Commodity Prices Revisited

William G. Tomek

Empirical models of commodity prices are potentially important aids to decision-makers, especially as the economy has grown more complex. A typical time series of commodity prices exhibits positive autocorrelation, occasional spikes, and random variability, and conceptual models have been developed to explain this behavior. But, the leap from theory to empirical applications is large because of model specification and data quality problems. When modeling price expectations, for example, should a price series be deflated and if so, by what deflator? The choice can have a large effect on empirical results. Nonetheless, it is possible in some applications to obtain relatively stable estimates of structural parameters that are useful for addressing specific problems. This may not happen often, however, because the incentives in academia do not encourage rigorous, in-depth appraisals of empirical results.

Much of economics is about the consequences of changes in relative prices, and the causes and consequences of changes in commodity prices have long been a topic of analysis. In 1928, for example, Warren and Pearson undertook a comprehensive empirical analysis of the relationship of farm prices to changes in production. In 1958, Cochrane (p. 3) noted "Farm prices are always on the move . . . . Out of this price variability . . . emerge several farm problems: . . . low incomes over extended periods, and uncertainty . . .," and he used a cobweb model to explain this behavior. In 1972, Tomek and Robinson (p. 1) introduced the subject of agricultural product prices by saying " . . . they strongly influence the level of farm incomes, the welfare of consumers, and, in many countries, the amount of export earnings." The question of whether or not the "terms of trade" were turning against farmers was (and remains) a major topic of analysis and debate (Tomek and Robinson, Chapter 10).

After a short hiatus, a renewed interest in the behavior of commodity prices has developed. One reason is the growing complexity of economies, both in developed and developing countries. Hence, modeling and simulating prices, as a basis for decision-making, have renewed importance, although they remain difficult to do well.

Examples of the renewed interest include Antle who, in his 1999 presidential address to the American Agricultural Economics Association, discussed the causes and consequences of declining real commodity prices as a part of the "new economy of agriculture." Also in 1999, Deaton criticized the state of knowledge about commodity price behavior, in light of inaccurate forecasts which led to poor policy prescriptions for African nations. Earlier, Tomek and Myers (p. 181) had noted "The pioneers of agricultural price analysis hoped to estimate econometric relationships which could be used for forecasting and policy analysis, . . . however, . . . the optimism of the past must be tempered by the reality of the present."

Another reason for a renaissance of interest in agricultural prices is the changes in government programs that have resulted in more variable prices in the 1990s. With increased variability, there is a need for a better understanding of price risk, so that farmers and merchants can better manage it. In sum, the analysis of commodity prices remains important, and while the renewed interest is driven by recent events, price analysis should be placed in a historical context. Current work should build on the past.

The objectives of this paper are (a) to review the empirical "facts" about commodity prices that need to be explained, (b) to summarize developments in the price-theory literature that are in-

Paper presented at the annual meeting of the Northeastern Agricultural and Resource Economics Association, University of Rhode Island, June 12, 2000. William G. Tomek is a professor of agricultural economics, emeritus at Cornell University.

I very much appreciate the assistance of Hikaru Hanawa Peterson in data collection and analysis and for useful discussions. Peterson's and my research is partially supported by USDA NRI Competitive Grants Award No. 99-35400-7796. I also wish to acknowledge the helpful comments of B.W. Brorsen, A.M. McGuirk, B.F. Stanton, and L.W. Tauer on an early draft of the paper.

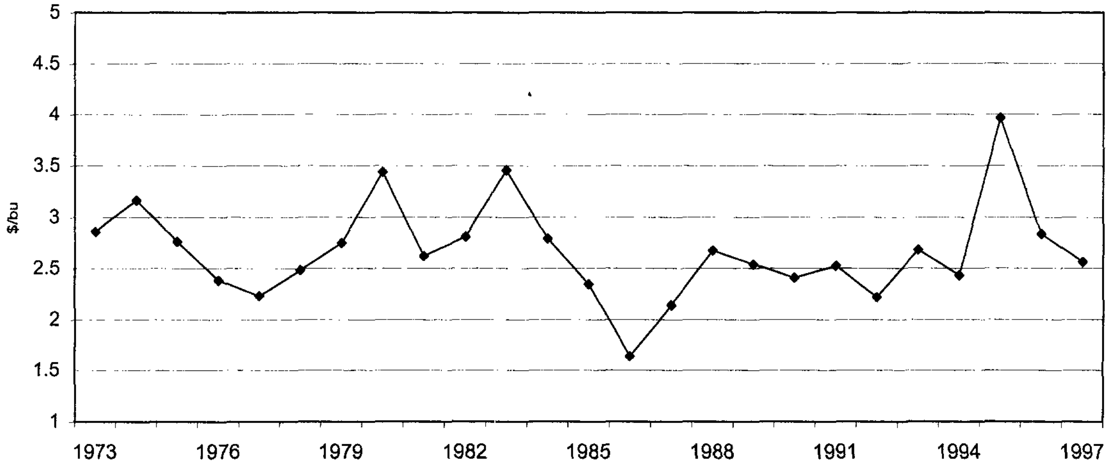

Figure 1. Nominal Price of Corn, Illinois, Crop Years 1973/4–1997/8

tended to explain these facts, and (c) to discuss the problems of moving from conceptual to the empirical modeling of commodity prices. In the concluding section, I address the question, what can we reasonably expect to accomplish in price analysis?

The "Facts" of Price Behavior

A typical time series of commodity prices exhibits both random variability and positive autocorrelation. Occasionally, spikes occur; i.e., prices jump rather abruptly to a high level relative to the series' long-run average. Thus, distributions of prices appear to be skewed to the right and display kurtosis (e.g., Myers; Deaton and Laroque). These generalizations apply roughly to series of varying frequency, but it is convenient to divide the discussion into the behavior of low frequency, inter-year observations and of higher frequency, intra-year observations.[1]

Inter-Year Behavior

Commodity prices through time can evidence "cyclical" behavior (i.e., reoccurring patterns) and trends. There is, of course, random variability from year to year, and sometimes large spikes in prices are observable. An annual price series for corn in Illinois illustrates the variability and has a spike, but these corn prices are not autocorrelated (figure 1). Also, the spike is more pronounced in monthly prices.

Trends in farm prices are clearest in deflated series; many commodity prices have declined relative to other prices over the past 30 years. The price of corn deflated by the Index of Prices Paid by Farmers (PPF) is shown in figure 2. For the crop years 1973–74 to 1997–98, nominal corn prices averaged $2.67 with a standard deviation of $0.47 per bushel. If the series is deflated by the prices paid index (1992 = 1.0), the mean price is $3.19 per bushel with a standard deviation of $1.08 per bushel. The nominal price varied around a constant mean; the deflated price varied around a decreasing mean.

Antle shows that the deflated index of prices received by farmers in the United States has been declining since 1960, but that the real price of food at retail has been constant over the same period. In other words, prices at the farm have declined relative to other prices in the economy, including the price of food at retail.

Intra-Year Behavior

Higher frequency data—especially daily, weekly, or monthly observations—have relatively more

[1] The empirical "facts" presented in this section are subject to qualifications. This is because a precise description of price behavior should make a distinction between marginal and various possible conditional probability distributions. Given a sample of monthly corn prices, for example, the parameters of a single, marginal distribution could be estimated based on the overall sample average. Alternatively, 12 distributions could be estimated using the 12 monthly means. The mean, variance, and skewness of corn prices changes systematically by month (see figure 4 below). The marginal distribution may be skewed, but the distributions conditioned on months provide additional information about price behavior. In addition, the nature of the conditional distributions will vary with the conditioning variables, hence with the research problem. The monthly prices of corn might be modeled as a non-linear function of the monthly stocks-to-use ratio, which presumably helps explain price variability. These conditional distributions will differ from those depicted in figure 4; i.e., the distributions of prices are now being estimated for (say) small, medium, and large ratios. The variances of these conditional distributions may differ systematically over the range of the ratios; a plausible hypothesis is that the variances increase as the ratio decreases; this hypothesis could be tested.

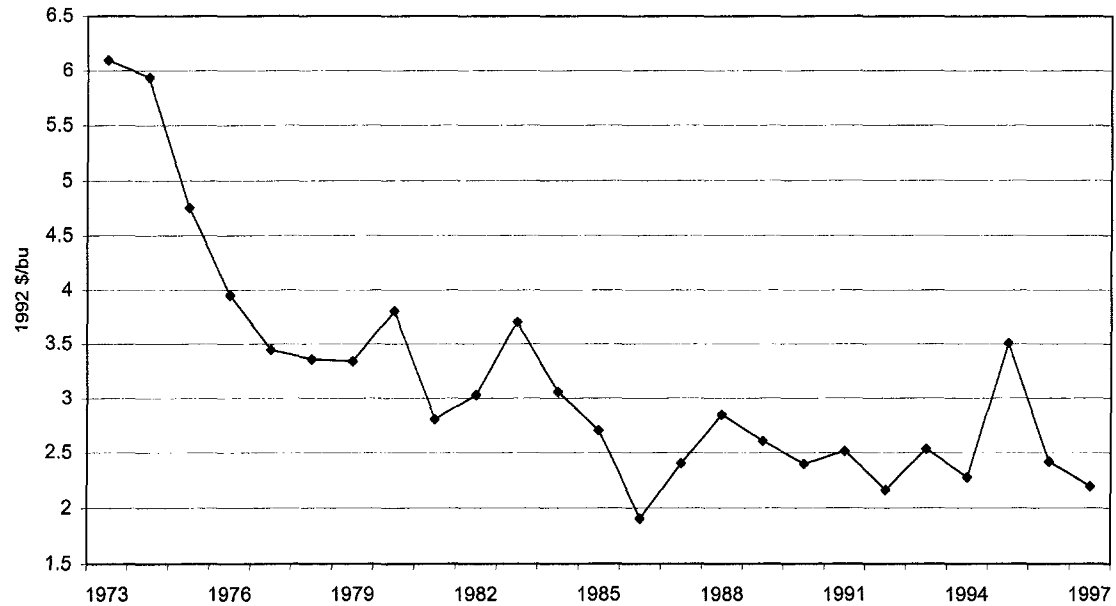

Figure 2. Price of Corn Deflated by the Index of Prices Paid by Farmers (1992 = 1.0), Illinois, Crop Years, 1973/4–1997/8

complex time-series patterns. This is not surprising because these data contain seasonal and short-run adjustment components as well as random components, and also include the longer-term trends and cycles. Most commodity prices have seasonality, and commodity prices in cash markets may not adjust "instantly" to new information. Arbitrage costs in commodity markets can be substantial.

A monthly price series for milk is plotted in figure 3, starting in September 1989 and ending in September 1999. (The figure also contains the plots of an AR(3) time-series model fitted to the

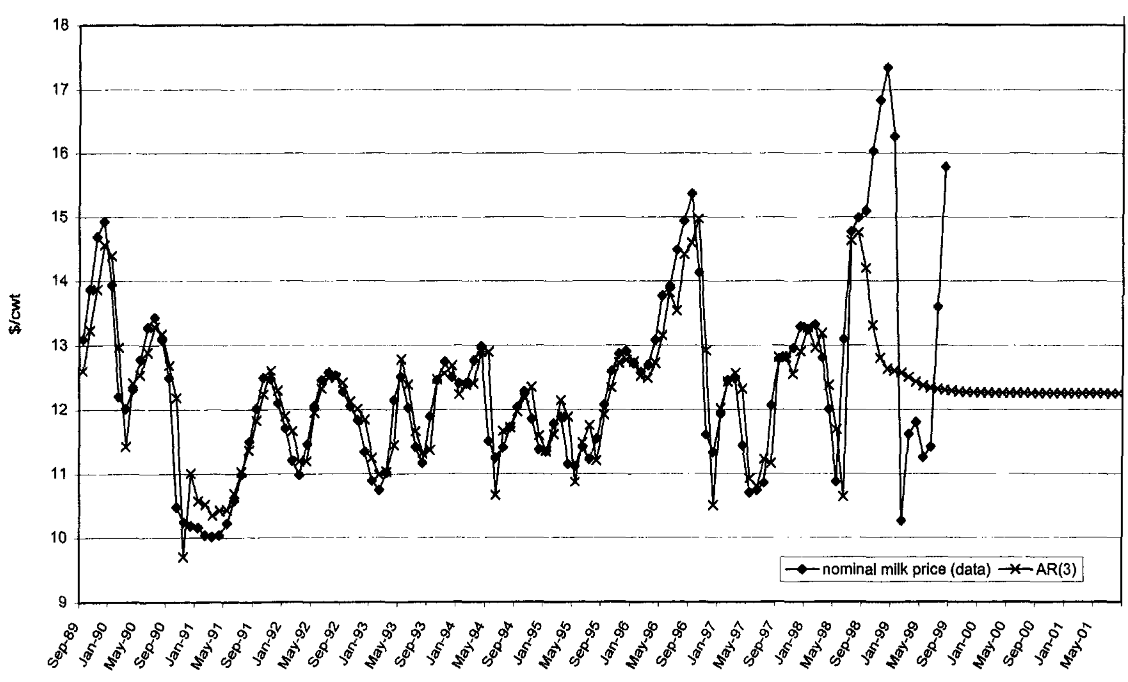

Figure 3. Nominal Price of Manufacturing Grade Milk, Minnesota-Wisconsin 3.5% Milkfat Basis, September 1989–September 1999

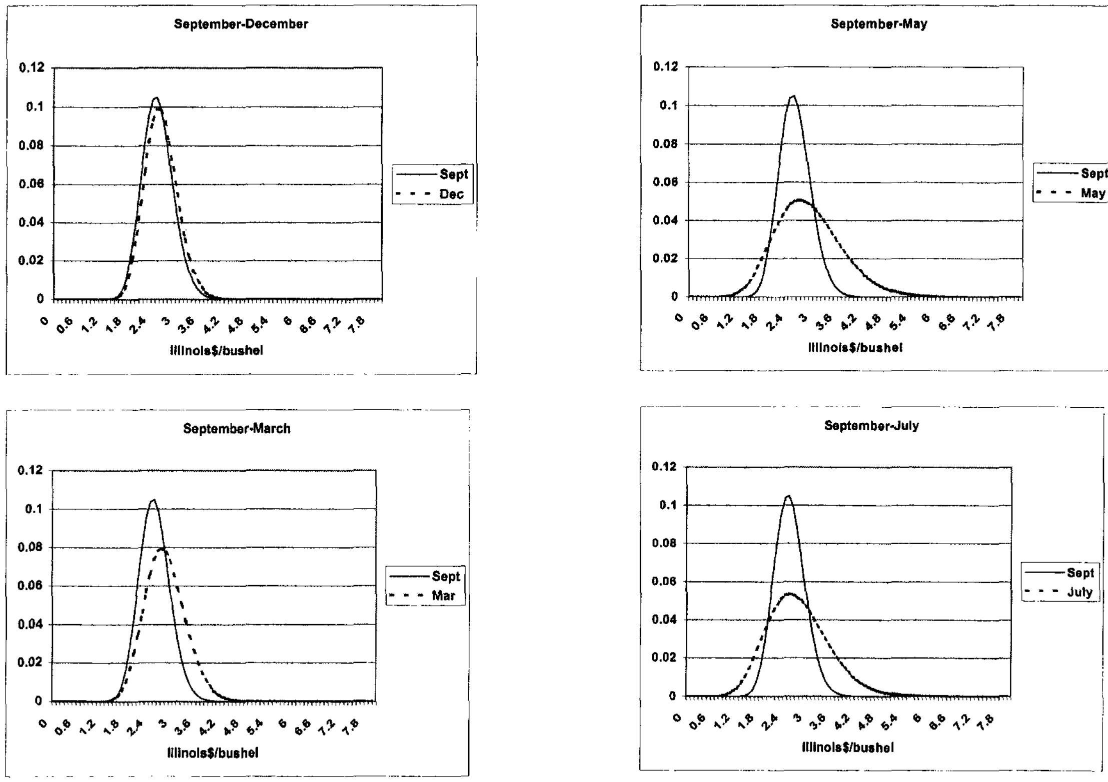

Figure 4. Probability Distributions of Monthly Corn Prices, Illinois (Estimated from monthly observations, 1989/90 to 1997/98 crop years, assuming a gamma distribution)

period September 1989 to August 1998 and simulated to May 2001, to be discussed.) Given the scale of the graph, it is difficult to see the seasonal component, but time-series analyses suggest that seasonality exists (Peterson and Tomek). For the sample period, September 1989–August 1998, the average price was $12.19 and the standard deviation was $1.18 per cwt. For the same period, the monthly price of corn averaged $2.69 with a standard deviation of $0.565 per bushel; these numbers are quite similar to those for the annual data (above). Although milk prices have been volatile in the 1990s, the standard deviation was "only" about 10% of the mean, while for corn, the standard deviation was over 20% of the mean. Cabbages, onions, and potatoes have even more volatile prices, sometimes changing 100% in a matter of weeks. Most commodity prices are variable, but some more-so than others.

Not only does the mean price have systematic behavior, but it is likely that the higher moments of the distributions vary systematically. For example, considerable uncertainty can exist about the size of an annual crop during the growing season, and this uncertainty results in larger variances of prices during the growing season. Subsequently, when the crop size is resolved at harvest, the variance of price is smaller. Thus, autocorrelation can exist in the variance, and given the possible skewness and kurtosis in prices, a variety of models, including ARCH and GARCH specifications, have been used to capture these effects (e.g., Yang and Brorsen).

To illustrate some of these points, estimated probability (Gamma) distributions for monthly corn prices are shown in figure 4. The four panels compare selected months with the September distribution. Clearly the mean grows post-harvest; the variance also increases from harvest time to summer; and there is positive skewness. Given the complexity of the behavior of commodity prices, numerous alternative time-series models have been proposed and estimated. The results typically fit the sample period well, but it seems fair to say that many of these models do not do a good job of reproducing out-of-sample price behavior.

Conceptual Models of Price Behavior

Some features of price behavior for farm commodities were recognized in the early literature of agricultural economics. Lags in a biological production process, for example, can produce dynamic behavior in prices. Hence, variants of the cobweb model were specified that assumed naive expectations in the supply equation (Waugh; Cochrane 1958). But, simple cobweb models of crops imply negative autocorrelation in annual prices, and estimates of the first-order autocorrelation are typically non-negative. Moreover, for livestock, "cycles" in quantities and prices are longer than those implied by simple cobweb models. Subsequent developments in the conceptual base for empirical analysis have made models more realistic representations of price behavior.

Commodity Supply

Agricultural economists have made major contributions to commodity supply analysis (for reviews, see Just; Tomek and Myers). Production decisions are necessarily a function of expected prices and yields, and rational, quasi-rational, and adaptive expectations have been used as alternatives to naive expectations. Moreover, since expectations are usually not realized, price and yield risk are often important arguments in supply functions.

A major factor driving the supply of farm commodities is improvements in technology, but the precise effects of new technologies are not easily forecast. Nonetheless, it is clear that technological change results in positive shifts in supply functions. A related hypothesis is that output response to price increases may differ from those for price decreases (Cochrane 1955). When prices increase, farmers make investments and adopt new technologies, but these technologies may not be abandoned when prices decline.

Asset fixity influences commodity output. Since buildings and equipment are often designed for particular production processes, farmers can not easily shift resources from producing one commodity to another. Short-run supply functions for farm commodities are price inelastic within the observable range of prices.

Livestock, livestock product, and perennial crop supply present additional modeling challenges (e.g., Rosen). Output is constrained in the short run by the size of the breeding herd (or number of bearing trees). If expected profits rise, young animals will be added to the breeding herd (orchards expanded), but long delays exist before output increases. Female animals must gain sexual maturity, and trees must reach full-bearing age. Moreover, for animal agriculture, short-run output is reduced (relatively) as female animals are added to the herd rather than slaughtered. It is, of course, possible to cull herds or orchards more rapidly than it is to expand them. Models, at their best, should capture the asymmetric dynamics inherent in the production process.

Annual crops presumably have a simpler (than livestock) dynamic behavior in production, but inventory behavior is a potentially important component in explaining prices. Building on the classic works of Brennan, Kaldor, and Working (1949), a supply of storage equation is logical in a crop model; such models typically use a rational expectations framework and assume a competitive market (Williams and Wright). The non-linear supply of storage equation helps explain the skewness (spikes) observed in prices as a function of small inventories. Also, the ability to carry inventories through time contributes to possible autocorrelation in prices, including both intra-year seasonality and year-to-year variability (Deaton and Laroque 1992; Rui and Miranda; Chambers and Bailey).

Inventory behavior is also potentially relevant for helping explain livestock prices. The farm price of milk, for example, depends partly on inventories of cheese and butter. This does not imply, however, that precisely the same model should be used for all commodities.

It is worthwhile to emphasize that the specification issues for supply and storage models, just discussed, relate to investment, production, and marketing decisions in the face of risk. Developments in the finance literature can assist in analyzing and explaining such decisions. For example, options pricing theory can help evaluate a choice of investing now versus delaying the decision (for a summary of related literature, see Tauer). This suggests that careful investment analysis can help ameliorate the effects of risk. Also, farmers have the opportunity to hedge production and marketing decisions via the use of forward, futures, and/or options contracts. Thus, the question arises, are the models of expectations and risk used in commodity price analysis internally consistent with the concepts of financial economics and the existence of markets for derivative instruments?

The current quote of a futures price is the expected value of the price at contract maturity, conditional on current information, and risk can be measured relative to futures prices (Gardner; Tronstad and McNeill). Moreover, if a futures market is efficient, then its prices can be viewed as measures of rationally expected prices, but typically rational expectations are defined as a function of a structural model. (The relationship of futures prices to forecasts from econometric models is noted below.)

Commodity Demand

On the demand side, research in agricultural economics has emphasized systems specifications that incorporate theory restrictions on the parameters of the price and income variables, using retail-level data (for a comparison of two prominent models, see Alston and Chalfant 1993). This work is not directly related to understanding the dynamic behavior of commodity prices at the farm level. Some models, however, have recognized the increasing complexity of the derived demand for commodities. Antle's stylized model incorporates the notions of characteristics of the population (as well as population size) and of product quality (characteristics).

Derived demands for agricultural commodities are indirectly based on many factors. First, the types of uses have increased. For instance, the domestic demand for corn as animal feed remains important, and this demand in turn depends on the demand for beef, milk, pork, chicken, eggs, etc. In addition, the domestic demand for corn for various processing uses has grown, e.g., the demands for sweeteners and alcohol. The varying uses create specialized demands for attributes. Quality, as measured by desirable and undesirable characteristics, influences prices. Demand in one region is influenced by demands in other regions; thus, prices also have spatial attributes (e.g., McNew).

Second, final demands for products, for which commodities are an input, have proliferated. Beef is an important item in menus for food eaten away-from-home, in frozen dinners, canned stews, etc. The demand for food eaten away-from-home (and for frozen and prepared meals eaten at home) is, in turn, influenced by trends in the socio-economic characteristics of the population. Consumer preferences can be influenced by new information about the healthfulness of various foods, by advertising, etc. In affluent economies, consumers are demanding foods with more built-in services, and they are increasingly concerned about the safety and healthfulness of foods.

Basically, the growing complexity of the national and international economy is defined by a proliferation of products to meet the diverse demands of society. It follows that modeling farm-level, derived demand is increasingly difficult. Because in a country like the United States the value of the commodity in a final product is often a small proportion of the retail price, variability in farm prices has little influence on variability at the retail level (e.g., Antle). Small shifts in derived demand relative to supply can, however, have relatively large effects on farm prices. Also, while some demand changes have abrupt effects (e.g., a health scare), the effects of other demand shifters are gradual (e.g., the response to an advertising campaign). Thus, distributed lag effects may exist on the demand side, and are another potential source of dynamic behavior in commodity prices.

Implications for Price Behavior

Stripped of the detail, commodity prices do indeed reflect shifts in supply relative to demand. An important driver of the demand for agricultural commodities is population growth. Income also can be an important determinant of demand, but in a country like the United States, the effect of income on the derived demand for most commodities is small. Perhaps the most important determinant of commodity supply is new knowledge and technological change (Johnson 2000). With this simple framework, analysts can make educated estimates of changes in the means of relative prices based on estimates of growth rates in population, income, and technology (e.g., Tweeten).

As the earlier discussion implies, however, farm-level prices are influenced by many different pieces of information. Since truly new information is a surprise, commodity prices change frequently in a seemingly random fashion. The magnitudes of these changes depend not only on the nature of the news, but also on the economic context in which the information arrives. If, for example, stocks are small relative to demand, new information can cause a large price change. Demand and supply are price inelastic, and small shifts in one function relative to the other result in large price changes. The speed of adjustment to news, however, depends on how well-informed traders are. It follows that price behavior depends on the quality of information and its distribution to market participants.

The effects of the numerous underlying factors, large and small, often acting with time lags, result in complex probability distributions of prices. The primary parameters of price distributions—mean and higher moments—often change systematically through time. Thus, we should not be surprised that, even with a solid conceptual framework, it is difficult to obtain robust empirical models that can be used for forecasting and policy analysis. Even the collection of high quality data on cash prices is difficult, because the diversity of transaction prices, for varying qualities and locations, creates a penumbra of prices around the central tendency.

Empirical Price Analysis

This section reviews, first, the objectives of commodity price analysis. Why are we doing these analyses? Then, I remind readers of the difficulties of doing high quality analysis. In the process, I review the consequences of the choice of whether to deflate prices and if so, by what deflator. This illustrates that a simple modeling decision, which is often done routinely, can have profound effects on empirical results.

Objectives and Applications

The objectives of empirical price analysis can be grouped under four main headings: forecasting, policy analysis, improved understanding of commodity markets, and hypothesis generation (Tomek and Myers). Forecasts and simulations of prices, that can be used for private and public decisions, are the most frequently mentioned reasons for doing price analysis. Perhaps the first objective should be, however, to develop and test hypotheses about the data generating processes of prices. If we can gain a deeper understanding of price behavior, then it may be possible to provide useful simulations for policy analysis and decision-making.

Suppose, for example, the research problem is to simulate the effect of a proposed change in farm policy on the supply of milk. Since the policy may influence both the variability and level of prices, the model specification should include the effect of changes in the riskiness of prices on farmers' production decisions. Risk is defined in terms of deviations from expected prices, and this immediately raises the question of measuring expectations. The researcher may decide that a rational expectations model is appropriate, but this does not determine the specification of rational expectations for the purposes of empirical estimation.

Moreover, there is the question of an appropriate characterization of the probability distribution of prices around the expected value. Is the variance a constant? Is the distribution symmetric? Thus, developing a useful evaluation of policy requires a deep understanding of the data generating process for the relevant prices. It is insufficient to claim that rational expectations is the appropriate concept for modeling farmers' production decisions; for empirical analysis, it is necessary to model what is meant by rational expectations; and to be useful, this model must be a close approximation of farmers' actual decision variables. Further, as seems likely, if farmers form expectations in different ways, then actual supply decisions are based on a mixture of expectation models, further complicating the modeling problem (Chavas). The choice of the expectations model will influence the simulation outcomes (e.g., Peterson and Tomek).

With respect to the forecasting objective, the purpose and value of price forecasts (estimates of expected prices) is often misunderstood. Forecasts are conditional on the information set used at the time the forecast is made; this information set includes both the model and the ancillary estimates of the explanatory variables needed to make the forecasts; and the conditional nature of forecasts should always be made clear to potential users. The estimates of the future values of the explanatory variables, such as crop size, are subject to change with the passage of time. Moreover, the analyst may have estimated the "wrong" model in the sense that a better, more complete specification, than the one used, exists.

Also, forecasts in the public domain, by definition, do not contain private information, hence it is unlikely that they can be used to make speculative or arbitrage profits. Often, competitive futures markets exist for agricultural commodities, and the current quotes for contracts for future delivery should reflect existing information about prices expected to prevail in the respective delivery months. Therefore, forecasts from econometric models can not be expected to outperform the futures markets' quotations (Tomek 1997b), and if this is true, then it is not possible to make speculative profits based on the forecasts of the econometric models. Note, this idea does not exclude the possibility of individual analysts having private information that can be traded profitably; such analysts may have better data (e.g., private crop forecasts) or better analytical skills.

Empirical analysis should be conditioned by the research objective. Why are we doing the forecast or simulation? For instance, the following question is too broad: has a structural change occurred in the demand for beef? The answer is conditional on the model used, and with such a general question, many alternative models are plausible. A more specific question is, have the benefits of advertising beef justified the costs of advertising? Or, should beef producers' dollars be spent on alternatives other than advertising? In this context, it may be necessary to ask, has advertising influenced the slope as well as the level of the demand function (e.g., Chung and Kaiser)? The model must be relevant to the research.

Sometimes the research may require an understanding of the relationship of commodity markets to the general economy. What can be said about changes in a commodity's price relative to the general price level? What are the possible consequences of these changes for farmers, consumers, and foreign exchange earnings? Descriptions of historical prices suggest that farm prices are correlated with the general price level, but tend to be more variable than non-farm prices. This divergent behavior is typically explained by the fix-flex paradigm (e.g., Andrews and Rausser). Prices of farm commodities are determined in relatively competitive, auction-style markets, while non-farm prices are determined in administered price-type markets. Also, commodity prices are influenced by the vagaries of supply, i.e., unfavorable weather conditions, pests, and diseases. This is less true in the non-farm sector. Thus, the questions raised above are not easily answered.

Various hypotheses have been proposed over at least the past 50 years about the causes of trends in relative prices (see Deaton; Tomek and Robinson, Chapter 10 and references therein). The differing hypotheses can be viewed as differing emphases on the factors that influence the demand for and supply of commodities. From the perspective of the year 2000, it is clear that technological change has been a major factor shifting the supply function for farm commodities. These improvements have tended to more than offset increases in input prices. Indeed, some inputs are themselves commodities (Johnson 1950); e.g., the supplies of animal products depend importantly on feed prices.

Thus, on balance, supply has tended to grow relative to demand, and with a competitive market, commodity prices move downward as average and marginal costs decrease. On occasion, demand "catches up" with supply; inventories are short; and as noted earlier, spikes in prices are observed. Of course, we also should not forget that comparisons of relative prices are influenced by the time period selected for the analysis. Changes in relative prices can be made to look more or less favorable to farmers by a judicious selection of the base period for the indexes used in the comparison (e.g., see Tomek and Robinson, third edition, Chapter 10).

In trying to answer the types of questions, just discussed, researchers should recognize that their "final result" may be best interpreted as a hypothesis that deserves further testing with new data. This is particularly true in econometric analysis, because the final model has often been arrived at via pretesting with a fixed data file, and as a consequence the type I error is unknown. The results may merely reflect a unique feature of the data set, not a fundamental relationship (Tomek and Myers). I turn next to more detail about the problems of empirical analysis of prices.

Difficulties in Empirical Price Analysis

Applied econometrics. Researchers face two categories of problems in applying econometric methods. The first relates to model specification. Historical practice placed heavy weight on the correctness of the model—the maintained hypothesis—since the properties of the estimators and hypothesis tests are conditional on the model. Researchers are assumed, for example, to be able to correctly classify variables as exogenous or endogenous and to correctly specify restrictions on the model. In this context, the best inference tools are selected.

In typical research situations, however, the correct model specification is uncertain. Although the analyst has access to relevant theory and previous research, competing theories often exist, and empirical results differ. Consequently, uncertainty exists about the appropriate model and inference method. This problem can be compounded in forecasting applications where it is necessary to assume that the model which was valid for the sample period remains valid for the forecast period.

Two interrelated issues in modeling are the constancy of the structure over the sample period and correctness of the model specification (e.g., Alston and Chalfant 1991). The parameters of interest for the research are typically assumed to be constant over the sample period used for estimation. Of course, one can test for parameter constancy, but such tests are conditional on the correctness of the remaining model specifications. Alternatively, one can test the correctness of selected model specifications, such as omitted variables, assuming the parameters are constant over the sample period. Joint tests also can be conducted for hypotheses related to model specification (nicely summarized in McGuirk, Driscoll, and Alwang), but all tests are conditioned by some minimal specification, which is assumed to be correct.

The second problem category relates to data quality. One major, potential problem is errors in variables. Errors may be made in recording, compiling, and manipulating data, but care in data handling can minimize this problem. Also, since observational data from secondary sources are subject to revision, the preliminary estimates may be viewed as containing errors (for additional discussion, see Tomek 1993). A more difficult issue is that observed variables are not good measures of the underlying economic concept. For example, how can a good proxy for farmers' expected prices be constructed?

Another data quality issue is that time-series variables can be highly collinear. We should not be surprised, for example, that the prices of substitutes are correlated. Collinearity is perhaps the most misunderstood problem in empirical econometrics. A sample of observations on a set of variables contains a fixed level of independent variability among those variables, and this cannot be changed by transformations. Of course, transformations can change correlations among regressors; the "ultimate" transformation is to orthogonalize the regressors. But, this merely transforms the problem. If the original data are highly correlated, then the transformed, uncorrelated variables will have nearly a zero variance (for a discussion of the complexities of measuring collinearity see Spanos and McGuirk, and for a discussion of misleadingly large r^2's see McGuirk and Driscoll).

Other questions about time-series variables relate to their stationarity and possible co-integration. There is concern, for example, that nonstationary variables result in spurious regressions. But, there is little justification for thinking that cash prices for an individual commodity should be a random walk. Indeed, conceptual models imply that prices will be autocorrelated with convergent cycles. Since traditional tests for stationarity have low statistical power, test results have been mixed, but as pointed out elsewhere, simulation models assume (and find) prices stabilizing at a constant mean.

The issues of errors in variables, collinearity, and stationarity in empirical analyses are related to practices of deflating prices. It is common to deflate prices, and this is often done routinely with little thought as to whether deflating is necessary for the research problem, and if so, what is the appropriate deflator? Thus, in the next sub-section, I remind readers of some problems associated with deflating.

Implications of deflating prices.[2]

Price analysis often, though not always, involves relative prices. The research objective and theory should provide guides to the appropriate deflator, but sometimes analysts appear to give little thought to the choice of the deflator and its implementation.

To illustrate, I consider the question of modeling the expected price of corn. The expected price and the riskiness of the price of corn are relevant variables in a supply function. In this context, should the analyst consider the nominal price of corn, the ratio of the price of corn to an Index of Prices Paid by Farmers (PPF, a broad measure of input prices), the ratio of the price of corn to the price of soybeans (a major alternative crop that could be produced with the same resources), or the ratio of the price of corn to the Consumer Price Index (CPI, a measure of retail-level prices)? In supply analyses for commodities, all of the foregoing have been used, and deflating by the CPI is rather common (e.g., Chavas; Antonovitz and Green).

Next, price expectations must be modeled. Quasi-rational expectations, for example, assume that producers form expectations as forecasts based on time-series models. However, the time-series properties for nominal prices and the various deflated prices differ. The idea that data transformations change time-series properties of the original data is not new (e.g., Harvey; Working 1960), but sometimes is forgotten by price analysts. The estimates of expected prices and the associated price risk can vary importantly, depending on the deflator (if any) that is used.

Nominal corn prices for the crop years 1973–74 through 1997–98 appear to be white noise. Periodograms, maximum entropy spectra, and ARIMA models all lead to this conclusion. Namely, annual prices varied randomly around a constant mean ($2.67 per bushel) during the 1973/74–1997/98 sample period. However, if corn prices are deflated by the CPI or the PPF, the resulting series seems to have a unit root, a stochastic trend, using conventional tests. Based on the estimated spectral densities, the first-differenced series are white noise, implying that deflating introduced the stochastic trend. That is, the price indexes may have a unit root which is imparted to the deflated corn prices.

Given the possible stochastic trend, one potential model is a random walk possibly with a drift term. Using the first differences of the PPF deflated prices, the preferred model, based on empirical criteria, seemed to be a first-order moving average process. This equation has a negative intercept. Alternatively, the deflated prices were modeled as having a linear deterministic trend with

Table 1. Time-series Models for Annual Price of Corn, deflated by PPF, 1973/74–1997/98[a]

First difference of prices

$$\Delta y_t = \underset{(0.07)}{-0.112} - \underset{(0.19)}{0.483}\, \Delta e_{t-1}$$

Price level

$$y_t = \underset{(0.58)}{5.009} + \underset{(0.16)}{0.663}\, y_{t-1} - \underset{(0.04)}{0.130}t$$

[a]y represents the deflated price series; t is a time trend; standard errors shown in parentheses.

[2] This section uses material from Peterson and Tomek (2000).

autocorrelation (table 1). If either of these models is used to estimate expected prices, the result rather quickly becomes "irrational." The out-of-sample forecast is ultimately negative.

Of course, one can argue that alternative models should be used. Perhaps nominal prices and the index should be modeled separately. Then, the ratio of the separate forecasts could be used. This approach requires the analyst to explicitly consider a model of the general price index, but if it is trending upward, the issue of a logical forecast can still occur. Or, the sample period could be lengthened (and the accompanying models modified) to capture possible changes in the trend. Or, some non-linear model may be better. The point is, however, that the equations in table 1 illustrate common practices in price analysis and that such practices can produce illogical results.

We need to ask, are the models, deflators, and other procedures appropriate for the research problem? If, for example, the problem requires the analyst to estimate expected prices and if expectations are defined as out-of-sample forecasts, then the methods should result in plausible forecasts. The so-called rationally expected price cannot be "irrational."

Conclusions

Agricultural economists have been analyzing commodity prices for over 75 years, and the problems being studied today are similar to those studied by our predecessors. Why are commodity prices changing relative to other prices? What is the economic consequence of a proposed price policy? What is the nature of price risk faced by farmers? The study of these and similar questions has improved the conceptual foundation for price analysis, and the econometric tools available for this research have grown more sophisticated. Nonetheless, the leap from concepts and methods to high quality empirical results remains large. (An appendix expands on this point, and Davis elaborates on the problem of moving from theory to useful empirical results.)

What can empirical price analysis reasonably expect to accomplish? As noted earlier, structural and time-series models can be built that fit a sample of data well. The evidence suggests, however, that such models often "break down;" the parameter estimates are unstable when confronted with new data. This potential problem should be addressed before using the model for simulations or forecasting.

Given relatively stable parameter estimates, a model should have the property that simulations beyond the sample period converge to some mean level. For example, a time-series model fitted to monthly observations for milk prices stabilizes at about $12.25 per cwt in post-sample simulations (figure 3). While this is a desired property of models, the consequence is that out-of-sample simulations do not look like the in-sample data. Also, although the model mimic's the sample data 1989–1998, it does not accurately forecast the actual price of milk in the 13 months immediately beyond the sample (figure 3).

Forecasts are conditional on the information at the time the forecast is made, and inevitably this information will change with the passage of time. By analogy, the current price of a contract for future delivery is also conditional on current information, but the futures market's "forecast" is revised continuously as new information enters the market. Forecasts from econometric models are revised infrequently.

Thus, formal models of commodity prices, at their best, can increase understanding of how an economic sector is working, but forecasts from such models are not likely to help farmers "beat the market." Commodity specialists in Land Grant Universities can conduct educational programs that help farmers and others understand the factors influencing prices, but in my view, extension specialists should not be making recommendations about the specific timing of marketings based on price forecasts.[3]

Standard models have concentrated on the mean of random variables, like price. It is possible, as noted above, to model other features of the probability distributions of prices. Time-series models can provide estimates of changes in the variance, and conceptual models, such as the rational expectations storage model, can be used as a foundation for simulating the probability distributions of prices (Peterson). In other words, it is feasible to develop models that produce simulated prices that look like historical series. This approach holds hope to better understand the consequences of alternative risk management choices that farmers and merchants can make.

Also, it is reasonable to expect that the conceptual foundation for the study of prices will continue to be refined and that additional econometric tools will become available. It is unlikely, however, that

[3] It is useful to build models to better understand the factors influencing prices, but this does not mean that forecasts from the models can out-perform the "forecasts" available from quotations on futures markets. Brorsen and Irwin discuss the relevance of research on price forecasting and how this research might be improved.

data quality will be improved,[4] although improved information would reduce the variance of prices.

I conclude, therefore, that it is possible, in some, but not all, applications to obtain estimates of structural parameters that are relatively stable and hence useful for addressing specific problems. These potentially useful results will depend on serious scholarship; they are not likely to be the outcome of casual empiricism. My pleas (e.g., Tomek and Myers; Tomek (1993, 1994, 1997a)) have been for rigorous appraisals of empirical results relative to their intended applications. I have argued that analysts should be required to demonstrate the alleged improvements in their results relative to competing models and to subject their estimated models to a battery of tests of adequacy. Details like the choice of deflator and proxies for price expectations should be clearly justified. Further, if key empirical results in the literature were duplicated and then replicated with new data to check parameter stability, research would be more cumulative.

A key issue is how to better combine theoretical models and empirical methods. It may be helpful to emphasize the distinction between the primary parameters of random variables (the means, variances, and covariances) and the parameters of the related econometric model (the intercept and slope parameters of statistical models), e.g., Spanos. An economic model should be internally consistent with the underlying probability distributions of the random variables being modeled.

Common practice, however, has placed little weight on these probability distributions. I am struck, for example, by the contrast of simulation analysis of policy alternatives, which assume stable means of prices, and tests of stationarity which conclude (erroneously in my view) that spot prices are random walks. It is important to ask, can an econometric model, with appropriate simulations of the explanatory variables and error term, produce estimates of the primary parameters of the probability distributions similar to those of the historical time series?

In concluding, I am well-aware that the reward system in academia does not favor using my suggestions. Thus, they may not, indeed probably will not, happen. Nonetheless, it appears that a necessary condition for useful empirical results is to subject them to more rigorous appraisals than has been the norm. My suggestions are intended to encourage such in-depth scholarship.

[4] As noted in the text, a huge variety of transactions prices exist, which are related to the varying attributes of individual lots, terms of trade, location, etc. Thus, it is costly to assemble accurate cash prices for agricultural commodities, although the USDA does the best it can within a limited budget. We need to recognize, therefore, that time-series data for commodity markets can have limitations compared, say, to prices from financial markets. Data quality and availability in commodity markets are perhaps falling behind the growing complexity of the economy. One role of professional societies is to lobby for more resources for data collection.

References

Alston, J.M., and J.A. Chalfant. 1991. "Can We Take the Con Out of Meat Demand Studies?" *Western Journal of Agricultural Economics* (now the *Journal of Agricultural and Resource Economics*) 16:36–45.

———. 1993. "The Silence of the Lambdas: A Test of the Almost Ideal and Rotterdam Models." *American Journal of Agricultural Economics* 75:304–313.

Andrews, M.S., and G.C. Rausser. 1986. "Some Political Economy Aspects of Macroeconomic Linkages with Agriculture." *American Journal of Agricultural Economics* 68:413–417.

Antle, J.M. 1999. "The New Economics of Agriculture." *American Journal of Agricultural Economics* 81:993–1010.

Antonovitz, F., and R. Green. 1990. "Alternative Estimates of Fed Beef Supply Response to Risk." *American Journal of Agricultural Economics* 72:475–487.

Brennan, M.J. 1958. "The Supply of Storage." *American Economic Review* 48:50–82.

Brorsen, B.W., and S.H. Irwin. 1996. "Improving the Relevance of Research on Price Forecasting and Marketing Strategies." *Agricultural and Resource Economics Review* 25: 68–75.

Chambers, M.J., and R.E. Bailey. 1996. "A Theory of Commodity Price Fluctuations." *Journal of Political Economy* 104:924–957.

Chavas, J-P. 1999. "On the Economic Rationality of Market Participants: The Case of Expectations in the U.S. Pork Market." *Journal of Agricultural and Resource Economics* 24:19–37.

Chung, C., and H.M. Kaiser. 1999. "Distribution of Gains from Research and Promotion in Multistage Production Systems: Comment." *American Journal of Agricultural Economics* 81:593–597.

Cochrane, W.W. 1955. "Conceptualizing the Supply Relation in Agriculture." *Journal of Farm Economics* (now the *American Journal of Agricultural Economics*) 37:1161–1176.

———. 1958. *Farm Prices: Myth and Reality.* Minneapolis: University of Minnesota Press.

Davis, L.G. 1997. "The Logic of Testing Structural Change in Meat Demand: A Methodological Analysis and Appraisal." *American Journal of Agricultural Economics* 79: 1186–1192.

Deaton, A. 1999. "Commodity Prices and Growth in Africa." *Journal of Economic Perspectives* 13:23–40.

———, and G. Laroque. 1992. "On the Behavior of Commodity Prices." *Review of Economic Studies* 59:1–23.

Gardner, B.L. 1976. "Futures Prices in Supply Analysis." *American Journal of Agricultural Economics* 58:81–84.

Harvey, A.C. 1993. *Time Series Models,* 2d. ed. Cambridge, MA: The MIT Press.

Johnson, D.G. 1950. "The Nature of the Supply Function for Agricultural Products." *American Economic Review* 40: 539–564.

______. 2000. "Population, Food, and Knowledge." *American Economic Review* 90:1–14.

Just, R.E. 1993. "Discovering Production and Supply Relationships: Present Status and Future Opportunities." *Review of Marketing and Agricultural Economics* 61:11–40.

Kaldor, N. 1939. "Speculation and Economic Stability." *Review of Economic Studies* 7:1–27.

McGuirk, A.M., P. Driscoll, and J. Alwang. 1993. "Misspecification Testing: A Comprehensive Approach." *American Journal of Agricultural Economics* 75:1044–1055.

______, and P. Driscoll. 1995. "The Hot Air in R^2 and Consistent Measures of Explained Variation." *American Journal of Agricultural Economics* 77:319–328.

McNew, K. 1996. "Spatial Market Integration: Definition, Theory, and Evidence." *Agricultural and Resource Economics Review* 25:1–11.

Myers, R.J. 1994. "Time Series Econometrics and Commodity Price Analysis: A Review." *Review of Marketing and Agricultural Economics* 62:167–181.

Peterson, H.H. Forthcoming. *Commodity Price Behavior and Its Implications for Agricultural Risk Management.* Ph.D. Dissertation, Cornell University.

______, and W.G. Tomek. 2000. "Implications of Deflating Commodity Prices for Time-Series Analysis." Paper presented at the NCR-134 conference, Chicago. April.

Rosen, S. 1987. "Dynamic Animal Agriculture." *American Journal of Agricultural Economics* 69:547–557.

Rui, X., and M.J. Miranda. 1995. "Commodity Storage and Interseasonal Price Dynamics." In *NCR-134 Conference Proceedings:* 44–53.

Spanos, A. 1995. "On Theory Testing in Econometrics: Modeling with Nonexperimental Data." *Journal of Econometrics* 67:189–226.

______, and A.M. McGuirk. 2000. "The Problem of Near-multicollinearity Revisited: Erratic vs. Systematic Volatility." Virginia Tech, Department of Economics, Blacksburg, VA. Revised: April: 26 pages.

Tauer, L.W. 2000. *Investment Analysis in Agriculture.* Cornell University, Department of Agricultural, Resource, and Managerial Economics Staff Paper 2000–03, April.

Tomek, W.G. 1993. "Confirmation and Replication in Empirical Econometrics: A Step Toward Improved Scholarship." *American Journal of Agricultural Economics* 75 (75th anniversary issue, October):6–14.

______. 1994. "Economic Forecasting in Agriculture: Comment." *International Journal of Forecasting* 10:143–145.

______. 1997a. *Structural Econometric Models: Past and Future (with Special Reference to Agricultural Economics Applications).* Havlicek Memorial Lecture, Department of Agricultural Economics, Ohio State University.

______. 1997b. "Commodity Futures Prices as Forecasts." *Review of Agricultural Economics* 19:34–44.

______, and K.L. Robinson. 1972. *Agricultural Product Prices.* Ithaca, NY: Cornell University Press (3d ed. 1990).

______, and R.J. Myers. 1993. "Empirical Analysis of Agricultural Commodity Prices: A Viewpoint." *North Central Journal of Agricultural Economics* (now the *Review of Agricultural Economics*) 15:181–202.

Tronstad, R. and T.J. McNeill. 1989. "Asymmetric Price Risk: An Econometric Analysis of Aggregate Sow Farrowings." *American Journal of Agricultural Economics* 71:630–637.

Tweeten, L. 1998. "Anticipating a Tighter Global Food Supply-Demand Balance in the Twenty-first Century." *Choices, The Magazine of Food, Farm, and Resource Issues,* Third Quarter. 4–7.

Warren G.F., and F.A. Pearson, 1928. *Interrelationships of Supply and Price.* Cornell University Agricultural Experiment Station Bulletin 466.

Waugh, F.V. 1964. "Cobweb Models." *Journal of Farm Economics* (now the *American Journal of Agricultural Economics*) 46:732–750.

Williams, J.C., and B.D. Wright. 1991. *Storage and Commodity Markets.* Cambridge: Cambridge University Press.

Working, H. 1949. "The Theory of Price of Storage." *American Economic Review* 39:1254–1262.

______. 1960. "Note on the Correlation of First Differences of Average in a Random Chain." *Econometrica* 28:916–918.

Yang, S-R., and B.W. Brorsen. 1992. "Nonlinear Dynamics of Daily Cash Prices." *American Journal of Agricultural Economics* 74:706–715.

Appendix

A correct model is necessarily defined relative to a specific research objective. The problem might be to estimate a conditional mean, say $E[Y_t|X_tZ_t]$, or it might be to estimate the net effect of X_t on Y_t. The proposed statistical model is

$$Y_t = \beta_o + \beta_1 X_t + \beta_2 Z_t + \epsilon_t.$$

To shorten the discussion, I concentrate on

$$\beta_1 = \frac{\sigma_{zz}\sigma_{xy} - \sigma_{xz}\sigma_{zy}}{\sigma_{xx}\sigma_{zz} - \sigma_{xz}^2},$$

where σ_{xx} = variance of X_t, σ_{xy} = covariance between X_t and Y_t, and so forth. The point is that the model parameters are related to particular primary parameters of the random variables.

Thus, this specification implies that other variables, say W_t, need not be included for the purposes of this research. If W_t truly has a non-zero parameter and is related to X_t, then the estimate of the parameter β_1 is picking up a combined effect of X_t and W_t, and in this sense the estimator is biased. But, an estimator can be best for *this model;* hence, does the research require an estimate of the effect of X_t and Y_t net of Z_t or net of both Z_t and W_t?

Also, X_t and Z_t are assumed to be measured without error for the purposes of answering the research question. In other words, is the effect of a change in X_t, as measured in this model, what we want to know?

Another way of looking at these issues is to ask, are the β's based on appropriate σ's? Does the econometric specification include appropriately measured variables, and what are the implications of the means, variances, and covariances of these random variables for the model parameters? Typically, as above, the model parameters are specified as constants which depend on constant primary parameters. One of the points of this essay is, however, that some parameters of conditional distributions of commodity prices are not constants. Also, the probability distributions of deflated prices are likely to differ from those of the nominal price series.

In sum, researchers should thoroughly understand the conditional probability distribution of the random variables appropriate to the research problem. This paper has tried to outline the complexities of this task.