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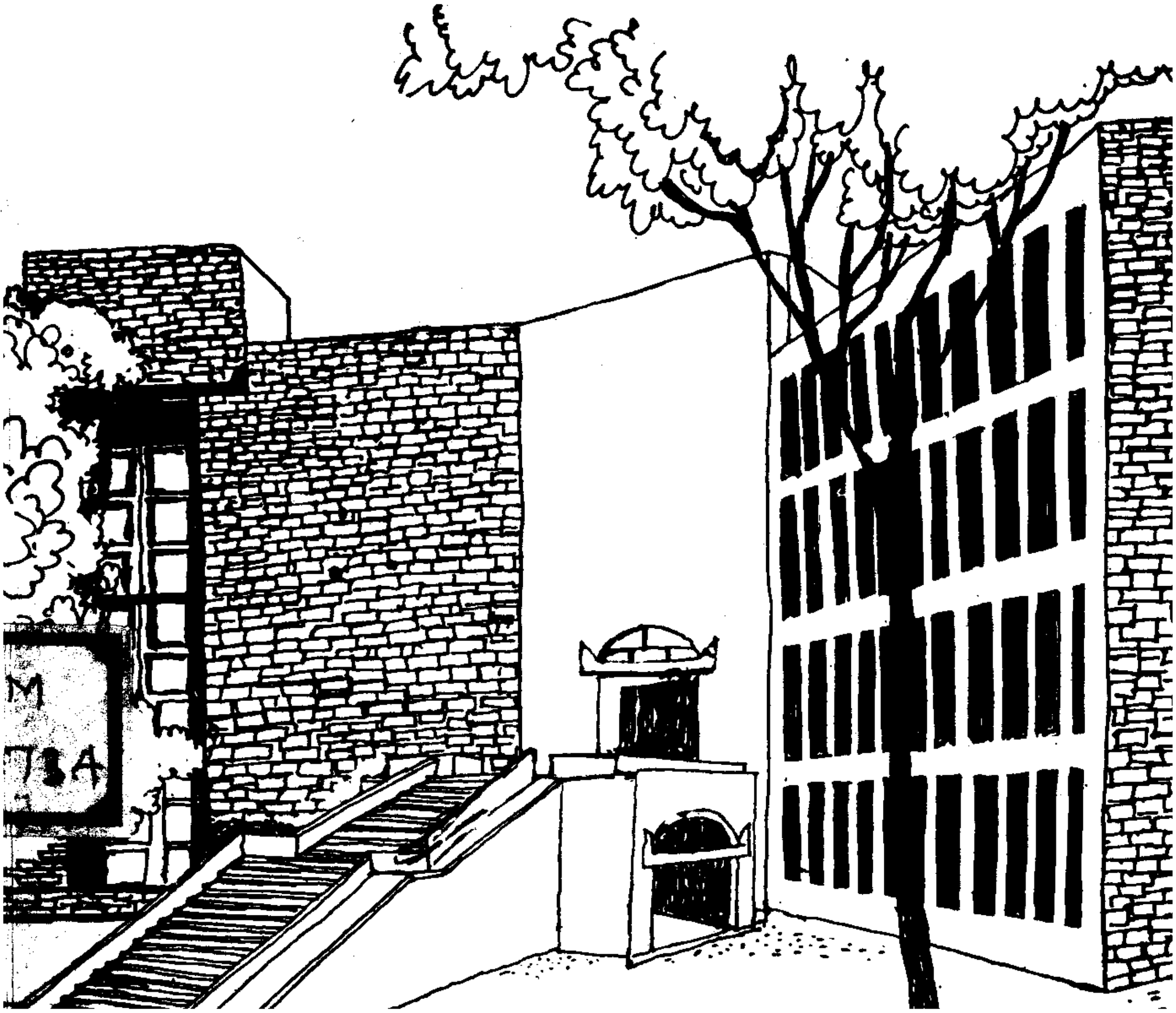

ENERGY PRICE IMPACTS MODELLING IN AGRICULTURE SECTOR

By

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Energy is an important input in the farm or agricultural production. For example, crop production requires a large amount of fuel, fertilizers, and pesticides, etc; similarly, livestock production involves both indirect use of energy inputs through feed grains and direct use of fuel through machinery use. Fuel and fertilizers, however, constitute a major proportion of total energy use in agricultural production and, infact, are also a major expense in a farmer's budget. Furthermore, contribution of these inputs, in particular fertilizers, to productivity has been reported to be as high as one-half to two-thirds of total production in the Western countries (Fluck and Baird, 1980, p.87). In developing countries such as India, fertilizes are sometimes credited upto three-fourths of production. Thus, economics of farm production very much depends upon the availability and prices of energy inputs.

The importance of energy inputs in agricultural production, or for that matter in the whole economy, was intensely realized when the OPEC (Organization of Petroleum Exporting Countries) unilaterally raised crude oil price in 1973. Since then crude oil prices have followed a rising trend; however, in recent years energy prices have been slightly falling or stagnating. Nevertheless, the long-run trend is still expected to be of increasing type. Researchers, particularly agricultural economists, have been very interested in studying the impacts of rising energy prices on agriculture sector, the fact which has led to a flood of energy price impact studies in the theoretical and applied economics journals. Several types of modelling techniques have been used for estimating the energy price impacts, however, each technique has its own shortcomings. The major objective of this paper is to discuss various energy price impacts and different modelling techniques used to estimate them; and, then to conceptually develop a systems framework for energy price impacts analysis. The whole paper is divided into five sections. Section one describes different types of energy uses in agriculture and a classification of energy inputs; followed by a discussion on different types of energy price impacts in section two. Modelling techniques are reviewed in section three. A conceptual systems framework for energy price impacts analysis is developed in section four; an appropriate model for estimatiom of impacts in a systems framework is also described in this section. The last fifth section provides summary and conclusions.

1.0 Energy Use in Agriculture

Total energy use in agriculture sector can be classified in two categories: (1) that related to farm production; and (2) that not related to farm production (Figure 1). The former type of use is not directly associated with the farm production process; for example, fuel used in driving car or tractor for pleasure purpose can be included in this category. The latter type of energy use is directly associated with the farm production process. For example, application of fuel, fertilizers, chemicals, and farm machinery in the production of crop or livestock are included here.

Based on the form in which energy inputs are used in farm production, they can be classified into two categories: (1) direct energy inputs such as fuel; and (2) embodied energy inputs such as fertilizers, chemicals, and farm machinery (see Figure 1) Embodied energy inputs are produced using large amounts of direct energy for their production and marketing prior to their use in the farm production process.

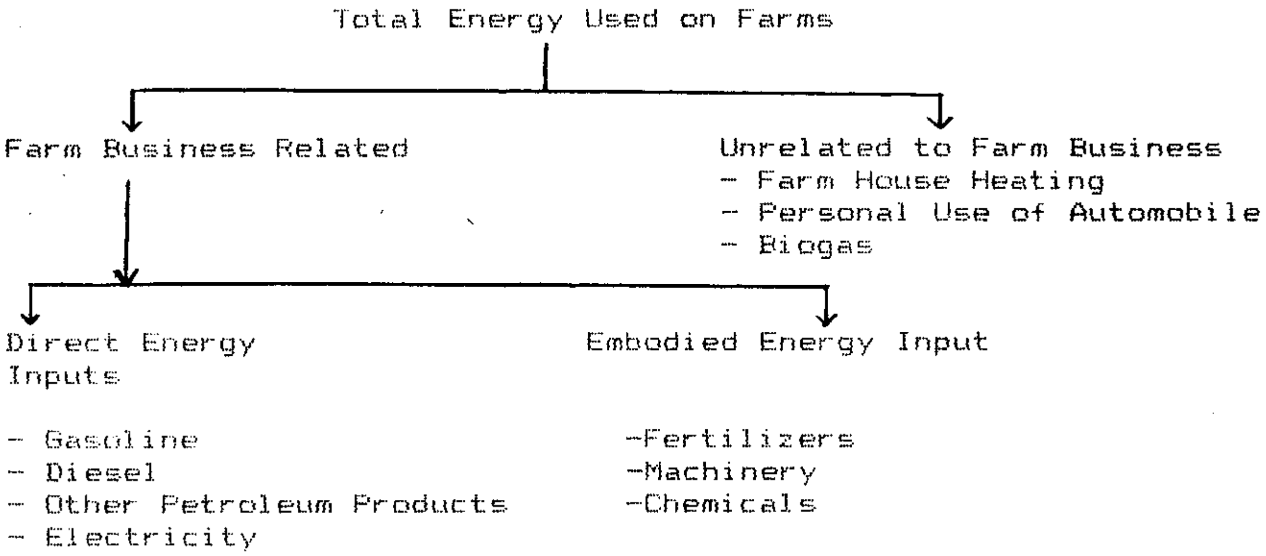

Figure 1: A Classification of Energy Use in Agriculture

2.0 Energy Price Impacts in Agriculture

The impacts of rising energy prices on agriculture can be grouped into two categories: (1) non-economic or environmental impacts; and (2) economic impacts. Non-economic impacts refer to the environment related changes such as reduction or increase in the level of soil erosion, air and water pollution. Economic impacts are felt directly through rising cost of energy inputs experienced in production or indirectly through rising energy costs in transporting farm produce from farm gate to terminal points (see Figure 2)

2.1 Non-Economic Impacts

Rising energy prices may change the profitability of alternative crop enterprises on farms and in a region. This may bring a new crop-mix which can bring change in the level of soil erosion, depending upon the soil erosiveness of individual crops. For example, Zinser et al. (1985) has suggested significant reduction in soil erosion under rising energy price regime. This is because rising energy prices induce a switch from more energy-intensive methods of production (which are also more soil erosive) to less energy-intensive ones (which are also less soil erosive). This may not be true always. For example, Swanson and Taylor (1977) reported increased soil erosion as a result of new crop-mix predicted under rising energy price regime in some regions of the Corn Belt of the United States. This was due to the substitution of soybean for corn in response to increased energy prices, and soybean, having higher soil loss factor than corn, increased the soil erosion. Dvoskin and Heady (1976, pp 116-118) state that reduction of irrigated acres due to rising energy prices would improve environmental quality, because dryland production requires relatively less fertilizers and pesticides compared with irrigated production hence reducing chemical pollution. Adoption of reduced tillage practices in response to increased fuel prices may promote the soil conservation, because reduced tilage can be less erosive than conventional tillage practices (Crosson, 1981, p.1)

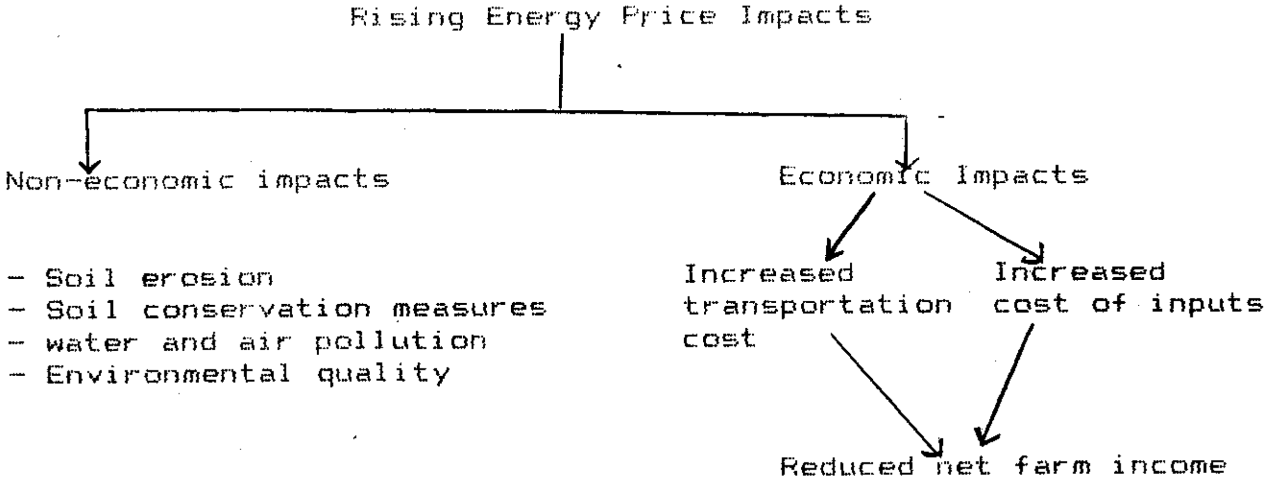

Figure 2: A Simplified Overview of Impacts of Rising Energy Prices upon Agriculture

2.2 Economic Impacts

Economic impacts of rising energy prices will be seen at both farm and sector levels. At the farm level, farmers are likely to substitute cheaper non-energy inputs or less energy-intensive inputs for costlier energy inputs in the production. As a result, a new input-mix would appear on farms. This will ultimately affect the level of production, net and gross farm incomes, nature of product or crop-mix on farms, and yield levels. Besides an aggregate effect of the above changes at farms, changes at sector level will be seen in : the interregional or international competitiveness, product prices, product demands in domestic and international markets, technology of production, level as well as location of production, land use pattern, etc. However, the types of impacts, and their magnitude, that could be felt upon agriculture sector would vary with location, soil, climate, and other conditions related to production and input use. Several types of economic impacts can be briefly discussed under the folowing headings.

2.2.1 Net Farm Income

Net returns to producers are reported to decline as a result of increased production cost due to rising energy prices (Mapp and Dobbins, 1976; Adams et al., 1977; Christensen et al., 1981; Moriak, 1975). Net returns can be improved sometimes by adopting some energy-saving technologies such as reduced tillage (Eidman et al., 1977; Kliebenstein and Chavas, 1977). Increased transport cost due to increased fuel prices may result in lowering farm gate prices hence net returns to producers.

2.2.2 Energy Use and Input Substitution

Energy use may decline as energy inputs become costlier. For example, Swanson and Taylor (1977, p.128) estimated a reduction of 15 percent in the consumption of mitrogenous fertilizers in the Corn Belt with a doubling of energy prices from the 1974 level. Tewari (1986) predicted a decline of about 27 percent in fertilizer consumption in Saskatchewan (Canada) with a doubling of energy prices from 1984 level.

Demand for energy inputs is found to be inelastic as energy consumption is curtailed under rising energy price regime (Dvoskin and Heady, 1977a, p.57). Fuel demand is found to be more inelastic than fertilizers, suggesting large scope for reducing fertilizers under increased energy price regime (Adams, Lacewell and Condra, 1976). Kliebenstein and Chavas (1977) have shown that with a five-told increase in fuel prices (from the 1975 level) the Midwest farms in the U. S. will reduce fuel consumption by only 15 percent.

Non-energy inputs can be substituted for energy inputs either under existing production technology (for example conventional tillage) or by adoption of some other energy-saving technologies (such as reduced tillage practices). Labor is suggested to be a good substitute for energy inputs (Lopez and Tung, 1982). However, substitution of capital for energy inputs is limited to an extent (Debertin and Pagoulatos, 1980).

2.2.3 Structural Changes

Several structural changes in agriculture sector may be seen in terms of: level and location of production, yield, crop-mix; income distribution; size and number of farms; product demands and product prices.

Production, Yield, Crop-mix, and Location of Production

Crop production is predicted to decline in response to rising energy prices (Lopez, 1982; Christensen et al., 1981). Livestock production may also be reduced through producers' response to higher feed costs resulting from high energy prices (Christensen et al., 1981). Basically, the decline in production is caused by reduced consumption of fertilizers per acre on farms (which reduces yield levels) or/and decrease in cropped acreage of individual crops. However, magnitudes of decrease in production are reported to be different from one location to other.

Crop-mix on farms may also change. More energy-intensive crops may be replaced by less energy-intensive ones (Zinser et al., 1985; Swanson and Taylor, 1977). For example, soybean acreage is prdicted to increase at the cost of corn in the Corn Belt of the United States (Swanson and Taylor, 1977). Crops that require less energy in terms of fertilizers such as legumes will be favored (Kliebenstein and Chavas, 1977; Dvoskin and Heady, 1977a).

Income Distribution

Relative production advantage of one region over the other may also change; production is likely to shift to more energy efficient regions. As a result of this change in production patterns, income distribution would change across a region. For example, income transfers are predicted from irrigated to dryland production region in the U.S. agriculture (Dvoskin and Heady 1977b). Income transfers may also occur across farms; Warnken (1976) has shown that energy price increases in Nicaragua are eroding the comparative advantage that energy-intensive farms have had over the traditional farms.

Size and Number of Farms

Rising energy prices are exptected to enhance the increasing farm size in agriculture by making small holdings uneconomical. Large holdings are more energy efficient than small ones (Kulshreshtha and Gould, 1984). The impact of intense cost-price squeeze, resulting from rising energy prices, will be felt most on small or family farms (Holland, 1980). Hence, reduction in the number of farms will occur at the expense of small farms.

Product Demands and Product Prices

Demand for energy inputs is derived from the demand for agricultural products, and energy demand is estimated to become more inelastic as energy use is curtailed in response to rising energy prices (Dvoskin and Heady, 1977a, p.57). As a result, rising energy prices will cause an increase in the total cost of production, requiring higher product prices to maintain or to increase production levels (Dvoskin and Heady, 1977a; Mapp and Dobbins, 1976). In short run, commodity prices may not be affected, but in the long run they are bound to increase (Dvoskin and Heady, 1977a). Increased product prices faced by buyers in the domestic and international markets may result in a decline in demand for farm products (Moriak, 1975).

2.2.4 Technology of Production

Energy-saving technologies (such as reduced tillage) will become more attractive as producers face increased energy cost of production. Of course, adoption of such technologies will depend upon several factors including profitability. Dvoskin and Heady (1977b) have shown that, when maximizing farm profits is the primary goal, energy price levels have a minimal impact on adopting the reduced tillage practices in the U.S. agriculture. However, when minimization of energy use is the primary objective, there is a substantial shift from conventional to reduced tillage practices. Eidman et al. (1977) found that the reduced-tillage corn production was preferable to the conventional-tillage in Oklahoma (U.S.) under rising energy prices. Some studies suggest that at a very high level of energy prices, reduced tillage practices become uneconomic (Kliebenstein and Chavas, 1977).

In areas where irrigation is an essential component of production technology, rising energy prices may cause severe damage to irrigated farming (Shipley and Goss, 1978; Mapp and Dobbins, 1976). This, however, depends upon the method of irrigation. Production based upon more energy-intensive methods of irrigation (such as sprinkler method) will suffer more than that based upon no energy-using methods (such as flood method).

2.2.5 Interregional or International Competitiveness

Rising energy prices have added to the competitiveness of energy-efficient regions (Dhillon, 1981; Casavant and Whittlesey, 1974). Dhillon showed that the greenhouse industry in the northern U.S. has suffered, relative to Florida and Mexico tomato production, as a result of increased energy prices. Less energy efficient regions are thus going to become less competitive in the market.

2.2.6 Miscellaneous Impacts

Various other miscellaneous types of impacts will also be felt. For example, new energy sources could become economic. These sources could be in terms of: production of methane and feed from plant or animal waste (Miranowski, 1979); solar energy for grain drying or greenhouse production (Sutherland and Sonka, 1982; Dhillon and Rossi, 1982); fuel from crop residues (Ronald et al., 1980; Hertzmark et al. 1980; Hitzhusen and Abdullah, 1980). Impacts may also be felt upon prices of fixed inputs such as land. Long run land prices may decline in response to rising fuel prices (Lopez, 1982). However, Kliebenstein and Chavas (1977) reportd that land values decline first as energy prices are increased to an extent, and any further increase in energy prices may lead to increase in the land values.

3.0 Approaches to Estimation of Energy Price Impacts in Agriculture

Various energy price impacts as described in the previous section have been estimated with different empirical techniques or methodologies. Selection of an appropriate modelling technique will however depend upon the nature of problem and choice of a research worker. An exhaustive survey of literature reveals that methodologies and model formulation used for evaluating the energy price impacts are very diverse. Model formulations vary from simple single econometric equation to sophisticated large mathematical programming models. Likewise, the scope of studies varies from a single farm to a large region or national agriculture. Basically three types of methodologies have been used: (1) econometric; (2) input-output (I-O) analysis; and (3) mathematical programming.

3.1 Econometric Approach

Two types of econometric approaches have been used to estimate the energy price impacts: (1) econometric simulation approach; and (2) cost/production function approach. Econometric simulation consists of developing an econometric model representing the agriculture sector and then using it to generate (simulate) the impacts of rising energy prices. Rising energy prices can be introduced as exogenous variables in the econometric model. By raising the level of energy prices, the analyst can generate forecasts of all endogenous variables in the estimated model. Econometric models have been used for simulating the impacts of rising energy prices by Christensen and Heady (1983), Dunn (1981), Beilock and Dunn (1982), and Moriak (1975).

Under the cost function approach, the Allen partial elasticities of substitution between energy and non-energy inputs are estimated from a set of factor share equations. The estimated elasticities of substitution provide insights into the scope of substituting non-energy inputs for energy inputs in production in response to rising energy prices. Examples of single cost function approach are Lopez and Tung (1982), Islam and Veeman (1980), Webb and Duncan

(1979), Binswanger (1974). Timmer (1975) used a single production function approach to explain the short- and long-term adjustments of grain prices to rising prices of energy inputs in developing countries.

The major limitation of econometric models in analyzing the energy price impacts is that these models are not equipped with a mechanism to incorporate resource constraints. This may lead to production forecasts that are inconsistent with resource availabilities. Single cost function studies are based on the assumption of constant production and product prices. Thus, input substitution is assumed, perhaps, not to be influenced by product prices. This may be an unrealistic situation on farms, particularly in the context of medium- to long-run.

3.2 Input-Output Analysis

The pioneering work for developing input-output analysis was basically done by Leontief (1936, 1941). Under this approach, each sector or subsector of the economy is modelled with some assumptions and intersectoral transactions to form linkages among various sectors of the economy. Input-output analysis has been also used to estimate the impacts of rising energy prices on agriculture or on the entire economy. For example, Lee et al. (1976) estimated the impacts of rising petroleum and natural gas prices on the Washington state economy. Vincent et al. (1979) estimated the impacts of the oil price increase on Australian agriculture and the entire economy. Kulshreshtha et al. (1982) used the I-O analysis to predict secondary adjustments in the Saskatchewan economy in response to changes occuring in agriculture due to increased energy prices.

Since technical or input-output coefficients in the I-O models have to be in monetary terms in order to maintain the consistency of intersectoral transactions, potential technologies are therefore difficult to incorporate in these models. This is because future prices are not available in advance. Hence, endogenizing new energy-saving technologies in the I-O model is difficult. Furthermore, I-O models are demand driven and thus are not suitable for an optimizing tool, as required for supply response analysis for agricultural sector.

3.3 Mathematical Programming Models

Mathematical programming models are of normative nature, based on some behavioural assumptions about producers and consumers. These models comprise an objective function (which is based on some behavioural assumptions) to be optimized subject to resource constraints.

Two types of mathematical programming models have been used in analyzing impacts of rising energy prices on agriculture; first, models whose objective function is that of maximizing profit at a given level of input and output prices; second, models whose objective is to maximize net social payoff (which is equal to the sum of consumers and producers surpluses) subject to resource or production constraints. The former type of models are called price exogenous programming models (PEXP), and the latter are termed price endogenous programming (PENP) models.

3.3.1 Price Exogenous Programming (PEXP) Models

Dvoskin and Heady (1976), Mapp and Dobbins (1976), Zinser et al. (1985) have used PEXP models to estimate the impacts of rising energy prices on agriculture. Dvoskin and Heady (1976) used a linear programming model to estimate the energy price impacts for the U.S. agriculture, while Mapp and Dobbins (1976) used a recursive linear programming model for the Oklahoma Panhandle area. Zinser et al. (1985) used a linear programming model for estimating the impacts of rising energy prices on crop land erosion in the Iowa River Basin.

One major limitation of the PEXP models is that they are based on the restrictive assumption of fixed market prices or quantities (Heady and Srivastava, 1975, p.420). Hence, they ignore the interrelationships of aggregate price and quantity. As a result, the level of increase in product prices caused by rising energy prices cannot be predicted. Furthermore, these models allow substitution of inputs to occur only through the technology set. Thus, product substitution on demand side is not taken into account.

3.3.2 Price Endogenous Programming (PENP) Models

The restrictive assumption of fixed market prices and demands in the PEXP models is overcome in the PENP models. The relevance of the PENP models increases as the degree of interdependence among farm products increases in consumption or in production.

The price endogenous programming models have been used for estimating the energy price impacts by Adams et al. (1977), Swanson and Taylor (1977), Kulshresththa et al. (1982). The PENP model can be formulated under either a quadratic or linear programming framework. The major advantage of the PENP models is that they are capable of simultaneously determining equilibrium prices, quantities demanded in the domestic and international markets, optimal production and input use patterns, and returns to fixed inputs. In addition, these models allow input substitution to occur not only through the technology set (like in the case of PEXP models) but also through substitution in product demands. Thus, these models can provide information on regional allocation of resources and pricing, and at the same time can incorporate a market equilibrium (i.e., allowing the interrelationship between price and quantity)

The major limitation of mathematical programming models is that they are normative in nature. Hence, their predictions are based on behavioural assumptions about producers and consumers. Producers are assumed to maximize profit and consumers to maximize utility under perfectly competitive conditions. Thus, resources are assumed to flow their most productive use. However, in real-world situation, considerations other than economic efficiency may affect the resource use.

4.0 Energy Price Impacts Analysis: An Analytical Framework

This section builds upon the previous reviews of energy price impacts and modelling techniques. The objective here is to develop a conceptual framework for analyzing different energy price impacts in a systamatic manner, and to suggest an appropriate modelling technique. A conceptual framwork for energy price impacts analysis is developed in the subsection one. An emprical model of agriculture sector for energy price impact analysis is suggested in subsection two.

4.1 Conceptual Model

Basically, energy price impacts are responses of agriculture sector to exogenous energy price shocks. The nature and magnitude of impacts depends upon the time of adjustment considered. Conceptually two time runs can be considered (1) short-term; and (2) medium- to long-term. A short-term period can be defined as a time period in which producers cannot respond to rising energy prices by changing their production plans. Producers can probably cut back on fertilizers immediately but cannot lower fuel use. For a farm manager, this could be a period of up to one crop year. On the other hand, the medium- to long-term period can range from more than one year to several years. Hence, there is a larger scope for adjustment under this period.

In the short-term, increased energy cost in production as a result of rising energy prices will result in reduced net farm income to producers, and there is not much scope to change acreage, crop-mix, input use, etc. As the time of adjustment is lengthened, producers respond to rising prices: by using more of non-energy or less energy-intensive inputs in place of energy inputs; by changing their production plans and product- or crop-mix; and, by using new energy-saving technologies of production, etc. As a result, several other types of enrgy price impacts, in addition to declinging net farm income, in terms of input usage, production patterns, technology, income distribution, and other structural changes can also be observed in the agricultural sector. The medium- to long-term impacts are therefore more important from the policy-making and planning purposes, and therefore are of interest of this study.

Since agriculture sector is a system of prices, production, acreage, yield, and institutions among others, energy price impacts should be studied in a manner which systematically integrates all of the components of the system. A systems framework takes into account the interrelations among different varibles that would take place as a result of increased prices of fuel and fertilizers. A schematic representation of a typical agriculture sector is shown in a systems framwork in Figure 3.

Fuel and fertilizer prices increase due to increase in crude oil and natural gas prices. Obviously, the magnitude of increase in prices of energy inputs depends upon the demand-supply situations in the international energy market. As per neoclassical theory, producers will respond to this exogenous increase in energy prices by substituting relatively cheaper non-energy or less energy-intensive inputs for relatively costlier energy inputs in farm production. The input substitution process on farms will, however, be influenced by the scope of substitution possibilities under the

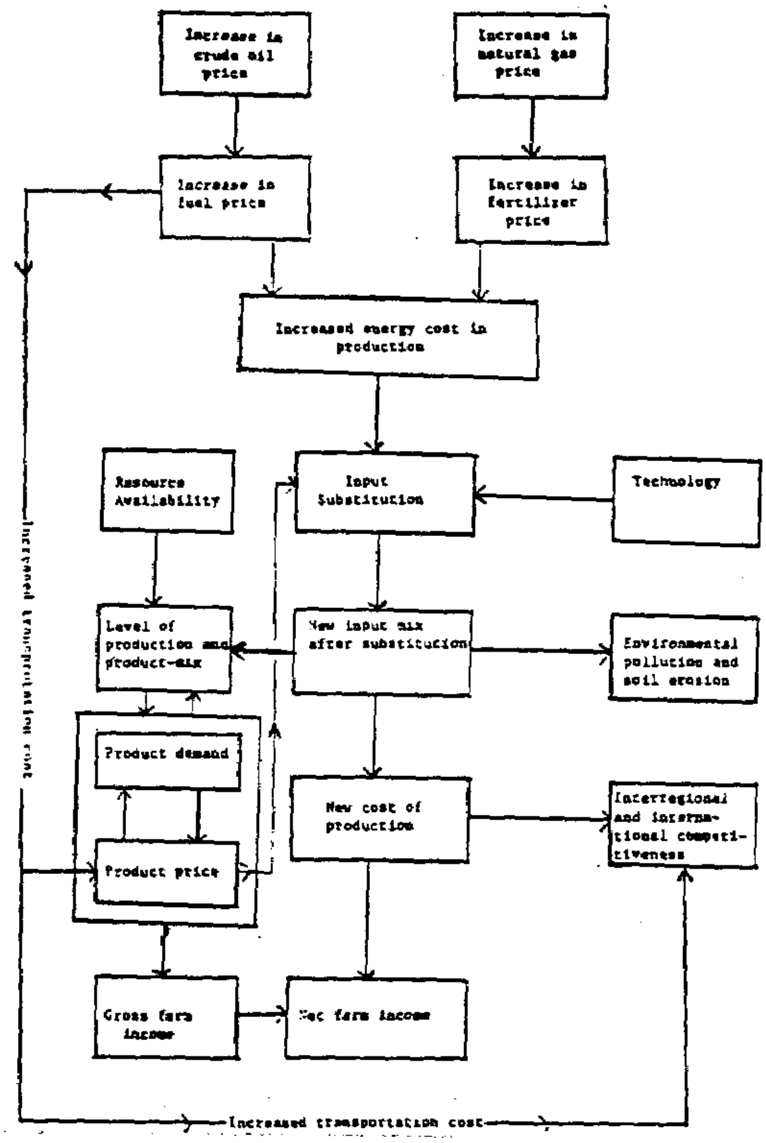

Figure 3: A Conceptual Model for Energy Price Impacts Analysis

currently available and potentialy feasible technologies (for example, substitution posiibilities are differnent under conventional and reduced tillage practices). The economic advantage of substituting non-energy inputs in production will also depend upon the demand for and price of products. Input substitution process is thus influenced by both demand and supply forces as shown in Figure 3.

Increased prices of fuel and fertilizers, other things remaining the same, will cause an increased cost of energy inputs in production. As a result, producers will curtail consumption of fuel and fertilizers and a new input-mix will appear on farms (see Figure 3). Impact of a new input-mix on the level ofproduction will depend upon the marginal productivities of both energy and non-energy inputs. Most likely, production will decline because of decline in consumption of fertilizers which have very high productivity.

The location or spatial patterns of production will also adjust depending upon the cost competitiveness of different producing regions. Production may shift to more energy efficient regions. Thus, interregional and/or international competitiveness of a production region will change depending upon its energy-intensiveness in production. Also, more energy efficient technologies of production will become more economic to be adopted on farms. Adoptabilty depends, however, on several factors including profitability, social constraints, and above all the availability of energy-saving innovations from natural and physical sciences.

Besides the above changes, the new input-mix will have repercussions on the level of environmental pollution and soil erosion. A decrease in the level of fuel and fertilizer use is expected to improve the environmental quality. However, the amount of soil erosion will depend upon the new crop-mix resulting from energy price increase. Depending upon the soil erosiveness of crops, the aggregate amount of soil loss from a region many increase or decrease.

Impacts will also be felt upon product prices and product demands (including both domestic and international demand). As energy prices rise, different producing regions in the world will adjust and cost of production of farm products will go up leading to increase in product prices, which ultimately will slash demand for agricultural produce, Increased energy prices will cost more foreign exchange and reduce the purchasing power of importing countries; this is particularly true for low income less developed countries (LDCs) which happen to be net importer of energy in the world energy market. Decline in product demand is thus experienced not only by energy price increase but also by decline in foreign exchange reserves of low-income less developed countries. This will produces a negative income effect on demand; in other words, it will shift the demand schedule toward left or inside.

On the other hand, net energy exporting countries will experience increased foreign exchange reserves which may increase product demand. Thus, net exporting counties may exert a positive income effect on demand, i. e., shifting the product demand schedule toward right or outside. The aggregate net income effect will depend upon the weightage of net energy exporters and importers in the international demand for agricultural commodities. Thus aggregate net income effect cannot be decided a priori and is a matter of empirical investigation. Two things must be made clear that a change in product demand can result from two sources: (1) due to increase in product prices or price effects; and (2) due to shift in the product demand schedule or income effect.

Ultimately the impact of rising energy costs will be felt upon net farm income. Net farm income may decrease or increase depending upon the following: (1) the level of decrease in production due to reduced energy use, particularly fertilizers, caused by rising energy prices; (2) the magnitude of increased cost of production per unit of output (this is because the derived demand for energy inputs in agricuture is expected to become more inelastic as their usage is curtailed); and (3) the magnitude of increase in product prices due to increased energy prices. Farm production is thus influenced by an array of variables: prices of energy inputs, product demand and product prices, input constraints, and type of production technology (Figure 3).

Impacts of increasing energy prices will also be felt indirectly upon agriculture through a change in the cost of transporting products from farms to terminal points (Figure 3). As the transportation cost between farm gate and terminal point increases, the net farm gate price is reduced, thus further squeezing the level of net farm income. Rising transportation cost due to increased fuel prices may favor the local feeding or processing of agricultural produce in the production regions and thus changing the regional competitiveness in the market.

Although both non-economic and economic impacts are of interest, economic impacts directly affect the agricultural production and therefore are of more interest to producers and policy makers. Recently, environmental impacts have become of major concern, however. Nevertheless, the major focus here is to concentrate on estimation of economic impacts in a systems framework, and for this a sectoral price endogenous programming model of agriculture is suggested to be the best.

4.2 A Sectoral PENP Model of Agriculture

A sectoral PENP model of agriculture is suggested to be the best for estimating the medium- to long-run energy price impacts for several reasons. First, the PENP model is more realistic than I-O and econometric models for it can accommodate resource constraints and is capable of simultaneously determining equilibrium prices, quantities demanded in domestic and international markets, optimal production and input use patterns across production region or subregions, and returns to fixed inputs. Second, the PENP model can incorporate an adequate range of potential technologies (for example, more than one type of tillage practices with several fertilizer application rates and with different crop production practices). The model is therefore very flexible to include several types of activities and is useful to estimate changes in agriculture sector in a systems framework. Furthermore, the PENP model allows input substitution process on farms to be influenced by both forces of supply and demand - a very realistic situation as we discussed in the conceptualization stage. Predictions from the PENP model are therefore expected to be more realistic and dependable.

Furthermore, a sectoral price endogenous model can be developed in both partial and general equilibrium framework. The general equilibrium framework endogenizes the shifts in demand schedule due to income effects as discussed in the conceptualization stage. This, however, requires more efforts and resources. Unless income effect is deemed to be very large and significant, a partial equilibrium approach will do. For more details on treatment of partial and general equilibrium price endogenous sector models of agriculture, readers are suggested to see Hazel and Norton (1986). We will thus focus mainly on partial equilibrium approach. A sectoral price endogenous programming model can be described by dividing it into the following components: (1) an objective function containing product demand and input supply schedules. (2) a technology matrix containing technical coefficients; and (3) the right hand side (RHS). A representation of the model is shown in Figure 4.

4.2.1 The objective Function

The objective function is to maximize the net social pay-off-- the sum of consumers' and producers' surpluses. Hence, it contains the input supply and product demand schedules. Theoretical relevance of this objective function is explained elsewhere

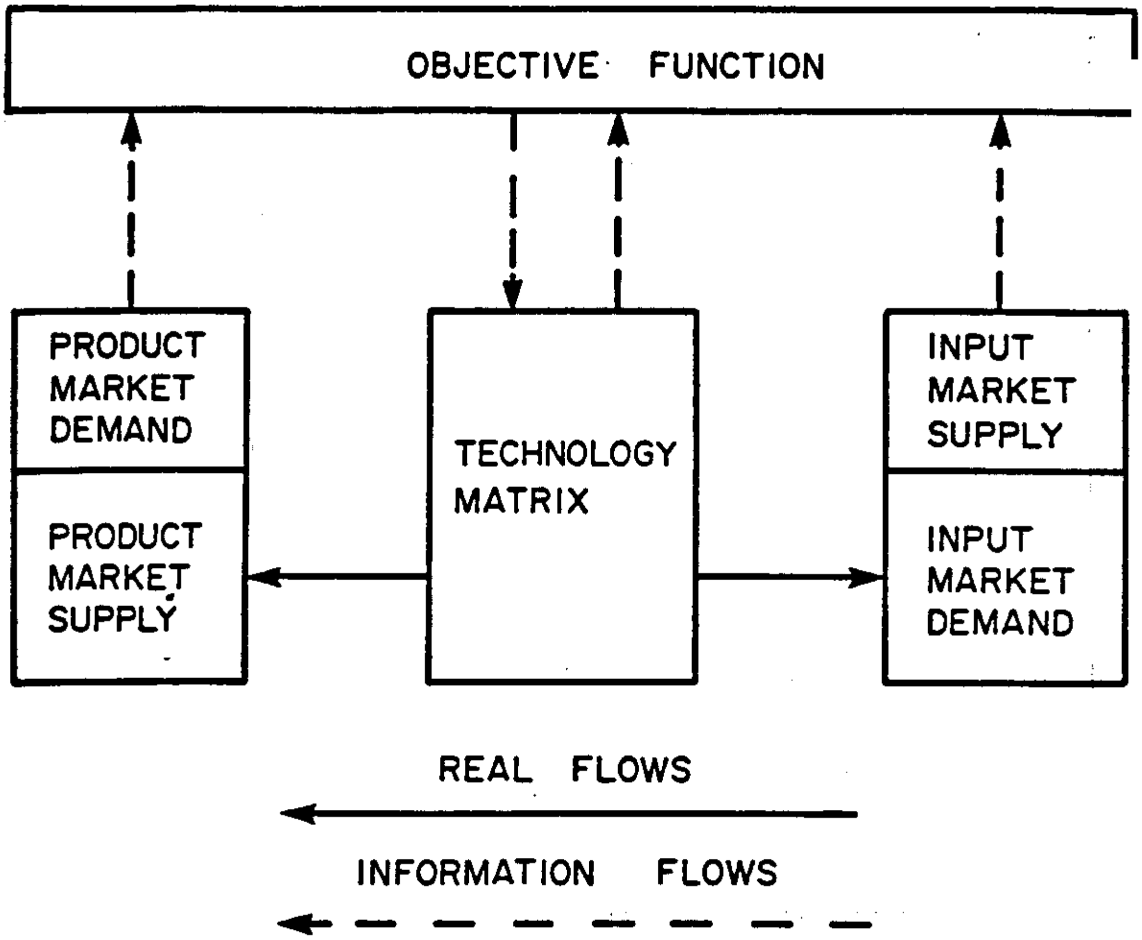

Figure 4: A Price Endogenous Programming Model for Energy Price Impacts Analysis

(Samuelson, 1952), hence it will not be repeated here. Actually, the objective function is the main driving force in the model, determining what to produce, how much to produce, where to produce, where to sell, and how much inputs to use, etc. The product demand schedules are determined exogenously, and are put in place on a production control and as a final market price determiner. They generate a price for every product included in the model, and objective function uses this price to value inputs and to make production decisions. Product supply schedules come from the technology matrix and are influenced by both product demand and input supply schedules. The endogenous product supply schedules are thus function of production cost and the prices of competing products.

Generally the price dependent linear demand functions are placed in the objective function. The linear schedules are formed directly by estimation or by taking the elasticity and a known price quantity point, and then forming a tangent linear schedule (McCarl and Spreen, 1980, p.93). Input supply schedules can also be constructed in a manner similar to product demand. Both domestic and international demand for a product or products can be incorporated in the objective function. Demand can also be disaggregated in terms of quality differences if quality makes a significant difference in terms of pricing of a product. Various types of agriculture products that can be included are: food grains, coarse grains, oilseeds, other annual corps, livestock meat products (cattle, hog) dairy cattle, poultry and other farm produce.

Input supplies in the PENP sector model can range from perfectly elastic nature to perfectly inelastic. In the case of perfectly elastic input supply schedules, price of input is exogenous and only quantity of input use is endogenized (Beaton, 1980). This is done by including a fixed price of the input in the objective function. In the case of perfectly inelastic input supply schedule, the quantity of available input is exogenously fixed and input price is endogenized (labour supply in Duloy and Norton, 1973). This is done by constraining the input supply from the right hand side (RHS). A postively sloped input supply schedule can be constructed in a fashion similar to a product demand schedule, and, under this case both quantity and price of input or inputs are endogenized. Main categories of inputs that can be specified in the energy price impacts model are: labor, capital, fuel, fertilizers, lands.

However, each input group can be further disaggregated depending upon the modelling needs. For example, labor can be broken down into: family and hired types, seasonal versus non-seasonal. Capital can be disaggregared into: farm machinery, building depreciation, insurance, taxes, utilities, and other miscellaneous items. Fuel consumption can also be divided into gasoline, diesel, propane, and other. Similarly, different types of fertiliizers such as nitrogen and phosphorous can be accommodated in the model. Yield response to fertilizers can vary with the type of land. Land thus can be divided into several categories based on soil productivity, irrigation availability, erodibility, slope, and any other criterion.

4.2.2 Technology Matrix

Technology matrix is the most important component of the model, since both product supply and input demand schedules are endogenously derived from here. All the information on the amount of specific inputs needed for any production activity is stored here in terms of technical coefficients. In sum, information on all types of production technologies (including current and potentially feasible) and cultural practices are included in the matrix. As with crops, different production and management techniques of livestock production can also be included here. Hence, this is the most important part in sectoral model building.

4.2.3 Right Hand Side

The RHS controls the amount of any input physically available, regardless of price. If input supply is not constrained from the RHS, then model can use any amount of that particular input at zero cost, at a constant cost, or at an increasing cost depending upon its value in the objective function. If an input is constrained, then the maximum amount that can be used at any price is determined by its value in production, and input price is endogenously determined in the model as explained before.

The objective function and the RHS are attached to the technology matrix, and only then the model is complete. The to and fro flow of information between the objective function and technology matrix helps to find equilibrium quantities and prices, and the sectoral product supply and sectoral input demand schedules are internally derived from the matrix (see Figure 4). This model can be used to simulate the energy price impacts by simply changing the prices of energy inputs exogenously in the model, and then by comparing the simulated results to the validated base results (This procedure is known as comparative static analysis). Hence, a validated benchmark or control simulation is required first in order to use the model for the impacts analysis.

4.2.4 Validation

Process of validation is very crucial in order to use the model for energy price impacts analysis. The criteria of validation are therefore to be sorted out in advance. It should be noted that validation of a model itself is not an objective but a means to make the model accurate in order to use it for further economic analysis. No model by definition is ever totally representative of the system. There is always some degree of abstraction involved in modelling.

Generally the model can be validated in three stages (Naylor and Finger, 1971) The first stage involves the conceptual validation. ie. whether the model is logically consistent based on a prioristic reasoning. A researcher does this in the initial stage of model building and the model is thus deemed to be conceputally validated. The second stage calls for the empirical verification of some the model's results. Generally, the model can be validated for the major responses of interest for which it is being developed.

The following empirical validation criteria for the energy price impact models can be suggested: product prices, product demand; acreage, yield, crop-mix, and the over-all land-use pattern; intraregional distribution of acreage and production; input use levels and expenditures; gross and net farm incomes, consumer and producer surpluses. Stage three consists of testing the model's ability to predict the behaviour of the system, which may involve several types of experiments for estimating the predictive performance of the model.

Basically, validation of the model means proving that the model is true by comparing the model's behaviour with the real system. This is an iterative process of comparing the model results with the real system, making adjustments to the model and comparing again and so on until the model is judged to be sufficiently accurate. Once the researcher is satisfied with the process of validation, the validated model can be used for comparative static analysis of energy price impacts, and its results can serve as benchmark or contorl for comparison with increased energy price scenarios.

4.2.5 Data Needs

Data needs for the PENP model are of varied types. Most important task is to obtain and prepare reliable and accurate technical coefficients of the technology matrix. The specification of the matrix will thus determine the amount and types of data required. An energy price impact model should include yield responses to fertilizer appliccation rates under different production technologies and in different production subregions specified in the model. Similarly different levels of fuel consumption can be incorporated for a given yield response to fertolizers. Fuel application rates can also be varied across different technologies (such as under convential and reduced tillage technologies).

Other important data required are: elasticities of product demand and input supplies. Generally these are gathered from the past studies or can be estimated. The intent is that the elasticities should reflect the medium- to long-run adjustments in the agriculture sector, selection of elasticities is thus a crucial step in the energy price impacts model building.

There is a lot of confusion which surrounds the definition of long-term demand and long-term demand elasticity. The distinction between short- and long-term arises because real world impediments prevent instantaneous economic adjustments (Nerlove, 1958). Hence, the complete adjustment of demand (quantity) to a once-for all price change is spread over a time of various short-term periods. The long-term adjustment period is the dated time required for the complete adjustment of quantity demanded to a price shock. The adjustment time will however also depend upon the supply response period. Hence the knowledge of the period of complete adjustment to a price change is a crucial information required for choosing the long-term elasticities.

The adjustment period for most agricultural commodities (both crop and livestock products) can range from one to three year.

Tomek and Chochrane (1962, p.70) argue that the adjustment period for most food demands is one year or less. Hence it is suggested that annual elasticities should approximate the long-run adjustment, and that annual demand elasticities should be preferred over quarterly or monthly estimates. Similar type of arguments can be applied to selection of input supply elasticities.

5.0 Summary and Conclusions

A voluminous literature on energy price impacts modelling in agriculture has come after the energy crisis. Different types of energy price impacts can be broadly classified into two categories: (1) economic, and (2) non-economic. Economic impacts are felt directly through rising cost of energy inputs (mainly fuel and fertilizers) and indirectly through rising energy costs in transporting farm produce from farm gate to terminal points. Economic impacts have been estimated on several variables of agriculture sector. For example, net and gross returns to producers, energy consumption and input substitution, technology, several types of structural changes, and influence on the interregional competitiveness and income distribution have been estimated as revealed from the literture review. Environmental impacts are to be seen in terms of changes in soil erosion, air and water pollution.

Different types of energy price impacts, as described above, have been estimated with different empirical techniques or methodologies. A exhaustive survey of literature suggests that methodologies and model formulation used for evaluating the energy price impacts are very diverse. Model formulations vary from simple single econometric equation to sophisticated large mathematical programming models. Different approaches can be broadly divided into: (1) econometric, (2) input-output analysis, and (3) mathematical programming models.

Based on the review of types of energy price impacts and methodologies, it is suggested that a systems framework is more appropriate for energy price impacts estimation in agriculture. The major objective of this paper was to conceptualize different energy price impacts in a systems framework, and to suggest an appropriate model for estimation in a systems framework. I have suggested a sectoral price endogenous programming model (PENP) of agriculture sector which can be developed in both partial and general equilibrium framework. A partial equilibrium PENP model is deemed to be appropriate in terms of its usefulness and costs involved.

The objective of the PENP model is to maximize net social payoff (consumers' and producers' surpluses) subject to resource constraints. Different types of crops, livestock enterprizes can be accommodated in the model. The yield response to different fertilizer application rates in different producing regions under different types of technologies can be incorporated as activities in the model. Similarly several types of fuel-saving technologies can be endogenized. Also, model is very flexible and can be adapted to various conditions. The model has to be validated against the historical data set before it can be used for comparative static analysis of energy price impacts. The model can be used: (1) to estimate energy price impacts in agriculture under the current technology; (2) to estimate the economic feasibilty of new energy-saving technologies as energy prices rise in the future. It can be modified to evaluate the impacts of other inputs prices as well.

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