A Review of Selected Methodological Issues in the Analysis of Agricultural Income Instability

Isaac K. Arap Rop
James R. Russell
and
David M. Henneberry

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Department of Agricultural Economics
Oklahoma State University
Stillwater, OK 74078

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by

Isaac K. Arap Rop

James R. Russell

and

David M. Henneberry*

*Graduate Student, Associate Professor, and Assistant Professor, respectively. Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

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It is generally acknowledged that instability in agricultural commodity markets has significant repercussions on the welfare of a country. To this end, instability has attracted a large body of research. Economists have sought to identify and analyze its sources, effects, and means of control. This phenomenon has had neither a precise definition nor a unifying principle underlying its quantification (Gelb, 1979). The purpose of this paper is not to present a comprehensive review of the theoretical and methodological research on the subject. Rather, the focus is on contributions relevant to the analysis of income instability in the agricultural sector of a developing economy. This paper is thus divided into two main sections. The first section examines common methods of measuring instability of one or more variables. The literature on market models of instability is described in the second section.

Measuring Instability

The array of past measures of instability can be categorized according to their purpose. Two categories are readily identifiable. First, are those that attempt to capture the degrees of instability among single variables. Second, for functionally related variables, are those that endeavor to apportion variability among their components using statistical identities. In both cases, the degree of instability has been measured without any explicit assumption about the underlying structural relationships.

Single Variable Indices of Instability

According to Gelb (1979), at least 16 different indices of instability have been reported in development literature. The concern is that for a given study, different conclusions are reached depending on the approach. For example, on the negative impact of export earnings instability, supporters of the proposition include Glezakos (1973) and, to a limited extent, Kenen and Voivodas (1972), as well as proponents of commodity stabilization. MacBean (1966) and Johnson (1967) do not support the proposition. Another major concern is that using similar time series data, but employing different indices, often results in widely differing conclusions. This has serious policy implications. Glezakos (1973) presents a statistical verification of some indices that have been used in export instability studies. Some of these indicators are discussed by Knudsen and Parnes (1975) and a recent review of the measures is presented by Offutt and Blandford (1983). Disparity among the measures arises primarily from methods used to eliminate trend and to weight the deviations from the trend. Indices derived from variance and mean absolute deviations are discussed below.

One of the earliest indices of instability, a logarithm-variance type, was developed by Coppock (1962). The index, Ic, is defined as:

$$Ic = \text{antilog of } \frac{1}{n-1} \sum_{t=1}^{n-1} \left[\log \left(\frac{X_{t+1}}{X_t} - M \right)^2 \right]^{\frac{1}{2}} \qquad (1)$$

where

X_t = the logarithmic first difference of the variable

t = time

n = the number of observations

$$M = 1/n-1 \sum_{t=1}^{n-1} \log X_{t+1}/X_t$$

Two advantages of the index are apparent. First, by taking the first difference, much of the linear trend is removed. Secondly, influences of peripheral observations are abated by taking logarithms of the data. The major drawback is that the formation of expectations depends on the first and the last points of the data set. As shown by Knudsen and Parnes (1975), the trend eliminating term is a function of the two points. From equation (1), M can be rewritten as:

$$\begin{aligned} M &= 1/n-1 \; (\log X_2 - \log X_1 + \log X_3 - \log X_2 + \ldots + \log X_n - \log X_{n-1}) \\ &= 1/n-1 \; (\log X_n - \log X_1) \qquad (2) \end{aligned}$$

Equation (2) demonstrates that the formation of the expectations revolves around X_1 and X_n, the first and the last observations, respectively. Thus, intermediate observations are excluded in the process. This raises conceptual problems. There is no reason to assume only X_1 and X_n as the basis for forming expectations. Furthermore, the exclusion makes the index sensitive to the period selected. However, it has been used in a number of studies related to export trade instability. Recent examples include Leith (1970), and Rangarajan and Sundarajan (1976).

Instability among single variables can be compared by coefficients of variation (CV), which express the standard deviation for each variable as a percent of the arithmetic mean of its observations. The index is frequently used and easily interpretable. For a set of observations, the index is defined as

$$I_{CV} = \frac{100}{\bar{X}} \left[\frac{\sum_{t=1}^{n} (X_t - \bar{X})^2}{n-1} \right]^{\frac{1}{2}} \tag{3}$$

where

X_t is the value of the variable in time t, t = 1 . . . n.

$\bar{X}$ is the arithmetic mean of X.

As defined in (3), the I_{CV} index is independent of the length of the series of the data. Unlike Coppock's index, all the data are considered in its development. However, most of the time series data in agriculture exhibit some form of trend. Hence, it is necessary to separate the long run trend component from the short run variations about the trend. Cuddy and Della Valle (1978) indicated that I_{CV} would overestimate the degree of instability if the trend is statistically significant. Nevertheless, the World Bank (1975), Labys and Thomas (1975), and Labys and Perrin (1976) have used the untrended CV (I_{CV}) index.

The importance of trend removal cannot be overemphasized. Massell (1970) stated that the type of trend fitted to time series data determines the index of instability obtained. He postulated that countries tend to plan in terms of growth rates rather than in terms of absolute increments. Consequently, using an exponential rather than a linear form is justified. Although he used the linear form, he observed that, empirically, the former function provided a better fit than the latter for the sample of countries considered. The fitting of a logarithmic function presumes an exponential relationship between the deterministic part of the dependent variable and time. Depending on the properties required of the estimate, the random component can be either independent of time or autocorrelated. Yotopoulus and Nugent (1976, p. 331) assumed the exponential relation in detrending their data.

By fitting a linear form to remove trend, the exact part of the dependent variable is proportional to time. In using this form, Hazell (1982) stated that it does not assume a deterministic component for any relationship between the variance of the dependent variable and time. Hazell (1985) used quadratic forms because of the above assertions and the ease with which unbiased and efficient estimates of the variances and covariances are obtained from the resulting variance-covariance matrix.

The basic procedure uses ordinary least squares to fit the desired functional form. The linear form:

$$X_t = a + bt + e \tag{4}$$

where

X_t denotes the value of the variable in time t, t = 1, 2,...n.

e_t is the error term.

Using the linearly detrended data, Massell (1970) arrived at his index, I_{Me}, as follows:

$$I_{Me} = \frac{1}{\bar{X}} \left[\frac{\sum_{t=1}^{n} (X_t - \hat{X})^2}{n} \right]^{\frac{1}{2}} \tag{5}$$

where

I_{Me} denotes Massell's index.

$\hat{X}$ is the fitted value of X, estimated as per equation (4). The variant of Massell's index used by Yotopoulus and Nugent (1976) is defined as

$$I_{My} = \frac{1}{\log\bar{X}} \left[\frac{\sum_{t=1}^{n} (\log X_t - \log\hat{X})^2}{n} \right]^{\frac{1}{2}} \qquad (6)$$

where

I_{My} refers to the index used by the above authors.

$\hat{X}$ is the fitted value of X, estimated using the transformation where

$$\text{Log } (X_t) = a + bt + e \qquad (7)$$

Cuddy and Della Valle (1978) noted the statistical bias in I_{Me} and I_{Ml}. In their derivation, the divisor, n, was used instead of the generally accepted n-2, the degrees of freedom in equations (4) and (7). Also there is a debate as to whether to use linear or exponential functions when detrending the data. To alleviate the problem, the authors developed a general approach. The starting point is R^2, the coefficient of multiple determination from a multiple regression model:

$$R^2 = 1 - \frac{\sum_{t=1}^{n} (X_t - \hat{X})^2}{\sum_{t=1}^{n} (X_t - \bar{X})^2} \qquad (8)$$

The relationship in (8) can be expressed as

$$\Sigma(X_t-\hat{X})^2 = (1-R^2) \sum_{t=1}^{n} (X_t-\bar{X})^2$$

$$= (n-k)(1-R^2)\left(\frac{n-1}{n-k}\right)\left(\frac{\sum_{t=1}^{n} (X_t-\bar{X})^2}{n-1}\right) \tag{9}$$

where k is the number of independent variables. Note that the square of the standard error (SEE) of the regression and the standard deviation of X can be derived from (9). Using the definition of the coefficient of variation, and the relationship given in (9), an index, I_{Ga}, can be derived as

$$I_G = 100 \frac{SEE}{\bar{X}} = CV\ (1-R^2)\ \frac{n-1}{n-k} \tag{10a}$$

Recognizing that [·] above is equal to one minus the adjusted coefficient of multiple regression, $\bar{R}^2$, equation (10a) can be simplified as

$$I_G = CV[(1-\bar{R}^2)]^{\frac{1}{2}},\ \bar{R}^2 \geq 0 \tag{10b}$$

The above general approach has the following advantages:

1. The index can be compared across several types of trend relations

2. The index is bounded by the lower and upper limits of the CV of the data. Thus, given that $\bar{R}^2 = 1$, then $I_G = 0$ implying the observations show no deviation from the estimated regression line. If $\bar{R}^2 = 0$, then $I_G = CV$ suggesting that no additional information to that in CV accrues from the regression model.

The main disadvantage is that $\bar{R}^2$ assumes only positive real numbers for I_G to be useful.

The Cuddy-Della Valle approach was also used by Schmitz and Koester (1984) in a study on the sugar market policy of the European Economic Community (EC).

The mean absolute percentage deviation (MAPD) is an alternative index of instability to those derived directly from the variance. Defined as

$$MAPD = I_{AD} = 100/n \sum_{t=1}^{n} \left| \frac{X_t - \bar{X}}{\bar{X}} \right| \tag{11}$$

Newbery and Stiglitz (1981) showed that it can be converted to CV if certain assumptions about the distribution of X are made. For a normally distributed series about $\bar{X}$, with CV as σ,

$$\begin{aligned} \sigma &= I_{AD} \left| \frac{\pi}{2} \right| \\ &\doteq 1.25 I_{AD} \end{aligned} \tag{12}$$

A log-normally distributed series would enhance the approximation to the index.

On export trade, Brodsky (1983) showed that the indices are highly sensitive to the units in which the exports are measured. Thus, the use of a strong currency such as the U.S. dollar as the numeraire currency when developing export earnings instability for a developing economy may yield invalid conclusions. He suggested that an export weighted measure or a proxy, calculated as a basket currency may be a relevant numeraire currency.

Gelb (1979) asserted that instability should be treated as a variation measure on a filtered stochastic process. Using spectral analysis procedures, time series data could be decomposed into Fourier components. The sum or the integral of the variances of the components yields the variance of the series. Gelb classified the components into frequency groups with very high frequency components being associated with a duration of one year. A duration of over 5 years was associated with low frequency components. He concluded that:

1. The common indices of instability do not explicitly indicate which components are being considered.
2. Using short time series data (10 to 15 years) worsens the situation.
3. At least on costs of buffering the export earnings instability, research and policy emphasis should be toward the lower frequency components.

Based on Gelb's findings, Newbery and Stiglitz (1981) pointed out that very short duration components could be easily taken care of by the agricultural producers. Also, very long period components could be accommodated gradually. Therefore, the main concern is on the medium period fluctuations. The common indicators of instability described above measure the components imprecisely because short time series data are commonly used. The authors' study suggests that, for a nonstochastic case, an adequate measure for price instability can be obtained if:

1. The time series data cover a period of twenty-five years.
2. An exponential form is used to remove the trend.

3. The deviations about a centered five-year moving average are then used.

4. The prices are real.

So far, certainty with respect to the values of the variable has been assumed. This is not always true. Newbery and Stiglitz (1981) argued that forecast errors are better measures of instability that could be alleviated through intervention by the policy makers. These could be defined as the standard deviation of the residuals found by regressing the current values of the variables on those lagged one period.

Identity Functions

Some random variables are identity functions of other random variables. There are additive and multiplicative identities. Additive identities are used to partition the total variance of an aggregate into that attributable to its components. Multiplicative identities are used to apportion variances of products into those attributable to their elements.

The decomposition procedure is as follows: Let $X_1, \ldots, X_n$ be a random vector having multivariate distribution with variances $\sigma_1^2, \ldots, \sigma_n^2$. For aggregate identities, the aggregate value, $S_n = \sum_{i=1}^{n} X_i$ and the variance of S_n is given by

$$\mathrm{Var}(S_n) = \sum_{k=1}^{n} \sigma_k^2 + 2 \sum_{j,k} \mathrm{Cov}\,(X_j, X_k) \tag{13}$$

The last term extending over each of the (n/2) pairs of (X_j, X_k) with $j < k$. Dividing both sides by $\mathrm{var}(S_n)$ yields

$$1 = \frac{\sum_{k=1}^{n} \sigma_k^2}{\operatorname{var}(S_n)} + \frac{2 \sum_{j,k}^{n} \operatorname{Cov}(X_j, X_k)}{\operatorname{var}(S_n)} \tag{14}$$

The first term on the right hand side may be considered as the variability that is associated with the individual components. The second set of terms indicates the contribution of the interaction between X_j and X_k. Thus equation (14) can be used to identify sources of instability. This assumes that variance is an appropriate measure of instability.

Rourke (1970) applied the above formulation in a study of world coffee variability. He demonstrated that Brazil contributed 86.13 percent of the total variability. The interaction between Brazil and other countries contributed only 13.87 percent. Rourke extended the study to the contribution of individual states in Brazil. His conclusions were that in terms of world instability, the focus should be on Brazil. Within Brazil, the attention should be on Parana and São Paulo. Nevertheless, the procedure does not provide an explanation as to the causes of instability. Offutt and Blandford (1983) suggested that more information could be obtained by decomposing the mutliplicative relationship between area and yield.

Decomposition of multiplicative identities has drawn substantial interest in agricultural production because of policy implications. Early studies include the works of Foote, Klein and Clough (1952) and Meinken (1955). They calculated annual changes in yield and acreage as a percentage of the sum of average annual changes as a percentage of acreage. Sackrin (1957) criticized the approach because it does not strictly equate the changes in production with changes in acreage and yield. He proposed taking the natural logarithm of the identity and thus obtaining an additive relation in terms of logarithms. Production is then regressed on acreage and yield independently. The sum of the coefficients is equal to unity, implying that total change in output is explained.

The primary criticism offered by Burt and Finley (1968) is that Sackrin's model does not account for the interaction of the two variables. In consequence, Burt and Finley developed an alternative procedure similar to Goodman's (1960). The approach rests on a Taylor series expansion. Thus, given the function $y = x_1 x_2$, the Taylor's series expansion is

$$y = \bar{x}_1\bar{x}_2 + (x_1-\bar{x}_1)\bar{x}_2 + (x_2-\bar{x}_2)\bar{x}_1 + (x_1-\bar{x}_1)(x_2-\bar{x}_2) \tag{15}$$

where x_1 and x_2 are jointly distributed random variables with $\bar{x}_1$ and $\bar{x}_2$, their arithmetic means. The mean of y can be obtained by taking the first moment of y such that

$$E[y] = \bar{x}_1\bar{x}_2 + \mathrm{Cov}(x_1, x_2) \tag{16}$$

The variance of y is defined as

$$\begin{aligned} \mathrm{Var}(y) &= E[y-E(y)]^2 \\ &= E[(x_1-\bar{x}_1)\bar{x}_2+(x_2-\bar{x}_2)\bar{x}_1+(x_1-\bar{x})(x_2-\bar{x}_2) - \\ &\quad \mathrm{Cov}(x_1,x_2)]^2 \\ &= \bar{X}_2\mathrm{Var}(x_1)+\bar{X}_1\mathrm{Var}(x_2)+2\bar{x}_1\bar{x}_2\mathrm{Cov}(x_1,x_2) + \\ &\quad E[(x_1-\bar{x}_1)(x_2-\bar{x}_2) - \mathrm{Cov}(x_1,x_2)]^2 + \\ &\quad 2\bar{x}_1E(x_1-\bar{x}_1)(x_2-\bar{x}_2)^2 + 2\bar{x}_2E(x_1-\bar{x}_1)(x_2-\bar{x}_2) \end{aligned} \tag{17}$$

Given two products of jointly distributed random variables, the exact expression for their covariance is given by Bornstedt and Goldberger (1969).

In equation (17), the first two terms are the direct contribution of x_1 and x_2 to total variance. The third term is the first order interaction effect. The last two terms involve higher order cross moments than the covariance terms. Burt and Finley (1968) and Hazell (1982) stated that in most cases, the last two terms are relatively unimportant and their sum can be treated as residual. Assuming the fourth term neutral, then the first three terms could be used to make asymptotic approximations of the total variance.

Offutt and Blandford (1983) applied the Burt and Finley method to actual farmers revenue data for ten U.S. field crops. In the study, revenue is the product of price and output and the two variables are not independent. The result of the decomposition indicated that price was the most important source of revenue instability for eight of ten commodities. Also the results suggested that higher order terms were often too large to be ignored. However, the higher order terms are not easily interpretable in an economic sense.

Burt and Finley (1970) noted an improvement in the approximation when linear trended data were used. Offutt and Blandford observed that the improvement is outweighed by the loss of identity of the original data upon which the Taylor's series expansion is based. The basic flaw of the Burt and Finley procedure is its inability to provide information on structural relationships.

Hazell (1982) developed a procedure for identifying sources of change in instability between two periods through the decomposition of multiplicative identities. The technique assumes that changes in variances is a measure of changes in instability of the variables being studied. From equation (17), the following relationship can be used to express total variance:

$$Var(y)=\bar{x}_2 Var(x_1)+\bar{x}_1^2 Var(x_2)+2\bar{x}_1\bar{x}_2 Cov(x_1x_2)-Cov(x_1x_2)^2+R \qquad (18)$$

where R is the residual term. Equation (18) shows that means of the variables are involved. Therefore, their changes affect the change in total variance. Similarly, the expectation of y given in equation (16) is influenced by changes in covariance between x_1 and x_2. Starting with equation (16) and taking period 1 as the base, Hazell derived the changes as follows:

$$E[y_1] = \bar{x}_{11}\bar{x}_{21} + Cov(x_{11},x_{21}) \qquad (19)$$

In a similar way, the relationship for period 2 can be written as:

$$E[y_2] = \bar{x}_{12}\bar{x}_{22} + Cov(x_{11},x_{22}) \qquad (20)$$

This can be rewritten as:

$$E[y_2] = (\bar{x}_{11}+\Delta x_1)(\bar{x}_2+\Delta x_2)+Cov(x_{11},x_{21})+\Delta Cov(x_1,x_2) \qquad (21)$$

where Δ denotes change in the respective variable, that is, the value in period 2 less that in period 1. Changes in the mean of y over the two periods is given by:

$$\begin{aligned} \Delta E[y] &= E(y_2) - E(y_1) \\ &= x_1\Delta x_2+x_2\Delta x_1+\Delta x_1\Delta x_2+\Delta Cov(x_1,x_2) \qquad (22) \end{aligned}$$

The first two terms in equation (22) are the direct effects. The third and the last terms refer to interaction and changes in variability of x_1 and x_2, respectively. Following a similar procedure, the variance of y, Var(y), can be obtained.

Hazell (1982), using the above methodology, analyzed instability in Indian food production. He examined the following propositions:

1. The development of less risky technologies is a direct way of alleviating production instability in India; and
2. Instability can be reduced through stabilization of year-to-year adjustments in crop cereals sown.

The results indicated large increases in yield and area-yield correlations between crops. Consequently, the first proposition would be a useful target for farm or microlevel stabilization policies. The presence of high intercrop and interstate correlation would reduce the effectiveness of the second proposition when the whole of India is considered. These observations suggest that instability could be reduced by taking advantage of the covariance to allocate production in a more risk-efficient way.

In a comparative study between the instability in Indian and United States' cereal production, Hazell (1984) attributed the increase in yield covariances in India to increased adoption of improved production technologies. Other sources of variability include increases in price variability, unpredictable rainfall patterns and unstable supplies of inputs. For the U.S., the increase in total cereal production was dominated by increases in means and variances of yields. The increases in interstate yield correlation were restricted to corn. This could be attributed to the narrowing of the crop's genetic base.

Hazell (1985) applied the same procedure in an attempt to identify sources of instability in world cereal production. The most important sources of total production instability were increases in yield variances, interregional yield correlations for the same crop and different crops, and a decline in yield-area correlation. As in the earlier two studies, the author suggested a more detailed study to identify fully the sources of these changes. Again, Hazell's model does not present any information on underlying cereal production.

Piggott (1978) outlined an alternative method of decomposition. It involves apportioning total variance of gross revenue into components that are attributable to demand and supply variability and the variability of the interaction between demand and supply. The model assumes linearity in the demand and supply functions. Constant slopes over time and additive disturbances as shifters are also assumed. Demand and supply functions are estimated and equilibrium values are determined from which gross revenue, expressed as product of equilibrium price and quantity, is derived. The analysis yields similar results as the Burt and Finley approach for price elastic demand and perfectly price inelastic supply.

Piggott's procedure cannot be used to identify composition of the shifters. Moreover, the assumptions are too restrictive to be usefully applied to agricultural production and marketing studies.

Murray (1978) applied the decomposition of identities procedure to identify the source of export earnings instability for several countries. Assuming that the variables were normally distributed in logarithms, the variation in export earnings (E) were decomposed into price and quantity components from the identity:

$$\mathrm{Var}(\log E) = \mathrm{Var}(\log P)+\mathrm{Var}(\log Q)+2\mathrm{Cov}(\log P,\log Q) \quad (23)$$

The sign of the covariance term, positive or negative, indicates whether the variations in supply or demand, respectively, have been the main source of instability. The results indicated that supply was the primary source of instability. Furthermore, earnings instability was relatively unimportant where price volatility was the dominant factor. Similar analysis based on individual commodities supported the above results (Riedel, 1983).

Corden (1974) stated that in a situation where supply instability is general to the economy, not limited strictly to export commodities, and the authorities have no foresight, second-best policies designed to stabilize the economy, such as an export tax, may not be appropriate. The models reviewed thus far are analytically silent on this issue.

Anderson et al. (1977) stated that economic theory is ambiguous on the need for price stabilization schemes. One argument is that uncertainty is undesirable if followed by market failure. In this case, correcting the failure is preferred to the removal of uncertainty. However, Samuelson (1972) argued that an economy in a Pareto equilibrium without uncertainty cannot improve itself by generating uncertainty. Hence stabilization policies should attempt to eliminate the source of risk. Price stabilization is adopted for lack of an alternative practical approach. It is not necessarily the best alternative because price variability is a manifestation of structural sources of instability that include uncertainties in supply and exchange rates in export trade.

Abbott (1979) developed an econometric model that was used to show the need to endogenize the role of government in international trade. McKinnon (1982) argued that domestic stabilization policies that manipulate money supply and exchange rates enhance global instability. Chambers and Just (1979) presented a theoretical and empirical critique of agricultural trade. Their analysis led them to suggest that exchange rates are important determinants of agricultural trade flows. The presence of money and exchange rates disguise exchange in real goods. The situation is exacerbated by a government's interference with the market determination of exchange rates.

Developing countries, in general, peg their exchange rates to convertible currency or baskets of currencies. Presently, the major hard currencies have floating exchange rates in the sense that the market forces of demand and supply determine their values. McCalla and Josling (1985) note that the impact on the domestic economy of a change in the exchange rate of hard currency is variable and sometimes ambiguous. Depreciation of hard currencies does not necessarily help the developing economies because they are basically exporters of primary commodities and importers of manufactured and capital goods (McCalla, 1982). As the foreign currency depreciates relative to the domestic currency, international prices in terms of domestic currency rise but the quantity of imports may not adjust accordingly. Absence of quantity adjustments may not be offset by gains in foreign exchange resulting from more competitive exports.

Gulhati et al. (1985) state that many post-independence African governments did not consider the exchange rate as a possible policy instrument. Three factors are identified as causes for aversion to the use of the instrument. African governments believe that devaluation of their exchange rates would increase domestic inflation, increase budgetary deficits and generate few benefits from international trade. If exports have low elasticities of demand in international markets, then changes in real exchange rates may have little influence on the quantity exported and subsequent income to producers. Moreover, in many African countries, fiscal resources are derived from the agriculture sector. Inflation and declining demand for export commodities increase taxation of the sector with deleterious consequences on the domestic agriculturally-based economy.

Instability in foreign exchange rates has drawn the attention of policy-makers because of the possible repercussions on domestic-currency value of internationally traded commodities. There is general agreement that exchange rates changes affect prices, supplies, and quantities demanded. Currently, there is no strong theoretical consensus as to the most relevant forms of fluctuations (Bank of England, 1984). The choice of exchange rate standard does not affect external terms of trade. Rather, the concern is its effects on internal trade, income distribution and domestic allocation of resources (Lipschitz, 1978). Nevertheless, Lanyi and Suss (1982) found that choice of the exchange arrangement affects exchange rate instability. Their study suggested that minimizing the instability of nominal effective exchange rates also minimizes that of the real effective exchange rate and vice versa. Since 1973, some countries have had exposure to flexible exchange rates and have chosen exchange rate regimes that attempt to minimize costs associated with exchange rate instability.

Often, unit value of an export commodity is fixed for the contract period in terms of an easily convertible foreign currency. If domestic currency fluctuates against the currency, exporter's earnings would vary accordingly. The inability of the exporter to control variability represents a cost to him. So long as the exporter is risk-averse, his/her interest would be to minimize the deviation between expected and actual values in terms of domestic currency. Individual transactors are interested in the exchange rate for the hard currency in which export earnings are denominated. Therefore, the export instability facing an individual is appropriately calculated using the relevant transaction currency.

Brodsky (1983) tested the validity of the notion that measured export instability is independent of the transaction currency used. Exports of each country considered were valued using seven different numeraire currencies. The standard error from the least squares exponential trend regression equation was used as the instability measure.

Proponents of the theory of underdevelopment emphasize that lags in food production in the Third World arise from their dependence on a global economic system. The development of a dichotomous agriculture that has generally favored export over domestic market oriented production has caused this dependency. While the agricultural sector of a number of developing countries exhibits this dichotomy, some authors believe that economic complementarity exists between commodities produced for the export market and domestic food crops.

Concerning producers' income instability and agricultural exports, Bautista (1986) using a procedure similar to that in Schmitz and Koester (1984) studied commodity combinations that minimize total income instability in the Philippines. Consider the following additive identity:

$$I = I_e + I_d \tag{24}$$

where I is total income, I_e and I_d denote income from exports and domestic marketings, respectively. The variance of I is given by

$$Var(I) = Var(I_e) + Var(I_d) + 2Cov(I_e, I_d) \tag{25}$$

The coefficient of variation (CV) and the variance of income have the following relationship

$$Var(I) = CV_I^2 \bar{I}^2 \tag{26}$$

In terms of CV's, equation 26 can be written as

$$CV_I^2 I^2 = CV_{Ie}^2 \bar{I}_e^2 + CV_{Id}^2 \bar{I}_d^2 + 2r\bar{I}_e \bar{I}_d CV_{Ie} CV_{Id} \tag{27}$$

In the above equation, r is the correlation coefficient between $\bar{I}_e$ and $\bar{I}_d$. The share of income attributable to the respective market can be derived by dividing both sides of (27) by $\bar{I}^2$ to yield

$$CV_I^2 = S_e^2 CV_{Ie}^2 + S_d^2 CV_{Id}^2 + 2S_e S_d r CV_{Ie} CV_{Id} \tag{28}$$

S_e denotes the share of income attributable to export market while S_d is that from the domestic market.

Given the CV's and r, then total income instability is determined by the contribution of each category. Assuming that the country's variables remain unchanged, then total differentiation of equation and rearranging (28) gives

$$dCV_I = \frac{CV_{Ie}^2 S_e dS_e}{CV_I} + \frac{CV_{Ie}^2 S_d dS_d}{CV_I} + \frac{S_d rCV_{Ie} CV_{Id} dS_e}{CV_I}$$

$$+ \frac{S_e rCV_{Id} CV_{Ie} dS_d}{CV_I} \tag{29}$$

Noting that $S_e + S_d = 1$ and $dS_e = -dS_d$, equation (29) can be rearranged thus:

$$\frac{dCV_I}{dS_e} = \frac{-CV_{Ie}^2 - rCV_{Ie}CV_{Id}}{CV_I} + \frac{[CV_{Ie}^2 + CV_{Id}^2 - 2rCV_{Ie}CV_{Id}]}{CV_I} S_e \tag{30}$$

Bautista noted that, if

$$S_e > \frac{CV_{Id}^2 - rCV_{Id}CV_{Ie}}{CV_{Id}^2 + CV_{Ie}^2 - 2rCV_{Id}CV_{Ie}} \equiv S_e^* \tag{31}$$

then greater total income variability ensues from a rise in the share of export earnings. Assuming that $\bar{I}_e$ and $\bar{I}_d$ are independent, that is, $r = 0$, then

$$S_e > \frac{CV_{Id}^2}{CV_{Id}^2 + CV_{Ie}^2} \equiv S_e^* \tag{32}$$

Minimum conditions are achieved when second order conditions are met. Rearranging (32) yields

$$S_e > \frac{1}{1 + CV_{Ie}^2/CV_{Id}^2} \equiv S_e^* \tag{33}$$

Thus, the ratio of CV^2_{Id} to CV^2_{Ie} determines the export crop share that minimizes income instability. If the ratio is unity so that $S^*_e=0.5$, then minimum total income variability arises from equal proportions of income from exports and domestically marketed commodities.

As for the Philippines, Bautista found that after the second world war, income instability from exports has been higher than for food crops. He concluded that the nature of export-food crop tradeoffs in a developing country is an important policy consideration.

Market Models of Instability

Market models of instability have appeared in two basic categories: Partial or Marshallian framework and the general equilibrium approach. Most of the studies on commodity price stabilization fall into the former category. The complexity of modeling instability in a general equilibrium framework is reflected by the few studies that started with the work of Brainard and Cooper (1968). Recently, Jabara and Thompson (1980) specified and empirically tested a general equilibrium model of agricultural trade for Senegal. The present study centers on the commercial subsector of the Kenyan economy. Thus, this review of literature concentrates on partial rather than general equilibrium.

The Waugh-Oi-Massell Framework

The early theoretical framework for analyzing price stabilization within a partial-equilibrium framework was advanced by Waugh (1944), Oi (1961), and Massell (1969, 1970). Waugh used the concept of consumer surplus to examine the effects of price instability on consumers of agricultural products. Assuming that consumers purchased more at low prices and less at high prices, Waugh concluded that, for a given unstable demand and supply situation, consumers would benefit from instability. Oi arrived at similar conclusions for producers using the producer surplus concept. The model presumes that producers respond instantaneously to price changes. Schmitz (1984) stated that similar results could be obtained by assuming that the expected prices and quantities are realized.

Both Waugh and Oi models consider consumers and producers of agricultural products separately. Massell (1969) demonstrated that instability is not beneficial to either group if they are jointly considered and the supply and demand curves are not perfectly inelastic. Linear supply and demand curves and additive disturbances are assumed. A complete costless price stabilization scheme is optimal to society as a whole. However, this is not usually achievable. Consequently, the effects of partial price stabilization strategies have been studied. In this context, Massell (1970) and Just, Schmitz and Turnovsky (1978) utilized buffer stock as a policy action and assumed a linear adjustment rule in their studies. The presence of asymmetric market conditions understates the validity of the rule.

Extensions of the Waugh-Oi-Massell Approach

In a graphical exposition, Schmitz (1984) explained the effects of a nonlinear demand curve with supply as the source of instability.

The results indicate that for a sufficiently nonlinear demand curve, consumers would gain from stability while producers would lose from it. These contradict the findings of Massell (1969). Also, converse effects are obtained for the case of a sufficiently nonlinear supply curve when the demand is the source of instability. Nevertheless, the net effect is positive when both groups are considered jointly. The policy implications of a non-linear demand curve are expressed in Hillman, Johnson and Gray (1975) and supported by the findings of Just et al. (1978). In this context, a steeply sloping demand curve at higher prices while shallowly sloping at lower prices, would lead to a change in storage policies from those favoring producers to those which are beneficial to consumers.

Turnovsky (1976) extended Massell's approach to include nonlinear demand and supply and multiplicative disturbances. The results indicated that, unlike the additive case, the need to stabilize prices depend upon the deterministic component of supply and demand curves rather than the source of instability.

Hueth and Schmitz (1972) extended the basic Waugh-Oi-Massell framework to international trade where external markets are unstable and internal supply reacts instantaneously to price changes. The study did not consider the effects of price uncertainty or the cyclical behavior of prices. Their findings suggested that consumers and producers prefer instability when its source is external to the country. However, countries taken together prefer price stability. Just et al. (1978) found that, for nonlinear demand and supply functions, importing countries were likely to gain more from price stabilization than exporting countries.

The free trade assumption of the Hueth-Schmitz model was relaxed by Bieri and Schmitz (1973) through the institution of trade restrictions. Specifically, the study looked at tariffs and the use of marketing boards that introduce less than perfectly competitive marketing conditions. The intriguing results were:

1. If trade is restricted by tariffs, and the source of price instability is abroad, the importing country benefits from price stability.
2. If trade is restricted by marketing boards and the source of instability remains external, the importing country loses from price stabilization.

Implicitly, the latter proposition provides an approach to alleviating producer risks in an exporting country through the use of marketing boards.

Just et al. (1978) modified the Hueth-Schmitz model to include distorted trade situations with nonlinearity and alternative forms of stochastic disturbances. Policies leading to this form of imperfect trading conditions, commonly practiced in western Europe, imply that domestic commodity prices are insulated and instability is transferred to the trading partners. Thus, consumers in importing countries lose from instability while producers in exporting countries gain. Various government intervention policies on price instability were studied by Bale and Lutz (1979). Their main conclusion was that governments are primarily interested in domestic rather than global stability.

The welfare effects of storage under a production cartel have been analyzed by Young and Schmitz (1984). With reference to the U.S. milk industry, the imperfect market situation is generated by presence of large producer cooperatives and marketing orders. In this case, price stabilization through the use of buffer stock is curtailed. Results suggest that the government should allow storage and institute pan-territorial pricing, that is, a uniform price country-wide. But, the sensitivity of the conclusions to the assumptions about the demand function necessitates empirical analysis as a basis for determining the relevant assumptions.

Konandreas and Schmitz (1978) applied the Hueth-Schmitz model to study the welfare implications of grain price stabilization in the U.S. The findings indicated that price stability of the feed grain sector benefits both consumers and producers in the aggregate. However, for the wheat sector, the results were not conclusive although they tended to suggest that price instability in the wheat sector is desirable.

Zwart and Meilke (1979) compared effects of changing domestic policies and buffer stocks on price stability of the world wheat industry. They concluded domestic pricing policies have more effects on instability than policies based on buffer stocks. On a similar issue, Sarris and Freebairn (1984) demonstrated the aggregate impact of domestic intervention on rice trade. On average, they lead to artificial increases in world price and an increase in instability, a conclusion arrived at by Bigman (1979). Furthermore, major rice producing countries have the most leverage on world rice prices. Small producers, although large in terms of rice exports, have a lesser influence on price.

Subotnik and Houck (1976) analyzed welfare implications of stabilized consumption and production. They demonstrated stabilized consumption is the least beneficial in terms of welfare.

The basic assumption of the Waugh-Oi-Massell framework is that producers and consumers are risk-neutral. The model captures transfer gains but not risk-response. Just (1975) found that with the exception of strongly regulated crops, risk is an important factor in explaining producer supply response. Just and Hallam (1978), on the same issue, concluded that a price stabilization policy should depend on the identification of important risk preferences. Recently, Quiggin (1983) studied the effects of different sources of risk in wool prices on the risk borne by users. He concluded that the long-run effects of price stabilization is to decrease risk faced by wool producers and increase that faced by users if the major sources of risk are fluctuations in final demand or exchange rates.

Studies on exchange rate volatility have been inconclusive. Akhtar and Hilton (1984), in a study of international trade in manufactured goods for West Germany and the U.S., concluded that uncertainty in the nominal exchange rate had a statistically significant impact on trade. Gotur (1985) extended this model to include more countries. He demonstrated that Akhtar and Hilton's results were not universal. Schuh (1974) argued that an overvalued exchange rate can influence the need for government intervention policies. McCalla and Josling (1985) succinctly show the importance of the exchange rate in international trade and development.

Van Kooten and Schmitz (1985) incorporated producer price uncertainty into the basic Waugh-Oi-Massell framework. As stated earlier, this approach considers only price instability. The following results were found:

1. The Waugh-Massell case always overestimates the true gain to society from price stabilization.

2. The Oi-Massell case suggests that price stabilization is Pareto-optimal.

Regarding food-grain consumption in developing countries, Reutlinger (1982) concluded that unstable domestic consumption is attributable to internal and not external price or supply instability. Bigman and Reutlinger (1979) and Bigman (1982) studied the impact of trade policy on food insecurity. They showed that more trade liberalization alleviates food insecurity than does protectionism. Valdés (1982) supported Reutlinger's (1977) argument that the instability problem for less developed countries (LDC's) stems from fluctuations in real income within the LDC. Valdés argued that the availability of foreign exchange to import food when required is important for the stability of food consumption. Concerning food aid, Reutlinger (1976) observed that within limits, additional economic benefits from storage without food aid are sufficient to change a net loss to a net gain for society. In this case, storage reduces the cost of food aid.

The Newbery-Stiglitz Approach

Newbery and Stiglitz (1981) provided a systematic procedure for assessing the desirability of price stabilization through the use of buffer stocks. They asserted that the relevance of policy analysis depends on the identification of the variables to be measured. On specific price stabilization proposals based on the Waugh-Oi-Massell approach, their contention is that such policies have less benefits in situations where risk plays an important role as in the case of most developing economies. Specifically, their study centers on the following aspects:

1. effects of risk and uncertainty on consumption and productions; and
2. the structure of policies that are implemented by decision-makers in response to the unstable environment.

Newbery and Stiglitz showed that under certain situations, price stabilization leads to income instability and if a price stabilization policy is to be effective, it has to reduce producers' risk. Among other issues, the authors argued that producers are basically concerned with the costs associated with commodity instability. These costs "are better measured by income variability, which will also depend on supply variability. Moreover, the impact of stabilization schemes depends quite sensitively on the location of the source of the instability, which may vary from place to place" (p. 289). Consequently, the problem of what to stabilize is empirical and location specific.

Bigman (1985) developed a simulation model for analyzing food prices under instability. Noting the effects of producer income instability in rural areas, and without referring to any country, Bigman analyzed the impacts of alternative producer price support and stabilization programs. For a closed economy scenario with risk neutral producers, minimum price supports, government procurement programs, guaranteed income and buffer stock policies effectively eliminate producer income risk. Under similar production assumptions, but in an open economy, the policies are also effective at reducing income risk. With risk-averse producers in a closed economy, the policies contributed to greater output and decreased mean prices. However, in this case, producers' income depended on the price elasticity of demand for the commodity.

For internationally traded commodities, Bigman reconsidered the issue, first raised and analyzed by Newbery and Stiglitz, that with risk-averse producers and incomplete risk markets, free trade may be Pareto-inferior to no trade. His simulation analysis showed the above conclusion applies to price elasticity of demand values that are above 0.6. At lower values, autarky is Pareto-inferior (to farmers) to free trade. Nevertheless, if substitution is possible, the production stability of the substitute and its price elasticity of demand would be important determinants of optimality. Like Newbery and Stiglitz, Bigman (1985) concluded that the issue is essentially empirical.

Producers' Expectations

The above literature assumes producers have perfect foresight on prices and quantities. But, agriculture abounds with cases where there is no such ex ante information. Concerning formation of price expectations, Turnovsky (1974) considered two formulations: adaptive and rational.

In the adaptive expectation mechanism, producers supply decisions are based on anticipated prices as follows:

$$S(P_t^*) = \alpha_0 + \alpha_1 P_t^* + v_t \tag{34}$$

where P_t^* is the anticipated price at time t, v denotes error term. The hypothesis about the formation of expectations is defined as

$$P_t^* - P_{t-1}^* = \gamma(P_{t-1} - P_{t-1}^*), \quad 0 \leq \gamma \leq 1 \tag{35}$$

where denotes the coefficient of expectation. Equation (35) postulates that expectations are revised each period by a fraction of the forecast error of the previous period.

Turnovsky's study demonstrated that conclusions arrived at by Oi on the effects of price stabilization do not hold universally. The conclusions depend on the relative slopes of the demand and supply curves, the length of the lag in the formation of expectations, and the autoregressive properties of the error term. The Waugh results, based on consumer surplus, still held. Nevertheless, price stabilization leads to an overall welfare gain despite the loss by one group.

In the rational expectation hypothesis, price formulation can be defined as

$$P_t^* = E_{t-1}(P_t) \tag{36}$$

where E_{t-1} defines conditional expectations at the time t-1. Accordingly, producers are rational if their predicted prices for period t are equal to that predicted conditional on all information at the time of forecasting. This approach eliminates the ad hoc nature of the extrapolation existing in the adaptive expectation hypothesis (Bigman, 1985). Rational expectations, in the sense of Muth (1961) assume that producers behave as utility- and profit-maximizing agents, operating in a perfectly competitive world.

Based on rational price expectations, Turnovsky (1974) demonstrated that:

1. There was an overall positive gain in welfare.

2. If the source of instability is random shifts in the supply curve, consumers lose from price stabilization policies.

3. If the source of instability is the random shifts in demand, producers lose from price stabilization. This is true whenever the random disturbances are not autocorrelated.

Thus, whether the Oi framework is applicable to this group of decision-makers or not depends on the way expectations are formulated.

Hazell and Scandizzo (1975, 1977) argue and demonstrate that in risky production environments, where output variations are multiplicative and output decisions are based on price expectations, competitive markets are socially inefficient. If decisions are based on expected unit revenues rather than price, the inefficiency is eliminated. Revenue expectations account for the joint distribution of price and output. The authors found that if production is undertaken in risky conditions, revenue expectations lead to less output than price expectations. Consequently, optimal policy formulations should be based on empirical studies based on the nature of production risks and the formulations of expectations by producers.

In line with the arguments put forward by Hazell and Scandizzo, Bigman (1985) asserted that a producer equates his marginal cost, which is deterministic, to the expected price less the risk premium. The risk premium is assumed to be proportional to the variability of the unit revenues and price formations follow the adaptive expectation hypothesis.

Summary

A review of major contributions in instability studies has been presented. The first section described the methodologies that have been put forward in an attempt to measure the degree of instability in time series data. In the second part, specific market models of instability and their extensions were surveyed.

It was shown that the problem of measuring instability is yet to be resolved despite the large number of indices that have been developed. The basic problem concerns what instability reflects. Gelb (1979) states that it should be treated as a measure on a filtered stochastic process. Newbery and Stiglitz assert that common indicators could be relevant if they could measure medium period fluctuations.

Where random variables are identity functions of other variables, statistical decomposition provides a means for identifying sources and the degree of instability of their components. The identities may be additive or multiplicative. The decomposition of multiplicative identities has drawn a lot of interest because of policy implications. Goodman (1960) developed the procedure for decomposing identities. This was popularized among agricultural economists by Burt and Finley (1968). Decomposition of identities is undertaken without any explicit assumption of the underlying structural relationships. Piggott (1978) outlined an alternative method that considers the structural relationship but it involves restrictive assumptions that limit its application in agricultural studies.

Waugh (1944), Oi (1961), and Massell (1969, 1970) advanced the basic risk-neutral theoretical framework for sectoral analysis of the effects of instability. The concept of consumer and producer surplus is the basis for the analysis. With producer price uncertainty coupled with instability, the Waugh-Oi-Massell production mode does not hold. In an alternative framework, Newbery and Stiglitz (1981) argue that producers are basically concerned with costs associated with commodity instability. Thus, stabilization measures are location specific and therefore what to stabilize is an empirical problem. This proposition is supported by Bigman (1985).

Studies on expectations, in the context of instability, have revolved around adaptive and rational price expectations. However, under risky production conditions, socially efficient markets are obtained when the expectations are based on unit revenues rather than price. Hence, information on producer's production conditions and his formation of expectations are essential for optimal policy formulation (Hazell and Scandizzo, 1975, 1977).

The stock of literature on instability emphasizes empirical findings as bases for appropriate policies on stabilization. There is an empirically determined information gap on income instability where:

1. agricultural producers are risk-averse;
2. government intervention is prevalent;
3. producers face both open and closed economic situations depending on the commodity they produce; and
4. commodities are functionally related in terms of their resource requirements so that income instability affects all commodities in one way or another.

These are common phenomena in most countries.

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