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AGRICULTURAL GROWTH AND THE PRICE OF FOOD

by

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Agricultural Growth and the Price of Food[1]

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INTRODUCTION

In discussing the price of food in the context of growth food is usually associated with agriculture. Thus the problem becomes that of determining the price of agriculture relative to that of non-agriculture along the growth path. This however does not reveal the whole story since food purchased by the consumer contains non-agricultural inputs such as processing, packaging, transportation, refrigeration,as well as food consumed in restaurants. The quantity of the non-agricultural inputs and their prices affect the consumer price of food. The non-agricultural inputs of food are not forced on the consumer, but rather demanded by him. Consequently, it is of interest to analyze the determinants of the agricultural and non-agricultural inputs of food. To simplify the discussion all the non-agricultural inputs of food are aggregated. The utility function of a representative consumer is written as

(1) $u = U[F(A, Q), N]$

This function is weakly separable in food (F) and non-food (N). Food has an agricultural component, A, and a non-agricultural component, Q. The ratio $q = Q/A$ can serve as a measure of quality of food. The expenditure on food is decomposed according to the two components, that received by agriculture P_AA and that received by non-agriculture P_NQ, where P_N is the price of the non-agricultural product. Thus, the food budget is:

$$(2) \quad B_F = P_AA + P_NQ$$

The average price paid by the consumer for food, per unit of A, to which we refer as the consumer price is:

$$(3) \quad P_F = B_F/A = P_A + P_Nq$$

and its ratio to the price received by farmers is

$$(4) \quad R_A \equiv P_F/P_A = 1 + pq$$

where $p \equiv p_N/p_A$.

This is also equal to the ratio B_F/P_AA, the receiprocal of the share of the farmer in the consumer's dollar. The price of food in terms of the non-agricultural product is:

$$(5) \quad R_N \equiv B_F/p_N = \frac{1}{p} + q$$

It is clear that R_A and R_N both increase with the quality of food but are affected differently by the price ratio p. The remaining of the analysis will examine the behavior of p, q, R_A and R_N in the process of growth. That requires an analysis of the product market along the growth path.

We begin by providing some empirical evidence. The share of agriculture in the retail cost of food in the U.S. is published by the USDA. The value for 1983 was 33 percent. Dunham places this value in a perspective by stating that it "...was trended down gradually since the mid forties when the share was nearly 50 percent."[2] A casual review of the time series of this share indicates considerable fluctuation. The trend can be attributed, at least in part, to a positive income response of q which implies that the income elasticity of Q is larger than that of A. The fluctuations can be attributed to fluctuations in prices. A study by Houston for the U.K. covering 1963-1975 concludes that "The relative stability of these marketing costs, despite the trend towards increased consumption of processed and convenience foods, suggest that improvement in marketing techniques and advances in food technology have to some extent offset the cost of additional services provided by services and manufecturing."[3] This conclusion can be interpreted as an increase in q and a decline in p, thus leaving R_A fairly stable. Some scattered information is provided by Mittendorf and Hertag for developing countries. The information shows wide spread across countries and the sample is small. Nevertheless the conclusion is suggestive "Nevertheless the data indicate that the share of marketing costs in relation to the consumer price is higher in the developed countries (due to considerable higher labor costs and higher levels of processing packaging and presentation of food items)".[4] Again, a suggestion of an increase in p and q with level of economic development.

An analytic formulation of the farm-retail price spread was provided by Gardner. The essense of his model consists of a production function for food consisting of two inputs, A and Q in terms of our notation. There is a demand function for (aggregate) food which depends on the price of food and a shifter. The model is closed by assuming supply functions for A and Q and imposing the competitive conditions. In this framework, the composition of food is determined by the producers and the consumer has to buy the food provided at the profit maximizing combination of A and Q. This assumption is restrictive and as indicated above it is alleviated in the present analysis. Aside of this, we deal with developments along a growth path.

The discussion begins with the derivation of the demand functions for the two components of food as well as for non-agriculture. The supply side is the standard two sector model. The short run equilibrium is determined within a competitive framework of a closed economy. We deal with a closed economy, although food is tradable, because the world is a closed economy and this fact determines the major developments in the variables of interest. The growth path is then generated by treating individually and exogenously some of the major determinants of growth: capital accumulation and different kinds of technical change. This is followed by some consequences of removing the assumption of competitive factor markets. In view of the space limitation, the analysis is largely graphical, based on some general known properties and concentrates on essentials.

DEMAND

The problem of the representative consumer is to maximize (1) subject to the budget constraint: $B = [p_A A + p_N Q] + p_N N \equiv B_F + B_N$

Using obvious notations, the first order conditions are:

(6) $U_A = U_F F_A = \lambda p_A, \quad U_Q = U_F F_Q = \lambda p_N, \quad U_N = \lambda p_N$

The utility function is weakly separable, so that the composition of food is independent of the level of N. This is seen from

(7) $\dfrac{U_Q}{U_A} = \dfrac{F_Q}{F_A} = \dfrac{p_N}{p_A} \equiv p$

Thus the demand for A and Q conditional on the food budget are:

(8) $A(p_A, p_N, B_F) = A(p, B_F/p_A)$

$Q(p_A, p_N, B_F) = Q(p, B_F/p_A)$

The expression to the right of the equality sign utilizes the homogeneity property of the demand functions. The solution is illustrated in Fig. 1, Point E indicates the optimal choice at the budget level $B_F/p_A = F_1$ The income consumption curve ICCF is drawn to illustrate two assumptions: (1) Both components, A and Q are normal; (2) The income elasticity, with respect to B_F, of A is smaller than one and that of Q is larger than one. Thus, the quality of food q, increases with the food budget. Turning to (4) and (5) it is seen that under (i) increasing expenditure on food, and (ii) constant prices, both R_A and R_N increase. The increase in the price of food, either in terms of A or N, reflects the consumer preference for quality.

The unconditional demand functions can be obtained by finding the optimal food budget and using it in (8). Alternatively, they can be obtained directly. Those are presented below in the Hicks compensated form with the signs of the partial derivatives attached:

(9) $(p_A \; p_N \; u) \quad (p \; u)$

A(− + +) = (+ +)

q(? ? +) = (? +)

N(+ − +) = (− +)

Since all the three components are normal goods, each of these functions is monotone increasing in u. Thus we can substitute A for u and write

(10) Q(p, A), N(p, A)

These functions are drawn in Fig. 2. They represent the loci of optimal points achieved at price ratio p and increasing levels of expenditures.

It should be noted that the price effects reflect two forementioned assumptions. First, the utility function is weakly separable and second, the price of Q is the same as the price of N. A decline in p_A causes a substitution within food of A for Q. However, a decline in p_A makes food cheaper relative to N and hence a substitution in favor of food. This intergroup substitution causes an increase in Q and A. Hence, $\partial A/\partial p_A$ is clearly negative whereas sign $\partial Q/\partial p_A$ is ambiguous depending on the relative strength of the intra food and intergroup substitutions. $\partial N/\partial p_A > 0$ because of the intergroup substitution in favor of food. A decline of p_N reduces the price of food and of N but the price of food decreases less because Q constitutes only one input in F. Consequently, the intergroup substitution will be in favor of N hence $\partial N/\partial p_N < 0$. To the decline in food we now add the changes within food. A substitution in favor of Q causes a decline in A so that the inter and intra group effects supplement each other and $\partial A/\partial p_N > 0$. On the other hand, sign $\partial Q/\partial p_N$ is ambiguous because the two effects are contradicting.

It is possible to put some boundries on the effects. Since the price of Q and N is the same, we can view $Q + N = \bar{N}$ as a composite good, and write the utility function as $U(A, \bar{N})$, resulting in demand functions

$$(11) \quad A(\underset{+}{p}, \underset{+}{u}), \quad \bar{N}(\underset{-}{p}, \underset{+}{u})$$

and those are clearly signed.

THE ECONOMY IN THE SHORT RUN

Under the space limitation, it is most efficient to analyze the proces within a neoclassical framework of a two sector model of a closed economy and thereby build on some known results. The model consists of constant returns to scale sectoral production functions:

$$Y_i = F_i(K_i, L_i, T_i) \qquad i = 1, 2$$

where K_i and L_i are sectoral employment of capital and labor respectively and T_i is a measure of technology. Sector 1 is agriculture and 2 is non-agriculture. It is assumed that factors are fully employed and their supply is exogenously given. This latter assumption only simplifies, but does not modify the qualitative results. Finally, it is assumed that the competitive conditions are met in that factors of production are paid their value marginal productivities. Under these assumptions, the production possibilities of the economy are given by the transformation curve in Fig. 3.a. The relationship between the (supply) price and points on the transformation curve is summarized by the supply function for agriculture in Fig. 3.b. Note that $p = p_N/p_A$, hence, when the economy specializes in agriculture ($y_1 = \bar{y}_1$) p is at its minimum level ($\underline{p}$) and conversely, when the economy specializes in non-agriculture ($y_2 = \bar{y}_2$) the price is at its maximum, $\bar{p}$. Also, p increases with y_2 and declines with y_1.

Next we turn to the demand functions. Combining the two equations in (11), the demand can be sumarized by:

$$x_1 = D(\underset{+}{p}, \underset{\mp}{x_2}) \quad (12)$$

where x_1 is percapita demand of A, and x_2 is percapita demand of $\bar{N}$. It is assumed that $D(p, 0) = 0$, as $p \to 0$, $D \to 0$, and as $p \to \infty$, $D \to \infty$.

Under these assumptions there is a unique stable short run equilibrium. That is, there exist a price p_e such that $x_1(p_e, y_2(p_e)) = y_1(p_e)$. This is illustrated by point E in Fig. 3. The determination of the equilibrium can be demonstrated in Fig. 3.b. For this, we evaluate x_1 only at points $[p, y_2(p)]$, where $y_2(p)$ is the percapita production at price p. At $\bar{p}$, $y_2(\bar{p}) = \bar{y}_2 > 0$ but $y_1(\bar{p}) = 0$, hence $x_1[\bar{p}, y_2(\bar{p})] - y_1(\bar{p}) > 0$ implying an excess demand for x_1. The opposite occurs at $\underline{p}$ where $y_2(\underline{p}) = 0$ and therefore $x_1(\underline{p}, 0) = 0$, hence excess supply. As $\partial y_1(p)/\partial p < 0$, $\partial y_2(p)/\partial p > 0$, $\partial x_1/\partial p > 0$, $\partial x_1/\partial x_2 > 0$, the excess demand declines with p, and E is achieved where the excess demand is zero. Having determined p, A and $\bar{N}$, the demand functions facilitate decomposition of $\bar{N}$ into N and Q and thus the determination of food, F(Q, A). This outline of a graphical proof can be repeated in each of the following cases to determine the displacement in the equilibrium position.

The analysis can be generalized to the case where the factor supplies in the economy are increasing functions of their prices. Such an extension will add technical details but will not affect the qualitative results.[5]

CAPITAL ACCUMULATION

By capital accumulation it is meant an increase in the capital labor ratio for the economy as a whole. An accumulation facilitates an expansion of the production possibilities of the economy and thereby causes a positive income effect for all the commodities.

The evaluation of the price effects of accumulation requires an assumption on the capital intensity. It is assumed here that agriculture is the labor intensive sector. That is, at any price regime, $k_1 < k_2$, where $k_i \equiv K_i/L_i$. Under this assumption, the Rybczyncki proposition indicates that under constant prices capital accumulation leads to an expansion of the output of the capital intensive sector and to a decline of the output of the labor intensive sector. Thus, at the initial prices capital accumulation causes an increase in the demand x_1 due to the increase in income, and a decline in the supply y_1, hence excess demand. A new equilibrium is achieved at a higher price for y_1, that is a decline in p. Consequently the equilibrium output of y_1 will increase if the income effect is stronger than the substitution effect and will decrease if the converse holds. The decline in p supplements the income effect for $\bar{N}$ and its equilibrium output will increase. Finally, in view of the price change, the quality of food, $q = Q/A$ increases. This reflects two effects, a stronger income elasticity for Q than for A, and a substitution in favor of Q due to the decline in p. However, the total quantity of Q depends on the equilibrium consumption of food. If A does not decline, then Q will increase. If A declines, it is possible that food consumption will decline even though its quality will improve.

The foregoing analysis shows a decline in p, the price of the capital intensive product. How does it affect the relative price of food? By (5) R_N, the price of food in terms of N, increases. However, by (4) the change in R_A, the price of food in terms of A, is ambiguous. Since p declines and q increases, the outcome will depend on the relative changes. If the income effect is weak, it is possible that the change in price will dominate and R_A will decline. The change in p depends on the supply and demand elasticities and will not be discussed here. It is however likely that the income effect an q is strong and dominant and R_A will increase.

TECHNICAL CHANGE

Technical change (TC) is basically the engine of growth. However it is not a simple concept. It takes various forms and at least in part is endogenous in the economic system. The best we can do under the limited space is to illustrate some leading cases. Such cases are selected to illuminate the importance of the income and price elasticities of demand. We begin with Hicks neutral technical (HNTC) of equal rates in the two sectors. Fig. 4a presents transformation curves for two technologies, 0 and t. Point E is the initial equilibrium. Under HNTC of equal rates in the two sectors, the supply price at H, located at the intersection of the outer transformation curve and a ray through E, is the same as at E. However, at this price and the new production possibilities the demand is given by point C. Thus, there is an excess supply of A and p increases until a new equilibrium point E_1 is reached. It can be shown that this point is located between H and C. The location of C, and therefore E_1 to the right of H reflects the fact that the income elasticity of A is less than 1.

The increase in p makes food cheaper relative to N. Hence, the percapita consumption of food increases due to the income and price effects. Yet, both effects are not sufficient to increase consumption of A at the rate of the TC. Consequently, the consumption of N + Q increases by more than the rate of the TC and the income effect dominates the price effects. This is also true for the two components, N and Q, individually, implying an increase in q. The final outcome is an increase in pq and therefore an increase in R_A. On the other hand the sign of the change in R_N is ambiguous. But again, the increase in quality may dominate the change in price and thus leading to an increase in R_N.

Another extreme case is that of TC in one sector only, say in agriculture. Fig. 5 illustrates HNTC in agriculture alone. At point B the resource allocation is the same as at the initial point because it produces the same quantity y_2 under constant technology. However, due to the TC the relative price of agriculture declines (p increases) and hence point H representing the initial price p_E is to the left of B. The demand under the initial price is at C. The new equilibrium point will be in the segment BC when the price elasticity of demand for A is less than 1. It will be in the segment BH if the elasticity is larger than 1. Empirically, such elasticity is smaller than one. In this case HNTC in agriculture alone leads to an increase in p and in the consumption of both commodities. The increase in the consumption of non-agriculture reflects the income effect, since the economy becomes more affluent due to the TC. It can produce a larger output of food with fewer resources and the resources saved can be diverted to non-food production. Note, however, that this result depends crucially on the demand elasticity, for if the demand for A were elastic, such a change would have reduced the equilibrium consumption of non-agriculture.

The effect of this change on q depends on the strength of the intrafood substitution between A and Q. Since p increases, such a substitution reduces q. However, this may be dominated by the income effect on q. If q does not decline then R_A increases and if q does not rise R_N declines. The other possibilities are ambiguous.

The foregoing two cases of HNTC facilitates a more general analysis. To show this, let T_1 and T_2 be the rates of the HNTC in the two sectors, then the consequences of such a change can be analyzed in two steps: (1) Equal rates: Assume that $T_1 > T_2$, then analyze first the system under the assumption of $T_1 = T_2$. (2) Differential rate: Now analyze under the assumpltion of TC in agriculture alone at a rate $T_1 - T_2$. Over a long swing, it is likely that even if the rates are not the same, the common part is dominating and therefore the results obtained for equal rates of HNTC are more relevant.

DISEQUILIBRIUM ANALYSIS

The foregoing analysis dealt exclusively with equilibrium points. When dealing with the growth of agriculture, the assumption of equilibrium might be too restrictive for the analysis to be empirically pertinent. The low income elasticity for A forces resources to flow out of agriculture as the economy expands. For reasons not discussed here, this flow particularly in the labor market, is not fast enough in order to equate wages across sectors and consequently the agricultural wage is lower than that of non-agriculture.[6] In this sense the economy is not operating efficiently. This is illustrated in Fig. 6 by point H, which is not on the frontier. The demand curve that passes through H determines the price which clears the product market at H.

Assuming that labor migrates to the sector with the higher wage, there will be a flow of labor out of agriculture. This will cause a decline of A and an increase of $\bar{N}$ as shown by the arrows in Fig. 6 which illustrates convergence to E on the transformation curve. Note that such a process of convergence to the frontier increases the consumption possibilities and as such has a positive income effect on A, Q and N. In addition to the income effect there is also a price effect. The partial effect of the off-farm migration is to narrow the wage gap and thereby to increase the cost of production in A and to decrease it in $\bar{N}$. Assuming that competition prevails within each sector, the average cost is equal to the product price (zero profit) and therefore p declines. Such a decline in p facilitates the absorbtion of the expanding production in non-agriculture. Note that such a convergence to the efficiency frontier shows negative relationships between sectoral outputs and their prices.

The positive income effect and the price effect increase Q whereas A declines and therefore q increases. However, the sign of the change in R_A is ambiguous whereas R_N increases.

The foregoing analysis assumed constant resources and technology. Once this assumption is removed, we will have a simultaneous movement toward the transformation curve and a movement of the curve itself. This is the reason that the process takes so long to complete.

SUMMARY

The discussion can be summarized with Table 1.

AN EMPIRICAL ANALYSIS

The foregoing analysis suggests positive relationship between q, R_A, R_N and between income and it is somewhat less definite on the net effect of p. Thus, the empirical analysis can test the qualitative results and supplement them. The analysis is of the US data for the period 1946-82. Such data were readily available[7]. It would be interesting to repeat the analysis on other data.

The analysis consists of computing regressions of ln q and ln R_A on ln p(Lp), lny (Ly) where y is percapita disposable income deflated by the consumer price index, and an interaction term (Lp) (Ly). The average compounded rates of change of these variables are: p = .0116, q = .00295, y = .021 and $p_A A/B_F$ = -.0035. Thus, the terms of trade of agriculture deteriorated at an annual rate of about 1 percent whereas q increased at the rate of about .3 percent. In terms of Table 1 it means that the effect of the TC dominated that of capital accumulation and of flow of resources in its effect on the terms of trade. This statement should be qualified to allow for the role of the U.S. as an exporter of food. However, this qualification is not that simple and conspicuous and is avoided here. In terms of q we see that its growth is consistent with the HNTC of equal rates and not inconsistant with the others.

The regressions are summarized in Table 2. Two regressions are presented for each of the two dependent variables, with and without the interaction term. The contribution of the interaction term is particularly important for the Lq regression where it improves the fit and eliminates the serial correlation. The price elasticities were possitive at the low income level, they gradually declined, become negative at about the mid point of the sample. The average for the period was -.047 whereas the extreme values were -.30 and .24.

Recall that an increase in p reduces the relative price of food and thereby affects positively Q and A. This is the intergroup effect. It is proportional to the income elasticities of Q and A and therefore, by our assumption it increases q. The intrafood substitution due to an increase in p leads to a decline in q. Since we obtain positive price elasticities for the low income years it implies that at such income levels the intergroup effect dominates the intrafood substitution. That is, the main effect of an increase in p, which implies a lower price for food, is to increase food consumption. The change in the quality due to intrafood substitution is less important. The situation is reversed as income increases.

The income elasticity of quality was stronger at the early period and declined gradually and become negative in the last three years. This trend reflects the increasing price of quality(p) and indirectly the increase in income. Thus, at high income and high price of quality, the intra food substitution dominated and that called for a decline in q.

The second set of regressions reports the response of R_A to changes in p and y. In this set, the interaction, though significant, contributes less to the simpler regression (3), but still as in the previous case reduces the serial correlation. Nevertheless, there is little difference in the average elasticities between the two regressions. Thus, the elasticity of R_A is about .55 with respect to p and .075 with respect to income. That indicates that R_A increased with p and y. Recall that R_A is the receiprocal of the share of agriculture in the food budget, and this declines with p and y. This of course reflects the changes in q.

Footnotes

[1] An invited paper to be read at the International Conference of Agricultural Economists, August 26-Sept. 4, Malaga, Spain. I am indebted to Bruce Gardner, Dennis Dunham and Ulrich Koester for assistance in locating the empirical evidence. The study was supported by the International Food Policy Research Institute and by Grant No...... from BARD - The United States-Israel Binational Agricultural Research and Development Fund".

[2] Dunham, p. 10.

[3] Houston, p. 59.

[4] Mittendorf and Hertäg, p. 31.

[5] In this case, the slope at the transformation curve is not equal to the supply price. However, the supply function is still positively

sloped and the equilibrium determination according to Fig. 3.b. is still valid. (Mundlak, 1984).

[6] Cf. Mundlak, 1979.

[7] Sources of data: R_A was derived from Dunham. The remaining variables are obtained from USDA, Agricultural Statistics, different volumes.

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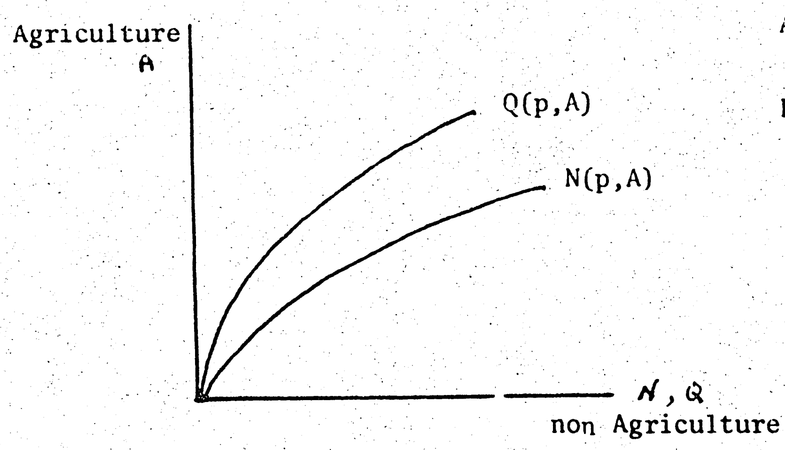

Fig: 2. Unconditional Income Consumption Curves

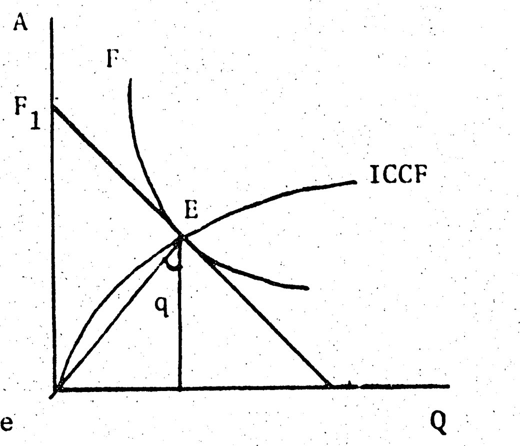

Fig: 1. The Composition of Food

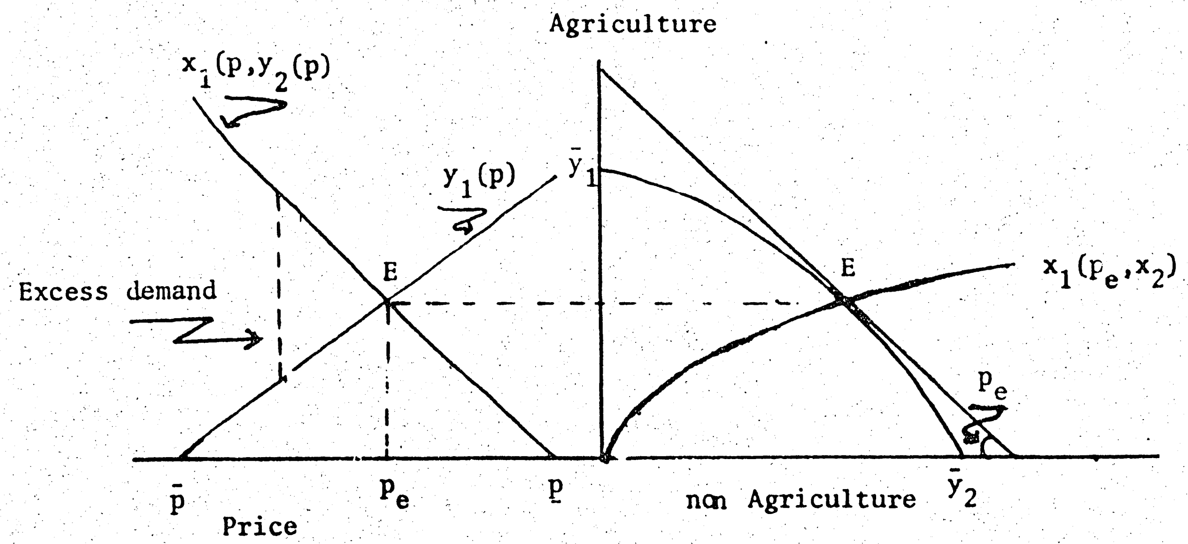

Fig: 3.b

Fig:3.a

The Economy in the Short Run

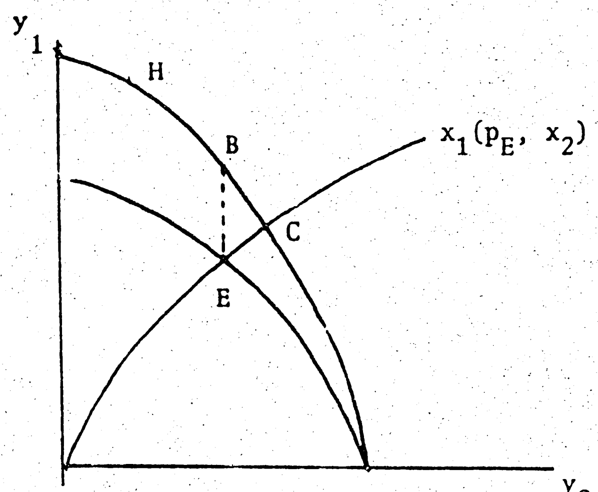

Fig. 5: HNTC in Agriculture

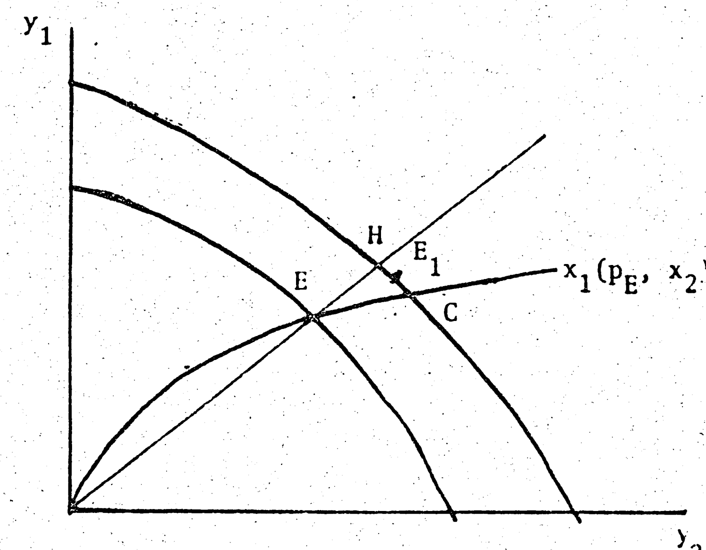

Fig. 4: HNTC of Equal Rates

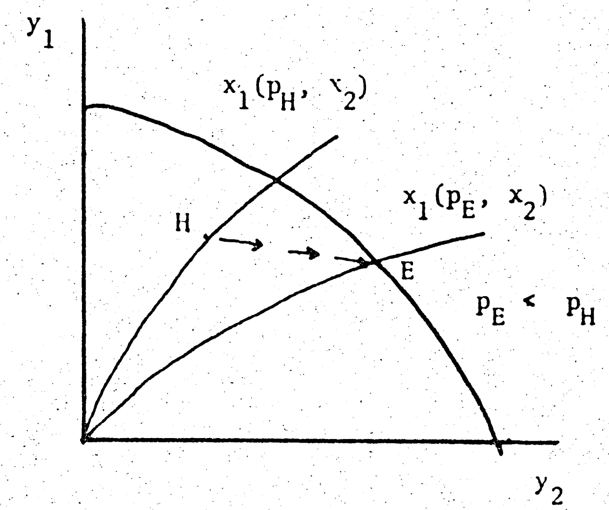

Fig. 6. Convergence to Equilibrium

Table 1: The Response to the Various Growth Determinants

Single Variable	Sources of Growth			
	K-ACC	HNTC $T_1=T_2$	HNTC $T_1 > 0$	Resource Flow
p	-	+	+	-
A	?	+	+	-
Q	+	+	+	+
q	+	+	?	+
R_A	?	+	?	?
R_N	+	?	?	+

Note: K-ACC = Capital Accumulation
HNTC = Hicks Neutral Technical Change
T_1, T_2 = the rates of the HNTC
Resource flow = out of agriculture

Table 2

Regression No	(1)		(2)		(3)		(4)	
Dependent Variable	Lq		Lq		LR_A		LR_A	
R^2	.38		.66		.966		.976	
DW	.78		1.46		1.02		1.59	
Constant	.70	(3.7)	-.88	(7.2)	1.09	(11.6)	.254	(3.7)
LP	-.014	(.2)	2.25	(5.7)	.56	(18.4)	1.55	(7.0)
Ly	.15	(3.5)	.35	(7.6)	.088	(4.0)	.173	(6.7)
(Ly)(LP)	---		-.80	(5.8)	---		-.350	(4.5)
EP: average	-.014		-.047		.56		.544	
SD	0		.19		0		.08	
Ey: average	.151		.12		.088			
SD	0		.13		0		.074	

Notes to Table 2

Numbers in parentheses are t ratios of coefficients to the left.
DW: Durbin-Watson statistic
EP: Elasticity of the dependent variable with respect to price.
Ey: Elasticity of the dependent variable with respect to income.
Average: Average for the period.
SD: Standard deviations of the computed elasticities.

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