it reduces the expected food deficit for all groups

most and decreases the percent malnourished (by 3 percent) more than export-led growth.

Agricultural terms of trade are almost 10 percent higher with export-led growth than with agricultural development. Farmers therefore fare much better than do urban groups under this strategy; more of the incidence of malnutrition is shifted towards urban groups. Export-led growth has better mean-variance properties than agricultural development for farmers and both lower mean and lower variance for the urban poor. As a result, farmers would prefer export-led growth to agricultural development and urban groups would prefer agricultural development to export-led growth (table 5).

#### The Mean-Variance Frontier

Agents whose utility can be represented as a function of the mean and variance of their instantaneous utility will only select policies on the mean-variance frontier. The frontier is the set of policies that have maximal mean for given variance. Since the six policies and the base case affect different groups differently, there is no guarantee that any policy is mean-variance efficient for all the groups. In the case of the policies considered here, there appears to be a dichotomy between rural and urban groups as to which policies are mean-variance efficient.

The agricultural development policy is the most efficient high-mean, high-variance policy for all nonfarm households except industrial capitalists who prefer food aid. Agricultural development is thus the preferred high-risk choice for the overwhelming majority of the urban sector. The agricultural development policy is high risk because it increases the quantity of food that is subject to random shocks in food

production. The high-variance, high-mean policy preferred by rural groups is export-led growth. For farmers it leads to higher mean income and lower variance than does agricultural development. Agricultural terms of trade for farmers are 10 percent higher under export-led growth, which raises urban demand for grain without increasing domestic production. It has lower income-variance because there is smaller domestic grain-production that is subject to production shocks.

At the low end of the mean-variance frontier there are two candidate policies that are mean-variance efficient: the dual-price policy and world-price stabilization. Both policies achieve extremely low variances in above-subsistence incomes by reducing the variance in grain prices, either by operating on domestic grain-prices or on world-prices. The dual-price policy is the most efficient low-variance choice for farm households, for service sector workers, and for industrial capitalists. For other households deriving their incomes from manufacturing and for agricultural capitalists, world-price stabilization is the most efficient low-risk choice.

Moving to moderate-mean, moderate-variance policies, there is little consistency among different groups about efficient policies. There is, however, a general tendency to rely on world-market-oriented measures for mean-variance-efficient moderate-risk food-security programs. World-price stabilization is the efficient moderate-risk policy for the rural sector; workers in the service sector find both world-price stabilization and food-aid mean-variance efficient; organized labor would choose food-aid as mean-variance efficient for moderate degrees of risk aversion; marginal labor would select export-led growth; and moderately risk-averse agricultural capitalists would choose grain-price subsidies.

## Multipliers

To check the sensitivity of our results to the choice of program magnitude, we estimated program multipliers (table 6). To compute the multipliers, we increased the program magnitudes for each component (e.g., taxes, tariffs, foreign aid, etc.) of all the food-security experiments by 50 percent and reran the 100 replicates with the same random shock sample as for the \$20 million experiments. We reproduce results for the effects on the percent malnourished and the food deficit in table 6. For each food-security program and each group, the entries in the table indicate the percentage change from the \$20 million program induced by the 50 percent increase in the program.

The table indicates that at a larger scale grain price subsidy, agricultural development, and world-price stabilization would all become relatively more attractive policies, while export-led growth would become significantly worse.

## 4. Conclusions

How efficient are the food-security policies analyzed? An unrealistic but idealized standard of comparison would be how much calorie-deficit reduction could be accomplished with a "frictionless" \$20 million program. Visualize a program in which \$20 million is spent to increase the calorie-availability of the poorest third of the population; and assume that the program is perfectly targeted, costlessly implemented, and has no indirect effects on prices or quantities. Such a program would represent a 3 percent increase in the availability of processed and unprocessed food to the poor and would cut the average daily calorie-deficit of the malnourished by between one fourth and one eighth, depending on the group. None of the



Table 6  
Impact multipliers

	World price stabilization	Food import insurance	Food aid	Grain price subsidy	Agricultural development	Export-led growth
<u>Percentage change in percent malnourished</u>						
Small farmers	-0.23	0.08	0.33	-0.26	-0.41	0.17
Marginal laborers	0.36	-0.13	-0.03	-0.35	0.28	0.17
Organized labor	0.00	-0.78	-1.15	-1.78	1.94	3.4
Service workers	0.21	-1.04	-0.02	-1.14	-1.14	3.4
Total population	-0.10	-0.13	0.09	-0.67	-0.23	0.76
<u>Percentage change in calorie deficit</u>						
Total	-0.40	-0.13	-0.03	-0.47	-0.24	0.75

Source: Computed as the percent change from the policies costing \$20 million to those costing \$30 million.

food-security programs modeled accomplish nearly as much. The most effective food-deficit reduction programs cut the average calorie deficit by only 3 percent--12 percent of the "frictionless" program. Actual programs thus have substantial leakages to the nonpoor, significant indirect effects mostly through prices, and large implementation costs. These combine to greatly reduce the expected effectiveness of all food-security programs relative to this, unrealizable, ideal program.

To maintain comparability among programs, we calibrated all programs to a \$20 million cost and examined their food-security effects one year after implementation. The programs are feasible, but moderate in size. However, our multiplier calculations indicate that a 50 percent increase in the cost of the programs does not generate a dramatic change in effectiveness.

Among the food-security programs we examined, we found that the best food-security policies are those that are implementable at the national level. The international policies considered in our experiments--grain-price stabilization, food-import insurance, and food aid--achieve less in terms of food-security than do the national policies and strategies. Price stabilization of grains is useful in reducing the incidence of catastrophic outcomes and many groups would be willing to pay for this policy, but it has virtually no effect on decreasing the percentage of malnourished or the food deficit on the average. The other international food-security policies impoverish domestic farmers and reduce their production incentives. In addition, IMF-type food-import-bill insurance schemes have perverse effects, paying off in periods of national prosperity and not paying off in periods of crop failure. Finally, in the absence of measures to counteract

the adverse effects of food-aid on the incomes of farmers, food-aid is an overall food-security disaster, though it does help a few urban groups.

Agricultural development and export-led growth are the most effective approaches to reductions in expected malnutrition. In our simulations, agricultural development dominates export-led growth as a food-security strategy. Both strategies generate growth in GNP relative to the base, though agricultural development generates higher GNP-growth. Both strategies generate substantially higher mean incomes and higher income variances than the base. And both strategies diffuse income growth in their sector to producers in the complementary sector. But agricultural development leads to the lowest percent malnourished. Furthermore, agricultural development increases food consumption and releases foreign exchange for the import of machinery and intermediate inputs so that it helps the export-drive of the manufacturing sector. By contrast, export-led growth induces an increase in the price of grains, a decrease in overall grain consumption and an increase in net imports of grain.

Our simulations indicate that the choice among food-security measures is sensitive to the risk-aversion of the population or of its government. Agricultural development is the preferred high-risk choice of the overwhelming majority of the urban population, and export-led growth is the preferred rural strategy, while price-stabilization policies (national or international) are the preferred low-risk choices. International measures come into their own only as moderate-risk, moderate-income programs, but they achieve very little decrease in average expected malnutrition.

Also, group preferences among policies differ among groups. The dichotomy among net food sellers and net food buyers tends to run across

our results, though it is not as simple as all that since the policies have both direct and indirect effects on prices and incomes.

How general are the conclusions of our simulations? The results of the simulations were generated by considering how international and agricultural production shocks affect a model economy. They, therefore, reflect the economy's exposure to shock and the institutional rules of the game portrayed in the model. Less open economies, or oil or primary-exporting economies, will face different shock-covariance matrices. Similarly, rigidities in factor or commodity markets will accentuate income-shocks and transmit them through either enhanced price or quantity-fluctuations. Our experiments, which assumed a flexibly adjusting economy, thus overstate the mitigating effects that substitution would have upon adjustment to shock in an economy with greater rigidities. The covariance of internal prices with international price or demand-fluctuations will be greater in a more rigid economy. Stabilization policies may then accomplish more in terms of food-security. Furthermore, the fixed, or less flexibly adjusting, factors will bear a larger fraction of the adjustment cost and experience greater variances in incomes. Differences in program-incidence may be magnified. In our experiments, we allowed only marginal workers to migrate between rural and urban occupations and did not allow for compensating changes in urban-rural remittances. These would tend to reduce, though not eliminate, the dichotomy between how different food-security programs affect rural and urban groups in the short run. In addition, our model was a flexible-wage model. A fixed-wage economy would allocate the incidence of an external shock differently among wage earners and capitalists in a given sector and would change the distribution of income among workers

(the employed versus the unemployed) in response to shocks but would have very little effect on the urban-rural allocation of malnutrition and on the overall extent of malnutrition [Adelman and Robinson (1988)]. Our economy had no sharecropping and no tenancy, only owner-operators with different plot sizes and different degrees of reliance on hired labor. Shocks, therefore, tended to affect all farm operators in the same way. In economies with more varied tenancy structures, there would be greater differences in the impact of shocks on different types of farmers. The risk-sharing properties of different farming systems would be different.

Before drawing definitive conclusions, it would, therefore, be desirable to experiment with alternative institutional specifications and redo the food-security simulations for different types of economies. We, nevertheless, believe that the group-specific results of our simulations, which describe how different individual groups are affected by individual programs, are probably qualitatively generalizable. We suspect that for most poor, food-deficit economies, the relative ranking of food-security policies for individual groups would not differ much from ours. We therefore think that our results offer a qualitatively good basis for extrapolating to economies with different compositions of poverty, different relative income levels, and different exposures to shocks by appropriate reaggregation.

In particular, we believe that the relative ranking of national versus international food-security policies and of income-stabilization versus mean-income-growth food-security policies are quite robust since the reasons for effectiveness or ineffectiveness of most programs are rather fundamental. Thus, import-bill-stabilization fails because it provides ineffective insurance to any country--large or small, open or closed, rigid or

flexible--that can and will use increased income to purchase food. Price-stabilization does not reduce malnutrition much in other studies [Reutlinger (1976)] geared to less open economies. More fundamentally, stabilization policies achieve a higher probability of being close to the mean in food intake; if that intake is inadequate, they are a prescription for malnutrition with increased certainty. These conclusions are unlikely to depend much on the type of country or model. On the other hand, for a two-price system or for food-aid, it matters a great deal what the tenancy arrangements are. Because Korea was a land of small owner-operators, it was possible to run a two-price system that neutralized some of the losses to the potentially malnourished small farmers. For much the same reason, uncompensated food-aid hurt this group of poor and hence increased food-insecurity. Developing nations with very different tenancy arrangements could expect different food-security results from such policies, but our experiment may well be the best case for both of these policies. Finally, the major result of our simulation experiments--that development strategies that raise the rates of growth of the incomes of the poor constitute the most effective approach to reducing malnutrition in the long run--is extremely unlikely to be affected by model-specification or exposure to shock.

But how robust is the relative ranking of agricultural vs. export-led growth as food-security strategies? We must ask this question since export-led growth, though dominated in our experiments by agricultural development for the majority of the population which is urban, was a close second-best policy to agricultural development. Clearly, the relative ranking of the two strategies must depend on their relative potential for raising the incomes of the poor and on their relative riskiness. Among newly industrializing countries, the potential for industrial development is

more uniform than the potential for agricultural development. The inherent short-run potential of agriculture for productivity improvement and the riskiness of agriculture is likely to vary significantly among countries with different topographies and land-densities, degrees of institutional responsiveness to market incentives in agriculture, size distributions of landholdings, and levels of rural education. Furthermore, successful agricultural development requires maintaining a delicate balance among: the growth of productivity of the agricultural sector; the composition of output of the agricultural sector, especially as between food-grains and feed-grains; and the growth in urban incomes, and hence level and composition of demand for food of the nonagricultural sector. Agricultural development can fail as a food-security strategy in the medium run, if the growth of agricultural productivity is too fast relative to the rates of growth of the nonagricultural sectors plus either agricultural import-replacement or agricultural exports. On the other hand, if agricultural development is too slow, it can pose a major bottleneck for industrial development. What matters for the success of both the industrial and the agricultural food-security strategies is the balance between the growth of the two sectors in the medium run.

In the medium run, it is possible to improve agricultural productivity faster than the growth in urban demand plus net import-replacement. This did not happen in our experiment with agricultural development because of the way the productivity estimates came out and because of the large share of agricultural imports in the base year. In our experiments, the rate of growth of productivity of agriculture in the agricultural development experiment was slower than the rate of growth of industrial productivity, but applied to a much larger base.

The relationships we estimated are, however, not limited to Korea alone. De Janvry and Sadoulet (1986) provide general evidence concerning the changing relationships between agricultural growth, growth in overall GNP, and international trade in less-developed countries. Their estimates suggest that countries start with low growth in agriculture, relying on agricultural exports for both industrialization and GNP growth. They then start industrializing, and they neglect and tax agriculture. The result is that the slow growth in agricultural output becomes a binding constraint on industrial growth. At this point, most newly industrializing developing countries start engaging in serious efforts to improve agricultural productivity. They then first go through an import-substitution phase (the Korea of our experiment) and, if they continue the agricultural strategy, they next move to a second agricultural-export phase (e.g., Indonesia). Then, with continued urban-income growth, there is a shift in the composition of demand towards animal proteins. This, in turn, entails a vastly enhanced demand for feed-grains and increased pressures for improvement in the productivity of the agricultural sector. At this point, countries again turn to importing either feed-grains or food-grains or both (e.g., Mexico). So, in the long run, there can't be too much improvement in agricultural productivity if cropping patterns are flexible, and there is worldwide evidence that they are.

In sum, the case for agricultural development as a preferred food-security strategy appears strong, especially for the newly industrializing countries and the least-developed countries. But it is not likely to be universal. What is likely to be universal is that the primary hope for a poor food-deficit country to achieve food-security is to grow out of it through development strategies that raise the rates of growth of the incomes of the



poor. Other food-security measures should be viewed as stop-gap measures, worth implementing only till the right type of growth takes hold.

### Footnotes

<sup>1</sup>Hall (1980) argues Brazil financed its two-price policy with subsidized grain from the U. S. PL 480 program, a very similar policy to the one discussed here.

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