WVU REGIONAL RESEARCH INSTITUTE PAPER SERIES

COMMODITY PRICE FLUCTUATIONS: A CENTURY OF ANALYSIS

By

Walter C. Labys

RESEARCH PAPER 2005-1
Revision 1

Professor of Resource Economics
Faculty Research Associate, Regional Research Institute
Natural Resource Economics Program, West Virginia University
Morgantown, WV 26506-6108
wlabys@wvu.edu

JEL Classification: C2, C3, C5, C6, Q10, Q30

Key–words: Commodity prices, price trends, price cycles, price volatility, futures markets, time series analysis, econometric models, mathematical models, forecasting.

Abstract: Commodity prices again! The twentieth century has only been the latest spectator to the impacts and importance of commodity price fluctuations. It is reasonably well known that commodity price records have come down to us from the ancient civilizations of India, Mesopotamia, Egypt, Greece and Rome. Earlier in the century, formal research began on the relationships between agricultural demand, supply and prices in a market context. This research not only evolved in sophistication but extended to mineral and energy commodities. Also at the beginning of the century, some of the earliest work took place on applying statistical methods to price series. The purpose of this paper is to review how this progress has contributed to analyzing commodity markets and prices and to solving price forecasting problems, concentrating on more recent advances in econometric modeling and time series analysis. Attention is also paid to spatial developments that have implications for regional price modeling.

This is a working paper subject to revision. The usual disclaimer applies. This work was supported in part by the WV Agricultural Experiment Station.

COMMODITY PRICE FLUCTUATIONS:
A CENTURY OF ANALYSIS

Walter C. Labys

"Prices are ever changing. They change from hour to hour, from day to day, from season to season, and year to year. Every change affects the relationships of individuals, of groups of people, and of nations… Many factors combine to make prices what they are… Prices are both a cause and an effect. The causes may be analyzed just as substance may be analyzed chemically, and the proportion due each cause ultimately may be determined. The science of price analysis is still new but has progressed far enough to be of help."

Warren and Pearson
PRICES (1933, p2)

Commodity prices again! The twentieth century has only been the latest spectator to the impacts and importance of commodity price fluctuations. According to Fischer (1996), commodity price records have come down to us from the ancient civilizations of India, Mesopotamia, Egypt, Greece and Rome, some from as early as circa 1800 B.C. Beginning in the twelfth century, price series of high quality can be found. Recall the Granger and Elliott (1967) time series study of early grain prices. Formal research on the relationships between agricultural demand, supply and prices in a market context began earlier in the century. This research not only evolved in sophistication but extended to mineral and energy commodities. In substance it analyzed market history, explained commodity prices, evaluated commodity policies and forecast commodity prices. Also at the beginning of the century, some of the earliest work took place on applying statistical methods to price series. In fact the study of prices has been one of the few areas in economics in which we have allowed the data to help us to formulate theory, as has been strongly advised, i.e. see Granger (1992), Hendry (1995) and Roehner (1997). This work recently reached a peak in the awarding of the Nobel Prize in Economics to Dr. Clive Granger (shared) in 2003 for his advances in time series econometrics, including applications to commodity prices.

The purpose of this paper is to review how this progress has contributed to analyzing commodity markets and prices and to solving price forecasting problems, concentrating on more recent advances in quantitative modeling and time series analysis. It consists of the following sections: the Challenge, Structural Approach, Non-structural Approach, Remaining Problems, and Conclusions.

1. The Challenge

The possibility that commodity market quantities and prices are often random introduces a large amount of risk and uncertainty into the process of market analysis and forecasting. Of course, randomness is implied generally and the nature of the price fluctuations varies as we observe them and their likely causes in the long, medium or short term. The economic analysis of long term price movements has had an extensive and interesting history. Some studies of mention include Abel (1935), Barnett and Morse (1963), Dick (1998), Drame et al. (1991), Fischer (1996), Froot (1995), Granger and Hughes (1971), Kondratief (1935), Labys (1993), Lewis (1949), Mills (1927), Persson (1994), and Terraza (1981), Usher (1930,1931) and Warren and Pearson (1933). These prices also relate to the long run inflations which have occurred in different nations and in different periods, e.g. Brown (1985, 1988). More recently long term price trends have been studied concerning their role in declining commodity terms of trade in developing countries, e.g. Cuddington (1992). From a practical viewpoint, the prediction of long run price trends has been important for evaluating investments in commodity industries, particularly in mineral and energy projects in developing countries, e.g. Duncan (1984), World Bank (1994).

Commodity markets are subject to shocks or changes in trend, which range from natural catastrophes and political/military interventions to structural market changes. The econometric methods of interest have been those dealing with structural breaks, booms and slumps, and secular movements, e.g. see Cashin and McDermott (2002), Perron

(1989), and Cuddington and Urzua (1989). Commodity shocks tend to be irregular in nature and cause abrupt shifts in prices usually to higher, but, sometimes, to lower levels. Examples include the impacts of the Korean war and Vietnam war, the petroleum price increases of 1973-1978, the Gulf war, and the Iraq invasion. Sometimes the return of a market to normality is quick; at times the shocks persist; and, at other times price changes reoccur, resulting in a series of consecutive turning points. Methods recently developed that help to analyze such trend changes appear in Andrews (1993), Badillo et al. (1999), and Perron (1989).

In the medium term, factors that shock commodity markets can also be of a political or cataclysmic nature, but they tend to be more related to national economic conditions or to market forces themselves. Such market forces tend to be observed in demand and supply conditions and in underlying market equilibrium. The analysis of medium term price movements or price cycles also has had a long history. Kondratief (1935) proposed that commodity and consumer prices reveal cycles that reoccur every 50-60 years. Much greater importance has been placed on the role of commodity price cycles in motivating the great depression e.g. Lewis (1949). Fluctuations in national economic conditions, commonly observed in the form of business cycles, can cause changes in industrial production and consequently in mineral demands or in interest rates and ultimately in commodity prices. This led the National Bureau of Economic Research in the United States to spawn a series of business cycle studies that dealt with agricultural prices as well as with minerals and raw materials commodity prices, e.g. Mills (1927, 1936). More recent studies have examined the interrelations between commodity prices and business cycles, e.g. Bosworth and Lawrence (1982), Ding (1998),Kaldor (1987). Related econometric methods have not only used spectral analysis but also have involved structural time series models, which emphasize cyclical components, e.g. Labys and Granger (1970), Harvey (1985).

Variations in weather conditions induce changes in agricultural supply and hence in product prices. The formal analyses of the impact of these kinds of shocks has appeared in modeling studies, such as, Adams and Behrman (1978), Ghosh et al. (1987), Labys (1973, 1999), Marquez (1984), and Rausser and Hochman (1979).

In the short term, market shocks come primarily from financial factors, particularly those related to speculation and hedging on commodity futures, options and other derivative markets. The resulting price behavior has been termed random, because it reflects the flow of randomly appearing information. In fact the price behavior can be identified more specifically as being stochastic or following a nonlinear dynamic or other form of stochastic process (e.g., autoregressive conditional heteroscedastic), or even a chaotic process. It can also be related more specifically to financial shocks such as in interest rates or exchange rates. A substantial literature exists attempting to explain this short-term behavior. Examples include Adams and Vial (1988), Barkoulas et al. (1997, 1999), Decoster et.al. (1992), Holt and Aradhgula (1990), Hudson et al. (1987), Teysseire et al. (1997), Yang and Brorsen (1992), and the Chicago Mercantile Exchange –see Conferences on Applied Commodity Price Analyses, Forecasting and Risk Management (1994-99).

Short term price analysis has recently experienced the most interest, particularly in relation to the study of futures markets and the discovery of chaos and nonlinear dependence. Much of this work has been related to tests of the efficient market hypothesis in futures prices. Short term commodity price movements had early been discovered to possess random walk behavior or a variant known as a martingale, e.g. Working (1958), Samuelson (1965). While this behavior implies an independence of price changes, other work has confirmed deviations from random walk in the form of occasional autocorrelations or linear dependence, e.g. Houthakker (1961), Labys and Granger (1970). Hints of prices possessing nonlinear rather than linear dependence have been revealed in studies testing for fractal or chaotic structure, e.g. Mandelbrot (1963), Frank and Stengos (1989). More recently, nonlinear dependence has been confirmed in some price series using fractional integration methods and a shift to examining volatility as well as means, e.g. Cheung and Lai (1993). Such discoveries also have led to improved possibilities for forecasting commodity price movements.

In summary the described price fluctuations, which vary frequently and extensively, have made market and price forecasting an extremely difficult task. Structural models have emphasized explaining market interactions with prices as an outcome. Nonstructural models based on linear and nonlinear time series methods often applied to stock prices and financial markets have been employed in commodity price analysis. Business cycle methods that have performed effectively in macroeconometric forecasting have also been integrated into in commodity market forecasting. Nonetheless, commodity market forecasters have become frustrated in their search for improvements in the performance of these methods. My intention is thus not only to trace the evolution of this research but also to suggest research problems to be solved.

2. Structural Approach

The most comprehensive commodity market analytical methods stem from structural models which are soundly based in microeconomic and econometric theory, but also include other modeling theories, e.g. optimization, programming, input-output, computable general equilibrium. Because these structural models trace the interaction between endogenous market variables such as prices and demand and exogenous variables such as industrial production, they can explain market behavior and performance. The scientific process involved usually requires model specification, estimation, and simulation. Model simulation can estimate the historical behavior of price and quantity variables over time and/or space; it can provide conditional estimates of various commodity policy impacts; or it can forecast the variables into the future. In the case of conditional forecasts, one can forecast endogenous variables conditional upon forecasts of macroeconomic variables or upon maintained assumptions concerning the behavior of policy makers. These models come from a distinguished background of theoretic developments in agricultural, mineral and energy economics. A previously prepared bibliography (Labys, 1987) lists a variety of such models. Apart from the Labys (1999) update on mineral and energy models, no recent appraisal exists of sgricultural commodity models.

Standard Commodity Model

The beginnings of structural commodity models stem from the earliest work on econometric models. Some landmark works include those of the Cowles Commission (Hood and Koopmans, 1953; Christ, 1994 ref to earlier work; Tinbergen, 1939; and Klein and Goldberger 1955). Some of the first work on supply-demand models concerned agricultural commodities. Examples include the research of Fox (1958), Hildreth and Jarrett (1955), Meinken (1955a, b), Moore (1914), Wallace and Judge (1959), and Waugh (1964). This work expanded to include other commodities such as Adams and Griffin (1972) on petroleum, Behrman (1971) on rubber, Burrows (1971) on cobalt, Desai (1966) on tin, Houck et al. (1972) on soybeans, Labys (1973) on lauric oils, Labys et al. (1979) on coal, Rausser (1971) on oranges, Weymar (1968) on cocoa, Witherell (1968) on wool, and Zusman (1962) on potatoes. Commodity modeling became formalized in the works of Labys (1973, 1975) and Adams and Behrman (1978). Other econometric modeling guides include Hallam (1990), Ghosh et al. (1987) Guvenen et al. (1991), Labys (1999) and Lord (1991).

The most basic type of commodity model from which econometric and modeling methodologies have developed is the competitive market model. Such a model initially neglects market imperfections and assumes that commodity demand and supply interact to produce an equilibrium price reflecting competitive market conditions. Such a model may consist of a number of combined regression equations, each explaining separately a single market or sector variable. Market models or the equivalent industry models are applicable to all agricultural, mineral or energy production and use categories. Their greatest utility is in providing a consistent framework for planning industrial expansion, forecasting market price movements, and studying the effects of regulatory policies. The basic structure of such a model typically explains market equilibrium as an adjustment process between demand, supply, inventory and price variables, e.g. see Labys (1973, 1975, 1999) or Lord (1991).

Most simply it would consist of the following equations:

$$\mathbf{D_t = d\,(D_{t-1}, P_t, PC_t, A_t, T_t)}$$

$$\mathbf{Q_t = q(Q_{t-1}, P_{t\Theta}, N_t, Z_t)}$$

$$\mathbf{P_t = p(P_{t-1}, dI_t)}$$

$$\mathbf{I_t = I_{t-1}, + Q_t - D_t}$$

where:

D = Demand
Q = Supply
P = Prices
PC = Prices of substitutes
P (-Θ) = Prices with lag distribution
I = Inventories
A = Income or activity level
T = Technological factors
N = Resource characteristics
Z = Policy variables influencing supply

Commodity demand is explained as being dependent on prices, economic activity, prices of one or more substitutes and possible technological influences. Other possible influencing factors and the customary disturbance term are omitted here and below to simplify presentation. Accordingly supply would depend on prices as well as the underlying production factors, such as geology or resource exhaustibility, and a possible policy variable. A lagged price variable is included since the supply process is normally described using some form of the general class of distributed lag functions. Commodity prices can be explained by changes in inventories, although this equation is sometimes inverted to explain inventory demand. The model is closed using an identity that equates inventories with lagged inventories plus supply minus demand. The utilization of this model involves further specification, estimation and simulation (Labys, 1973, 1978, 1999). Some experimentation has also taken place using system dynamics (Meadows, 1970; Ruth and Hannon, 1997).

There is no doubt that commodity modeling evolved from agricultural economics. In the beginning of the twentieth century, Lehfeld (1914) and Moore (1914, 1917) employed regression methods to analyze relationships between agricultural commodity demand and prices. Moore's writings continued to influence econometric research not only to measure true demand and supply curves but also to forecast expected prices (Stigler, 1962). Emphasis also was placed on analyzing price behavior itself, as witnessed in studies by Haas and Ezekiel (1926) on hogs, Killough (1925) on oats, and Working (1922) on potatoes.

This approach spread very rapidly. Warren and Pearson (1928) concentrated on the supply-side of modeling. Works by European economists included Hanau (1928) on hogs, Leontief (1929) on price indexes and Roy (1935) on price methods. Several modeling books began to emerge. Worthy of interest are Ezekiel (1959) on market correlation and Koopmans (1950) on econometric models. Demand analysis included works by Schultz (1938), Stone (1958), Brandow (1961), Working (1927), Fox (1953), Waugh (1964), Wold and Jureen (1953), Meinken (1955a, b) and Nerlove (1958). Price analysis also expanded with studies by Thomsen (1936), Shepherd (1941), Waite and Trelogan (1948), Thomsen and Foote (1952), Foote (1958), Harlow (1962), Labys and Granger (1970) and Labys (1973). Discussion of the structural modeling of agricultural markets appears in Chen (1994), Brookfield (1991), Ferris (1998), Labys (1973, 1975), Heady and Kaldor (1954), Hinson (1991) and Hallam (1990).

The development of econometric models suitable for analyzing mineral markets possessing competitive behavior has evolved more recently. One of the first was the Desai (1966) tin model that explained tin price fluctuations on a world basis. The copper market has also been subject to several modeling efforts. Most notable, Fisher et al. (1972) built a world copper model that was recognized as one of the first major econometric mineral modeling efforts. Charles River Associates (CRA, 1978) later extended the supply sector of the Fisher copper model to include long run adjustments in exploration and discovery as well as subsequent mining capacity formation. This long run adjustment process was combined with a short-run inventory adjustment process in a distinctly disequilibrium form of copper model by Labys (1980a). Such an approach to modeling the copper market was suggested by Richard (1977) with his continuous time, differential equation approach. More recent developments on the structural modeling and forecasting of mineral markets appear in Labys (1999).

Applications to energy markets have not been as extensive because of the difficulties in dealing with regulatory and non-competitive influences on market behavior. Nonetheless, a variety of such models can be found in Labys (1999) and in Lesourd et al. (1996). Verleger (1982, 1993) has shown how such models can be applied to explain disruptive shortages. His model links econometric equations for oil spot prices, consumer demand, and supply shortage conditions. MacAvoy and Pindyck (1975) have built an econometric model of the natural gas industry which has been used extensively to analyze the effect on the industry of federal regulation of the wellhead price of gas and of permissible rates of return for the pipeline industry. Labys et al. (1979) have modeled the U.S. coal market using this approach to forecast future levels of coal demand, supply, prices and inventories. Most recently, Trieu (1994) et al. have reported their modeling of the world uranium market.

The several econometric approaches taken to model noncompetitive market configurations are essentially similar. For example, the monopoly case involves one dominant (monopolist) producer and many (perfectly competitive) consumers. The single producer thus maximizes his own profits given the aggregate demand function for the commodity of interest and the supply response of the other firms in the industry. Examples of applications to OPEC and the crude oil market include Blitzer et al. (1975), Cremer and Salehi-Isfahani (1991), and Pindyck (1978b). Regarding intermediate mineral market configuration, Pindyck (1978a) developed a model to determine optimal price and quantity paths that would result from cartel behavior on the part of producers' organizations in the copper and bauxite markets. To this day, OPEC would have been richer had they followed Pindyck's advice.

Finally it should be recognized that the specification of the above model is given in its structural form. This formulation can be conveniently converted to a reduced form in which the endogenous or dependent variable appears only on the left-hand side of an equation and the exogenous variables on the right-hand side. Such a modeling format will be shown later to be the basis for nonstructural price analysis. Cross-over between these areas can be seen in Chen and Bessler (1990).

<u>Spatial Equilibrium and Programming Models</u>

While a common element of the above models is examining market behavior over time, another class of economic models is concerned with models describing commodity process at one point in time or representing commodity transfers over space. Such a modeling approach has been applied to commodity markets and derives from classical activity analysis or mathematical programming theory. The methodology of linear and nonlinear programming and numerous practical applications are described by Dantzig

(1963), Wagner (1969) and more recently Brooke et al. (1998). These types of models have been applied to commodity markets in the form of linear or transportation programming, process programming, quadratic programming, mixed integer programming, linear complementarity programming, and variational inequalities. Further analysis of this approach can be found in Labys et al. (1989) and Labys and Yang (1991, 1997).

Mathematical programming has been used in commodity modeling to capture the technical or engineering details of specific supply and utilization processes in a framework that can also facilitate price interpretation. In mathematical programming, series of activity variables are defined representing the levels of activity in specific processes. These can be arranged in a series of simultaneous equations representing, for example, demand requirements, supply capacities, and any other special relationships that must be defined to typify technical reality or other physical constraints that must be satisfied. An objective function to be minimized or maximized must be specified (usually cost, prices and quantities, or profit); there are many algorithms available to solve very large problems. The linear programming (LP) technique has been used far more than any other mathematical programming methods because of its efficiency in solving large piecewise linear or step function approximations. An example of application can be found in the Adams and Griffin (1972) model of the petroleum industry. Linear complementarity, nonlinear (e.g., quadratic), variational inequality and dynamic programming techniques are also used for special purposes, but more often these methods limit an overall market-conditions approach.

Quadratic spatial models have been shown to be particularly useful, because they determine demand, supply and prices endogenously in a simultaneous context. As developed by Takayama and Judge (1971), the quadratic programming formulation features (1) a system of equations describing the aggregate demand and supply for one or more commodities in different demand and supply regions, (2) the distribution activities over these regions, (3) the market equilibrium conditions, and (4) equilibrium price determination. Although the demand and supply equations imply a structure similar to that of a temporal market model, the equilibrium process identifies profits to be realized from the flow of commodities, i.e., the price differential between two regional points minus transportation costs. Profit maximization is assured by a computational algorithm that transfers commodities until demand equals supply in every spatially separated market. To evaluate policy decisions, the equilibrium conditions and other definitional equations can be used to impose constraints on the model parameters. The objective function necessary to complete the model goes beyond the cost minimization goal of linear programming. It maximizes the global sum of producers' and consumers' surplus after the deduction of transportation costs. This form of market-oriented quasi-welfare function has been termed net social payoff (NSP) by Samuelson (1952). The multi-period linear mixed integer programming model (MIP) of the type developed by Kendrick (1967) and Kendrick and Stoutjesdijk (1978) combines attributes of both the spatial and intertemporal equilibrium models. An application of mixed integer programming to the coal industry can be found in Suwala and Labys (2002).

To model commodity substitution, the linear complementarity programming approach of Cottle and Dantzig (1968) was developed in a spatial context. It frees the spatial equilibrium model from being normative and restrictive and maintains the efficiency of its quadratic programming counterpart. Although the linear complimentarity programming model does not maximize net social payoff, that concept is not always relevant for model applications. Instead, this model optimizes revenues or costs consistent with a set of operational rules that follow the underlying Kuhn-Tucker (1951) conditions. The theoretical linear complementarity programming structures conforming to this formulation are reviewed in Takayama and Labys (1986) and Takayama and Hashimoto (1984).

More dramatic applications of linear complementarity programming provide intertemporal linkages through investment determination, for example, as in the Hashimoto and Sihsobhon (1981) iron and steel model. The major advance of their model is its incorporation of market expectations based on forward information and market dynamics. One version assumes that the steel industry plans and implements investments in production facilities rationally, with perfect foresight. Another version assumes that the industry follows less than perfect investment plans. Model solutions give projections for the following variables: (1) investments in steel production capacities, (2) prices, demand and supply quantities for steel products, and steel production capacities, and (3) the industry's requirements for major raw materials and inputs. The results help to explain the output and investment cycles that have characterized that industry.

Going beyond linear complementarily programming, Nagurney (1987) has shown how the variational inequality approach can be combined with network theory to study spatial price equilibrium problems, specifically policy interventions considered as disequilibrium, or constrained equilibrium problems. Although the perfectly competitive spatial price problem is addressed within an equilibrium/disequilibrium framework, the variational inequality problem has been specified to contain not only those problems but also minimization problems and virtually all of the classical problems of mathematical programming, such as linear and convex programming, and linear complementarity problems. In addition, variational inequality constitutes an alternative approach to fixed point problems, minimax problems, and noncomplementarity problems, i.e. also see Labys and Yang (1991, 1997).

Input-Output Models

Input-output is a conceptualization of the interdependence of economic production units in national economic accounting systems that has been used over the years both as a modeling and forecasting device. The input-output (I-O) framework, as developed by Leontief (1951), cannot be employed directly to model commodity market behavior. However, it does provide a disaggregated view of how the demand and supply patterns for different commodities relate to the interindustry structure and the aggregate or macroeconomic variables of a national economy, i.e. see Rose and Miernyk (1987). The construction of input-output models that also explain prices often requires that some mathematical or econometric model be used in conjunction with an appropriately organized I-O table. However, a price solution is also inherent to these models.

In terms of methodology, the interindustry flow table may be converted into a coefficient table measuring the quantity of an input required from one sector per unit of output for another sector. The coefficient matrix represents a model of the production process. This technique provides a means of linking technical coefficients relating input requirements (e.g., agricultural, mineral or energy) per unit of output with behavioral models of demand for primary factors of production (capital and labor), and the demand for final goods and services. Thus, the interindustry framework provides a natural bridge between programming and econometric models of resource/economy interactions. The best early example of such an integrated model was that of Hudson and Jorgenson (1974), which also facilitated the explanation of energy prices.

The received input-output methodology has influenced commodity modeling in two ways. First, it has made clear the usefulness of depicting the supply side by means of detailed sectors. For such a purpose each producing sector is defined as a component of the system having a homogeneous output for a given technology. Second, it requires that production must satisfy not only final demand but also intermediate demand needed directly and indirectly to yield final demand. The main contribution of the received input-output structure is that it allows the list of final demands to be transformed into a vector of sectoral outputs. An early application to market forecasting that involved the ferrous and nonferrous metals is that of Kruegar (1976) who employed an input-output table derived from one prepared by the Bureau of Economic Analysis of the U.S. Department of Commerce. See Rose and Kolk (1987) for applications to natural gas demand, Rose (1989) and Park (1982) for analyses of energy consumption, and Bocoum and Labys (1993) for explanations of phosphate industry impacts in Africa.

An extension of this approach to the international level can be seen in the Leontief et al. (1983) minerals modeling effort. The resulting minerals projections feature production as well as consumption variables and are based on a systematic integration of the factors which determine domestic production, such as the level of final demand, import dependence, recycling rates and materials substitution. Consumption, production and price forecasts are generated for a number of nonfuel minerals. Here consumption includes final demand categories, exports, imports, and changes in inventories; and production includes mine output, by-product output, imports, and releases from government stockpiles. Using technological updating for the 1972 I-O coefficients, mineral projections were prepared to the year 2000 for the United States and to the year 2030 on a global basis.

3. Nonstructural Approach

The analysis of commodity prices independent of other market variables had been popular long before structural modeling made its appearance. This form of price analysis, which essentially relates to a single economic sector, lends itself well to reduced form or nonstructural equation methods. Recall that most any structural commodity model, consisting usually of a multi-equation market equilibrium formulation, can be reduced to single equations with endogenous variables appearing on the left-hand side and only exogenous variables on the right-hand side. This form of model can be specified based on econometric regression equations or on econometric time series equations. The latter can be univariate, where a single variable is explained in terms of its past statistical history, or multivariate, where the past statistical history of several variables is combined. A number of variations exist on the univariate and multivariate themes. Over time several of these have evolved as being useful for analyzing and forecasting commodity markets.

Beginnings

The origins of the nonstructural approach to commodity market analysis stem from earlier attempts to determine whether commodity prices followed some form of random or deterministic linear or nonlinear process. Linear patterns of price behavior are closely related to the theory of market efficiency, whereas nonlinear models have explored dependence and chaos theories. Volatility models now also help to clarify this behavior. The idea of prices following a random walk was first suggested in a pioneering study by Bachelier (1900). Working (1934) later promoted the use of a random walk as a basis to study commodity price movements in the short run. He attempted to simulate the random behavior of a price series by summing a series of random numbers. Kendall (1953) further advanced this approach, while Larson (1960) and Houthakker (1961) conducted empirical evaluations of random walk using corn and cotton prices, respectively. Working (1958) further confirmed his beliefs by arguing that the continuous flow of different kinds of information into the market causes prices to behave randomly. In this process, futures prices are stochastic and the expected price in the next period equals the current price. Labys and Granger (1970), in performing spectral analysis of commodity futures prices, found some evidence for a modified random walk process. See also Labys (1976) and Leuthold (1972, 1996).

Samuelson (1965) postulated that futures prices follow a Martingale process. This idea of price behavior assumes that commodity traders have rational expectations and, thus, incorporate available information concerning fundamentals into their decisions. In this framework, prices are efficient in processing available information. Three different forms of market efficiency were considered depending on the information available to traders at that time. The weak form reflects traders who possess only past information on prices. In the semi-strong form, the trader has all published information available. In the strong form he has this information plus some agent's private information. These hypotheses have been explored for a number of commodities.

Garcia and Leuthold (1992) studied efficiency by measuring the effect of unanticipated information (the difference between the USDA crop report and the anticipated private analyst's forecast) on market prices for corn and soybeans. The study also examined the effects of new information on cash and future markets and across different futures contracts. The efficient market hypothesis tested was: "prices should only respond to the unexpected component of the announcement with the expected component already incorporated into price." They found that the unanticipated information explained the largest percent of the change in price on the first day and then it followed a decline on a gradual basis. On the fifth day they explained variability was much smaller. However, this was not the case with deferred contracts and cash prices where unanticipated information appeared to explain only a small portion of the changes.

Price analysis later shifted to include nonlinear as well as chaotic behavior. The latter approach requires the use of nonlinear equations generating chaotic behavior. Mandelbrot (1963) developed such a model for cotton price behavior by replacing the Gaussian approach with the stable Paretian. He attempted to discover orderly behavior within what appeared to be a random series of price fluctuations. Mandelbrot should not be forgotten for these and other contributions he made to understanding nonlinear price behavior. Frank and Stengos (1989) confirmed the Martingale hypothesis for silver and gold prices but also provided evidence of the presence of nonlinear structure. Deng (1998) attempted a purely stochastic explanation of commodity prices. DeCoster et al. (1992) followed the analysis of Frank and Stengos and their results strongly supported the presence of a nonlinear structure in future prices for sugar, coffee, silver, and copper.

Another contribution to studies explaining deviations from a random walk is that of Peterson et al. (1992) who tested the random walk hypothesis in the daily cash prices of seventeen commodities traded on futures markets. Using variance-ratio tests they found evidence of violations of the random walk hypothesis in many financial markets. A conclusion was reached for price series containing a component independent of the underlying fundamentals that can be used to predict future prices. They argued that such a component could be related to some form of market irrationality, since positive dependence of prices may be a result of fads in the market. This also could reflect some kind of market rigidity in the form of traders' adjustments to unexpected information, the speed of information releases, serial correlation based on information disclosures not fully anticipated, or institutional restrictions that prevent the market from being cleared immediately.

Deaton and Laroque (1992) also found evidence of deviation from random walk in their study of thirteen commodities using annual prices by investigating the standard rational expectations competitive storage theory. To compare the prices simulated by such a theory with real commodity prices, the authors used a generalized method of moments technique to estimate the conditional variance of prices. Since the random walk was not closely confirmed, evidence supported the competitive storage theory.

Finally, chaotic behavior in commodity prices also has been the subject of several studies. Of interest are those by DeCoster et al. (1992), Kyrtsou et al. (2004), and Bernard and Streeter (1993).

Time Dependent Processes

The possibility that any of the above linear or nonlinear forms of price behavior could be more formally modeled and predicted also has early origins. In particular, Slutsky (1927) and Yule (1927) suggested that simple linear difference equations driven by purely random stochastic shocks can be employed to model and to forecast a variety of economic time series. These forms of equations explain autoregressive processes, where current values of a variable can be regressed on lagged transforms of that variable. They are also linked to moving average processes, where current values of that variable can be regressed on current and lagged random shocks alone. Wold (1954) later proposed that the stochastic component of the series can be modeled by some combination of these two processes. But it was not until Box and Jenkins (1976) that a formal modeling procedure was established in the form of the autoregressive-moving average (ARMA) model. They also contributed to forming a sequential approach to all time series forecasting, which consists of model identification, estimation, diagnostic checking and finally prediction. Brown (1963) proposed the exponential smoothing alternative.

Another approach to nonlinear behavior is that followed by Barkoulas et al. (1997, 1999) who have explored dependence in the form of fractional dynamics. The origins of fractional dynamics in commodity prices stems from nonlinear dynamic models built to explain the irregular movements in spot prices as found in works of Brock (1988), Boldrin and Woodford (1990), Burton (1993), Chavas and Holt (1991), and Jensen and Urban (1984). As argued by the authors, some nonlinear dynamic models can generate deterministic chaos, while others can generate periodic behavior in the form of repeated sequences or reversals. The question of classical integration explaining prices better than fractal estimation depends on the kind of memory (long as compared to short) displayed by the series. Long memory describes the correlation structure of a series with long lags and characterizes a series as having distinct but nonperiodic cyclical nonlinear patterns. On the other hand for short memory series, the correlations among observations at long lags are negligible and precluded by autoregressive processes. Barkoulas et al. (1999), for example, have confirmed long memory and fractional orders of integration for tea, soybeans, copper, gold, and wool. Possibilities for nonlinear models are discussed in Granger and Terasvita (1993). See also Mackey (1989) for commodity price applications.

Because computer software had been developed to deal easily with the related estimation and forecasting problems, autoregressive-moving average methods have proven popular for explaining and predicting commodity variables, e.g., see Box and Jenkins (1976), Nelson (1973), and Granger and Newbold (1986). It is particularly appropriate when dealing with the prediction of variables that are observed on a short term basis, i.e., quarterly or monthly. More recently, the level of integration can be fractional and the model becomes ARFIMA. Kouassi et al. (1998) and Labys and Kouassi (2004) have used this approach to forecast commodity prices. More general forecasting issues appear in Agnon et al. (1999) and Baillie and Bollerslev (1992).

Consideration of a wider set of explanatory factors for a given price or quantity variable introduces two additional concepts to the above analysis. First, it is necessary to examine and make use of any theory that postulates relationships determining the dependent variable. Second, one can utilize this theory to build bivariate or multivariate explanatory models. The determination of causal relations between these variables has been suggested by Granger (1969). The multivariate extension of the autoregressive model given above would analyze the relationship between such variables and is known as the vector autoregressive (VAR) model, i.e. see Sims (1980). An extension of this model when co-integration is present has become known as the Vector Error Correction model (VEC), i.e. see Engle and Granger (1987). In addition, cointegration tests have been applied between energy demand, energy prices and gross domestic product to better interpret energy demand elasticities, e.g. see studies by Bentzen (1994), Bentzen and Engsted (1993 a,b), Hunt and Manning (1989), Harvie and Vantloa (1993), and Yu and Jin (1992).

The analysis of comovements among commodity prices has been an interest of economists for some time. Labys and Perrin (1976) rejected this possibility when they analyzed whether the UNCTAD Integrated Program for Commodities could use the upturns in several commodity price series to offset the downturns in other commodity price series. The investigation of factors possibly influencing similar movements among different price series was advanced by Pindyck and Rotemburg (1990) who suggested that macroeconomic forces might play a role here. Cashin et al (1999b) extended this analysis using concordance measures of comovements among different commodity price cycles. While Cashin et al. found little evidence of comovement, Labys et al (1999) employed a more comprehensive approach, dynamic factor analysis, to find that macroeconomic forces have exerted some influence on comovement, at least for metals prices.

The explanation and forecasting of commodity prices also depends on whether the researcher is interested in long run as compared to medium run or short run price behavior. The modeling of long run behavior involves basic linear or nonlinear trend models as shown earlier. The explanation of medium run behavior can involve models capable of generating some form of price cycles; examples include ARIMA, ARFIMA, exponential smoothing, VAR or structural time series (STS) models. The deciphering of short run behavior often is concerned with stochastic or random processes, such as those associated with the discovery of futures price movements.

Empirical applications of these methods to commodity prices has been extensive and can only be briefly reviewed here. A first direction has been to discover the time series generating processes underlying price behavior. One early approach useful in this context has been that of spectral analysis employed by Labys and Granger (1970), Labys et al. (1971), Slade (1981) and Talpaz (1974). Today more emphasis has been placed on discovering the order or fractional order of integration using special testing procedures, e.g. see Barkoulas et. al. (1997, 1999). Studies such as Giraud (1995), and Plourde and Watkins (1995) have employed less robust methods.

A second direction of this work has been to construct models more of a reduced-form nature to explain commodity price behavior. Some studies such as Chu and Morrison (1984) have been longer-term and more macroeconomic in their approach. Studies which concentrate more directly on the use of reduced form models are numerous. More recently Labys and Kouassi (2004) have applied the structural time series approach to discover stochastic cyclical behavior in commodity prices. Special interest in electricity pricing can be found in works such as Munasingha and Meier (1993), Schweppe et al. (1988) and Turvey (1968). Other studies such as those presented in Winters and Sapsford (1990) employ models which are larger scale in nature and thus closer to the econometric models discussed in the next sections.

Finally, a third direction of price forecasting has been to predict both levels and turning points of price behavior, e.g. see Driehuis (1976) and Leuthold et al. (1970). Such price forecasting exercises have long been conducted by the World Bank, as described by Duncan (1984) and Labys and Pollack (1984). A review of just how different univariate and multivariate methods can be applied to minerals and metals prices was produced by the United Nations (1984) and also is useful. Finally, Kouassi et al. (1998) among others have shown how more modern univariate methods can be applied to these same prices.

The evaluation of the quality of forecasts produced by these methods have been extensive. Interested readers should see Andrews (1994), Armstrong and Collapy (1992), Crato and Ray (1996), Cromwell et al. (1994), Cumby and Modest (1987), Cole et al (1994), Fildes (1992), Gerlow et al. (1993), Granger (1989), Harvey and Todd (1983), Henriksson and Merton (1981), Labys (1982, 1993), Makradakis et al (1984), and Stekler (1987).

Trend-breaks

The above price modeling approaches consider all components of a time series process to be explained at once: trend, seasonal, cyclical and irregular. However, forecasting is sometimes aided by explaining or modeling each of these components separately. Most recently this has involved state-space approaches to explain trend and cycle changes.

The analysis of commodity market trends has emphasized the concepts of structural changes or trend-breaks. Much of this work has involved long term analysis of trends in real prices concerning terms of trade. Examples include Cuddington (1992), Cuddington and Urzua (1989), Perron (1989), Reinhart and Wickham (1994), and Thirwall and Bergevin (1985). Some research has been done to test for the presence of a structural break in the trend of real prices in the post-war period. Examples include Cuddington (1992), Cuddington and Urzua (1989), Grilli and Yang (1988), Perron (1989), Reinhart and Wickham (1994), and Sapsford (1985).

The investigation of changing secular trends in commodity prices has been a consequence of crude oil price shocks starting in 1973. Methods of selecting trend break-points are controversial, since the exogenous selection of these breaks using visual or graphical techniques lacks statistical rigor. Perron (1989) advanced structural break analysis by stipulating that most macroeconomic time series are best construed as stationary fluctuations around a deterministic trend, if allowance is made for the possibility of a shift in the intercept of the trend (a crash) and a shift in slope (a slow down in productivity. To this end, Zivot and Andrews (1992), Bannerjee et al. (1992) and Perron (1994) have developed recursive and sequential testing procedures of the unit root and trend-break hypothesis in which the breakpoint is estimated rather that fixed. These procedures overcome many of the bias problems reported in the literature. In particular, the test proposed by Zivot and Andrews (1992) and Andrews (1993) treats the break as unknown a priori. They thus provide the asymptotic distribution of the estimated break point statistic. To investigate the improvement in the identification of commodity price breaks that might result from this approach, Badillo et al. (1999) compared exogenous and endogenous break-point results for a group of monthly commodity price series. They confirm the usefulness of endogenous break point selection for the identification of turning points in commodity price swings. Not only will commodity price cycle timing be better determined, but also the identification of leads and lags between price cycles and cycles in important maroeconomic variables.

Cyclical Behavior

The possibility of directly modeling the mentioned cycles has been encouraged by recent advances in econometric methods. Some examples of cyclical analyses include Gelb (1979) on coffee, Houthakker (1961) on cotton, Chavas and Holt (1991) on pork, Meadows (1970) on poultry, Goodwin (1994) on turkeys and cattle, Labys et al. (2000) on some twenty-one international commodity prices, Moore (1980) on metal prices, Rausser and Cargill (1970) on broiler prices, and Weiss (1970) on cocoa. In particular, Labys and Lesourd (1995) and Labys et al. (2000) evaluated the behavior of commodity prices in terms of cyclical identification using NBER methods and tests of cyclical duration, cyclical volatility, and cyclical persistence. This work was repeated by Cashin et al. (1999a) who identified specific booms and slumps in commodity prices. Cashin et al. (2000) also developed an explanation of these breaks by analyzing the persistence of impending shocks.

A recent breakthrough in modeling economic cycles, however, is due to the development of the "unobserved component" or structural time series (STS) models by Harvey (1989 and 1994) and Harvey and Todd (1983). They constitute a class of univariate time-series models which are directly formulated in terms of underlying trend, cyclical, seasonal and irregular components. Empirical studies based on these models have confirmed their promise in areas such as intervention analysis and forecasting (e.g., see Andrews, 1994; Harvey and Souza, 1987; and Harvey, 1989) or detecting outliers (e.g., see Harvey and Jaeger, 1993). In addition, an attractive feature of these models, or more generally of the broader class of unobserved component models (e.g., see Harvey, 1989) is that they offer an immediate interpretation of the underlying components. The models are, therefore, a natural vehicle for seasonal adjustment and forecasting; moreover various studies have shown the STS approach to be an interesting alternative to the above Box-Jenkins methodology (see e.g., Harvey, 1989 and 1994).

Applications to commodity price analysis and forecasting have been made by Labys and Kouassi (2004), Kouassi et al. (1998), and Labys et al. (1998, 1999). These studies have emphasized the behavior of commodities traded on more than twenty international commodity markets, and have specialized also in metal and agricultural price analysis. An alternative approach to modeling price cycles would involve the application of wavelet analysis. The possibility of modeling the cyclical or frequency properties of different variables stems from work on multi-resolution analysis, i.e., see Daubechies (1990, 1992), Meyer (1992), and Wickerhauser (1994). This analysis is based on a combination of both time and frequency information in terms of levels of time resolution. A recent study performed by Davidson et al. (1997) analyzed commodity price cycles by estimating the wavelet resolution and time-localization using semi-non-parametric regression methods. To identify the localization of the frequency patterns in time, the authors found the method to be valuable for studying prices in terms of four characteristics: volatility; the effects of random shocks in giving rise to outliers; the impact of market conditions causing structural breaks; and the common influence of economic events causing commodity price cointegration.

Volatility

Commodity price instability has long been studied by economists interested in the impacts of instability on the export earnings of developing countries or on the efficiency of spot and futures markets. Attempts to stabilize the earnings often depended on the establishment of buffer stock or other price stabilization schemes that would assure that prices might fall within certain bands. Studies often mentioned in this area include Adams and Klein (1978), Just et al. (1977), Labys (1980c), Labys and Perrin (1976), Newberry and Stiglitz (1981), O'Donnell (1993), Reutlinger (1976), and Sarris and Taylor (1978). Instability analysis has been renewed with the development of volatility models stimulated by Engle's (1982) demonstration of ARCH processes. An empirical analysis of changes in commodity price volatility can be found in Cashin and McDermott (2002). In addition Cuddington and Liang (1998) investigated how commodity price volatility varies during the time when different exchange rate regimes are implemented. GARCH as well as other hetereoscedastic models are estimated to investigate this phenomenon. They conclude that the price instability does, in fact, vary across these regimes. Pindyck (2002) extended this analysis in a multivariate context by examining the relationship between energy commodity inventories, spot and futures prices and volatility using a VAR approach. Based on his model of commodity price dynamics, he found that some portion of commodity price variability does not depend just on market fundamentals but also on speculative noise trading and herd behavior. This finding was to some extent prefigured in the results achieved by Labys and Granger (1970). Shifting the volatility analysis to the importance of price expectations, Kyrtsou et al. (2004) suggest that commodity prices could follow a mean process that is dynamic or noisy chaotic when coupled with a variance that follows a Mackey-Glass form of GARCH process. This stems from a combined or mixed linearity in the mean and conditional variance in a group of metals futures price series.

4. Remaining Problems

The challenges presented to commodity price analysts and forecasters have been discussed and are reflected in the respective structural and nonstructural forecasting methods that have been reviewed. Among other difficult problems to be solved is the considerable uncertainty that pervades the markets: speculative runs, exogenous shocks, political interventions, and structural breaks. This uncertainty is also related to endogenous instability such as that caused by time-varying price elasticities, excessive price speculation, and links to business cycles. Also relevant are supply-side shocks such as those due to biotechnology or genetic adjustments. Influences on the demand side include business cycle fluctuations or the sudden appearances of new technologies. On a global scale, market destabilizing factors range from changes in OPEC policies or military uprisings to exchange rate changes and lapses in debt service. Most of the problems concerning price modeling have already been discussed, but below some remaining important issues are further specified.

Risk and Uncertainty

Many commodity price decisions are made when outcomes are uncertain. This uncertainty evolves from the international instability of commodity markets, financial market linkages and a host of other factors, i.e. see Hurt and Garcia (1982). Uncertainty has only recently been recognized as a feature in policy analysis and a complexity for commodity policy modeling. Important advances that deserve attention in policy analysis and modeling recognize choice under uncertainty. For mineral market forecasting of this nature, see Torries (1998). The correspondence between decision making at individual and market levels and the relatively strong assumptions on the utility functions required also are important.

Nonlinearities

Short-term price analysis is more related to hedging, speculation and trading on commodity related futures and derivative markets. Problems of explaining these prices relate to the complex nonlinearities existing in both means and variances. Research in this area has been stimulated by the time series and econometric methods that have been developed for analyzing and forecasting financial market and price movements, i.e., see Diebold (1998a). Some of this work concerns random walks, chaos and fractile behavior (DeCoster et al., 1992; Frank and Stengos, 1989). Other works dwell on the possibility that ARFIMA models might better be applied to forecasting when long memory is present in prices by using a fractional rather than an integer value for the degree of integration (Barkoulas et al., 1997, 1999; Cheung and Lai, 1993; Sowell, 1992). While this form of model emphasizes nonlinearity in price means, modeling based on nonlinearity in price variance or volatility has continued in the form of the variety of autoregressive heteroscedastic models (Bollerslev, 1986; Engle, 1982; Kouassi et al., 1996; Subba 1981; Tong, 1983).

Structural Change

The theory underlying a commodity price model will suggest the functional form for the structural equations. The typical relationships are estimated either in linear form or in a form that is linear in the parameters, for example, log-linear or some other transformation. While these forms generally conform to a theoretically formulated model, the functional form only broadly approximates the theoretical specification. This creates the problem of deriving non-linear estimates when short sample periods are involved. While simplified functional forms, even linear approximations, may be suitable for price simulations covering a "normal" period, the difficulty is that the abnormal or extreme periods are precisely the points where the non-linearities of the model should become effective.

The problem of structural change occurs frequently in commodity prices, often variations in the parameters of commodity models used for forecasting purposes. Such coefficient variations may occur as a result of imposing an incorrect functional form. Replacing complex nonlinear relationships by simpler functional forms along with observations outside the narrow samples range might better be accompanied by varying parameter structures. Coefficient variation may also be due to the omission of the relevant variables. It has been suggested that changes in coefficients related to omitted variables will produce variation in the coefficients of included variables in the regression, unless the omitted variables are uncorrelated with both the dependent and independent variables.

The time-varying coefficient model is an alternative approach that allows one to deal with the problem of parametric variation or the instability in commodity relationships by assuming that a unit change in one of the independent variables, all else equal, will not have a constant expected effect on the dependent variable at all points in time. Commodity modelers have thus explored the use of stochastic coefficient estimation based on a non-stationary or time-varying random process to overcome some of the above-mentioned instability problems. Should it be preferable to switch coefficients, it is important to identify correctly the breakpoint for such switches. Zivot and Andrews (1992), Banerjee et al. (1992) and Perron (1994) have developed recursive and sequential testing procedures of the unit root and trend-break hypothesis in which the breakpoint is estimated rather that fixed. These procedures overcome many of the bias problems reported in the literature. In particular, the test proposed by Zivot and Andrews (1992) and Andrews (1993) treats the break as unknown a priori. They thus provide the asymptotic distribution of the estimated break point statistic. To investigate the improvement in the identification of commodity price breaks that might result from this approach, Badillo et.al. (1999) compared exogenous and endogenous break-point results for a group of monthly commodity price series. They confirm the usefulness of endogenous break point selection to identify price turning points to switch coefficients.

<u>Macroeconomic Influences</u>

Implications have been made at several points about the influence of macroeconomic factors and business cycles on commodity price movements. Actually a sizeable literature has grown that attempts to analyze the interactions between macroeconomic variables and commodity prices and other market variables. Mostly the emphasis is on how macro variables affect commodity prices such as in the case of changes in industrial activity and commodity demands. Research on macroeconomic influences includes Bosworth and Lawrence (1982), Chambers and Just (1992), Chu and Morrison (1984), Cooper and Lawrence (1975), Fama and French (1988), Labys and Gijsbers (1989), and Labys and Maizels (1993). Labys and Maizels have investigated causal relations between the variables and organized areas of interaction to be: Industrial output, gross domestic product, interest rates, money supply, employment, unit labor costs, wages, consumer prices, producer or wholesale prices, exchange rates and balance of payments.

Concerning price influences on the macroeconomy, the most direct link often cited is that commodity price increases can lead to periods of inflation, the latter reflected in changes in the producer and consumer price indexes, e.g. Kaldor (1987). For manufactures and processors, higher commodity prices lead to lower corporate profits, higher unemployment and result in less consumer spending. In an overheated economy, increased futures trading activity on the part of speculators can amplify already rising commodity prices. Related to this phenomenon is the price influence on the cost of living and subsequently on wages and employment. Concerning monetary impacts, commodity prices can affect interest rates through inflation; not-surprisingly these interest rates can affect commodity markets in return. For example, inventory holding changes and this can affect the basis relationship between commodity spot and futures prices. At the external level, foreign exchange earnings will decline with falling prices. This earnings effect will also pass to importing countries and this will reduce trade further.

A final linkage comes from the extent to which an economy relies on the imports of primary commodities to sustain its own production, consumption and services. Commodity price swings are thus important for industries with higher commodity import requirements per unit of output. Concerning commodity price impacts in this direction, Lefebvre and Poloz (1996) point to regional impacts in Canada, while Bohi (1991), Labys (2000) and Barsky and Kilian (2004) demonstrate the impacts of oil prices on the US economy. In a more comprehensive study dealing with commodity prices and the OECD economy as a whole, Cristini (1999) has reported mixed results, with the causality between prices and the economy reversing depending on the variable-pairs examined.

Cyclical Phenomena

Medium-term price analysis and forecasting is more concerned with price cycles arising either because of endogenous, disequilibrium adjustments in individual markets or because of exogenous shocks related to national and international business cycles. Here the most difficult problem is that of predicting the turning points in these cycles. The study of metal and material price cycles began with the seminal work of the NBER, and today has expanded using tests for cyclicality developed in the macroeconomic domain (Davutyan and Roberts, 1994; Harvey, 1985: Labys et al.,1995; Labys and Kouassi, 2004; Moore, 1980) The prediction of these price cycles is important not only for efficient materials inventory management, but also for anticipating market movements. The relation of price cycles to macroeconomic adjustments has been concerned with inflationary price movements and the impacts of expansions and recessions on the mineral and energy industries (Bosworth and Lawrence, 1992; Fama and French, 1988; Chu and Morrison, 1984; Moore, 1998).

Some of this research has been advanced by tests of duration and persistence and structural time series (STS) modeling. With almost all econometric forecasting models, it is difficult to produce out-of-sample forecasts that are nonlinear in nature. STS models permit a forecast that is cyclical in nature and thus can be used to predict turning points.

Spatial Interactions

The problem of explaining spatially separated commodity prices has not been attacked as vigorously as that of prices delineated by time. Spatial commodity price analysis has improved because of cointegration analysis, spatial econometrics and the more economically limited GIS analysis. In his paper on spatial competition, Hotelling (1929) opened the way to the development of imperfect competition and spatial price discrimination theories. Later on, Hoover (1948) and Isard (1956) advanced spatial price analysis in their classic theoretical works on location and space-economy. Subsequently, the process of spatial price arbitrage was formalized as equilibrium among more than two markets by Enke (1951) and Samuelson (1952). Spatial price relations also are the subject of international trade theory. Since the appearance of the Heckscher-Ohlin principle and Samuelson's factor price equalization theorem (i.e., Samuelson, 1948, 1949), there have been a number of attempts to model the impact of variables such as distance, location and transport cost on international prices (Roehner, 1996; Baulch, 1997; Froot, 1995, Fafchamps and Gavian, 1996). The historical aspect of spatial price relations has been studied by Drame et al. (1991). Roehner (1995, 1996) also has provided a framework for analyzing spatially separated prices.

Also from trade theory the law of one price, initially intended to examine the closeness of prices of traded goods, has been applied to integration among primary commodity markets and prices, i.e. see Miljkovic (1999) and applications such as Ardeni (1989), Baffes (1991), Goodwin (1992), Goodwin and Schroeder (1991), and Goodwin et al. (1990). Possibilities for commodity price convergence have been suggested by Baffes and Ajwad (2001) to fall under either the notion of the law of one price (e.g. Protopapadakis and Stoll, 1986; Ardeni, 1989; Goodwin, 1989; Miljkovic, 1999) or under the notion of market integration (e.g. Ravallion, 1986; Sexton, et al., 1991; Gardner and Brooks, 1994; Fafchamps and Gavian, 1996; Baulch, 1997). Other attempts to examine price integration include Bukenya and Labys (2005), Goletti and Babu (1994), Alexander and Wyeth (1994), Barret and Rong Li (1992), Gordon (1994), and Dercon (1995).

Interventions

There is also the problem of untangling more carefully the nature of commodity market structures and the role played therein by different forms of market interventions such as regulated prices, subsidies, taxes and trade controls. The potential of multidisciplinary analysis in this area might be limited, unless the disciplines of quantitative political analysis and of industrial organization advance in this direction. Attention to market structure in mineral and energy models has been expanded by Pindyck (1987a,b), Salant et al. (1981), Kolstad (1982), Lord (1991), and others. We have thus seen the embodied structure of the petroleum market advance from simple monopoly to rather complex forms of oligopoly. Greater attention to commodity market structure appears in Labys (1980b) and Lord (1991). A lesser amount of work has taken place regarding the role of market interventions and disruptions. Commodity price models are thus likely to improve in the direction of offering a more realistic picture of these two related aspects of market structure.

Combining the Structural and Nonstructural Approaches

Finally, new attention is being directed to the problem of combining the structural and nonstructural analytical and forecasting approaches mentioned above. There is much to be gained here. The structural modeling approaches embed the forecasting models in a sound economic theoretic framework. At the same time, the nonstructural approaches enhance forecast ability by not only including the useful past history of each time series variable but also by paying attention to problems such as nonlinearities, hetereoscedasticity, residual or error modeling, etc. The multivariate extension of the autoregressive model given above would analyze the relationship between such variables, as has been attributed to the vector autoregressive (VAR) model, i.e. see Sims (1980). An extension of this model when co-integration is present has become known as the Vector

Error Correction model (VEC), i.e. see Engle and Granger (1987). Lastly there are new extensions in the use of multivariate GARCH models and other models that are volatility based.

5. Conclusions

This paper has attempted to review the major issues involved in the modeling and forecasting of commodity prices. A considerable legacy exists concerning the research that has taken place in the twentieth century. There are many problems, nevertheless, remaining to be solved. Time series methods are evolving so rapidly that it is difficult to track their frequent applications to price analysis. Because of the importance of and active interest in primary commodity markets and prices, there is no doubt that research in this area will continue to develop and to improve.

References

Abel, W. (1935). *Agricultural Fluctuations in Europe*. New York: St. Martins Press.

Adams F.G. and J.R. Behrman. (1978). *Econometric Modeling of World Commodity Policy*. Lexington, MA: Heath Lexington Books.

Adams, F.G. and L.R. Klein (1978). *Stabilizing World Commodity Markets*. Lexington: Heath Lexington Books.

Adams, F.G. and J. Vial. (1988). "Explaining Recent Metals Price Swings." *Resources Policy,* 14:85-96.

Adams, F.G., and J.M. Griffin. (1972). "An Econometric Linear Programming Model of the U.S. Petroleum Industry." *Journal of the American Statistical Association,* 67: 542-551.

Agnon, Y., Golan, A., and M. Shearer. (1999). "Nonparametric, Nonlinear Short-term Forecasting: Theory and Evidence for Nonlinearities in the Commodity Markets," *Economic Letters*, 65, pp. 293-299.

Alexander, C. and J. Wyeth. (1994). "Cointegration and Market Integration: An Application to the Indonesian Rice Market". *Journal of Development Studies*, 30: 303-328.

Andrews, D.W. (1993). "Tests for Parameter Instability and Structural Change with Unknown Change Point," *Econometrica*, 61:821-56.

Andrews, R.L. (1994). "Forecasting Performance of Structural Time Series Models," *Journal of Business and Economic Statistics,* 12:129-133.

Ardeni, P. G. (1989). Does the Law of One Price Really Hold for Commodity Prices? *American Journal of Agricultural Economics,* 71: 661-669.

Armstrong, J.S., and F. Collopy. (1992). "Error Measures for Generalizing about Forecasting Methods: Empirical Comparisons," *International Journal of Forecasting*, 8: 69-80.

Asche, F., Bremnes, H. and C.R. Wessells. (1999). Product Aggregation, Market Integration, and Relationships between Prices: An Application to World Salmon Markets. *American Journal of Agricultural Economics,* 81: 568-581.

Bachelier, L. (1900). "Theory of Speculation," Reprinted in *The Random Character of Stock Market Prices*, P. Cootner (ed). Cambridge: MIT Press 1964.

Badillo, D., Labys, W. C., and Yangru-Wu. (1999). "Identifying Trends and Breaks in Primary Commodity Prices," *European Journal of Finance,* 5:315-330.

Baffes, J. (1991). "Some Further Evidence on the Law of One Price: The Law of One Price Still Holds," *American Journal of Agricultural Economics,* 73: 1264-1273.

Baffes, J. and M. I. Ajwad. (2001). "Identifying Price Linkages: a Review of the Literature and an Application to the World Market of Cotton," *Applied Economics*, 33:1927-1941.

Baillie, R. T., and T. Bollerslev (1992). "Prediction in Dynamic Models with Time-Dependent Conditional Variances," *Journal of Econometrics*, 52: 91-113.

Bannerjee, A. Lumsdaine, R.L. and J.H. Stock (1992). "Recursive and Sequential Tests for a Unit Root: Theory and International Evidence." *Journal of Business and Economic Statistics* 10: 271-287.

Barkoulas, J., Labys, W., and J. Onochie. (1999). "Long memory in commodity futures prices," *Financial Review,* 34:117-132.

Barkoulas, J., Labys, W. C., and J. Onochie (1997). "Fractional Dynamics in International Commodity Prices," *Journal of Futures Markets*. 17: 2:161-189.

Barnett, H.J. and C. Morse (1963). *Scarcity and Growth*. Baltimore: Johns Hopkins Press.

Barrett, C.B. and J. Rong Li. (2002). "Distinguishing Between Equilibrium and Integration in Spatial Price Analysis." *American Journal of Agricultural Economics*, 84,2:292-307.

Barsky, R.B. and L. Kilian. (2004). "Oil and the Macroeconomy since the 1970's." *Journal of Economic Perspectives*, 18,4: 115-134.

Baulch, B. (1997).”Transfer Costs, Spatial Arbitrage, and Testing for Food Market Integration”. *American Journal of Agricultural Economics*, 79: 477-487.

Behrman, J.R. (1971). “Econometric Simulations of the World Rubber Market.” In L.R. Klein (ed) *Essays in Industrial Econometrics,* Vol III., Philadelphia: Wharton School.

Bentzen, J. (1994). “An Empirical Analysis of Gasoline Demand in Denmark using Cointegrated Techniques,” *Energy Economics,* 16: 139-144.

Bentzen, J. and T. Engsted. (1993a). “Expectations, Adjustment Costs and Energy Demand,” *Resource and Energy Economics*, 15: 371-85.

Bentzen, J. and T. Engsted. (1993b). “Short and Long Run Elasticities in Energy Demand: A Cointegration Approach,” *Energy Economics,* 15: 9-16.

Bernard, J. C., and D. H. Streeter (1993). "Chaos Theory and its Implications for Research on Futures Markets: A Review of the Literature,” *NCR-134 Conference of Applied Commodity Price Analysis, Forecasting, and Market Risk Management*. 170-180.

Blitzer, C., Meeraus, A. and A. Stoutjesdijk. (1975). “A Dynamic Model of OPEC Trade and Production,” *Journal of Development Economics,* 2: 319-335.

Bocoum, B. and W. C. Labys. (1993). “Modeling the Economic Impacts of Future Mineral Processing,” *Resources Policy,* 19:1-27.

Bohi, D.R. (1991).”On the Macroeconomic Effects of Oil Price Shocks.” *Resources and Energy*, 13,2: 145-162.

Boldrin, M., and M. Woodford (1990). "Equilibrium Models Displaying Endogenous Fluctuations and Chaos,” *Journal of Monetary Economics,* 25: 189-222.

Bollerslev, T. (1986). "Generalized Autoregressive Conditional Heteroskedasticity,” *Journal of Econometrics,* 31: 307-327.

Bosworth, B. and R. Z. Lawrence. (1992). *Commodity Prices and the New Inflation*, Washington D.C.: The Brookings Institute.

Box, G. E .P., and G. M. Jenkins (1976). *Time Series Analysis: Forecasting and Control,* Revised edition. Oakland, CA: Holden–Day.

Brandow, G. E. (1961). “Interrelations Among Demands for Farm Products and Implications for Control of Market Supply.” Pennsylvania Agricultural Experiment Station Bulletin 680, University Park.

Brock, W. A. (1988). "Nonlinearity and Complex Dynamics in Economics and Finance,” in Anderson, P.W., Arrow, K. and Pines, D. (eds.). *The Economy as an Evolving, Complex System.* New York: Addision-Wesley Publishing.

Brockwell, P. J., and R. A. Davis (1991). *Time Series: Theory and Methods* 2nd edition, New York: Springer Verlag.

Brooke, A. D., Kendrick, D. and A. Meerus. (1998). *GAMS*, San Francisco: Scientific Press.

Brookfield, D. (1991). "Structural Relationships in United Kingdom Livestock Markets,” *Journal of Agricultural Economics*, 42:11-22.

Brown, A. J. (1985). *World Inflation Since 1950.* London: National Institute of Economic and Social Research.

Brown, A. J. (1988). "World Depression and the Price Level," *National Institute Economic Review,* 123:65-79.

Brown, R. G. (1963). *Smoothing, Forecasting, and Prediction*, Englewood Cliffs, NJ: Prentice Hall.

Bukenya, J. O., and W. C. Labys. (2005). “Price Convergence on World Commodity Markets: Fact or Fiction,” *International Regional Science Review*, forthcoming.

Burrows, J. (1971). *Cobalt: An Industry Analysis.* Lexington, Mass: Heath Lexington Books.

Burton, M. (1993). "Some Illustrations of Chaos in Commodity Models,” *Journal of Agricultural Economics*, 44:38-49.

Cashin, P. and C.J. McDermott (2002). “Long-run Behavior of Commodity Prices: Small Trends and big Variability.” *IMF Staff Papers*, 49,2:175-199.

Cashin, P., Liang, Hong, and C.J. McDermott. (2000). "How Persistent are Shocks to World Commodity Prices?" *IMF Staff Papers*. 47,2:177-217.

Cashin, P., McDermott, C. J. and A. Scott. (1999a). "Booms and Slumps in World Commodity Prices." WP/99/155. International Monetary Fund, Washington, D.C.

Cashin, P., McDermott, C. J. and A. Scott. (1999b). "The Myth of Co-moving Commodity Prices." WP/99/169. International Monetary Fund, Washington, D.C.

Chambers, R. G. and R. E. Just. (1992). "An Investigation of the Effects of Monetary Factors in Agriculture." *Journal of Monetary Economics*, 9,2: 235-247.

Charles River Associates. (1978). "The Economics and Geology of Mineral Supply: An Integrated Framework for Lon-Run Policy Analysis." Report No. 327, Charles River Associates, Boston.

Chavas, J. P., and M. T. Holt (1991). "On Nonlinear Dynamics: The Case of the Pork Cycle," *Journal of the American Agricultural Economic Association*, 73: 820-828.

Chen, D. T. (1994). "Empirical Analysis of Agricultural Commodity Prices: A Practitioner's Viewpoint on Structural Models," *NCR-134 Conference Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, 37-55.

Chen, D. T., and D. A. Bessler. (1990). "Forecasting Monthly Cotton Prices with Structural and Time Series Approaches," *International Journal of Forecasting*, 6: 103-113.

Cheung, Y. W., and K. S. Lai. (1993). "Do Gold Market Returns Have Long Memory?," *Financial Review,* 128: 181-202.

Chicago Mercantile Exchange (1994-1999). *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management,* Chicago, Several Issues.

Christ, C. F. (1994) "The Cowles Commission's Contributions to Econometrics at Chicago, 1939-1955." *Journal of Economic Literature,* 32: 30-59.

Chu, K .Y. (1978) "Short Run Forecasting of Commodity Prices: An Application of Autoregressive Moving Average Models." *IMF Staff Papers* 1: 90-111.

Chu, K. Y., and T.K. Morrison. (1984). "The 1981-82 Recession and Non-Oil Primary Commodity Prices," *IMF Staff Papers,* 31: 93-140.

Cole, C., Mintert, J., and T. Shroeder (1994). "Forecasting Feeder Steer Prices: A Comparison of the Econometric, VAR, ARIMA, Feeder Cattle Futures, and Composite Approaches," *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, 66-76.

Cottle, R. W. and G. B. Dantzig. (1968). "Complimentary Pivot Theory of Mathematical Programming," *Linear Algebra and Its Applications,* 1: 103-25.

Crato, N., and B. K. Ray (1996). "Model Selection and Forecasting for Long-Range Dependent Processes," *Journal of Forecasting,* 15: 107-125.

Cremer, J. and Salehi-Isfahani, D. (1991). *Models of the oil Market.* Chur, Switzerland: Harwood Academic Publishers.

Cristini, A. (1999). *Unemployment and Primary Commodity Prices*. New York: St. Martin's Press.

Cromwell, J., Labys, W. C. and E. Kouassi. (2000). "What Color Are Commodity Prices? A Fractal Analysis." *Empirical Economics*, 25:563-580.

Cromwell, J. B., Labys, W. C., and M. Terraza (1994). *Multivariate Tests for Time Series Models*, Thousand Oaks, CA: SAGE Publications.

Cuddington, J. (1992). "Long-run Trends in 26 Primary Commodity Prices: A Disaggregated Look at the Prebisch-Singer Hypothesis," *Journal of Development Economics,* 39:207-227.

Cuddington, J. and C. Urzua (1989). "Trends and Cycles in the Net Barter Terms of Trade: A New Approach," *The Economic Journal,* 99:426-442.

Cuddington, J. T. and Hong Liang. (1998). "Commodity Price Volatility Across Exchange Rate Regimes." Working Paper, Department of Economics, Georgetown University.

Cumby, R. E., and D. M. Modest (1987). "Testing for Market Timing Ability: A Framework for Forecast Evaluation," *Journal of Financial Economics*, 19: 169-189.

Dantzig, G. B. (1963). *Linear Programming and Extensions.* Princeton, NJ: Princeton University Press.

Daubechies, I. (1990). "The Wavelet Transform Time-Frequency Localization and Signal Analysis," *IEEE Transactions on Information Theory*. 36: 961-1003.

Daubechies, I. (1992) *Ten Lectures on Wavelets*, Philadelphia: Society for Advanced Mathematics.

Davidson, R., Labys, W. C. and J. B. Lesourd (1997). "Wavelet Analysis of Commodity Price Behavior," *Computational Economics,* 11: 103-128.

Davutyan, N. and M. Roberts. (1994). "Cyclicality in Resource Prices." *Resources Policy*, 20:49-57.

Deaton, A .S., and G. Laroque (1992). "On the Behavior of Commodity Prices," *Review of Economic Studies,* 59: 1-24.

DeCoster, G. P., Labys, W. C., and D. W. Mitchell (1992). "Evidence of Chaos in Commodity Futures Prices," *The Journal of Future Markets,* 12: 3: 291-305.

Deng, Shijie. (1998). "Stochastic Models of Energy Commodity Prices and their Applications". Working Paper, Industrial Engineering, Georgia Institute of Technology.

Dercon, S. (1995). "On Market Integration and Liberalization: Method and Application to Ethiopia," *Journal of Development Studies*, 32: 112-143.

Desai, M. (1966). "An Econometric Model of the World Tin Economy." *Econometrica*, 34: 105-134.

Dick, T.J.O. (1998). *Business Cycles since 1820*. Cheltenham, UK: Edward Elgar.

Diebold, F. X. (1998). *Elements of Forecasting,* Cincinnati: Southwestern.

Drame, S., Gonfalone, C., Miller, J. and B. Roehner. (1991). *Un Siecle de Commerce du Ble en France, 1825-1913.* Paris: Economica.

Driehuis, W. (1976). *Primary Commodity Prices: Analysis and Forecasting,* Rotterdam: Rotterdam University Press.

Duncan, R. C. (1984). "The Outlook for Primary Commodities, 1984 to 1995," Staff Working Paper No. 11, World Bank, Washington, D.C.

Engle, R. F. (1982). "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica,* 50: 987-1007.

Engle, R. F. and C. W. Granger. (1987). "Cointegration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55: 251-76.

Enke. S. (1951). "Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue." *Econometrica,* 19: 40-48.

Ezekiel, M. J. B. (1959). *Methods of Correlation Analysis.* Wiley & Sons, editions of 1930 and 1941. Third edition with Karl A. Fox.

Fafchamps, M. and S. Gavian. (1996). "The Spatial Integration of Livestock Markets in Niger," *Journal of African Economies*, 5: 366-405.

Fama, E. F. and K. R. French. (1988). "Business Cycles and the Behavior of Metals Prices," *Journal of Finance*, 43: 1075-1088

Ferris, J. N. (1998). *Agricultural Prices and Commodity Market Analysis*, Boston, MA: WCB/McGraw-Hill.

Fildes, R. (1992). "The Evaluation of Extrapolative Forecasting Methods," *International Journal of Forecasting,* 8: 81-98.

Fischer, D. H. (1996). *The Great Wave: Price Revolutions and the Rhythm of History*. New York: Oxford University Press.

Fisher, F. M., Cootner, P. H. and M. Bailey. (1972). "An Econometric Model of the World Copper Industry," *Bell Journal of Economics*, 3: 568-609.

Foote, R. J. (1958). *Analytical Tools for Studying Demand and Price Structure.* Agricultural Handbook No. 146. Economic Research Service, U.S. Department of Agriculture, Washington, D. C.

Fox, A. (1953). “The Analysis of Demand for Farm Products.” U.S. Department of Agriculture Technology Bulletin, 1081, Washington, D.C.

Fox, K.A. (1958). *Econometric Analysis for Public Policy.* Ames: Iowa State College Press.

Frank, M., and T. Stengos (1989). "Measuring the Strangeness of Gold and Silver Rates of Return,” *Review of Economic Studies,* 56: 553-567.

Froot, K. A. (1995) “The Law of One Price Over 700 Years”. WP 5132, National Bureau of Economic Research. New York.

Garcia, P., and R.M. Leuthold (1992). "The Effect of Market Information on Corn and Soybean Markets,” *NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management*, 47-58.

Gardner, B. and K. M. Brooks. (1994). “Food Prices and Market Integration in Russia: 1992-93,” *American Journal of Agricultural Economics,* 76: 641-646.

Gelb, A. H. (1979). "A Spectral Analysis of Coffee Price Oscillations,” *International Economic Review*, 20: 495-514.

Gerlow, M. E., Irwin, S. H. and T. R. Liu. (1993). "Economic Evaluation of Commodity Price Forecasting Models,” *International Journal of Forecasting*, 9: 387-397.

Ghosh, S., Gilbert, C. A. and A. J. Hughes. (1987). *Stabilizing Speculative Commodity Markets*. Oxford: Clarendon.

Giraud, P. N. (1995). “The Equilibrium Price Range of Oil,” *Energy Policy,* 23: 35-49.

Goletti, F. and S. Babu. (1994). “Market Liberalization and Integration of Maize Markets

Goodwin, B. K. (1989). “Empirically Testing the Law of One Price in International Commodity Markets: A Rational Expectations Approach,” In *International Financial Markets and Agricultural Trade*. Boulder: Westview Press.

Goodwin, B. K. (1992). “Multivariate Cointegration Tests and the Law of One Price in International Wheat Markets,” *Review of Agricultural Economics*, 14,1: 117-24.

Goodwin, B. K. and T. C. Schroeder. (1991). “Co-integration Tests and Spatial Prime Linkages in Regional Cattle Markets,” *American Journal of Agricultural Economics*, 73: 452-64.

Goodwin, B .K., Grennes, T. J., and M. K. Wohlgenant. (1990). “A Revised Test of the Law of One Price Using Rational Price Expectations,” *American Journal of Agricultural Economics,* 72: 683-693.

Goodwin, J. W. (1994). *Agricultural Price Analysis and Forecasting,* New York: John Wiley and Sons.

Gordon, H. F. (1994). “Grain Marketing Performance and Public Policy in Tanzania,” Ph.D. Dissertation, Fletcher School of Law and Diplomacy.

Granger, C. W .J. and T. Terasvirta. (1993). *Modeling Nonlinear Economic Relationships*, Oxford: Oxford University Press.

Granger, C. W. J. (1969). “Investigating Casual Relations by Econometric Models and Cross-Spectral Methods,” *Econometrica*, 37: 424-38.

Granger, C. W. J. (1989). *Forecasting in Business and Economics,* Second Edition, San Diego, CA: Academic Press.

Granger, C. W. J. (1992). “Evaluating Economic Theory.” *Journal of Econometrics*, 51: 3-5.

Granger, C. W. J. and A. Hughes (1971). “A New Look at Some Old Data: The Beveridge Wheat Price Series,” *Journal of the Royal Statistical Society* A 134: 413-428.

Granger, C. W. J. and C. M. Elliott. (1967). “A Fresh Look at Wheat Prices and Markets in the Eighteenth Century,” *Economic History Review,* 357:365.

Granger, C .W. J., and P. Newbold (1986). *Forecasting Economic Time Series*, 2nd ed., Sand Diego, CA: Academic Press.

Grilli, R. E., and M. C. Yang (1988). "Primary Commodity Prices, Manufactured Good Prices, and the Terms of Trade of Developing Countries: What the Long Run Shows," *World Bank Economic Review,* 2: 1-48.

Guvenen, O., Labys, W. C. and J. B. Lesourd. (1991) *International Commodity Market Models.* London: Chapman-Hall.

Haas, G. C. and M. J. Ezekiel. (1926). "Factors Affecting the Price of Hogs," U.S. Department Agricultural Bulletin 1440, Washington, D.C.

Hallam, D. (1990) *Econometric Modeling of Agricultural Commodity Markets.* London: Routledge.

Hanau, A. (1928). Die Prognose der Schweinpreise. Institut Fur Konjunkturforschung, Berlin.

Harlow, A. (1962). "Factors Affecting the Price and Supply of Hogs," U.S. Department of Agriculture Technology Bulletin, 1274, Washington D.C.

Harvey, A. C. (1985). "Trends and Cycles in Macroeconomic Time Series," *Journal of Business and Economic Statistics,* 3:216-227.

Harvey, A. C. (1989). *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge: Cambridge University Press.

Harvey, A. C. (1994). *Time Series Models,* 2nd. Ed., Cambridge, MA: The MIT Press.

Harvey, A. C., and A. Jaeger. (1993). "Detrending Stylized Facts and the Business Cycle," *Journal of Applied Econometrics*, 8: 231-247.

Harvey, A. C., and P. H .J. Todd. (1983). "Forecasting Economic Time Series with Structural and Box-Jenkins Models: A Case Study," *Journal of Business and Economic Statistics*, 1: 299-315.

Harvey, A. C., and R. C. Souza. (1987). "Assessing and Modeling the Cyclical Behavior of Rainfall in Northeast Brazil," *Journal of Climate and Applied Meterology*, 28: 1339-1344.

Harvie, C .H. and T. Vantloa. (1993). "Long-term Relationships of Major Macro-Variables in a Resource-Related Economic Model of Australia: A Cointegration Analysis," *Energy Economics,* 15: 258-261.

Hashimoto, H., and T. Sihsobhon. (1981). "A World Iron and Steel Economy Model: The WISE model", In *World Bank Commodity Models*. Washington, D.C: The World Bank, 1-46.

Heady, E. O., and D .R. Kaldor (1954). "Expectations and Errors in Forecasting Agricultural Prices," *Journal of Farm Economics,* 62: 34-47.

Hendry, D.F. (1995). *Dynamic Econometrics*. Oxford: Oxford University Press.

Henriksson, R. D., and R. C. Merton. (1981). "On Market Timing and Investment Performance: Statistical Procedures for Evaluating Forecasting Skills," *Journal of Business,* 54: 513-533.

Hildreth, C. and F. J. Jarrett. (1955). *A Statistical Study of Livestock Production and Marketing.* New York: John Wiley and Sons.

Hinson, R. A. (1991). "A Risk Assessment of Selected Fresh Market Vegetables," Bulletin No. 829, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center.

Hoffman, K. C. and D. W. Jorgenson. (1977). "Economic and Technological Models for Evaluation of Energy Policy", *Bell Journal of Economics,* 8: 444-466.

Holt, M. T., and S. V. Aradhyula.(1990). "Price Risk in Supply Equations: An Application of GARCH Time-Series Models to the U.S. Broiler Market." *Southern Economic Journal,* 57: 230-42.

Hood, W. C. and T. C. Koopmans, (eds.) (1953). *Studies in Econometric Method.* New York: John Wiley and Sons.

Hoover, Edgar M. (1948). *The Location of Economic Activity*. New York: McGraw-Hill.

Hotelling, H. (1929). "Stability in Competition," *Economic Journal,* 36: 41-57.

Houck, J. P., Ryan, M. E. and S. Subotnik. (1972). *Soybeans and their Products: Markets, Models and Policies.* Minneapolis: University of Minnesota Press.
Houthakker (1961). "Systematic and Random Elements in Short-Term Price Movements," *American Economic Review*, 51: 164-172.
Hudson, E. A. and D. W. Jorgenson. (1974). "U.S. Energy Policy and Economic Growth. 1975-2000," *Bell Journal of Economics*, 5: 461-514.
Hudson, M. A., Leuthold, R. M., and G. F. Sarassoro,. (1987). "Commodity Futures Price Changes: Recent Evidence for Wheat, Soybeans, and Live Cattle," *Journal of Future Markets,* 74:287-301.
Hunt, L. and N. Manning. (1989). "Energy Price- and Income–Elasticities of Demand: Some Estimates for the UK Using the Cointegration Procedure," S*cottish Journal of Political Economy,* 36: 183-93.
Hurt, C., and P. Garcia (1982). "The Impact of Price Risk on Sow Farrowings," *American Journal of Agricultural Economics*, 64: 1967-1978.
Isard, P. (1956). *Location and Space-economy*: *A General Theory Relating to Industrial Location, Market Areas, Trade and Urban Structure*. Cambridge, Mass.: MIT Technology Press.
Jensen, R. V., and R. Urban (1984). "Chaotic Behavior in the Non-Linear Cobweb Model," *Economic Letters,* 15: 235-40.
Just, R. E., Schmitz, A. and S. Turnovsky. (1977). "The Distribution of Welfare Gains from International Price Stabilization." *American Journal of Agricultural Economics,* 59: 652:661.
Kaldor, N. (1987). "The Role of Prices in Economic Recovery," *World Development,* 15: 645-56.
Kendall, M. G. (1953). "The Analysis of Economic Time Series Part I: Prices," *Journal of the Royal Statistical Society,* 96: 11-25.
Kendrick, D. (1967). *Programming Investments in the Process Industries: An Approach to Sectoral Planning.* Cambridge: MIT Press.
Kendrick, D. and A. Stoutjesdijk. (1978). *The Planning of Industrial Investment Programs: A Methodology.* Baltimore: Johns Hopkins University Press.
Killough, H. B. (1925). "What Makes the Price of Oats?" U.S. Department of Agricultural Bulletin 1351, Washington, D.C.
Klein, L. R. and S. Goldberger. (1955). *An Econometric Model of the United States*. 1929-1952. Amsterdam: North-Holland.
Kolstad, C. D. (1982). "Noncompetitive Analysis of the World Coal Market." Working paper. Energy Laboratory, Los Alamos.
Kondratief, N. D. (1935). "The Long Wave in Economic Life," *Review of Economic Studies,* 17: 10515.
Koopmans, T. C. (ed.) (1950). Statistical Difference in Dynamic Economic Models. John Wiley & Sons, New York.
Kouassi, E., Labys, W. C., and D. Colyer (1998). "The Structural Time Series Approach to Forecasting Commodity Prices". Working Paper, Natural Resource Economics, West Virginia University, Morgantown.
Krueger, P. K. (1976). "Modeling Future Requirements for Metals and Minerals." *Proceedings of the XIV Symposium of the Council for the Application of Computers and Mathematics in the Minerals Industry*. University Park, PA: Pennsylvania State University.
Kuhn, N. W. and A. W. Tucker. (1951). "Nonlinear Programming," In J. Neyman (ed). *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability,* Berkeley: University of California Press.
Kyrtsou, C., Labys, W. C. and M. Terraza. (2004). "Chaotic Dynamics in Commodity Markets. " *Empirical Economics,* 29:489-502
Labys, W. C., Achouch, A., and M. Terraza. (1999). "Metal Prices and the Business Cycle," *Resources Policy*, 25: 229-238.

Labys, W. C., Paik, S. and A. M. Liebenthal. (1979). "An Econometric Simulation Model of the U.S. Steam Coal Market," *Energy Economics,* 1: 19-26.

Labys, W. C., and J. B. Lesourd (1995). "Commodity Price Cycles: Fact or Fiction," Working Paper, Natural Resource Economics Program, West Virginia University.

Labys, W. C. (1978). "Commodity Markets and Models: The Range of Experience," In F. G. Adams, (ed.) *Stabilizing World Commodity Markets: Analysis, Practice and Policy,* Lexington, MA: Heath Lexington Books.

Labys, W. C. (1980a). "A Model of Disequilbrium Adjustments in the Copper Market," *Materials and Society*, 4: 153-164.

Labys, W. C. (1982). "Measuring the Validity and Performance of Energy Models," *Energy Economics,* 4: 159-168.

Labys, W.C. (2000). "Can World Market Volatility Upset the US Economy?" *Economic Directions*. Center for Economic and Policy Research, St. Vincent College, Latrobe PA.

Labys, W. C. (1993). "Model Validation," In J.P. Weyant and T.A. Kuczmowski. (eds.) *Systems Modeling Handbook*, New York: Pergamon Press.

Labys, W. C. (1999). *Modeling Mineral and Energy Markets.* Boston: Kluwer Publishing Company.

Labys, W. C. (ed.) (1975). *Quantitative Models of Commodity Markets*. Cambridge, MA: Ballinger.

Labys, W. C. and E. Kouassi. (2004). "Cyclicality, Non-stationarity and the Forecasting of Commodity Prices." In C. Kyrtsou (ed). *Progress in Financial Market Research,* New York: Nova Science Publishers.

Labys, W. C. (1973). *Dynamic Commodity Models: Specification, Estimation, and Simulation*, Lexington, MA: Lexington Books.

Labys, W. C. (1980b). *Market Structure, Bargaining Power, and Resource Price Formation.* Cambridge, MA: Ballinger.

Labys, W. C. (1987). *Commodity Markets and Models: An International Bibliography*. London: Gower Publishing Company.

Labys, W.C. (1993). "The Impact of Commodity Price Fluctuations on the Instability of the World Economy." In M. Nissanke and A. Hewitt (eds), *Economic Crisis in Developing Countries,* London: Pinter Publishers.

Labys, W.C. (1976). "Bidding and Auctioning on International Commodity Markets." In Y. Amihud (ed.) *Bidding and Auctioning for Procurement and Allocation*. New York: New York University Press.

Labys, W.C. and D. Gijsbers (1989). "Monetary and Economic Influences in Econometric Models of Commodity Price Behavior." In R.I. Guimares, B.G. Kingsman and S.J. Taylor (eds.) *A Reappraisal of the Efficiency of Futures Markets*, New York: Springer-Verlag.

Labys, W. C. and C. W. Yang. (1997). "Spatial Price Equilibrium as the Core to Spatial Commodity Modeling." *Papers in Regional Science* 76: 199-228.

Labys, W.C. and A. Maizels. (1993) "Impact of Commodity Price Fluctuations on the Developed Economies." *Journal of Policy Modeling* 15,3: 335-352.

Labys, W. C. and Y. Perrin. (1976). "Multivariate Analysis of Price Aspects of Commodity Stabilization," *Weltwirtschaftliches Archives*, 112: 556-564.

Labys, W. C., and C. W. Yang. (1991). "Advances in the Spatial Modeling of International Mineral and Energy Issues," *International Regional Science Review* 14: 61-94.

Labys, W. C., and C. W. J. Granger. (1970). *Speculation, Hedging and Commodity Price Forecasts.* Lexington, MA: Heath Lexington Books.

Labys, W. C., and E. Kouassi. (1996). "Structural Time Series Modeling of Commodity Price Cycles," Research Paper 9602, Regional Research Institute, West Virginia University.

Labys, W. C., and P. K. Pollak (1984). *Commodity Models for Forecasting and Policy Analysis*, New York: Nichols Publishing Company.
Labys, W. C., Badillo, D., and J. B. Lesourd. (1995). "The Cyclical Behavior of Individual Commodity Price Series," Document de Travail 95B03, GREQAM, Universities Aix-Marseille II, III, Marseille.
Labys, W. C., Elliot, C., and H. Reese (1971) "Copper Price Behavior and the London Metal Exchange," *Applied Economics* 3: 99-113.
Labys, W. C., Takayama, T., and N. Uri. (1989). *Quantitative Methods for Market Oriented Economic Analysis Over Space and Time.* London: Gower Publishing Company.
Labys, W. C., Kouassi, E. and M. Terraza. (2000). "Short-Term Cycles in Primary Commodity Prices." *Journal of Developing Economies,* 38,3:330-342.
Labys, W.C. (1980c). "Commodity Price Stabilization Models: A Review and Appraisal," *Journal of Policy Modeling* 2: 121-136.
Lalonde, R., Zhu, Z. and F. Demers. (2003). "Forecasting and Analyzing World Commodity Prices." WP 2003-24, Bank of Canada, Ottawa.
Larson, A. (1960). "Measurement of a Random Process in Future Prices," *Food Research Institute Studies*, 1: 313-324.
Lefebvre, M., and S. S. Poloz. (1996). "The Commodity Price Cycle and Regional Economic Performance in Canada." *Working Paper*, International Department. Bank of Canada, Ottawa.
Lehfeldt, R. A. (1914). "The Elasticity of Demand for Wheat." *Economic Journal, 2*4:212-217.
Leontief, W. (1951). *Input-Output Economics*. Oxford: Oxford University Press.
Leontief, W. (1929). Ein Versuch Zur Statistichen Analyse von Angebot und Nachfrage. Weltwirtschaftlisches Archiv., XXX .
Leontief, W., Koo, J., Nasar S.,and I. Sohn. (1983). *The Future of Nonfuel Minerals in the U.S. and World Economy: Input-Output Projections 1980-2030.* Lexington, MA: Heath Lexington Books.
Lesourd, J. ., Percebois, J., and F. Valette (eds.) (1996). *Models for Energy Policy*. New York: Routledge.
Leuthold, R. M. (1972). "Random Walk and Price Trends: The Live Cattle Futures Market," *Journal of Finance* 27: 879-889.
Leuthold, R. M. (1996). "An Analysis of Daily Fluctuations in the Hog Economy," *American Journal of Agricultural Economics*, 51: 849-865.
Leuthold, R. M., MacCormick, A. J., Schmitz, A., and D. G. Watts. (1970) "Forecasting Daily Hog Prices and Quantities: A Study of Alternative Forecasting Techniques," *Journal of the American Statistical Association,* 65: 90-107.
Lewis, W. A (1949). *Economic Survey: 1919-1939.* London: Allen and Unwin.
Lord, M. J. (1991). *Imperfect Competition and International Commodity Trade.* Clarendon: Oxford University Press.
MacAvoy, P. W., and R. S. Pindyck. (1975). *The Economics of the Natural Gas Shortage,* 1960-1980, Amsterdam: North-Holland.
Mackey, M. C. (1989). "Commodity Price Fluctuations: Price Dependent Delays and Nonlinearities as Explanatory Factors," *Journal of Economic Theory*, 48:497-509.
Makridakis, S., Andersen, A., Carbone, R., Fildes, R., Hibon, M., Lewandowski, R., Newton, J., Parzen, E., and R. Winkler (1984). *The Forecasting Accuracy of Major Time Series Methods,* New York: John Wiley and Sons.
Mandelbrot, B. B. (1963). "The Variation of Certain Speculative Prices," *Journal of Business,* 36: 394-429.
Marquez, J. R. (1984). *Oil Price Effects and OPEC Pricing Policy*, Lexington: Heath Lexington Books.
Marschak, J. (1953). *Studies in Econometric Method.* New York: John Wiley and Sons.

Meadows, D. L. (1970). *Dynamics of Commodity Production Cycles,* Cambridge: Wright-Allen Press.
Meinken, K. W. (1955a). "The Demand and Price Structure for Wheat. U. S. Department of Agriculture Technology Bulletin 1136, Washington, D.C.
Meinken, K. W. (1955b). "The Demand and Price Structure of Oats, Barley, and Soybean Grains." United States Department of Agriculture Bulletin TB-80, Washington, D.C.
Meyer, Y. (1992). *Wavelets and Operators,* Cambridge: Cambridge University Press.
Miljkovic, D. (1999). The Law of One Price in International Trade: A Critical Review. *Review of Agricultural Economics*, 21:126-139.
Mills, F. C. (1927). *The Behavior of Prices*. New York: National Bureau of Economic Research.
Mills, F. C. (1936). *Prices in Recession and Recovery.* New York: National Bureau of Economic Research.
Moore, G. H. (1980). *Business Cycles, Inflation and Forecasting,* Cambridge: National Bureau of Economic Research.
Moore, G. H. (1998). "Inflation Cycles and Metals Prices." *Mineral Processing and Extracting Metallurgy Review*. 3:95-104.
Moore, H. L. Economic Cycles: Their Laws and Cause (1914); Forecasting The Yield and Price of Cotton (1917); Generating Economic Cycles (1923); Synthetic Economics (1929). New York:Macmillan.
Munasinghe, M. and P. Meier. (1993). *Energy Policy Analysis and Modeling.* Cambridge: Cambridge University Press.
Nagurney, A. (1987). "Competitive Equilibrium Problems. Variational Inequalities, and Regional Science," *Journal of Regional Science.* 27: 503-18.
Nelson, C. R. (1973). *Applied Time Series Analysis for Managerial Forecasting.* San Francisco: Holden Day.
Nerlove, M. (1958). Distributed Lags and Demand Analysis for Agricultural and Other Commodities. U.S. Department of Agriculture Handbook.141, Washington, D.C.
Newberry, D. M. and J. E. Stiglitz (1981). *The Theory of Commodity Price Stabilization.* Oxford: Clarendon Press.
O'Donnell, C. (1993). *Commodity Price Stabilisation*. Aldershot, England: Ashgate Publishing.
Park, Se-Hark. (1982). "An Input-Output Framework for Analyzing Energy Consumption." *Energy Economics*, 4: 105-110.
Perron, P. (1989). "The Great Crash, The Oil Shock and the Unit Root Hypothesis," *Econometrica*, 57: 1361-1402.
Perron, P. (1994). "Trends, Unit Root and Structural Change in Macroeconomic Time Series," In B. Bhaskara Rao (ed), *Cointegration,* New York: St. Martin's Press.
Persson, K. G. (1994). "Integration and Deregulation of European Grain Markets, 1500-1900," WP 94-07. Institute of Economics, University of Copenhagen.
Peterson, R. L., Ma, C. K., and R. J. Ritchey. (1992). "Dependence in Commodity Prices," *Journal of Futures Markets,* 12: 4: 429-446.
Pindyck, R. S. (1978a). "The Optimal Exploration and Production of Nonrenewable Resources," *Journal of Political Economy*, 86: 841-61.
Pindyck, R. S. (1978b). "Gains to Producers from the Cartelization of Exhaustible Resources." *Review of Economics and Statistics*, 60: 238-51.
Pindyck, R. S. (2002). "Volatility and Commodity Price Dynamics." Working Paper, Department of Economics, Massachusetts Institute of Technology.
Pindyck, R. S. and J. J. Rotemberg. (1990). "The Excess Co-movement of Commodity Prices," *The Economic Journal*, 100: 1173-1189.
Plourde, A. and G. C. Watkins. (1995). "How Volatile are Crude Oil Prices?" *OPEC Review,* 19: 10-23.

Protopapadakis, A. A. and H. R. Stoll. (1986). "Some Empirical Evidence on Commodity Arbitrage and the Law of One Price. *Journal of International Money and Finance,* 9: 335-360.

Rausser, G. C. (1971) "A Dynamic Econometric Model of the California Orange Industry." PhD Thesis, University of California at Davis.

Rausser, G. C. and E. Hochman (1979). *Dynamic Agricultural Systems: Economic Prediction and Control*, New York: North-Holland.

Rausser, G. C., and F. Cargill (1970). "The Existence of Broiler Cycles: An Application of Spectral Analysis," *American Journal of Agricultural Economics,* 32: 109-121.

Ravallion, M. (1986). Testing Market Integration. *American Journal of Agricultural Economics*, 68: 102-109.

Reinhart, C., and P. Wickham (1994). "Commodity Prices: Cyclical Weakness or Secular Decline?" *IMF Staff Paper,* 41, 2: 175-213.

Reutlinger, S. (1976) "A Simulation Model for Evaluating Buffer Stocks for Wheat." *American Journal of Agricultural Economics,* 58:1-12.

Richard, D. (1977). "A Dynamic Model of the World Copper Industry," Working Paper, International Monetary Fund, Washington, D.C.

Ringwood, J. V., Austin, P. C. and W. Montieth. (1993). "Forecasting Weekly Energy Consumption," *Energy Economics*, 15: 285-296.

Roehner, B.M. (1995). *Theory of Markets: Trade and Space-Time Patterns of Price Fluctuations*. Heidelberg: Springer-Verlag.

Roehner, B.M. (1996). The Role of Transportation Costs in the Economics of Commodity Markets. *American Journal of Agricultural Economics*, 78, 2: 339-354.

Roehner, B.M. (1997). "The Comparative Way in Economics: a Reappraisal," *Economie Applique,* 4,7-32.

Rose, A. (1989). *Regional Analysis of Energy Demands,* New York: Oxford University Press.

Rose, A. and D. Kolk. (1987). *Forcasting Natural Gas Demand in a Changing World.* Greenwich, CT: JAI Press.

Rose, A. and W. Miernyk. (1987). "Input-Output Analysis: The First Fifty Years," *Journal of Policy Modeling.*

Roy, R. (1935). *Etudes Econometriques*. Paris: Sirely.

Ruth, M. and B. Hannon. (1997). *Modeling Dynamic Economic Systems*, New York: Springer-Verlag.

Salant, S., Miercort, F., Sanghvi, A. and M. Wagner. (1981). *Imperfect Competition in the International Energy Market.* Lexington, MA: Heath Lexington Books.

Samuelson, P. (1965). "Proof that Properly Anticipated Prices Fluctuate Randomly," *Industrial Management Review,* 6: 41-49.

Samuelson, P. A. (1948). "International Trade and Equalization of Factor Prices," *Economic Journal,* 58: 163-184.

Samuelson, P. A. (1949). "International Factor-Price Equalization Once Again," *Economic Journal*, 59: 181-197.

Sapsford, D. (1985). "The Statistical Debate on the Net Barter Terms of Trade Between Primary Commodities and Manufactures: A Comment and Some Additional Evidence," *Economic Journal*, 95: 781-788.

Sarris, A. H. and L. Taylor. (1978). "Buffer Stock Analysis for Agricultural Products." In F.G. Adams and L. Klein (eds) *Stabilizing World Commodity Markets.* Lexington: Heath Lexington Books, pp 149-160.

Schultz, H. (1938). *The Theory and Measurement of Demand*. Chicago: University Chicago Press.

Schweppe, F. C., Caramanis, M., Tabors, R., and R. Bohn. (1988). *Spot Pricing of Electricity.* Boston: Kluwer Publishing Company.

Sexton, R., Kling, C., and H. Carman. (1991). Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to US Celery” *American Journal of Agricultural Economics*, 73: 568-580.

Shepherd, G. S. (1941). *Agricultural Price Analysis*, Ames, Iowa State University Press.

Sims, C. (1980). "Macroeconomics and Reality,” *Econometrica*, 48: 1-49.

Slade, M. (1981). “Cycles in Natural Resources Commodity Prices: An Analysis in the Frequency Domain,“ *Journal of Environmental Economics and Management*, 9: 138-148.

Slade, M. (1988). *Pricing of Metals*. Center for Resource Studies, Queens University. Kingston, Ontario.

Slutsky, E. (1927). “The Summation of Random Causes as the Source of Cyclic Processes.” *Econometrica,* 5: 105-46.

Sowell, F. (1992). "Maximum Likelihood Estimation of Stationary Univariate Fractionally Integrated Time Series Models,” *Journal of Econometrics*, 53: 165-188.

Stekler, H. O. (1987). "Who Forecasts better?,” *Journal of Business and Economic Statistics*, 5: 155-158.

Stigler, G. J. (1962) “H.L. Moore and Statistical economics.” *Econometrica*, 30:1, 17-39.

Subba, R. T. (1981). “On the Theory of Bilinear Time Series Models,” *Journal of Royal Statistical Society B,* 43: 244-255.

Suwala, W. and W. C. Labys. (2002). “Market Transition and Regional Adjustments in the Polish Coal Industry.” *Energy Economics,* 24:285-303.

Takyama, T. and G. G. Judge. (1971). *Spatial and Temporal Price and Allocation Models.* Amsterdam: North Holland Publishing Company.

Takyama, T. and H. Hashimoto. (1984). “A Comparative Study of Linear Complementarity Programming Models and Linear Programming Models in Multi-regional Investment Analysis,” Paper 1984-1, EPDSC Division, World Bank, Washington, D.C.

Takayama, T. and W. C. Labys (1986). “Spatial Equilibrium Analysis: Mathematical and Programming Model Formulation of Agricultural, Energy and Mineral Models.” In P. Nijkamp (ed.) *Handbook of Regional Economics.* Amsterdam: North-Holland Publishing Company.

Talpaz, H. (1974). "Multi-Frequency Cobweb Model: Decomposition of the Hog Cycle,” *American Journal of Agricultural Economics,* 56: 38-49.

Terraza, M. (1981). “Economie des Processus Aleatoires: le Cas du Marche Cins de Consommation Courante.” Ph.D. Thesis, University of Monpellier, France.

Teyssiere, T., Gilbert, C. L., and C. Brunetti. (1997). “Non-ferrous Metals Price Volatility. A Fractionally Integrated Process”. In *Managing MetalsPrice* Risk. London: Risk Publication.

Thirwall, A. P., and J. Bergevin (1985). "Trends, Cycles and Asymmetries in the Terms of Trade of Primary Commodities". *World Development,* 13: 805-817.

Thomsen F. L. (1936). *Agricultural Prices*. New York: McGraw-Hill.

Thomsen, F. L. and R. J. Foote. (1952). *Agricultural Prices*. New York: McGraw-Hill.

Tinbergern, J. (1939). *Statistical Testing of Business Cycle Theories,* Vol. I,II. Geneva: League of Nations.

Tong, H. (1983). *Threshold Models in Non-Linear Time Series Analysis*, Berlin: Springer-Verlag.

Torries, T. F. (1998). *Evaluating Mineral Projects: Applications and Misconceptions,* Denver: Society for Mining, Metallurgy, and Exploration, Inc.

Trieu, L. H., Savage, E., and G. Dwyer. (1994). “A Model of the World Uranium Market,” *Energy Policy*, 22: 317-330.

UNCTAD. M*onthly Commodity Price Bulletin.* United Nations, Geneva.

United Nations (1984). "Price-Forecasting Techniques and their Application to Minerals and Metals in the Global Economy,” United Nations Publications, New York.

Uri, N. (1979). "A Mixed Time Series/Econometric Approach to Forecasting Peak System Load," *Journal of Econometrics,* 9: 155-71.
USGS. 2000. *Nonferrous Metal Prices in the US through 2003*. The U.S. Geological Survey Minerals Information Center, Department of Interior, Washington DC.
Usher, A.P. (1930). "The General Course of Wheat Prices in France: 1350-1788," *Review of Economics and Statistics,* 12,4: 159-169.
Usher, A.P. (1931). "Prices of Wheat and Commodity Price Indexes for England: 1259-1930," *Review of Economics and Statistics,* 13,3: 103-113.
Verleger, P. K. (1982). *Oil Markets in Turmoil.* Cambridge: Ballinger.
Verleger, P. K. (1993). *Adjusting to Volatile Energy Prices*. Washington, DC: Institute for International Economics.
Wagner, H. M. (1969). *Principles of Operations Research*, Englewood Cliffs, NJ: Prentice Hall.
Waite, W. C., and H. C. Trelogan (1951). *Agricultural Market Prices*, New York: John Wiley and Sons.
Waite, W. C., and H. C. Trelogan. (1948). *Introduction to Agricultural Prices.* New York: John Wiley and Sons.
Wallace, T. D., and G. G. Judge. (1959). "Econometric Analysis of the Beef and Pork Sectors of the Economy," Oklahoma State University Technical Bulletin T-75, Oklahoma State University.
Warren, G. F. and F. A. Pearson. (1928). "Interrelationships of Supply and Price," Cornell Agricultural Experiment Station Bulletin 466. Ithaca, New York.
Warren, G. F. and F. A. Pearson. (1933). *Prices.* New York: John Wiley.
Waugh, F. V. (1964). "Demand and Price Analysis, Some Examples from Agriculture." Technical Bulletin No. 1316, U.S. Department of Agriculture, Washington, D.C.
Weiss, J. S. (1970). "A Spectral Analysis of World Cocoa Prices," *American Journal of Agricultural Economics*, 52: 122-126.
Weymar, H. (1968). *Dynamics of the World Cocoa Market,* Cambridge: MIT Press.
Wickerhauser, M. V. (1994). *Adapted Wavelet Analysis: from Theory to Software,* Peaters:Wellesley Press.
Williams, J. C., and B. D. Wright (1991). *Storage and Commodity Markets*, Cambridge: Cambridge University Press.
Winters, L. A. and D. Sapsford. (1990). *Primary Commodity Prices: Economic Models and Policy*. Cambridge: Cambridge University Press.
Witherell, W. H. (1968). "Dynamics of the International Wool Market: An Econometric Analysis." Research Memorandum No. 91. Econometric Research Program, Princeton University.
Wold, H. and L. Jureen. (1953). *Demand Analysis.* New York: John Wiley and Sons.
Wold. H. (1954). *A Sudy in the Analysis of Stationary Time Series*. Uppsala: Almquist and Wicksell.
Working E. (1927). "What Do Statistical Demand Curves Show?" *Journal of Economics*, XLI.
Working, E. J. (1954). *Demand for Meat.* Chicago: University of Chicago Press.
Working, H. (1934). "Prices of Cash Wheat and Futures at Chicago since 1883," *Wheat Studies of the Food Research Institute.* 10: 103-117.
Working, H. (1958). "A Theory of Anticipatory Prices," *American Economic Review*. 48: 188-199.
Working, H. (1922). "Factors Determining the Price of Potatoes in St. Paul and Minneapolis," University of Minnesota Agricultural Experiment Station Bulletin 10, St. Paul, MN.
World Bank. (1994). "Commodity Price Forecasts," International Economics Department, World Bank, Washington, D.C.
World Bank. Several Years. *Commodity Trade and Price Trends*. International Economics Department, World Bank, Washington, D.C.

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

Yu, E. S. H., and J. C. Jin. (1992). "Cointegration Tests of Energy Consumption, Income, and Employment," *Resources and Energy.* 14: 259-66.

Yule, G. U. (1927). "On a Method of Investigating Periodicities in Disturbed Series, with Special Reference to Wolfer's Sunspot Numbers." *Philosophical Transactions*, 226A.

Zivot, E. and D. Andrews. (1992). "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit Root Hypothesis." *Journal of Business and Economic Statistic*s, 10: 271-287.

Zusman, P. (1962). "Econometric Analysis of the Market for California Early Potatoes." *Hilgardia*, 33: 539-668.