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CHAPTER FIVE

Behavior and Welfare under Risk

This chapter explores how risk affects the optimal behavior and the welfare of rural households as well as the food security of a nation. Yield and output price risks are introduced in section 5.1, and we consider the situation when they are correlated. Sections 5.2 to 5.5 explain the basic theory of supply when there is only one crop, no credit or insurance markets, and no storage, so that risk in production is directly transmitted as an income and consumption risk. For this presentation, we draw heavily on the work of Newbery and Stiglitz (1981). The basic measures of cost of risk and risk aversion are presented in sections 5.2 and 5.3. The behavior of risk-neutral farmers is considered in section 5.4. We show that, even if a farmer is indifferent between a risky return and a safe return, risk has an important effect on behavior. The theory of supply for risk-averse farmers is discussed in section 5.5. Risk generally shifts the supply curve inward, except for very risk-averse farmers who work harder in order to avoid disastrous outcomes. Section 5.6 considers households who both produce and consume. In the context of relatively segmented markets, the welfare cost of price fluctuations is higher for these households than for pure producers, but they can partly insure themselves against price extremes by increasing food production. This has important policy implications for the role of market integration. Section 5.7 shifts the analysis of risk to the national level and discusses alternative schemes commonly used for domestic price stabilization. Section 5.8 looks at different tests of the degree of market integration since well-integrated markets across space and commodities would allow targeting price stabilization efforts on only a few locations and commodities. Section 5.9 gives a brief introduction to the measurement of national food security. Section 5.10 concludes the chapter by examining a price stabilization scheme for an open economy, using Brazil as an example.

5.1. Price Determination and Sources of Fluctuations

Producers face two types of risks, production and price risks. Production (or yield) risks are those which arise because of natural causes such as variation in rainfall, weather, pests, or diseases. Yield fluctuations are largest for an individual plot of land. Therefore, a particular producer may reduce exposure to yield risk by farming geographically dispersed plots of land and diversifying crops. At the country level, fluctuations are also reduced by the diversity of climatic conditions. This is confirmed by Valdés and Konandreas (1981), who report on fluctuations of staple food production from 1961 to 1976. They find food production to be relatively stable in most large low-income countries (with coefficients of variation between 6% and 9% for India, Bangladesh, Indonesia, the Philippines, Sri Lanka, Ghana, Nigeria, Brazil, and Mexico), while variability is very high in most of the smaller countries, particularly North African and Middle Eastern countries (with coefficients of variation close to 30% in Algeria, Libya, and Morocco; 40% in Syria; and 65% in Jordan).

Price risks affect the prices of the commodities farmers produce and the inputs they buy. Because output price risk seems to be the most important element of farmers' decision-making processes, we concentrate our analysis on the impact of output price risk and ignore input price fluctuations. Newbery and Stiglitz (1981) report coefficients of variation of detrended real international market prices from 1951 to 1975 which range from 20% to 58%, with the following commodity figures: jute 20%, coffee 26%, cotton 30%, cocoa 31%, rubber 40%, and sugar 58%.

At the market level, price and production risks are intimately related. Hence, at a country level, a critical difference is whether the commodity is a nontradable or a tradable. For a nontradable, assuming fluctuations in demand to be negligible, the original source of risk lies in the fluctuation of domestic production. Price fluctuations are then directly linked to production fluctuations as low (high) equilibrium prices clear the market when production is high (low), implying a negative correlation between production and prices. For a tradable commodity, the fluctuations of price and domestic production will usually not be correlated. Because prices are given by world market equilibrium, they vary with the world supply and demand, which is not affected by domestic production unless the country is a large producer or buyer in the world market. At the farmers' level, prices are exogenous. However, local rural markets in developing countries are often isolated from national and international markets by high transportation and marketing costs. As yield fluctuations are highly correlated within a small area, local prices, determined by local production and demand, are both highly volatile and, for individual farmers, strongly negatively correlated with their own production. Hence, such farmers face both yield and price risks, with a level of correlation between these risks that depends on the level of regional market integration.

Given the long duration of the agricultural production process, an important distinction must be made between the ex ante supply schedule and the ex post supply curve. The ex ante supply schedule used for decisions made at the start of the season depends on expected future returns and is based on an average variability of yield and price. A theme of this chapter will be to characterize how this schedule is affected by risk as well as by alternative policies that reduce risk. At harvest time, the ex post supply curve depends on the weather and on ex ante decisions on input use. It does not, however, depend on the realization of price, since at harvest time producers can no longer respond to price incentives. This is illustrated in Figures 5.1 and 5.2, where the ex ante supply curve S is upward sloping and the ex post curve is represented by vertical lines. A low and a high realization around the ex ante optimal choice of J are shown in Figure 5.1.

5.2. Impact of Price Risk on the Level and Variability of Agricultural Income

Although many policy interventions are aimed at reducing the variability of prices, the more fundamental concern of farmers is not price but income variability. As we will see below, stabilization of price need not contribute to the stabilization of income. In certain cases, in fact, it will increase the variability of income.

Assuming that the ex ante supply function is invariant with risk, consider the closed economy case where the only source of price variability is that induced by production variability (Figure 5.1). Let q be the realization of production. The income of the farmers is $y = pq$. Assuming that the demand has a constant price elasticity $(-\varepsilon)$, the market clearing price will be:

$$p = q^{-1/\varepsilon},$$

which fluctuates with q.

Figure 5.1. Production fluctuation in a closed economy

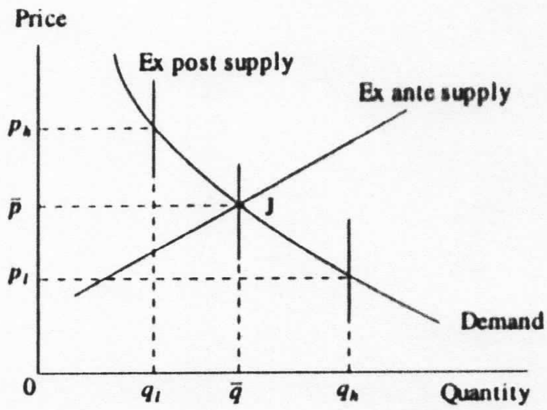
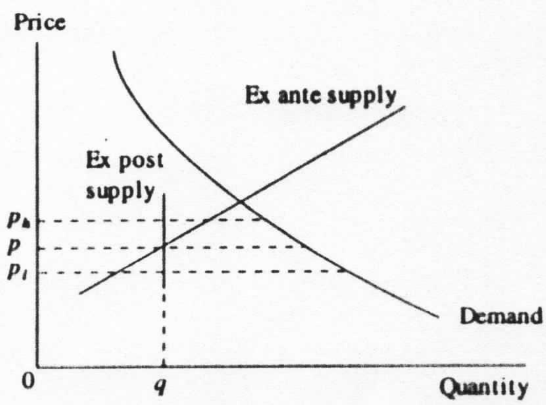


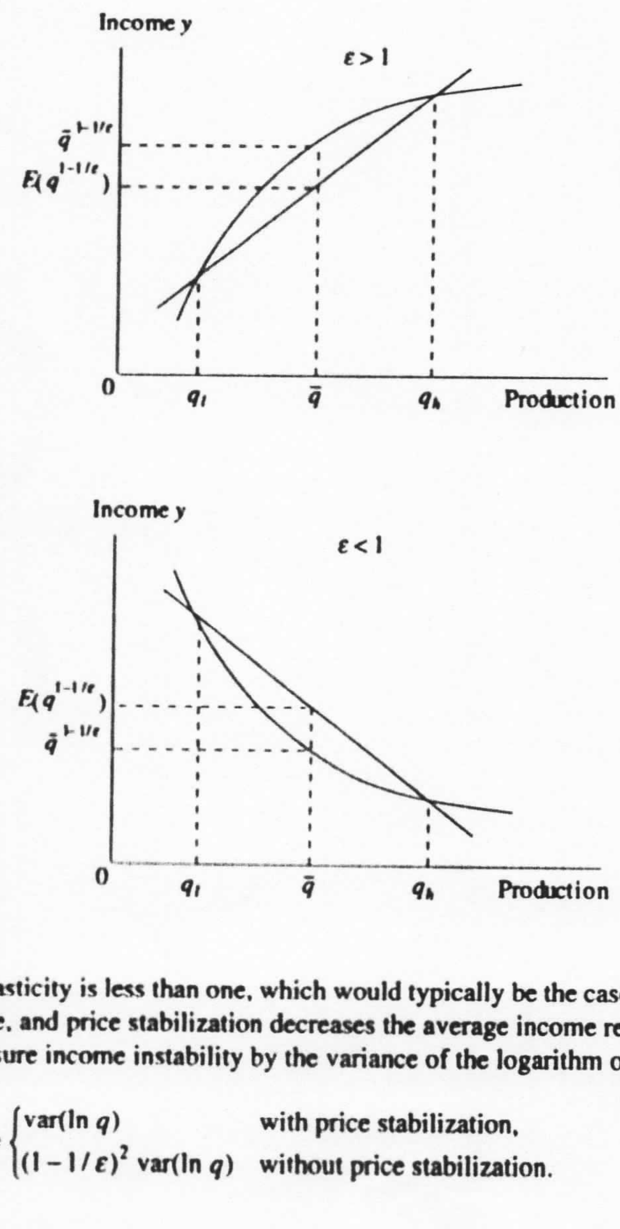
Figure 5.2. World price fluctuation in an open economy



Note first that if prices are to be stabilized, they must be fixed at the level $\bar{p}$ for which consumption is equal to average production $\bar{q}$ (i.e., at $\bar{p} = \bar{q}^{-1/\varepsilon}$, which is not the average of the fluctuating price). At a higher price, stocks will surely accumulate over time, and at a lower price the country will run out of supply, since demand is above average supply. In both cases, the economy could not remain closed to international trade.

With stabilization of prices, the income of farmers is $y = \bar{p}q$, with the mean value $Ey = \bar{p}\bar{q} = \bar{q}^{1-1/\varepsilon}$. Without intervention, the income is $y = pq = q^{1-1/\varepsilon}$, with mean value $Ey = E(q^{1-1/\varepsilon})$. The comparison of these two averages depends on the value of ε (Figure 5.3). If the elasticity of demand is greater than one, the income curve is concave in q and the average value of the variable income, $E(q^{1-1/\varepsilon})$, is lower than the income obtained with a stabilized

Figure 5.3. Welfare effect of production risk on a risk-neutral producer



price. If the elasticity is less than one, which would typically be the case for food products, the converse is true, and price stabilization decreases the average income received by the farmer.

If we measure income instability by the variance of the logarithm of income, then:

$$\text{var}(\ln y) = \begin{cases} \text{var}(\ln q) & \text{with price stabilization,} \\ (1 - 1/\varepsilon)^2 \,\text{var}(\ln q) & \text{without price stabilization.} \end{cases}$$

Whether stabilization reduces or increases the variability of income depends on whether ε is smaller or greater than 1/2.

In summary, if $\varepsilon < 1/2$, price stabilization decreases both the average and the variability of y; if $1/2 < \varepsilon < 1$, it decreases the average and increases the variability of income; and if $\varepsilon > 1$, price stabilization increases the average and the variability of income. Hence, there is no doubt that price stabilization is unfavorable to producers when demand elasticity is in the (1/2, 1) interval. For $\varepsilon < 1/2$ or $\varepsilon > 1$, producers face a trade-off between average level and variability of income. Whether they benefit from price stabilization depends on how they value the cost of risk.

5.3. Measuring the Cost of Risk

The first question here is to define the welfare of a farmer whose income is uncertain. This welfare function will serve to measure the welfare cost of risk. It will also give the basis of the theory of behavior under risk, if one assumes, as it is most logical, that farmers maximize their welfare. In the standard model of producer behavior where farmers operate under certainty, the welfare function is profit. This also applies to risk-neutral farmers who are indifferent between a safe income and a risky income of the same expected value. For risk-averse farmers, two broad approaches have been used. In the first, risk is defined as the probability that income will fall below a predetermined disaster level. Following this definition, various *safety-first* models have been developed (Pyle and Turnovsky, 1970). In Roy's model, producers choose the production plan which minimizes the probability that income will fall below the disaster level. In Telser's model, producers maximize their expected profit subject to the condition that the probability of falling below the disaster level is lower than a specified value. The second approach is an extension of the standard theory of consumer behavior. In this theory, consumers behave as if they had a utility function, defined over the consequences of their choice (in the case of the consumer, it is defined over the quantities consumed), and make their choices to maximize this utility. For choices involving risk, one can similarly show that, under certain assumptions, agents behave as if they were maximizing the expected value of the utility that they can derive from the outcome of their actions. This gives the *expected utility* model. It is usually thought that the expected utility model is a relatively general approach, while the safety-first model applies more specifically to situations where there is a clear discontinuity at the disaster level entailed, for example, by starvation or bankruptcy, which results in a drastic change of status for the agent (Buschena and Zilberman, 1992). In the rest of this chapter, we stay with the expected utility model.

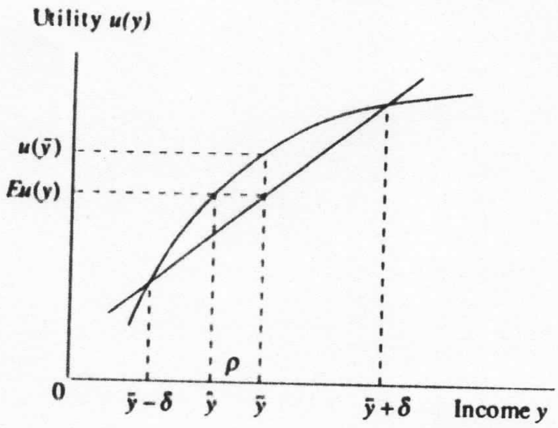
5.3.1. Certainty Equivalent Income and Risk Premium

Assuming that the producer's welfare is measured by the expected utility of income, we can now measure the risk cost of a risky income. Consider the utility function u defined over the income y. Risk aversion corresponds to a concave utility function as shown in Figure 5.4. To see this, assume that the random income y takes either one of two values, a low and a high value, with equal probability:

$$y = \begin{cases} \bar{y} - \delta & \text{with probability } 1/2 \\ \bar{y} + \delta & \text{with probability } 1/2. \end{cases}$$

The expected utility of this random outcome is the average value of the two utility levels, $Eu(y)$, which is less than the utility $u(\bar{y})$ associated with the sure income $\bar{y}$. The producer would prefer the sure income $\bar{y}$ to the uncertain income of the same average value and is therefore said to be risk-averse. Conversely, if one had considered a convex utility function, the expected utility derived from the uncertain income would be higher than the utility corresponding to the sure income. The producer would prefer uncertainty to security at the same average income and therefore would be a risk taker.

Figure 5.4. Measuring risk aversion



The difference between $u(\bar{y})$ and $Eu(y)$ is a measure of the cost of risk in terms of the welfare of the producer. One can also measure this cost in monetary terms by asking what would be the sure income that would give the producer the same utility as this random income. This is the certainty equivalent income, $\hat{y}$, defined by:

$$u(\hat{y}) = Eu(y),$$

and represented in Figure 5.4. The difference between $\hat{y}$ and $\bar{y}$ gives the amount of average income that the producer is ready to give up to exchange random income for sure income. It is referred to as the *risk premium*:

$$\rho = \bar{y} - \hat{y}.$$

The magnitude of the risk premium depends on both the shape of the utility function and the probability distribution of y. The more curved the utility function, the larger the risk premium for a given range of fluctuation of y. Hence, the agent's level of risk aversion is reflected by the curvature of the utility function. And, for a given utility curve, the larger the fluctuation in income and hence δ, the larger the risk premium. This represents the riskiness of income. In the definition of the risk premium given above, these two elements cannot, however, be easily separated. We now give a more precise measure of risk aversion as well as an approximate but explicit formula for the risk premium as a function of risk aversion and riskiness of income.

5.3.2. *Risk Aversion*

Consider a second-order Taylor expansion of the utility of the random income y around the average income $\bar{y}$:

$$u(y = \bar{y} + h) \approx u(\bar{y}) + hu'(\bar{y}) + \frac{1}{2}h^2u''(\bar{y}),$$

where h is a random variable assuming values $\pm\delta$ with equal probability. Taking the expected value of this expression, and given that $Eh = 0$ and $Eh^2 = \delta^2$, we find:

$$Eu(y) \approx u(\bar{y}) + \frac{1}{2}\delta^2u''(\bar{y}).$$

Similarly, we can use a Taylor expansion of the utility of the certainty equivalent income $\hat{y}$ around $\bar{y}$:

$$u(\hat{y} = \bar{y} - \rho) \approx u(\bar{y}) - \rho u'(\bar{y}).$$

Recall that $\hat{y}$ is defined by $Eu(y) = u(\hat{y})$. Setting equal these two expressions gives an approximation for the risk premium ρ:

$$\rho \approx -\frac{1}{2}\delta^2\frac{u''(\bar{y})}{u'(\bar{y})}.$$

In this expression, the risk premium contains two multiplicative elements, the riskiness of income, expressed by the variance δ^2 of income, and the ratio u''/u', which is independent of the variability of y and measures the curvature of the utility curve. This last term captures the concept of risk aversion. More specifically, one defines:

Absolute risk aversion: $A = -\dfrac{u''(\bar{y})}{u'(\bar{y})}$

Relative risk aversion: $R = -\bar{y}\dfrac{u''(\bar{y})}{u'(\bar{y})}.$

The risk premium, that is, the cost of risk, can then be written as:

$$\rho \approx \frac{1}{2}A\ \mathrm{var}(y) \quad \text{or} \quad \frac{\rho}{\bar{y}} \approx \frac{1}{2}R\sigma_y^2,$$

where σ_y is the coefficient of variation of income which is equal to standard deviation of $y/\bar{y}$.

These last relationships give some insights into the meaning of relative and absolute risk aversion. Take, for example, two farmers with respective average incomes of 100 and 1000. Assume that risk is multiplicative, with a coefficient of variation σ_y of 20%. This gives respective standard deviations of 20 and 200. With an assumption of constant relative risk aversion, R, the cost of risk is proportional to the average level of income, that is, the two farmers are prepared to give up R% of their income to avoid fluctuations. The richer farmer, with an average income and standard deviation 10 times higher than the poorer farmer, is ready to pay a premium 10 times higher than the poor counterpart. In contrast, assuming constant absolute risk aversion gives costs of risk equal to $200A$ and $20{,}000A$, respectively, or a cost of risk 100 times higher for the richer farmer. This example suggests that the assumption of constant absolute risk aversion is implausible over a wide range of income. This, however, does not prevent use of a constant A to analyze the decisions of a given individual. Conventional wisdom is that A declines with income or wealth, and R is relatively constant in the middle range of income. However, neither of these assumptions adequately reflects the high cost of risk at a very low level of income. In such an income range, we would expect R to increase as income falls.

A few remarks are in order in reference to these calculations:

a. The risky income may not be total income. Farmers may have secure labor income or remittances. Because they are concerned with fluctuations of total income rather than solely of agricultural income, the calculation of cost of risk has to be done with respect to total income, y. This means that the lower the share of the risky income in y, the lower the coefficient of variation σ_y, and the lower the cost of a given agricultural risk. Furthermore, because utility is really produced by consumption and not income, one can argue that if individuals have sufficient wealth, their consumption should not be very sensitive to fluctuations in their income, and risk should be defined on wealth and not on income. However, the quantification of wealth is difficult. Alternatively, one can base the evaluation of risk on income and consider that wealth influences the coefficient of risk aversion. In any case, one of the few empirical studies on this measure shows farmers to be responsive to income and not to wealth (Binswanger, 1980).

b. The cost of risk, ρ, increases with the risk aversion of the bearer and with the square of risk. This has important implications for risk sharing. Transferring risk to a less risk-averse individual will decrease the cost of risk. Landlords, middlemen, or individuals with higher incomes and assets would usually be less risk averse than small farmers, and shifting risk to them is efficient. Also, if one assumes constant absolute risk aversion, by dividing the risky income among several persons, the cost of risk borne by each individual is lower, and the total cost of risk is thus reduced. This can be seen as follows. The absolute size of the risk premium is $\rho = 1/2\ A\,\mathrm{var}(y)$. Hence, if we divide the risky income among n individuals, the variance of income will be divided by n^2, and the total cost of risk by n. This, however, does not hold under the assumption of constant relative risk aversion.

5.3.3. Utility Functions with Constant Absolute or Relative Risk Aversion

For any particular utility function, risk aversion, whether relative or absolute, will vary with the level of income. Two utility functions are particularly useful in solving problems under uncertainty.

The utility function with constant relative risk aversion:

$$u(y) = \frac{y^{1-R}}{1-R} \quad \text{for } R \neq 1, \quad \text{and} \quad u(y) = \ln y \quad \text{for } R = 1.$$

The utility function with constant absolute risk aversion:

$$u(y) = -k\, e^{-Ay}.$$

5.3.4. The Magnitude of Income Risk

How large is the coefficient of variation of agricultural income? In a widely referenced study, Roumasset (1976) estimated the income risk of rice production in the Philippines. He found that rain-fed rice produced using traditional techniques had a coefficient of variation σ of 20%, while the use of modern techniques, which increased mean income, raised σ to 50%. For irrigated rice, traditional techniques yielded a σ of 25%, while modern techniques almost doubled average income but yielded a σ of 33% to 42%. Another study by Schluter and Mount (1976) of 33 unirrigated farms in the Surat District of India over six years showed σ ranging from 5% to 32%, with an average value of 17%.

Empirical measures of risk aversion followed two approaches. In the first approach, experiments are designed in which farmers are asked to choose among alternative hypothetical lotteries, which differ by their average return and risk. In an experiment conducted in India, Binswanger (1980) found that farmers' choices are consistent with the expected utility model, as opposed to safety-first types of behavior; individuals are sensitive to fluctuations in income rather than to the impact that these have on their wealth; and attitude toward risk is quite well approximated by a constant relative risk aversion over income with a coefficient R between 0.3 for small fluctuations and 1.7 for larger fluctuations. This coefficient of constant relative risk aversion over income rather than wealth is often called the coefficient of partial risk aversion. Critics of this approach argue that farmers may not react to these hypothetical gambling situations as they would to their actual production decisions.

The second approach attempts to infer the parameters of risk attitude from the observed behavior of farmers. It consists in a comparison of the marginal product of a factor at the profit-maximizing optimum with the marginal product at the observed decision, based on an econometrically estimated production function. The difference between profit maximizing and observed levels of factor use is attributed to attitude toward risk. Moscardi and de Janvry (1977) conducted such a study of farmers in Puebla, Mexico, postulating a safety-first approach, in which the cost of risk is equal to $K\bar{y}\sigma_y$. They found a mean value of the risk aversion coefficient K equal to 1.12, which would correspond to a coefficient of relative risk aversion of about 2 if σ was 0.5, a correspondence suggested by Newbery and Stiglitz (1981). The difficulty with this approach is that, because risk is measured as a residual term, it will tend to capture many other factors not accounted for by the model, from a misspecification of the model itself to existence of household-specific credit constraints and transactions costs.

Combining these two types of measures gives orders of magnitude for the cost of income risk. If fluctuations in income are measured with a σ of 20% and relative risk aversion is 2, the welfare loss due to risk is 4% of mean income. With a σ of 40%, the welfare loss rises to 16% of income.

5.4. Welfare and Supply of Risk-Neutral Farmers

Consider an individual farmer, with production q as a function of a single input x and a random factor θ:

$$q = \theta f(x), \quad \text{with } E\theta = 1, \ \text{var}\,\theta = \sigma_\theta^2.$$

The output price p is also random, but the input price w is not, and profit $y = pq - wx$ is correspondingly random. A risk-neutral farmer maximizes expected profit:

$$Ey = E(pq) - wx = \bar{p}\bar{q} + \text{cov}(p,q) - wx.$$

Thus, given a negative correlation between the individual's own production and the market price, expected profit will be lower under uncertainty than under certainty. This would happen in a relatively isolated market, for example, where a good year for this individual would usually correspond to a good year for most of the other producers and, hence, to a fall in local market price. The intuitive reasoning behind this result is that, as the producer receives a low price whenever output is high, and a high price whenever output is low, for average production the farmer receives a price lower than the average price (Figure 5.1). This shows that risk affects the welfare of even risk-neutral producers.

Furthermore, because $\text{cov}(p,q)$ is also a function of x, the optimal choice of x, that which maximizes Ey, is affected by the presence of risk. For instance, specify the stochastic nature of p as:

$$p = \bar{p} - b(\theta - 1) + v, \quad \text{with } Ev = 0, \text{ and } E\theta v = 0.$$

Price variability has two components: an element perfectly correlated with output risk, and another uncorrelated to output risk. With this specification, $-b$ is the coefficient of correlation between θ, the risk element in production, and p. Therefore,

$$\text{cov}(p,q) = -b\sigma_\theta^2 f(x).$$

The producer's maximization problem,

$$\max_x Ey = E(pq) - wx = E\{[\bar{p} - b(\theta - 1) + v]\theta f(x)\} - wx,$$

yields:

$$(\bar{p} - b\sigma_\theta^2) f'(x) = w.$$

This shows that the producer behaves as if the price were $\hat{p} = \bar{p} - b\sigma_\theta^2$. This discounted price, called the "action certainty equivalent price," is the nonrandom price which leads to the same behavior as the random price.

A common graphic representation is shown in Figure 5.5, where risk is seen as shifting the supply curve inward. The difference between the marginal cost curve and the pseudo–supply curve is the markup $-b\sigma_\theta^2$. The farmer chooses the level of input such that marginal cost of production is equal to the certainty equivalent price $\hat{p}$ of the expected price $\bar{p}$. Note that while this pseudo–supply curve conveniently represents the producer's decision, it cannot be used to compute profit and surplus. The short-run supply will be a vertical line fluctuating around $\bar{q}$, taking at any time t the value q_t, for example. Corresponding prices and revenues are also fluctuating, taking, for example, the values p_t and $p_t q_t$ at time t, respectively. Profit is random and is measured as the difference between the variable revenue and the nonrandom cost under the marginal cost curve.

Note also that the relationship between $\hat{p}$ and $\bar{p}$ depends on the specification of risk. With additive risk on supply or a different model of price formation, the markup will take different forms and may not be constant.

In the case that we have developed here, the welfare of the risk-neutral producer Ey can also be written as a function of $\hat{p}$:

$$Ey = (\bar{p} - b\sigma_\theta^2)\bar{q} - wx = \hat{p}\bar{q} - wx.$$

This expression does not always hold, as it depends on the specification of risk. In general, the "welfare certainty equivalent price" $\hat{p}'$, defined by $Ey = \hat{p}'\bar{q} - wx$, is different from $\hat{p}$.

In conclusion, we have shown that:

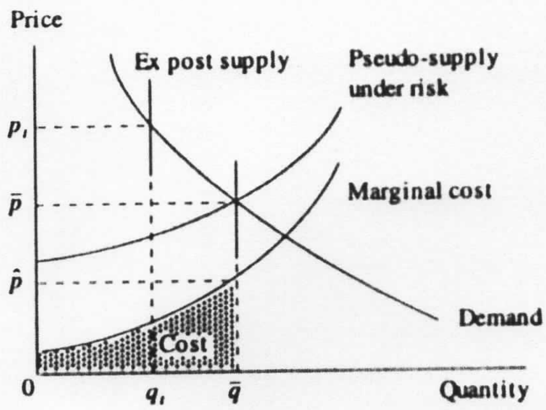
a. Even risk-neutral producers are affected by risk if there is any correlation between their own production and the price level. This will more likely occur in relatively segmented markets and with more homogenous conditions of production across producers.

b. For a producer, a negative correlation between production and the market price induces a lower expected profit than under certainty.

c. Some cases, for example, under multiplicative risk, can induce a lower marginal return to input use and an inward shift of the supply curve.

d. Consequently, price stabilization will usually induce an outward shift of the supply curve. This comes as a correction to our assumption in section 5.2, where we assumed that price

Figure 5.5. Supply of risk-averse producers under risk



stabilization did not affect the supply curve. This supply effect enhances the argument of section 5.2 by providing another justification for a stabilized price lower than the average of the random price.

5.5. Welfare and Supply of Risk-Averse Farmers

The risk-averse farmer maximizes not expected income, but rather expected utility:

$$\underset{x}{\text{Max}}\ Eu(y) = Eu[p\theta f(x) - wx].$$

To simplify the analysis, assume that the farmer uses only personal labor, with marginal utility w, and that the utility function is separable in revenue and leisure. Equivalently the utility is assumed additive in revenue and cost, that is, $Eu[p\theta f(x) - wx] = Eu[p\theta f(x)] - wx$. Assume also that the farmer has a constant relative risk aversion R on fluctuating income. The farmer's problem is rewritten as:

$$\underset{x}{\text{Max}} \left\{ E\left[\frac{(p\theta f(x))^{1-R}}{1-R}\right] - wx \right\}.$$

The two random terms p and θ can be combined in one random variable, $r = p\theta$, which gives the random return associated with one unit of expected quantity $f(x)$. The first-order condition of this problem gives:

$$E(r^{1-R}) f(x)^{-R} f'(x) - w = 0.$$

Under certainty, r is always equal to its average value $\bar{r}$ and the first-order condition is:

$$\bar{r}^{1-R} f(x)^{-R} f'(x) - w = 0.$$

If $R < 1$, $E(r^{1-R}) < \bar{r}^{1-R}$, and $f(x)^{-R} f'(x)$ under risk is higher than under certainty. As $f(x)^{-R} f'(x)$ is a decreasing function of x, input use x under risk is lower than under certainty. Conversely, if $R > 1$, input use and supply under risk are higher than under certainty.

To grasp the intuition behind this result, note that the marginal utility of effort x is:

$$u'(x) = r^{1-R} f(x)^{-R} f'(x) - w.$$

This can be decomposed into the marginal income produced by increasing effort, $dy/dx = rf'(x)$, the utility of each marginal unit of income, $du/dy = [rf(x)]^{-R}$, and the constant marginal cost of effort w. With risk aversion, the marginal utility of income, du/dy, declines with income. Values of R greater than one represent a very concave utility function and thus a steep decline of the marginal utility of income as income rises. This decline overwhelms the increase in income, $rf'(x)$, implying that the marginal utility of effort, du/dx, declines when r increases. Hence, high risk aversion places a high value on increased output at lower realizations of the random price. The utility of marginal effort is not only decreasing but also concave in r. Therefore, when risk increases, the expected value of a marginal unit of effort increases and producers work harder to avoid the extreme situations. With milder risk aversion, $R < 1$, an increase in r induces a decline in the marginal utility of income but an increase in the marginal utility of effort, although at a decreasing rate. Risk induces a decline in expected marginal return to effort and, hence, a decline in effort.

Although the effect of risk on effort and production is ambiguous, the effect on welfare is always negative. To see this, denote by $d\sigma$ a change in risk. The marginal effect on welfare is:

$$\frac{dW}{d\sigma} = \frac{d(Eu(y) - wx)}{d\sigma} = \frac{\partial(Eu(y) - wx)}{\partial x}\frac{dx}{d\sigma} + \frac{\partial Eu(y)}{\partial \sigma}$$

The first term is zero because producers are assumed to adjust their effort x to maximize their welfare, and the second term is negative since the utility is concave in the random term r.

In conclusion:

a. When risk increases, risk-averse producers will decrease their effort if they are mildly risk averse but increase their effort if they are very risk averse.

b. Whether a program that attempts to reduce income risk will induce an overall increase or decrease in output depends on the distribution of risk aversion across producers. However, if it does produce an increase in total supply, this may induce a lowering of the average price. This will in part curtail the anticipated benefit from price stabilization.

c. In all cases, risk decreases the producers' welfare.

5.6. The Household's Response to Price Risk*

To this point, we have concentrated on the effect of uncertainty on producers' welfare and behavior. We have not addressed the issue of the impact of price fluctuations on consumers. Without going into details, one can imagine that consumers will usually be risk averse with respect to fluctuations of the prices of what they consume. However, whereas producers fear low prices, consumers fear high prices. The question then is whether these two effects compensate for each other for rural households which both consume and produce the same commodities; the answer is yes. Comparing a net selling household with a pure producer, we will see that the household which consumes part of its production holds a type of insurance against low prices. In the case of a net buying household, home production of a part of its consumption needs serves as an insurance against high prices. Hence, because net selling households are partly protected against risk, they tend to produce more than pure producers with the same level of risk aversion. Net buying households also tend to produce more than pure producers because this provides them with a consumption insurance. Very risk-averse food-deficit households produce more under uncertainty than under certainty in order to reduce exposure to extreme prices.

Consider a household which produces only one agricultural good that it also consumes. Consider the case of price fluctuations only. Abstracting from the prices of all the other commodities that the household purchases, its indirect utility function is:

$$u(y, p), \quad \text{where } y = pf(x) - wx + T,$$

where T represents other sources of income. The input level x that maximizes the expected utility of the household is given by:

$$Eu'_y[pf'(x) - w] = Eu'_y \, pf'(x) - Eu'_y \, w = Eu'_y \, \bar{p}\left[1 + \sigma_{u'_y}\sigma_p \operatorname{cor}(u'_y, p)\right] f'(x) - Eu'_y \, w = 0.$$

As seen before, the impact of risk on production behavior relies on the sign of the correlation between u'_y and p. If p and y were not correlated, input use would be determined by $\bar{p}\, f'(x) = w$, independent of risk. If p and y are correlated, which is the case here, then input use and supply response are affected by risk. There are two elements in the influence of p on u'_y: one is a production effect, where an increase in price p induces an increase in income y and, hence, a decrease in marginal utility of income. The consumption effect counters this: an increase in price reduces the real income, thus inducing an increase in the marginal utility of income. The net of the two can be shown in the following approximation obtained by a Taylor expansion:

$$(1)\quad \operatorname{cor}(u'_y, p) = \sigma_p^2\left(R(s_p - s_c) + \eta s_c\right)$$

$$(2)\quad = \sigma_p^2\left(Rs_p - s_c(R - \eta)\right),$$

where R is the coefficient of relative risk aversion, η the income elasticity of consumption c of the food item, $s_c = pc/y$ the share of food consumption in total expenditure, and $s_p = pf(x)/y$ the share of the risky income in total income. Pure producers are defined as not consuming their own production, that is, $s_c = 0$.

These expressions reveal the determination of the degree of self-sufficiency of the household as critical in the impact of uncertainty on production:

a. For net selling households [defined by $f(x) > c$, or $s_p > s_c$], expression (1) is always negative. Hence, the marginal utility of income is negatively correlated with price, and input use and production under risk are lower than under certainty. As for pure producers, the negative effect of risk increases with risk aversion R.

b. For food-deficit households, expression (1) is negative for low values of R and positive for large values of R. Hence, net buying households with mild risk aversion behave as producers in reducing their production. Very risk-averse households increase their production in response to increases in risk.

c. The negative effect of risk on production is lower for households than for pure producers. This is seen in expression (2), as the income elasticity η is usually lower than R. A positive $R - \eta$ indicates that a household produces more than a pure producer with the same risk aversion. This is because consumption of its own production in years of very low prices ensures a certain level of utility to some of its product which is not marketed at the low price.

Econometric studies of attitude toward risk like those of Antle (1989) and Moscardi and de Janvry (1977) are usually based on the observed gap between expected revenue and marginal cost. What we now know is that, if the agent is a household, this gap depends not only on risk aversion R, but also on the income elasticity and the level of self-sufficiency.

In terms of welfare effect, Finkelshtain and Chalfant (1991) show that the risk premium is equal to:

$$\rho = \delta^2\left(-\frac{1}{2}\frac{u''_{yy}}{u'_y} + \frac{u''_{yp}}{u'_y}\right).$$

This risk premium is higher for households than for pure producers whenever u''_{yp} is positive, that is, when price and marginal utility of income are negatively correlated. Hence, despite the compensating role that consumption and production have on each other, and the adjustment made in production, the negative welfare effect of risk is higher on households than it is on producers. Households thus suffer a higher cost from risk in food price and, at the same time, produce more food than pure producers.

In the context of a combined cash crop–food crop production system and presence of both production and price risks, Fafchamps (1992) has used a similar argument to show that small farm households will tend to allocate relatively more of their resources to food crops and will be less responsive to price and technical opportunities in cash crop production than commercial farmers. This bias toward food production is due to the volatility of food prices and their correlation with individual production, inducing households to self-insure through higher food production.

This suggests an important entry point for policy aiming both at increasing the supply response of cash crops and relieving smallholders from the high welfare cost of risk. Food market integration would reduce the volatility of local prices and their correlation with individual production. The rationale for food self-sufficiency would decrease, and peasants would allocate their resources following a standard portfolio approach with an optimum diversification based on relative profitability and riskiness of the different crops. Market integration can be promoted by infrastructure investments, by removing regulatory impediments to domestic trade, and by direct support to trade through government shops or credit to the private sector.

5.7. Instruments of Price Stabilization

Preoccupation with the high welfare costs of price volatility has led many countries to establish schemes for domestic price stabilization. Although the explicit objective of these schemes is only to stabilize prices, they often result in support or taxation on the average price. A common example is that of export taxation by marketing boards. Another is the fixation of a price floor for staples without a symmetric price ceiling, which raises the average price while stabilizing it. While there may be a case for such changes in the average price, it must be seen as a separate issue, at least analytically if not politically. This is not to say that the stabilized price must be equal to the average of the fluctuating price. In a closed economy, the stabilized price must balance supply and demand, as modified by stabilization. Storage and administrative costs involved in price stabilization programs must also be imputed to the program. Taxation and price supports, however, must be viewed as a separate issue, as their objective is to transfer income from one group to another.

To measure the instability of a time series, it is necessary to extract the time trend of the series. This is done as follows:

a. Perform a regression using the logarithm of real price p as the dependent variable and time t as the independent variable:

$$\ln p_t = a + bt + \varepsilon,$$

where b is the annual growth rate of real price p, and ε a random error.

b. Compute the estimated values $\hat{p}_t = e^{a+bt}$ and the relative residuals

$$\hat{u}_t = (p_t - \hat{p}_t) / \hat{p}_t .$$

c. An index $I(p)$ of the variability of the series p is given by the standard deviation of $\hat{u}$:

$$I(p) = \sqrt{\frac{1}{n} \sum_t \hat{u}_t^2} .$$

In a cross-country analysis of price stabilization schemes, Knudsen and Nash (1990) compare instability indices of domestic prices with instability indices of international prices. Their study includes 15 crops across 37 developing countries and covers the period 1967–1981. In general, they find these programs to be successful. Domestic prices of grains were more stable than international prices on average by 15 percentage points, beverages by 7 percentage points, and fiber by 4 percentage points. However, in a number of cases, despite "stabilization" schemes, domestic prices were actually more unstable than the border price equivalent. This happened in 9% of the cases for grains, 31% for beverages, and 35% for fiber.

There are different types of institutions for price stabilization. An important differentiating characteristic among these institutions is whether or not they physically handle commodities. The first group includes marketing boards and buffer stock schemes. Marketing boards, which are common in Africa, have been denounced as major budget burdens. Without denying the possibility of administrative inefficiency, the deficits of these agencies in general derive from the fact that they manage pricing policies with goals that combine stabilization and redistribution. In the case of staple goods, high procurement prices are set to support producers, and, at the same time, low delivery prices are set to favor consumers. Such pricing policies make it impossible for private traders to operate profitably. Hence, even if this was not the original intention, marketing boards end up forced to carry out the total trading. In such cases, even a small discrepancy between unit cost and selling price may cause enormous losses. Alternatively, government agencies may tax producers of export crops as a revenue base. As parallel markets develop, the size of operation of the marketing board, its income base, and the foreign earning controlled by the government all shrink.

Variable tariffs and subsidies on imports and exports form the second group of price stabilizing institutions. In many countries, export taxes are not explicitly and systematically set with an eye toward price stabilization. However, some stabilization is generally achieved as export taxes are decided on a year-to-year basis, with ad hoc adjustments to variations in international prices. A major drawback of these variable tax schemes is that they transfer all the instability onto the government budget, making planning difficult. There is in addition a tendency to expand expenditures when revenues are high, with asymmetric difficulties in the necessary cuts in bad years. This instability tends to boost expenditures and generate deficits. A solution to this problem is to create a buffer fund for export commodities as in Papua New Guinea. When the world price is high, a tariff is levied and the proceeds are put in a fund which is used for subsidies when the world price is low. The rules for fixing the tax level are well established, with a tax rate equal to half the difference between world price and the previous 10-year average. This self-financing scheme has been successful in reducing instability in prices by 46% (Knudsen and Nash, 1990).

Analyses of price stabilization have led to the following general recommendations: it is better to avoid handling the commodity itself; partial stabilization gives a better benefit-cost ratio than total stabilization; and the average price should approximate the average market price to avoid an ever-increasing disequilibrium of reserves (Knudsen and Nash, 1990).

5.8. Market Integration and Price Stabilization

We have seen that price stabilization can be achieved through either buffer stocks or trade. Whichever approach is followed, the cost of stabilization is reduced if internal markets are well integrated in the sense that price movements are transmitted across spatially dispersed markets and across commodities: in this case, it will be sufficient to stabilize prices in one central market to which others are related and the price of one fundamental commodity to which the prices of other commodities are related. Since markets in LDCs are suspected of fragmentation and spatial oligopoly pricing (Basu and Bell, 1991), a number of recent studies have addressed the issue of testing empirically the degree of market integration.

Different approaches have been followed to test spatial market integration. The simplest approach is to see if there exist high correlations between prices in different markets (Blyn, 1973). Alternatively, we can see whether differences in market prices exceed transfer costs across markets (Hays and McCoy, 1977) or exceed normal seasonal fluctuations (Delgado, 1988). A more powerful approach consists in taking into account the structure of price determination across markets. The basic model was formulated by Ravallion (1986) who considered a radial distribution of markets where one central market with price p_r is related to n feeder markets not directly related to each others with prices p_i. The model of spatial price determination is thus:

$$p_r = p_r(p_1,\dots,p_n,x_r) \text{ central market price,}$$
$$p_i = p_i(p_r,x_i),\ i=1,\dots,n \text{ feeder markets prices,}$$

where the x are market-specific seasonal and exogenous variables which affect price formation. For estimation purposes, the dynamic structure of the feeder market price equations is specified as a function of past prices with a general structure of l lags as follows:

$$\text{(3)} \quad p_{it} = \sum_{j=1}^{l}\alpha_{ij}p_{i,t-j} + \sum_{j=0}^{l}\beta_{ij}p_{r,t-j} + \gamma_i x_{it} + e_{it},\ i=1,\dots,n.$$

Estimation of this equation, typically with monthly price quotations, can be used to test the following hypotheses about market integration:

Segmentation of market i: present and past central market prices do not influence the ith local market. In this case: $\beta_{ij}=0, j=1,\dots,l$.

Short-run market integration: a price increase in the central market is fully and immediately passed on the ith market without lagged effects. This corresponds to the criterion of equal spatial prices over time, net of transfer costs, established by Takayama and Judge (1971). In this case, $\beta_{i0}=1,\ \beta_{ij}=\alpha_{ij}=0, j=1,\dots,l$.

Long-run market integration: under long-run equilibrium, a permanent price change in the central market is fully passed over time to the feeder markets, but potentially through lagged effects. Solving (3) for the long-run equilibrium change dp_i due to a change dp_r in the central market price gives:

$$dp_i = \sum_{j=1}^{l}\alpha_{ij}dp_i + \sum_{j=0}^{l}\beta_{ij}dp_r, \text{ or } dp_i = \frac{\sum_{j=0}^{l}\beta_{ij}}{1-\sum_{j=1}^{l}\alpha_{ij}}dp_r.$$

The corresponding test of long-run market integration is thus: $\sum\alpha_{ij} + \sum\beta_{ij} = 1$.

If the market structure is not one of radial central-feeder markets, but more generally of pairwise interlinked rural markets, the test of integration is done by evaluating all pairwise price relationships (i, j) in the spatial relations considered as opposed to the pairwise relationships (i, r) (Faminow and Benson, 1990).

If there is only one lag, the feeder market price equations simplify to:

$$(4)\quad p_{it} = \alpha_i p_{i,t-1} + \beta_{i0} p_{rt} + \beta_{i1} p_{r,t-1} + \gamma_i x_{it} + e_{it},$$

which can be written in first differences as:

$$(5)\quad \Delta p_{it} = (\alpha_i - 1)(p_{i,t-1} - p_{r,t-1}) + \beta_{i0}\Delta p_{rt} + (\alpha_i + \beta_{i0} + \beta_{i1} - 1)p_{r,t-1} + \gamma_i x_{it} + e_{it}.$$

This relates the change in local price to past spatial price differentials, the current change in central market price, past central price, and market-specific exogenous variables. Since there is less multicollinearity in this difference equation (5) than in the price equation (4), it is this equation that is estimated. The tests of market integration are then:

Market segmentation: $\beta_{i0} = \beta_{i1} = 0$.

Short-run market integration: $\beta_{i0} = 1, \beta_{i1} = \alpha_i = 0$.

Long-run market integration: $\alpha_i + \beta_{i0} + \beta_{i1} - 1 = 0$.

With one lag and no x variables, Timmer (1987) suggests an index of market connectedness (IMC) defines as:

$$IMC = \frac{\alpha_i}{\beta_{i0} + \beta_{i1}}$$

which takes a value of zero for short-run integration and ∞ for full segmentation.

There is, however, a simultaneity problem in the estimation of the Δp_{it} equation (5) since Δp_{rt} is by definition endogenous as it is related to price formation in the local markets. Ravallion thus uses an instrumental variable approach to predict Δp_{rt} in a two-stage least squares estimation. Alderman (1993) has extended this framework to test for intercommodity price transmission in food markets in Ghana.

Results, in general, show that market integration is far from perfect. In his study of rice markets in Bangladesh, Ravallion finds that market efficiency varies both over seasons and during periods of famine. As to price transmission across commodities, Alderman finds that it is far from perfect in Ghana, attributing this to the fact that traders tend to specialize in one commodity, thus segmenting the process of acquiring information across commodities. In this case, stabilizing the price of one commodity would only partially carry to the price of other commodities.

Recent econometric advances in the theory of cointegration of time series have also been used to test the long-run integration of markets (Alderman, 1993; Alexander and Wyeth, 1994).

5.9. Measures of Food Security at the National Level

Food security is of utmost importance to all countries. Even though food security commands high priority in many policy debates, it is too often confused with or reduced to concepts of price stabilization or food self-sufficiency, which are only some of the many potential components of a food security strategy. It is beyond the scope of this chapter to fully address strategies for food security. However, to the extent that production and price risks are elements of the problem, we will briefly describe an aggregate measure of food security related to them.

In simple terms, food security is defined as access by all people at all times to food sufficient for a healthy life (Reutlinger, 1986). A controversial but unavoidable concept underlying this definition is that of "sufficient" food. Two types of food insecurity are commonly distinguished: chronic and transitory. Chronic food insecurity refers to situations where access to food is, on average, below the required level and is rooted in poverty. Temporary food insecurity refers to a short-run food decline due to fluctuations in income (e.g., because of illness or unemployment), production, or prices. These two types of food insecurity are closely related, since a household or a country that is in normal times close to the minimum level of food is more apt to fall into transitory food insecurity. Specific causes of food insecurity vary across countries, regions, and households. Hence, food security must be tackled with an array of policy instruments geared to these specific sources of risk.

While food security involves access to food by all individuals, it is defined and measured at different levels: country, region, household, or individual. The monitoring of food security at the household or individual level requires intensive household surveys, with appropriate measures of food intake. These surveys are usually taken at one point in time. Hence, they measure existing situations but neither the trends nor the fluctuations in consumption and thus cannot be used to rigorously measure food security. They may, however, be used in cross-sectional analyses to establish the relationship between nutritional status and socioeconomic and demographic variables such as income, wage, price ratios, assets, migration, gender, and education. These socioeconomic variables can then be used as proxies to analyze the level of food security, to predict the effect of external events, and to monitor the impact of different policies.

At the country or regional level, food security can, to some extent, be monitored in terms of indicators of production, availability, trade, stocks, and prices (Valdés and Konandreas, 1981). Availability is defined as:

Availability (C) = production − intermediate use and waste + net imports − increase in stocks.

Availability is an aggregate concept of final consumption, sometimes called "apparent consumption" or "disappearance," as opposed to a measure taken directly from the observation of consumption itself. Data on intermediate use and waste are not always available, in which case they are estimated as a given percentage of production.

Food security is analyzed in terms of the mean $\overline{C}$, trend $\hat{C}_t$, and variability $I(C)$ of availability and its components. From these, several indicators of food security have been used:

a. If the growth rate of availability is approximately zero, a mean-variance measure can be used:

$$\overline{C} - \frac{1}{2} A \operatorname{var}(C),$$

where A is the coefficient of absolute risk aversion.

b. By assuming that the relative residual $\hat{u}$ of availability follows a normal distribution, $N(0, \sigma_u)$, one can compute the probability that availability will fall below a minimum level C_m:

$$\text{Prob}(C < C_m).$$

c. When there is a definite trend in the series, the probability that availability falls below a certain percentage α of the trend value is calculated as:

$$\text{Prob}(C < \alpha\hat{C}).$$

More specifically, these indicators are calculated as follows:

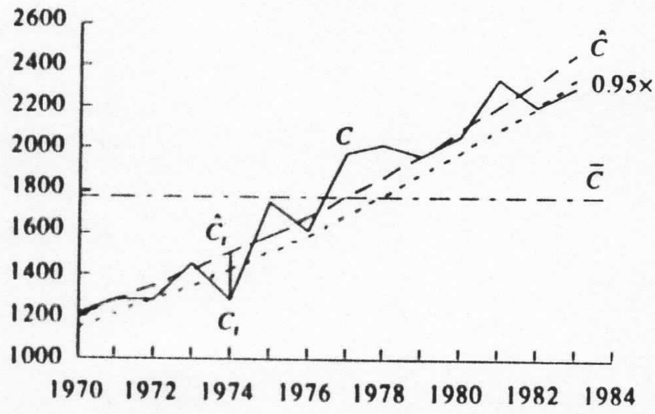
$$\text{Prob}(C < C_m) = \text{Prob}\left(\frac{C-\bar{C}}{\sigma(C)} < -\frac{\bar{C}-C_m}{\sigma(C)}\right) = 1 - F_{(\bar{C}-C_m)/\sigma(C)},$$

$$\text{Prob}(C < \alpha\hat{C}) = \text{Prob}\left(\hat{u} = \frac{C-\hat{C}}{\hat{C}} < -(1-\alpha)\right) = \text{Prob}\left(\frac{\hat{u}}{I(C)} < -\frac{1-\alpha}{I(C)}\right) = 1 - F_{(1-\alpha)/I(C)},$$

where $\alpha(C)$ is the standard deviation of C, $I(C) = \sigma_u$ the index of variability of C, and F the cumulative normal distribution.

In comparative studies of staple food consumption for the period from 1961 to 1976, Valdés and Konandreas (1981) found coefficients of variability of 6% to 8% for Asian countries and 15% to 25% in African countries. Correspondingly, the probability of falling below 95% of the

Figure 5.6. Availability of maize, Kenya (in thousand tons)



trend value is 20% to 27% in Asian countries and 37% to 42% in African countries. In the latter case, this implies that one should expect consumption to fall below 95% of the trend in about two years out of five. In the case of Kenya, represented in Figure 5.6, the index of variability of consumption is 10%, which gives:

for $\alpha = 0.95, ((1-\alpha)/I(C))\ F_{0.5} = 0.69,$

or a probability of 31% of falling below 95% of the trend line. In fact this has occurred three times (1974, 1982, and 1983) over the 15-year period examined (data from Pinckney, 1988).

5.10. Example: Evaluation of the Brazilian Price Band Proposal

In trying to avoid large price shocks in the 1980s, Brazil used erratic and short-term policy interventions rather than any explicit policy of price stabilization. In 1987, however, a price band rule was proposed for the major crops. The principle of a price band rule is that the government announces a reference price and a band around this reference price. When the market price fluctuates within the price band, the government does not intervene. When the price hits one of the borders of the band, the government intervenes with imports, exports, or changes in stocks to maintain the price at the limit. The setting of the reference price depends on whether the commodity is a tradable or a nontradable. For a nontradable, the reference price is built on a long-term trend of the equilibrium domestic price. For a tradable, the reference price is set on a long-term trend of international price. Braverman, Kanbur, Salazar Brandão, Hammer, Rezende Lopes, and Tan (1990) analyzed the potential impact of the rules proposed in 1987. We summarize their results for a nontradable (beans) and a tradable (rice).

As noted in section 5.3.2, the cost of fluctuation of income is measured by $(1/2)R\sigma_y^2\bar{y}$. When government intervention modifies the average income of the producers by Δy and its fluctuations by $\Delta\sigma_y^2$, the total benefits of the intervention are measured by:

$$B_p = \Delta y - \frac{1}{2} R\,\Delta\sigma_y^2\,\bar{y}.$$

The first term, called the "transfer benefit," indicates the gain or loss to all producers due to the change in average income, irrespective of their attitudes toward risk. The second term is the "pure benefit" from stabilization, which depends on each producer's risk aversion.

Braverman et al. (1990) used this approach to evaluate the risk costs of alternative pricing policies. They compared the historical observations under free trade and under a price band rule. For the beans sector, the free-trade price is the price which clears the market. Thus, its calculation requires both a supply and a demand function. Braverman et al. (1990) chose linear functions and solve for q and p over time:

$$q_t^s = a + bp_t$$
$$q_t^d = c + dp_t$$
$$q_t^s = q_t^d,$$

with the parameters b and d corresponding to average supply and demand elasticities of 0.36 and –0.50, respectively. Application of a price band rule on these computed equilibrium prices requires stocking or destocking whenever the price hits the lower or upper limit of the band. These limits are set at 17% below and above the long-run price. The long-run price, in turn, is defined as a 60-month moving average of past prices. For each of these simulated price series, the corresponding supply and demand are computed. Note, however (and this is an inconsistency in the analysis), that production is a function of price rather than of the expected price and the variability of prices, as the analysis in this chapter would suggest.

Historically, the average real price received by farmers for beans was Cr$10 per kilogram in 1986 cruzeiros, as noted in Table 5.1. These prices were very unstable, with a coefficient of variation around the trend of 30%. Producers' revenue was also characterized by a high degree

Table 5.1. Evaluation of a price band for Brazil, 1977–1986 (in 1986 cruzeiros)

	Price		Production		Producer income		Risk premium[b]		
	Average (Cr$/kg)	σ^a (%)	Average (1000 tons)	σ^a (%)	Average (million Cr$)	σ^a (%)	Average (million Cr$)	% of revenue (%)	Efficiency cost (million Cr$)
Beans									
Historical data	10.0	30	2,120	16	16,115	19	387	2.4	420
Free trade	10.2	35	2,132	17	16,573	33	1200	7.2	0
Band rule	8.3	12	1,976	24	13,264	26	596	4.5	
Wheat									
Historical data	3.1	14	2,240	27	7,091	39	717	10.1	
Free trade	2.5	11	2,026	30	5,265	37	479	9.1	0
Band rule	2.7	7	2,083	29	5,645	31	361	6.4	125

Source: Braverman et al., 1990.
[a] σ = Coefficient of variation around trend.
[b] Assuming constant relative risk aversion of 1.33

of variability, although less than that of prices. The risk premium that risk-averse producers would be willing to pay to have this instability eliminated, assuming a relative risk aversion of 1.33, is equal to 2.4% of their income. Under free trade, prices are slightly higher on average but more volatile. Thus, the existing policies have embodied producer price tax and stabilization components. Producers' revenue is also higher and more variable than under the implemented policy. The band rule is effective in reducing the variability in prices to a coefficient of variation of 12%. However, the average price is 18.6% lower. This happens despite a symmetric definition of the band around the trend price because the price fluctuations are not symmetric around the trend. Because the upper limit of the band is hit eight times while the lower limit is hit twice, a better definition of the band should leave a wider band above the average than below. Despite stabilizing prices, this policy does no better job at stabilizing producer income than the absence of a price band.

Government intervention in the wheat market is strong, with set producer and consumer prices and government-controlled marketing. With producer prices above and consumer prices below the world market, imports are larger than under free trade, and the government operation generates a large fiscal deficit. For wheat, the free-market price is the world market price. The price band is defined with a 12% margin above and below a reference price (calculated as a 60-month average of past world market prices corrected for transportation costs). Table 5.1 summarizes the results of the evaluation of the free-trade and the price band proposal. On average, the producer price was kept 23% above the world price. However, the domestic price has been more volatile than the free-trade price. The increase in risk cost associated with domestic intervention is equal to Cr$238 million, or 3.3% of producers' income. The price band policy would reduce the fluctuations in income compared with the historical data and with free trade. The risk benefit to producers is Cr$241 million, which has to be compared with the policy efficiency cost of Cr$125 million, defined as the sum of changes in consumer surplus, producer surplus, and government revenues (see Chapter 7).

Exercise 5
Food Security in India

This food security exercise (file 5FOODSEC) is based on the study by de Janvry and Sadoulet (1991). The objective is to analyze the achievement of India in terms of food security at the national level, during the period from 1950 to 1987, and characterize the evolution of the country's policy in combining strategies of production, imports, and stocks. We look at the two concepts of chronic and transitory food security by decomposing the analysis of a time series into its trend and its fluctuations.

Basic data on food grains supply are reported in Table 5E.1.

1. Self-Sufficiency

We first look at the issue of food self-sufficiency, a concept which is different from but often confused with food security. For this purpose, compute the indicator of import dependency, defined by the ratio of imports over total domestic supply, itself equal to the sum of imports and net production. Report this series on a graph. Save this graph under the name MDEPEND.pic.

Comment on the evolution of self-sufficiency. Recall that 1965 is the year when the Green Revolution started in India.

2. Components of Food Availability

The concept of food availability will be used to characterize food security. It is defined as follows:

Net availability = net production + imports − increase in stock.

Complete the table by computing net availability as defined above (note that you are given levels of stocks, not changes of stocks). Report both net food production and net food availability on the same graph. Similarly, report total imports and stocks on a third graph. A breaking point of 1966 appears on these figures, suggesting two distinct periods in India's food security policy.

3. Trend and Fluctuations of Production

The production performance is analyzed in terms of trend and fluctuations. The trend of a series x is measured by the estimated average growth rate during the period, which is given by the slope m of the regression of $\ln x$ on time t:

$$\ln x = a + mt.$$

The fluctuation of a series is measured by the coefficient of variation around the trend. This is the standard deviation std of the relative deviations around the trend:

$$I(x) = \text{std}\ [(x_t - \hat{x}_t)/\hat{x}_t],$$

where $\hat{x}_t = \exp(a + mt)$ is the estimated value for x_t.

To complete this analysis on production, prepare a table with columns containing t and $\ln q$. Perform two regressions of $\ln q$ using the rows corresponding to 1951–66 first, and then the rows for 1967–87. This gives estimated growth rates of production for the two periods. Add one column of estimated values $\hat{q}$ for q by using the results of the first regression in the cells that correspond to 1951–66, and the results of the second regression for the cells corresponding to the years 1967–87. To visualize your results, you can make a graph with both series q and $\hat{q}$. Add one column containing $(q - \hat{q})/\hat{q}$, and use the *@std* function to compute the coefficients of variation separately for the two periods again. Report these values of growth rates and coefficients of variation in Table 5E.1.

Discuss your results by contrasting the two periods. What do they show regarding the growth and the variability of production?

4. Strategy of Food Security

Repeat the same analysis for net food availability. Compare the growth rates of production and availability. You should see that the rate of growth of food availability has decreased in the second period, despite an increasing rate of production. The growth rate of availability is also higher than the growth rate of production in the first period but lower in the second period. Now compare the coefficients of variation. What can you derive from this comparison in terms of food security?

Using the trends in imports and stocks observed in the graphs above, discuss your findings in terms of the choices of strategy for food security followed by India.

5. Per Capita Availability

The achievement in food security may be better judged on a per capita basis. For that purpose, compute the growth rates in per capita availability during the two periods. Discuss.

6. Price Stabilization

Another goal of the Indian food strategy may be the stabilization of prices. To analyze its performance, two domestic prices, one for food grains and an overall price index, as well as an international market price are given. For comparison, compute an index of real price of food grains by dividing the price of food grains by the overall price index and an index of the international price of Thai rice with 1970–71 as a base. Analyze these two series with graph, growth

Table 5E.1 Food security in India

	A	B	C	D	E	F	G	H	I	J	K	L	M
4								Prices				Price indices	
6–9	Year	Population (millions)	Net production	Imports	Closing stocks with government	Net availability	Import dependency ratio (percent)	Wholesale price index: Foodgrains (base 1970 - 71 = 100)	Wholesale price index: All commodities (base 1970 - 71 = 100)	International price (Thai rice) (1980 $)	Per capita net availability (kg)	Relative foodgrains price index (base 1970 - 1971)	International price (Thai rice) (base 1970 - 1971)
			(million tons)	(million tons)	(million tons)								
11	1950				.7			44.5	48.5	604.9			
12	1951	363.4	48.1	4.8	1.3			49.8	53.3	553.3			
13	1952	369.6	48.6	3.9	2.0			48.2	45.5	572.5			
14	1953	376.1	54.0	2.0	1.5			48.5	46.3	656.8			
15	1954	382.9	63.2	.8	1.7			39.3	44.3	607.3			
16	1955	390.2	61.8	.6	.9			33.9	40.7	534.0			
17	1956	397.8	60.6	1.4	.3			43.7	45.7	499.6			
18	1957	405.8	63.3	3.6	1.2			48.0	48.3	490.0			
19	1958	414.3	59.2	3.2	.9			50.0	49.3	499.3			
20	1959	423.3	68.9	3.9	1.4			50.4	51.3	470.5			
21	1960	432.7	67.1	5.1	2.8			50.1	54.6	434.5			
22	1961	442.4	71.8	3.5	2.6			48.5	55.9	467.5			
23	1962	452.2	72.4	3.6	2.3			51.2	56.5	514.5			
24	1963	462.0	70.1	4.6	2.3			54.0	58.9	490.8			
25	1964	472.1	70.6	6.3	1.0			66.9	65.9	462.1			
26	1965	482.5	78.2	7.5	2.1			72.4	71.7	454.3			
27	1966	493.2	63.3	10.4	2.2			81.5	81.6	524.8			
28	1967	504.2	65.0	8.7	2.0			106.5	94.1	655.4			
29	1968	515.4	83.2	5.7	4.0			100.9	93.1	646.2			
30	1969	527.0	82.3	3.9	4.5			89.5	95.4	569.8			
31	1970	538.9	87.1	3.6	5.6			96.4	101.3	413.8			
32	1971	551.3	94.9	2.0	8.1			102.1	105.2	351.5			
33	1972	563.9	92.0	.5	3.4			114.6	113.0	367.5			
34	1973	576.8	84.9	3.6	3.1			135.0	131.6	754.3			
35	1974	590.0	91.6	5.1	2.7			183.6	169.2	959.3			
36	1975	603.5	87.4	7.4	7.9			187.0	175.8	578.2			
37	1976	617.2	105.9	.7	18.8			150.4	172.4	399.5			
38	1977	631.3	97.3	.6	17.3			167.2	185.4	388.9			
39	1978	645.7	110.6	.2	17.1			173.3	185.0	456.5			
40	1979	660.3	115.4	.0	17.4			179.8	206.5	363.3			
41	1980	675.2	96.0	.0	11.7			207.3	248.1	433.9			
42	1981	690.1	113.4	1.2	11.3			236.1	278.4	480.4			
43	1982	705.2	116.6	2.1	12.8			242.5	285.3	295.6			
44	1983	720.4	113.3	4.1	15.3			270.4	308.5	286.6			
45	1984	735.6	133.3	2.3	22.6			275.4	334.0	265.6			
46	1985	750.9	127.4	.0	24.2			289.5	353.3	225.1			
47	1986	766.1	131.6	.0	22.6					185.6			
48	1987	781.4	124.4	.0	14.0								

	A	B	C	D	E	F	G	H	I	J	K	L	M
49	**Table 5E.1 (continued)**												
50	**Annual growth rates**												
51	1951 - 66		2.4										
52	1967 - 87		2.8										
53	1951 - 87		2.6										
54	Coefficient of variation around trend												
55	1951 - 66		7.3										
56	1967 - 87		7.0										
57	1951 - 87		7.2										
58													
59	Sources: Government of India, Bulletin on Food Statistics, 1965, 1985, and Economic Survey 1987 - 88;												
60	World Bank, Commodity Trade and Price Trends, 1987-88, (Baltimore: Johns Hopkins University Press, 1988).												
61													
62													
63	**Working space**												
64													
65	Year	Net production			Net availability			Per capita	Relative foodgrains price			Thai rice price	
66								net					
67				(Obs-est)			(Obs-est)	availability			(Obs-est)		
68		Ln	Estimated	/est	Ln	Estimated	/est	Ln	Ln	Estimated	/est	Ln	Estimated
69													
70													
71	1950												
72	1951												
73	1952												
74	1953												

rates, and coefficient of variations. What can you conclude about the effectiveness of price stabilization in India?

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