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Food Security

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FOOD SECURITY: A MEAN VARIANCE APPROACH

by

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I. Introduction

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 shall accept the definition of food security offered by Reutlinger (1980)--that it represents a condition in which the probability of falling below an acceptably defined minimal target food consumption is quite low. But, while Reutlinger applies this definition on a per capita basis differentiating only consumers from producers, we shall apply it on a per-household basis differentiated by the socioeconomic class of each household. Thus, we shall take account of distributional effects within countries.

Aside from the conceptual problems inherent in defining minimal nutritional standards common to all food-security analyses, our approach requires evaluating the probability of below-subsistence food consumption for various population groups 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 the variance of food consumption. By Tchebychev's inequality, increasing the mean food consumption or reducing its variance will decrease the probability of below-subsistence food intake.

The major current policy proposals for attaining food security are: (1) the accumulation of buffer stocks aimed at stabilizing the world price of wheat [Reutlinger (1976); Cochrane and Danin (1976)]; (2) the accumulation of stocks aimed at ensuring supply availability [Bailey et al. (1974); Eaton et al. (1976)]; (3) an international insurance scheme to cover higher-than-trend food import bills [Johnson (1976); Konandreas et al. (1978)]; and (4) self-sufficiency in food [Frances Moore Lappe, (1978)].

With rare exceptions, the empirical evaluations of these policy proposals are carried out for an average country, without explicit recognition of the fact that policy proposals formulated to address food security problems do not affect all developing countries in the same manner. A price stabilization or buffer stock scheme will obviously affect net importing countries differently from the way it affects net exporting countries. Also, the effects of variance-reducing policies will impinge differently on countries whose mean per capita food supply is below subsistence from their effects on countries whose average per capita food supply in an average year is above subsistence but whose variability drives it below subsistence a significant portion of the time. Food-supply variance-reducing policies in countries whose average supply is inadequate will merely ensure that the population starves with a higher probability than it does at present. And a policy of increasing the mean foreign exchange earnings or of reducing their variability may well dominate food-variance reducing or mean-food-supply increasing policies for either type of country.

The complexities of formulating good food security policies become even greater when one recognizes that the food security of a country (defined as a low probability of average per capita food supply falling below a nutrition-

ally adequate target) is not synonymous with the food security of its people (defined as a low probability of vulnerable groups' per capita consumption falling below a nutritionally adequate target amount). As with countries, any given food security measure is likely to affect net suppliers of food differently from its effect on net demanders of food. In addition, policies designed to increase the mean or reduce the variability of national food supplies will not necessarily increase the ability of the poor to partake in that supply. Indeed, some policies may well reduce their incomes enough so that their food intake actually goes down.

The workings of the domestic economy translate food security measures undertaken at the national or international level into domestic group incomes and domestic prices. And, for some groups of poor, the means and variances of group real incomes--which determine their food security--may be either totally uncorrelated or negatively correlated with the corresponding country averages. What is therefore required for proper evaluation of food security proposals is an analysis which traces the effects of food security policies, as mediated by the interaction of the demand and supply responses within the economy, upon the incomes of the various groups in society and upon the prices of the commodities they consume. This paper implements such a model for a poor, chronic food-deficiency 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 their effects on the prices consumers face, not their incomes; (2) in 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 trans-

late the shocks in international prices and domestic production into the food consumptions and real incomes of consumers; and (4) we disaggregate consumers into income levels and into net suppliers or demanders of food. (Clearly, the income and welfare consequences of high food prices and, hence, of food security policies impinge quite differently on these different types of consuming households).

The next section describes the methodology of our study. Section 3 presents the results of simulated food security policies for the South Korea of 1963.

The Korea of 1963 was the pretake-off Korea. It was a very poor country, whose per-capita income was around $80 1963 dollars, converted at the official (overvalued) exchange rate. It was an open economy with a very large trade deficit; exports were 6 percent of GDP and the trade deficit accounted for 16 percent of GDP. About half of its labor force was employed in agriculture, 30 percent in manufacturing, and the rest in services. It was a consistent food-deficit country; its cereal imports accounted for about a quarter of its total consumption. Thus, the Korea of our study is very typical of nations with severe food-security problems--a poor, open, negative balance of trade, large-food-deficit country.

II. The Methodology

Agricultural output, internal and international terms of trade, oil prices, and the world price of food are all subject to seemingly random changes. Shocks to international markets or agricultural production arising from these sources affect consumers through their effects on consumer incomes and consumption prices. We describe these shocks to a national economy in terms of a multivariate normal 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, a welfare measure for each consumer group is computed from the distribution of incomes and prices. This measure depends upon the mean and variance of their real incomes.

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 method for evaluating food security and welfare from the probability distribution of incomes and prices.

The Shocks

In the model, we analyze shocks to food security arising from four different sources: variations in domestic production of cereals due to such factors as weather; changes in international price of cereal imports; changes in the prices of domestic exports, which affect the ability of the economy to import food; changes in energy prices, which affect the capacity of the economy to import food and the price of fertilizer. To set realistic magnitudes for the shocks and to accurately portray their interdependence, we calculate the variance-covariance matrix of the four different types of shocks using historical data from 1960-1980. Before calculating the variance-covariance matrix, the raw time series were first detrended by fitting second-order autocorrelated regressions.

The covariance matrix of the shocks is displayed in Table 1. The largest coefficient of variation is that of world grains prices, which is

approximately one sixth; the smallest is that of export prices, which is about one twentyfifth. There are three large off diagonal elements. There is an R^2 of +.78 between the price of petroleum and the price of Korean exports, reflecting a tendency for offsetting influences on the balance of payments, and an R^2 of -.28 between the world price of grain and domestic food production, again reflecting an offsetting influence. There is also an R^2 of +.24 between agricultural production and export prices, leading to cyclically reinforcing effects upon domestic incomes.

We then calculate the frequency distribution of the multivariate normal distribution which corresponds to the variance-covariance matrix of the shocks and has a mean of unity. The normalization rule for the shocks to a mean price of unity corresponds to that of the CGE model, in which base year prices are one. With the aid of a random number generator, we then chose 23 points from that distribution--that is 23 four-tuples of oil prices, agricultural production, export prices, and food prices. These 23 points are our representation of the likely distribution of shocks facing the Korean economy.

In addition to the likely shocks generated by the multivariate normal, we added several shocks of a disastrous nature which are individually quite unlikely (more than two standard deviations away from the mean) and whose combination is extremely improbable. These shocks were added to our experiments to reflect the extreme crisis situations which food security measures are designed to respond to. The extreme shocks were: a thirty percent increase in the world price of grain; a forty percent increase in the price of oil; a thirty percent decrease in the price of exports; and a twenty percent decrease in agricultural production. Combinations of three and four of these shocks were also added to the shocks generated by the multivariate

normal distribution. These six extreme shocks plus the 23 shocks generated by the multivarate normal comprise the 29 shocks we subjected the model economy to.

Mapping the External Shocks into Domestic Income and Price Variations

These 29 four-tuples of shocks were then applied to a CGE model, which was used to translate these shocks into the means and variances of the group incomes and of the consumer-goods prices which these groups faced. This model is well suited to the analysis of food security issues since it allows us to translate 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, domestic food production, and the incomes of farmers but also the real incomes of all consumers and their food consumptions. It also changes the balance of payments, the exchange rate and, therefore, other imports and exports. This chain links international food security policies to each class's food consumption. The model, therefore, enables us to trace through precisely how these policies affect the nutritional status of the poor. By contrast, most other 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 purchasing power of the poor and, hence, the ability of the poor to partake of the national supply of food.

The CGE model 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 et al. (1982)]. At the core of the model, we have the reconciliation

of potential demand and supply imbalances in the factor and commodity markets by price adjustments which simulate the workings of the markets for labor, commodities, and foreign exchange. The technological and behavioral functions in the model are nonlinear and incorporate substitution possibilities among factors in production and among commodities in final demand. Imports and domestic production in a given sector are not considered to be either perfect substitutes for each other or complete complements; rather, there is an elasticity of substitution among them which lies between zero and unity. 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, GNP, and balance-of-payments accounts as well as the functional and personal distributions of income.

Production technology is represented by fixed input-output coefficients for intermediate goods and CES functions for labor and capital. In the factor markets, labor demand arises from 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. 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 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. 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 it is forced to adjust directly to the enlarged or diminished supply of domestic plus foreign savings.

This CGE model was run 29 times, one for each of the previously computed combinations of shocks. The factor incomes for each group and the prices of consumption goods were saved and their means and variance-covariance matrix computed. These were then used to determine the welfare and degree of food security enjoyed by each group.

Evaluating Group Food Security and Group Welfare

Calculating the degree of food security of each group requires a stochastic version of consumer choice theory. The natural generalization from deterministic to stochastic choice would be to express ex ante utility as the expected value of the consumer's indirect utility. But this expected value function is often hard to evaluate because the computation requires that the indirect utility function be known exactly, not just up to a monotonic transformation. Instead, we use a mean-variance approach that does not depend on the cardinal character of the instantaneous indirect utility function. The justification for such a procedure is much the same as the justification for

the use of mean-variance functions in finance. One can either view the agent as actually maximizing a function of the mean and variance of income or view the mean-variance function as an approximation to the actual choice criterion. In the latter case, Markowitz and Levy (1979) have shown that the mean-variance criterion approximates quite closely the utility functions used in finance. In either event, computing mean-variance frontiers frees the analyst from the need to specify explicitly preferences over states of nature.

We assume that, for each group of agents, there exists an ordinal ex post utility function that represents its preferences among consumption goods after prices and incomes are known. Each of these agents maximizes this function subject to a budget constraint. Let w be the wage rate, t be the tax rate, L be the consumer's fixed supply of labor, T be transfers, p be the prices of consumption goods, A_i be the profits of the ith firm, and R_{im} be the share of the ith firm owned by the mth consumer group. Then, disposable income for a consumer in group m is, y_m. Suppressing the inessential subscript, m gives:

$$y = T + (wL + \Sigma_i R_{im} A_i) (1-t)$$

The consumer's problem after prices and incomes are known is to maximize utility as a function of consumer goods and savings subject to the constraint of not spending more than his disposable income. The solution to this problem is the indirect utility function, $V(y,p)$.

Since ex ante wages, profits, and prices are stochastic, so is the ex ante indirect utility function. Its mean and variance can be approximated by the

usual econometric technique (Thiel). The mean is approximately the value at mean wages, prices and profits and the variance is approximately

$$\text{grad}(V)\ \text{var}(p, w, A_i)\ \text{grad}(V)',$$

where grad is the gradient operator and var is the variance-covariance operator. Since profits (A_i) are themselves a function of prices, wages, and a stochastic term (u) which represents weather and the like, the above formulas can be written entirely in terms of p, w, and u. For the mean, simple substitution gives:

$$E\ V(y,p) \simeq V([T + (EwL + \Sigma_i\ R_{im}\ A_i(Eu,Ew,Ep))\ (1-t)],\ Ep)$$

For the variance, prices appear in V in two ways, once through profits and the other time directly as consumption prices. Similarly, wages appear twice and the exogenous shocks, only once. Calculating grad V, and subsituting into the variance approximation gives:

$$\text{var}(V) \simeq$$

$$D_yV \begin{bmatrix} \Sigma_i\ D_uA_iR_{im}(1-t) \\ (L - \Sigma_iR_{im}L^d)(1-t) \\ (1-t)\ S_i - X_i \end{bmatrix} \text{var}(u,w,p) \begin{bmatrix} \Sigma_i\ D_uA_iR_{im}(1-t) \\ (L - \Sigma_iR_{im}L^d)(1-t) \\ (1-t)\ S_i - X_i \end{bmatrix} D_yV$$

In the above equation we have made use of the fact that the derivative of the profit function with respect to prices is supply, S, (Hotelling's Lemma), and the derivative of the indirect utility function with respect to a prices is the negative of the marginal utility of income times demand, X, (Roy's identity). This aproximation of variance is notable for its dependence on the marginal utility of income only as a scale parameter and for depending on only easily observable variables.

The variance approximation shows that the variance of real income depends critically upon the agent's net supply of goods. A subsistence farmer is an agent producing slightly more food than he consumes. Thus, the variance in the price of food affects him only slightly. In contrast an agricultural capitalist produces far more food than he consumes and is much more sensitive to variance in agricultural prices.

The variance approximation also illuminates the role of covariances of internal shocks. For example, if a laborer spends all (or nearly all) his money on food and increases in the price of food are almost perfectly correllated with wage increases (as would be true in a general inflation) then, taxes aside, real income would have almost no variance. Less extreme examples of these covariances making a difference occur in our study.

III. Food Security Policies.

The policies selected for evaluation in this section include a price stablilizing policy, a food import bill insurance scheme, a food self-sufficiency policy and two standard development strategies--import

substitution and export expansion. For each of these policies we compute the likelihood of below subsistence food intake for each of four representative population groups. These probabilities are computed for the average member of each group. Of course, the distribution of incomes within groups, which we have ignored, increases the population below subsistence, but the changes in the mean incomes and variances of incomes remain a valid indicator of the food security effects of these policies. For the six policies considered, we have tabled the macro variables such as gross domestic product, consumption, and agricultural terms of trade in Table 2.

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 pre-set 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 operating revenues) of the buffer stock. In a very different model, Reutlinger (1980) performed a similar experiment. He found that a reduction in consumption variance of about 50% cost thirty-two 1980 U.S. cents per capita. This cost-of-stabilization result forms the basis for evaluating a world price stabilization scheme's effect on Korea. As will become clear below, the stabilization of import prices is so beneficial that costs could be three or more times the costs we roughly infer from Reutlinger's experiments without changing our results.

The costs to Korea in 1963 would have been 72 won per household. This cost is arrived at by deflating the cost of storage by the change in the price of grain from 1980 to 1968 and using the 1963 exchange rate to arrive at a cost for 1963 in 1968 Korean prices. The benefits are those flowing from a halving of the variance of the prices facing Korea.

This stock policy is modelled by (1) removing from the data set the Monte-Carlo replicates with the greatest deviations of world food prices from their mean and then (2) computing the CGE-predicted variance-covariance matrix of income and prices from the remaining replicates. Just enough extreme values were removed from the data set so that the variance of world food prices of the remaining replicates was half of its previous value. Although the variance in world prices was reduced by half, the variance in domestic food prices predicted by the CGE was only reduced by one third. Similarly, the experiment reduced the covariances between food prices and other prices and incomes. These reductions in 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 of this type change mean real incomes and macro variables (See table 2.) quite little. The largest changes in mean real income is for organized laborers, who gain about one per cent from this policy, and for subsistence farmers who lose about one per cent of real income. For all other groups mean real incomes remain about the same. The effects on the variance of real income, however, are quite marked. All groups have their variance in real income reduced. Table 3. gives, for each group, the mean and variance of real income for the six policies considered. The second row of that table gives the values for the price stabilization experiment. As a result of price stabilization, the food security of the economy increases somewhat: The probability of falling below subsistence food consumption is reduced from 11% in the base run to 9% for 1.5 million households (the marginal and the service workers).[1]

The second policy we consider is a food import bill insurance program. In this program a foreign guarantor pays the Korean government the amount of foreign exchange by which the food import bill exceeds 110% of trend. The payment is used by the government to finance a subsidy on domestic food prices in the same years as it receives the payments. The guarantor finances the insurance policy by charging the Korean government the fair actuarial value of the payments. In turn, the government finances the policy by levying a per-household tax. The insurance policy paid off in 40% of the Monte Carlo replicates with an average payment of 1.3 billion won, or 4% of the import bill. In most cases the payment was quite small, but in one case the payment reached 14 billion won, 45% of that year's import bill. The household's cost of this insurance was 260 won per year.

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. On the national level, the program has the problem of not paying off precisely when the extra income will be useful for averting starvation. A high food import bill in our replicates happens much more frequently as an outcome of high national income and demand than it does as a consequence of crop failure. The first two problems are not captured in this model while the third is.

A result of the imperfect correlation of payoffs and needs and of the relatively high price of the insurance is that the food import bill insurance policy reduces the mean income of all groups more than the price stablilization policy does and it reduces their variance by less. Thus it is inefficient. A more detailed look at the effects of the policy shows that when payments are made, the total food consumption increases, but not for all groups. The subsistence farmers and agricultural capitalists are the major beneficiaries of the government subsidy of food prices, and little of the subsidy is seen by the urban poor. But it is infrequent that the subsidy exceeds the per household costs, and the net result is that the insurance decreases the mean income of all groups. The third row of Table 3. gives the means and variances of this policy for various groups.

The last three food security policies consist of reallocations of the economy's capital stock and of changes in the tariff structure. Unlike the stabilization and insurance policies, these trade and investment policies strongly affect mean incomes as well as affecting variances. As a result, they have larger distributional effects than do the food security policies discussed earlier, and represent different mean variance tradeoffs for different groups in the economy. Thus these policies tend to increase food security for some groups while decreasing it for others.

The first reallocation of the economy's capital stock represents a food self sufficiency strategy. We increase the effective capital stock in agriculture by 10% of the economy's total capital stock and decrease all other capital stocks proportionately so as to maintain the economy's total capital stock unchanged. Such an increase in agricultural capital stock could represent land enhancing investments like irrigation programs or land

terracing. As might be expected the effects of this investment are to increase agricultural production (by 20%), and consumption (by 23%) and to decrease agricultural imports (by 33%). Despite the increase in total consumption and decline in imports, the agricultural commodity terms of trade decline by thirty percent. As a consequence, the incomes of small farmers declines to a mean value less than subsistence. Large farmers lose as well, but, since they are able to increase production proportionately more than small farmers, their incomes are reduced by only 19% as compared to a loss of 28% for small farmers. All worker groups benefit from this policy. The increase in mean utility ranges from 1% for organized labor to 225% for service workers. Industrial capitalists lose as well from the food self-sufficiency strategy, since their capital stock was cut and the consequent rise in the price of their output induces substitution in consumption towards both food and services. Capitalists in service industries consequently benefit; their income rises by 60%. The policy of investment in agriculture increases the income variance of all groups-- a paradoxical result for a policy that, by decreasing dependence on food imports, is supposed to reduce exposure to shocks arising from the world economy. The explanation for the increased variance is that the net imports of goods other than food increase to almost exactly offset the reduction in food imports, leaving the economy as open as before the shift, but subject to the vagaries of the prices of other goods rather than food. The likely number of households that will fall below their subsistence requirements under this policy with certainty is 2.5 million (all small farmers--see Table 4.), as compared to a 11% probability of falling below subsistence for 1.5 million households (marginal and service labor)in the base run. Although this policy is actually mean variance efficient for some groups, it is a food security disaster.

The import substitution and export expansion strategies were modelled in an analogous fashion. For the export promotion program, the capital stock in food processing and in light consumer goods (the labor intensive export industries) was increased by 10% of the economy's total capital stock with corresponding reductions in the capital stocks of the other sectors. At the same time, export subsidies of 20% (a modest value by international standards) were granted these sectors. For the import substitution program, the capital stock increase was allocated to the intermediate goods and capital goods producing sectors while contracting the remaining sectors, and the favored sectors were granted tarriff protection of 20% (an equally modest value by international standards).

At the macroeconomic level, the import substitution strategy looks better than the export expansion one: GDP and investment are somewhat higher while consumption is the same and the balance of payments deficit is 10% lower. Food production and consumption are very slightly higher with the export oriented strategy and food imports are slightly lower. But all these differences are of the order of only one or two percent. The major differences in the strategies are distributional. Subsistence farmers and agricultural capitalists are considerably better off under the export expansion strategy, in both mean and variance terms. The labor intensive export strategy raises the agricultural terms of trade by ten percentage points above their value in the import substitution strategy, by shifting income to groups such as farmers and urban workers with a high marginal propensity to consume agricultural out put. Industrial capitalists and service workers, on the other hand, do better under the import substitution strategy. The overall implications for food security of the population are that the export promotion program greatly

lowers the probability of falling below subsistence for half of the households in the economy while increasing it marginally for only .2% of the population.

The Mean Variance Frontier

Agents whose utility can be represented as a function of the mean and variance of their instantaneous (or state of nature) felicity, will, of their own choosing only select policies on the frontier of mean and variance of felicity. Points on the frontier represent the minimum variance for given mean felicity. Since the six policies affect the groups differently, there are six different frontiers and no guarantees that any policy is efficient for all groups.

The frontier provides an efficiency criterion for eliminating policies and the raw data for evaluating the welfare of agents at different points. It also provides enough information to compute the probabilities of falling below subsistence by means of Tchebychev's inequality (and an assumption of symmetry) or of a normal distribution. The instanteous utility indicator of the agents is an LES utility function with the "subsistence bundle" set as a true subsistence bundle. Thus instanteous utility is income less the cost of the subsistence bundle all times a function of prices. The probability of instaneous utility being zero or less is exactly the probability of not being able to purchase the subsistence bundle. We compute for the means of each group the number of standard deviations from zero under each policy and use Tchebychev's inequality and the normal distribution to find the likelihood of that occurrence or worse. The results are reported in Table 4. Below we discuss the table in terms of the worst case, which is, of course, Tchebychev.[2]

For subsistence farmers, all policies other than insurance are efficient. In order of increasing mean and variance they are: agricultural

expansion, stabilization, the base, import substitution, and export expansion. The policy with the greatest degree of food security is export expansion, which is also the policy with second smallest variance and greatest mean income. Price stabilization, which reduces variance in income drastically changes the probability of starvation by 30%, a laudable accomplishment, but still leaves farmers with a 2% chance of not being able to retain or purchase enough food for subsistence. Thus reducing the probability of a severe food crisis for small farmers is best accomplished by policies that raise their incomes, even at the expense of some increase in variance.

Only investment in agriculture and price stabilization are efficient from the point of view of organized labor. Unless their tradeoff between mean income and variance is quite extreme, they would almost certainly consider price stabilization to be their preferred policy. With this policy, they have an 1% chance of not purchasing a subsistence bundle.

Industrial capitalists find the base and stabilization schemes to be on their frontier. With a stabilization scheme in effect, not purchasing the subsistence bundle is very unlikely for these capitalists. Policies like export expansion, whose effects we have explained above, make even these capitalists have a nonzero probability of having insufficient income for subsistence.

Service workers are the poorest of the urban poor, only slightly better off than subsistence farmers on average, but experiencing a far higher variance in felicity. All policies but the insurance policy are efficient for them. Under all these policies they have appreciable probabilities of falling below subsistence, the lowest probabilities being with agricultural expansion (4%) and export expansion (13%).

The noncoincidence of these frontiers leaves little room for food security arangements that are Pareto improvements. Only the stabilization program makes all groups more food secure. Even that program increases the food security of most groups at a cost in terms of mean income. Although that cost is quite low, it means that if the groups marginal rate of substitution of mean for variance is high, the group will be made worse off by the change. This latter result seems unlikely. The stablilization program still leaves the urban and rural poor subject to appreciable probabilities of being in food shortage. Policies that further reduce the probability of one of these groups being in food deficit, increase the others' probability. Thus the concept of "national food security" is subject to the same problem faced by other measures of welfare. Commensurability of individuals is required, or as Samuelson said of Marshall,: "in consumers' surplus the aposthrophe is always after the s."

When the goal of policy is purely to minimize the expected number of people in food deficit, the optimal policy is export expansion. This strategy decreases the expected number of people in food deficit from over one-half million to under 50,000. As a result, the export expansion strategy is the best food security strategy of all.

IV. CONCLUSIONS.

Our experiments with the Korea model suggest that the food security of a country is enhanced most by policies which raise the mean incomes of the poor. Variance reducing policies, at the international level, help somewhat, but not nearly as much as do basic needs oriented development strategies which increase the purchasing power of the poor. The variance reducing policies are a Pareto improvement over the base policy, because they reduce the variance in all groups incomes leaving the means almost unchanged. The cost benefit ratio of variance reducing policies is less than one and they should be pursued. But, by themselves, variance reducing policies are unlikely to make much of a contribution to solving the problems of world hunger.

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Footnotes:

1. The food security numbers reported for this and subsequent experiments asusme that the food security of each group is synonymous with the food security of its mean income member.

2. Choosing policies based upon their probabilities of disaster is an example of a safety first rule. Turnovsky provides a good review of such rules and Berck discusses the use of Tchebychev inequalities in such rules when the distribution is allowed to be assymetric. Here we have assumed symmetry and computed the probability $1/(2\sigma^2)$.

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Table 1.
Variance Covariance Matrix of External Shocks

	pet. price	grain price	export price	food prod.
petroleum prices	.261	-.306	.016	.404
world grain prices		7.67	.014	-.433
export prices			.0015	.053
domestic food production				30.139

source: computed.

Table 2.
Macro Indicators for Six Food Security Experiments

	GDP	Con.	Inv.	Exch.	Output	Con.F	Imports	Prices
	----billion won------			won/$	--physical units------			won
base	753	594	186	146	435	279	32.3	.994
agricultural expansion	806	675	177	139	520	342	20.5	.699
import substitution	767	592	214	141	419	267	41.6	1.051
export expansion	751	592	196	151	423	270	39.2	1.51

Note: The insurance and price stabilization policies have the same macro values as the base. Inv is investment; Cons, consumption, Exch, the exchange rate, cons.f the consumption of food, output the output of food, imports, the imports of food and ag. prices, agricultural prices.

Table. 3.
Mean and Variances of Utility for Four Groups
and Six Policy Alternatives

	Farmers		Organized Labor		Ind. Capital		Service Labor	
	mean	var.	mean	var	mean	var	mean	var
base policy	1.88	.24	26.88	23.6	1,443	14,421	3.54	8.26
world price stabilization	1.86	.17	27.06	16.78	1,457	670	3.52	6.84
food import insurance	1.80	.22	26.88	23.84	1,442	14,292	3.46	8.45
agricultural expansion	NA	.30	27.08	32.11	1,274	19,559	11.47	10.76
import substitution	2.66	.23	7.61	19.46	788	17,609	7.52	8.92
export expansion	3.64	.2134	11.19	19.71	327	27,449	5.54	7.96

source: computed, see text.

Table 4.
Probability of Income Insufficient to Purchase
A Minimum Bundle for Six Policies and
Four Groups

	Farmers		Org. Labor		Ind. Capital		Service Labor	
	Tch.[a]	N.[b]	Tch.	N.	Tch.	N.	Tch.	N.
base	.03	0[c]	.02	0	0	0	.33	.11
stabilized world price	.02	0	.01	0	0	0	.28	.09
food import insurance	.11	.02	.02	0	0	0	.34	.11
agricultural expansion	[d]	[d]	.10	0	.01	0	.04	0
import substitution	.02	0	.17	.04	.01	0	.17	.04
export	.01	0	.08	.01	.13	.02	.13	.02

source: computed.
notes: a. computed using Tchebychev's inequality
b. computed using a Normal distribution
c. values less than .005 are reported as 0
d. mean value of income is very much less than subistence.