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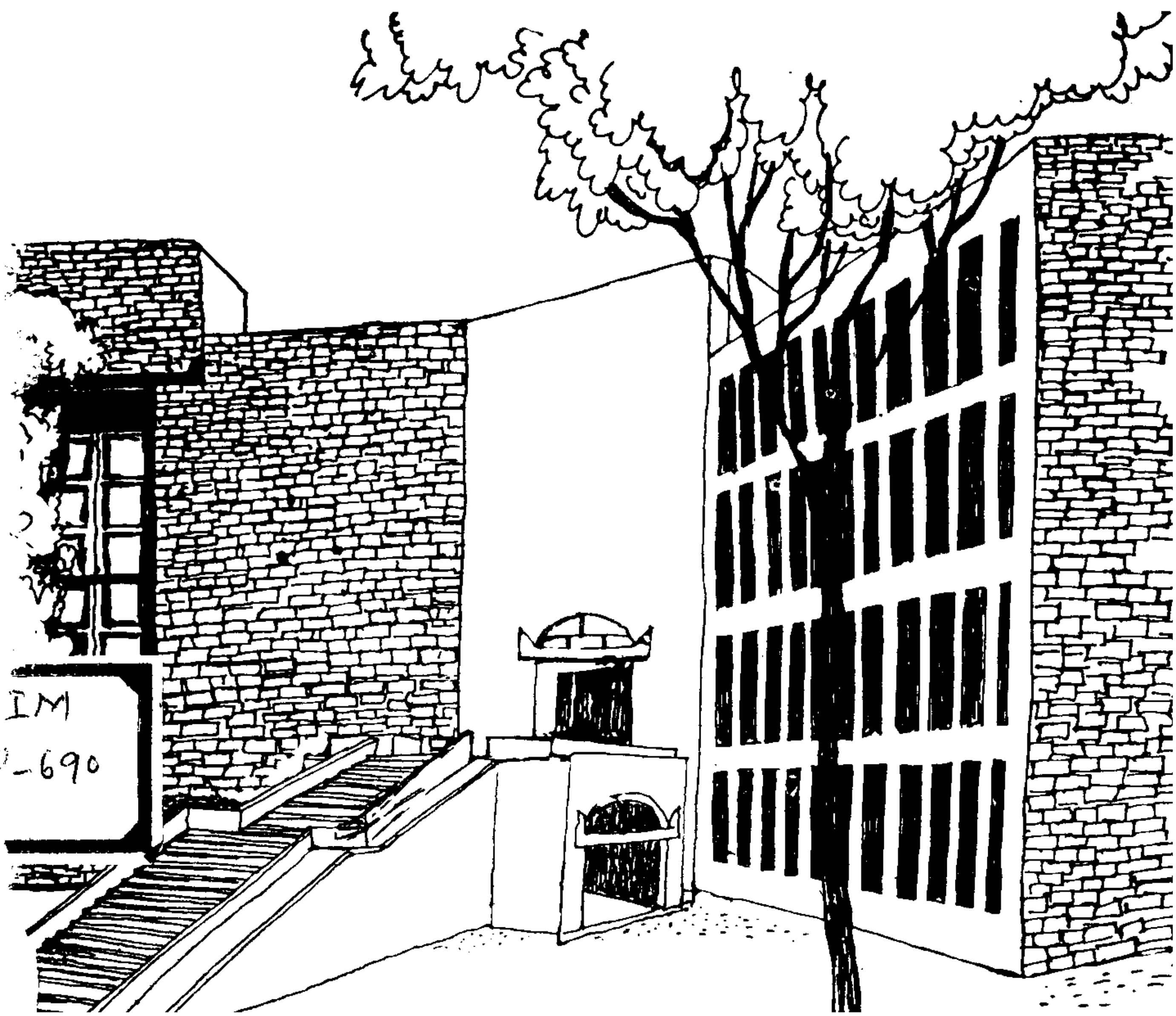
Working Paper



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W.P. No 690
July. 1987

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AN ECONOMIC ANALYSIS OF FOOD – ENERGY SECTOR : IMPLICATIONS FOR SUBSISTENCE BEHAVIOUR AND CREDIT POLICY

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W P No. 690
July, 1987

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AN ECONOMIC ANALYSIS OF FOOD - ENERGY SECTOR : IMPLICATIONS FOR SUBSISTENCE BEHAVIOUR AND CREDIT POLICY

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1. Introduction

Energy is one of the most significant input in the commercial production of food grains in India. It is therefore not surprising that most of the economic modeling has been to understand the market mechanism by which the changes originating in the energy sector are transferred into the food sector. However, there are a number of important issues which remain unanswered by this approach. Perhaps the most important of these is, how the food energy nexus operates in the case of those farmers whose primary goal for undertaking agriculture is to seek direct consumption, as opposed to the profit maximization practised by commercially oriented farmers[1]. This is an important issue for of the 81 million holdings in the country, as many as 60 million are small and marginal holdings with per capita income of Rs 2 per day. Over 70% of their budget is expended just on food grain consumption[2].

Hence, in this paper analytical models are developed to understand the operations within the food energy nexus by which that large aforesaid section of the rural population is affected. The paper here, to begin with, reviews briefly one of the early papers by Timmer, where the impact of rapid rise in energy prices in mid 70's has been analysed(3). Next it examines the validity of its approach with relation to the subsistence seeking segment of the farming population of the developing nations, particularly India. With appropriate assumptions, it then modifies this model. Finally, since limited funds and rising energy prices often pose serious limits on the use of energy in agricultural production, in developing countries, a model is developed to explain the impact of credit constraints on the food energy nexus.

2. Timmer's model (4)

An interesting analytical model linking food and energy sectors was developed by Timmer. This model helped in gaining useful insights into the mechanisms by which changes in energy prices affect the agricultural sector; the emphasis particularly on the food supply. The impact of rising energy prices on the food supply, along with its consequences on the social welfare in developing countries, were discussed in that paper in some detail.

Timmer's model consisted of an aggregate production function and an aggregate consumption function for one of the major food grains. To begin with, his food supply function includes fertilizer, irrigation, area harvested and labour as arguments. Whereas, his consumption function is made up of food price, income and population as variables. Since the primary interest is in the functioning of the food energy nexus, the model is simplified for the analytical reasons into the following systems:

(1) $Q_s = A_s E^{\gamma}$

(2) $Q_d = A_d P_o^{\alpha}$

where A_d is a function of income and population and A_s a function of area harvested and labour. For the purpose of the analysis , both these are assumed to be constant. Q_s and Q_d are the quantities of the food grains produced and consumed in a given year. E is the energy variable representing energy related variables such as fertilizers and irrigation. P_o is a food price and P_e an energy price in the model. γ and α are response elasticities for food supply and demand respectively. He assumes that in the short run the farmers treat energy price and food price as a given datum and proceed to take input-output decisions which will maximise their profits. Thus symbolically, the problem takes the following form:

(3) $\text{Max}\,\pi = P_o Q_s - P_e E$

S.T. $Q_s = A_s E^{\gamma}$

where π stands for profit.

Alternately,

(4) $\text{Max}\;\pi = P_o A_s E^{\gamma} - P_e E$.

Solution of this process yields short run response elasticities to energy price changes, both for energy demand and the associated food supply. Then, since in the long run equilibrium demand equals supply, he equates (1) and (2) to get the functional form of P_o. This, when plugged into the energy demand and food supply function, yield long run elasticities. These elasticities are presented in the Table 1. He observes that the short run elasticities are twice as large as long run elasticities.

Table 1

Short and Long Run Elasticities with respect to Energy Prices

	Energy Demand	Food Supply
Short Run	$\frac{1}{\gamma - 1}$	$\frac{\gamma}{\gamma - 1}$
Long Run	$\frac{\alpha}{\gamma + \alpha(\gamma - 1)}$	$\frac{\alpha \gamma}{\gamma + \alpha (\gamma - 1)}$

3. Subsistence Behaviour and Food Energy Nexus.

Timmer's model adequately explains the consequences of the disturbances originating in the energy sector on the food sector as long as the assumption that the farmers undertake agricultural activity with a commercial motive to earn profit is valid. However in India, as said earlier, small and marginal farmers undertake agriculture primarily with consumption as their goal. These farmers will adopt modern energy based agriculture only if it yields them higher consumption than what they can get from traditional methods.

In a subsistence economy farmer's attempt to maximise his consumption, in fact, amounts to output maximisation, where maximum output is determined by the production function consisting of traditional input. Using energy inputs, however, involves a market transaction. A farmer has to purchase his energy input from the market at a cost. He then has to recover these costs by selling a portion of his total output equivalent in value to the purchased energy input in the market. Any balance if left from his total output after this transaction is then available to him for his own consumption. A consumption optimisation problem thus reduces to:

(5) Max Q_c

S.T. (a) $\left(Q_s - Q_c\right) P_o = P_e E$

or

$$Q_c = Q_s - \frac{P_e E}{P_o}$$

(b) $Q_s = A_s E^{\gamma}$

where Q_s is the actual output produced by the subsistence farmer. Q_c is the output that this farmer is left with for consumption after having recovered the value of the purchased energy input by the sale of the output $(Q_s - Q_c)$ of equivalent value. P_e and P_o are, as said earlier, energy and food prices.

Alternately, the problem in (5) can be presented as

(6) Max $Q_c = Q_s - \dfrac{P_e E}{P_o}$

S.T. $Q_s = A_s E^{\gamma}$

Multiplying the objective function by P_o gives us the following:

$$(7) \quad \text{Max} \;\; P_o\, Q_c \;=\; P_o\, Q_s - P_e\, E$$

$$\text{S.T.} \quad Q_s = A_s\, E^{\gamma}$$

Thus, we see that (7) is similar to Timmer's formulation. What it says is that the value of the maximum consumption Q_c^* in monetary terms is same as the maximum profit π^* that a farmer with a commercial motive, with similar holding, would earn at optimum.

Optimal energy demandand consumption are in this case as given below:

$$(8) \qquad E^* = A_s^{\frac{1}{1-\gamma}}\; \gamma^{\frac{1}{1-\gamma}}\; P_o^{\frac{1}{1-\gamma}}\; P_e^{\frac{1}{\gamma-1}} \qquad , \quad \text{and}$$

$$(9) \qquad Q_c^* = A_s^{\frac{1}{1-\gamma}}\; \gamma^{\frac{1}{1-\gamma}}\; P_o^{\frac{\gamma}{1-\gamma}}\; P_e^{\frac{\gamma}{\gamma-1}} \;\; (\gamma^{-1} - 1)$$

The second order condition ensures that $\gamma < 1$ and therefore a positive surplus will be left for a subsistence farmer for his consumption.

However, one consequence which Timmer does not address is related to a possibility of a subsistence farmer reverting back to the traditional agriculture if $Q_c^* < C$, when energy prices rise. 'C' here is the maximum output that a subsistence farmer can get from traditional modes of farming. This problem can be represented as below:

$$(10) \quad \text{Max } Q_c = Q_s - \frac{P_e}{P_o} E$$

S.T.

$$(a) \quad Q_c \geq C$$

$$(b) \quad Q_s = A_s E^{\gamma}$$

$$(11) \quad \text{Max } Q_c = A_s E^{\gamma} - \frac{P_e}{P_o} E$$

$$\text{S.T.} \quad Q_c \geq C$$

The optimality condition for problem in (11) would be obviously same as in (8) and (9) only with an additional condition that

$$(12) \quad Q_c^* = A_s^{\frac{1}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} P_o^{\frac{\gamma}{1-\gamma}} P_e^{\frac{\gamma}{\gamma-1}} \left(\gamma^{-1} - 1 \right) \geq C$$

If (12) is not satisfied, then the subsistence farmer would go for subsistence farming rather than commercial agriculture and thus the commercial energy input will become almost negligible if the condition (12) is not met. The elasticities with respect to energy price will be the same as in Table 1 as far as condition (12) is met; otherwise the energy price elasticity will be non-existent as the subsistence farmer will not be using commercial energy inputs. An analysis of (12) shows that if parameters A_s and γ increase, Q_c^* would increase, meaning thereby that if production technology improves, a subsistence farmer shall shift to commercial agriculture at same level of A_s and γ which satisfy (12). Similarly, if the ratio of output price to input price (P_o / P_e) increases, a subsistence farmer would be prone to shift to commercial agriculture at same level of ratio determined by (12). Given the parameters, relation (12) decides the farmer's behaviour.

4. Implications of credit constraint

The discussion in above sections considered that the farmer has sufficient credit to buy energy inputs freely. In reality, farmers have limited capital and credit in the beginning of agriculture season which restrict the use of inputs and hence must be considered explicitly. This can be included in the model as an additional constraint (13).

$$(13) \qquad P_e E \leq M$$

or

$$P_e E - M \leq 0$$

where M is the maximum available credit in the economy. Now the farmer's optimisation problem can be written as

$$(14) \qquad \text{Max } \pi = P_o A_s E^{\gamma} - P_e E$$

$$\text{S.T.} \quad G(E) = P_e E - M \leq 0$$

This is a non-linear constrained optimization problem.

The Kuhn Tucker Conditions (6) for this problem can be written as

$$(15) \qquad \frac{d\pi}{dE} - \lambda \frac{d\,G(E)}{dE} = 0$$

$$(16) \qquad \lambda\, G(E) = 0$$

$$(17) \qquad G(E) \leq 0$$

$$(18) \qquad \lambda \geq 0$$

From (14) and (15), we obtain:

$$P_o A_s E^{*\,\gamma-1} - P_e (1 + \lambda^*) = 0$$

$$(19) \qquad E^* = \left(\frac{P_e (1+ \lambda^*)}{P_o \; \gamma \; A_s} \right)^{\frac{1}{\gamma-1}}$$

From (16) we get,

$$(20) \qquad \lambda^* (P_e E^* - M) = 0$$

Substituting (19) in (20),

$$(21) \qquad \lambda^* \left[P_e^{\frac{\gamma}{\gamma-1}} \left\{ \frac{(1+ \lambda^*)}{P_o \; \gamma \; A_s} \right\}^{\frac{1}{\gamma-1}} - M \right] = 0$$

Equation (21) implies that either

$$\lambda^* = 0 \qquad \text{or}$$

$$P_e^{\frac{\gamma}{\gamma-1}} \left\{ \frac{(1+ \lambda^*)}{P_o \; \gamma \; A_s} \right\}^{\frac{1}{\gamma-1}} = M$$

i.e. $\quad P_e^{\gamma} \dfrac{(1+ \lambda^*)}{P_o \; \gamma \; A_s} = M^{\gamma-1}$

i.e.

$$(22) \quad (1+\lambda^*) = (M^{\gamma-1})\, P_o\, \gamma\, A_s\, P_e^{-\gamma}$$

i.e.

$$(23) \quad \lambda^* = M^{\gamma-1}\, P_o\, \gamma\, A_s\, P_e^{-\gamma} - 1$$

From (18) $\lambda \geq 0$, therefore,

$$(M^{\gamma-1})\, P_o\, \gamma\, A_s\, P_e^{-\gamma} - 1 \geq 0$$

i.e.

$$(P_o\, \gamma\, A_s)^{\frac{1}{\gamma-1}}\, P_e^{\frac{\gamma}{1-\gamma}} \geq M$$

Thus we get conditions that if:

[I] $(P_o\, \gamma\, A_s)^{\frac{1}{\gamma-1}}\, (P_e)^{\frac{\gamma}{1-\gamma}} \geq M$ then,

$$\lambda^* \geq 0$$

[II] Else,

$$(P_o\, \gamma\, A_s)^{\frac{1}{\gamma-1}}\, P_e^{\frac{\gamma}{1-\gamma}} < M$$

Then, $\lambda^* = 0$

Thus in case if condition II holds, then the credit constraint at optimality will be slack and the optimum for this problem will be the same as for (3) and (4) ; and therefore all Timmer's conclusions will hold. However, if the condition I holds, then the credit constraint will be met with equality at optimum and,

$$(a) \quad \lambda^* = M^{\gamma-1} P_o \gamma A_s P_e^{\gamma} - 1$$

$$E^* = \left(\frac{P_e (1+\lambda)}{P_o \gamma A_s} \right)^{\frac{1}{\gamma-1}} \qquad \text{as in (19).}$$

or

$$(24) \quad E^* = \frac{M}{P_e}$$

and short run food supply is given by

$$Q_{s\gamma}^* = A_s M^{\gamma} P_e^{-\gamma}$$

i.e.

$$(25) \quad Q_{s\gamma}^* = A_s \left(\frac{M}{P_e} \right)^{\gamma}$$

Thus we see here that the energy demand is restricted by the availability of credit. Rising energy prices will further reduce it. Similarly, the food supply is restricted by the amount of energy inputs that can be used in the wake of credit restrictions. and rising prices.

Since using energy prices reduce the energy input use, they also affect the food supply position in the short run. Short run elasticities for this case are given in Table 2.

TABLE 2

Short Run Elasticities with respect to Energy Price when Credit Constraint is operative

	Energy Demand	Food Supply
Short Run Quantity	-1	$-\gamma$

Comparing these elasticities with the elasticities in Table 1 where credit was unconstrained, we find that in the economy with tight credit situation, elasticity of energy demand and food supply with respect to energy price is less than when credit is freely available.

From (14) and (24) we get,

$$(26) \qquad \pi = P_o A_s \left(\frac{M}{P_e}\right)^{\gamma} - M$$

The marginal addition to the profit by relaxing the credit availability can be discussed by:

$$(27) \qquad \frac{d\pi}{dm} = \gamma \frac{P_o}{P_e^{\gamma}} A_s M^{\gamma-1} - 1$$

Substituting (22) in (27), we find that

$$\frac{d\pi}{dm} = \lambda^*$$

Thus we find that the value of multiplier λ at optimality represents the marginal addition to profit by an additional unit of credit. Thus λ^* is the shadow price of money at optimality.

It is obvious that subsistence farmer's behaviour under credit constraint can be derived by using approach in sections 3 and 4. The subsistence farmer's behaviour can be presented by relation (28) below:

$$(28) \quad Q_c^* = A_s \, \varepsilon^{\gamma} - \frac{M}{P_o}$$

i.e.

$$Q_c^* = A_s \left(\frac{M}{P_e}\right)^{\gamma} - \frac{M}{P_o} \geq C$$

If the parameters satisfy (28), then the subsistence farmer will switch to commercial agriculture else will continue subsistence farming. In case the credit constraint has no slack at optimality, then the marginal increase in Q_c^* by increasing the credit will be obviously non-negative and thus from (28) it is evident that if more credit is available to purchase inputs, a subsistence farmer would be more prone to switch to commercial agriculture.

Conclusions

As seen in the early part of this paper, energy prices operate in a manner similar to the market mechanism, even when the agricultural production is undertaken primarily for fulfilling the personal consumption. When the food-energy price ratio is favourable, commercial energy based agricultural production technologies are adopted. When the ratio is not favourable, it induces a switch, so far as subsistence seeking farmers are concerned, in the favour of traditional technologies. Since small and marginal farmers constitute a bulk of these categories of farmers, from the policy point of view the food - energy price ratio must be a critical element in policy decisions given a level of technology.

Further, it must be added that the food price is a sensitive variable for the effect it can have across the economy on the prices in general. It is therefore important to maintain or augment supply when energy prices rise to maintain a corresponding increase in food prices, but this has serious welfare consequences. So from policy point of view there are two options:

(1) Either subsidise the food prices to the consumer in the form of food subsidies, or

(2) Subsidise the energy prices to maintain the food prices at its original level.

Which of these two policies is appropriate would depend on which form of subsidy is easy to administer as well as economically efficient.

Again as credit can operate as major constraint on the extent of use of energy in the food production, it is crucial that appropriate credit policies are specified, which will augment the food grain supply in the market as well as enable the farmers to obtain adequate profits.

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