Determinants of agriculture's relative decline: Thailand

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Abstract

During economic development, agriculture declines as a proportion of aggregate national output. A number of theoretical explanations for this phenomenon have been advanced in the economic literature, but their relative historical significance has not been clear. This paper develops an econometric methodology to analyze this issue and applies it to time series data for Thailand. The study investigates the importance of relative commodity prices, factor endowments and technical progress as explanations for changing sectoral GDP shares of agriculture, manufacturing and services. It is concluded that the movement in Thailand's aggregate factor endowment relative to labor was the most important determinant of agriculture's relative decline.

1. Introduction

The transformation of agriculture from the dominant economic sector in poor countries to a very small sector in the wealthiest countries is a central feature of economic development. Given the social importance of this phenomenon, its causes and consequences have appropriately received enormous attention. A number of economic forces contributing to agriculture's relative decline have been identified in the literature, including: (a) the effects that changes in income and population levels have on the demand for food relative to other goods and the resulting effects of these demand shifts on relative commodity prices; (b) differences in the rates of technical change between sectors; and (c) changes in aggregate supplies of capital and labor in the economy and their resulting effects on industry structure.

The causes of the decline in the agricultural sector, as identified above, are generally not policy variables, but most are subject to policy influence. Price policy for the agricultural and industrial sectors has a major impact on the relative prices of these goods, and in developing countries typically has a negative effect on agricultural output (Krueger et al., 1988). Similarly, the level of the capital stock can be influenced by taxation and investment policies while the size of the labor force can be influenced by policies on immigration and fertility. The rate of technical change, especially in agriculture, can be influenced by policy towards research, extension and education.

The analysis of this paper builds on a related study of structural change in the Indonesian

economy (Martin and Warr, 1993), which was based on a two-sector econometric model – agriculture and non-agriculture. Here we extend that model to three sectors – agriculture, manufacturing and services – and apply it to Thailand, a middle-income developing country experiencing rapid structural change (Warr, 1993; Siamwalla et al., 1993). Our analysis treats relative commodity prices, the overall rate of technical change in each sector, and the aggregate economy-wide supplies of factors of production, as predetermined variables. It attempts to determine their relative effects on changes in the composition of national output. Our approach is similar in principle to the 'Canadian' literature on modelling production by means of a GDP function (Diewert and Morrison, 1988; Lawrence, 1989), but applied to the sectoral structure of the economy instead of its trade structure.

A brief survey of the relevant literature is presented in the next section. The methodology is described in Section 3, and the data are discussed in Section 4. Results are presented in Section 5. Finally, we offer some tentative conclusions and proposals for future research.

2. Agriculture's relative decline

Economic thought on the role of agriculture in economic development has been dominated by two empirical observations. First, as economic growth proceeds, agriculture declines in economic importance relative to manufacturing and services. Second, at any stage of this growth process, resources frequently appear to be less productive in agriculture than in industry. The two phenomena are obviously connected. Higher economic returns to mobile factors of production in industry than in agriculture (the observed productivity difference) provide the economic incentive for their movement out of agriculture during the growth process (the observed secular decline of agriculture).

Economic policies toward agriculture have been influenced by the way these two phenomena have been interpreted. The decline of agriculture relative to industry has sometimes been misinter-

preted to mean that industrialization causes economic growth, rather than being a manifestation of it. The lower measured productivity of labor in agriculture has also been misinterpreted to mean that forced reallocation of resources from agriculture to industry will necessarily raise national income in the short term and promote growth in the longer term.

As is well known, the economic decline of agriculture produces problems of adjustment with profound effects on the environment in which economic policy is formulated. Development of appropriate policy responses to the problems arising from agriculture's decline obviously requires understanding of the economic forces that produce it. The present paper aims to contribute to this end. In the remainder of this section, we review some of the major determinants of the dynamic behavior of agriculture's share.

2.1. Demand factors

Among the causes of agriculture's decline during economic growth, demand-side factors are perhaps the best understood. First, consider a closed economy. As income rises per head of population, at given commodity prices expenditure shifts towards services and manufactured goods relative to food, the phenomenon known as Engel's Law (Schultz, 1953; Anderson, 1987). If all sectors expanded output at the same rate, excess supply of food would result. The mechanism by which demand shifts affect industry outputs is thus changes in relative commodity prices. This same mechanism operates at a global level. Low expenditure elasticities of demand for food relative to other traded goods can be expected to result in declining international prices of food relative to other traded goods over time (World Bank, 1982).

For an individual trading country this analysis changes, but only slightly. For given rates of domestic trade taxes and subsidies, international prices determine the relative domestic prices of traded goods such as food, raw materials and manufactures. For a small country these relative prices are independent of domestic demand conditions, but the level of these prices relative to

those of non-traded goods such as services is affected by domestic demand. A further determinant of relative commodity prices in an open economy such as Thailand, is national protection policy. Evidence cited in Warr (1993) confirms that in Thailand, as in most low and middle income developing countries, protection policy favors manufacturing over agriculture. However, the magnitude of this discrimination against Thai agriculture appears to have declined since the late 1960's (Wiboonchutikula et al., 1989).

Services typically have expenditure elasticities of demand greater than unity (Lluch et al., 1977), implying that the aggregate of all other goods – i.e. traded goods – has an expenditure elasticity below unity. A general rise in real incomes will increase demand for services relative to traded goods and tend to raise the relative prices of services. Alternatively, productivity growth may be less rapid in the service sector than in the more highly traded sectors (Falvey and Gemmel, 1991) which, with low demand elasticities for non-traded goods, will result in higher relative prices for services. Either explanation is thus consistent with the widely observed decline of traded goods prices relative to non-traded goods as economies develop (Kravis and Lipsey, 1988).

In summary, as incomes rise the above demand-side forces will lead to a decline in agricultural product prices relative to prices in general. Falling agricultural prices relative to other goods prices will reduce agriculture's share of GDP in two ways. First, provided GDP is measured at current prices, even if industry output levels were constant, agriculture's measured share of GDP would fall due to valuation effects. Second, in response to the relative price changes, resources will move away from agriculture towards other sectors where their returns are greater, thus affecting outputs.

2.2. Differential rates of technical change

Differences in rates of technical change between sectors will also contribute to changes in the composition of GDP. If, as is widely thought, the agricultural sectors of developing countries experience slower rates of technical change than

their non-agricultural sectors (Chenery et al., 1986, p. 74), then this would directly contribute to a decline in the share of agriculture in the economy.

2.3. Factor accumulation

Another possible influence on the size of the agricultural sector is changes in the total supply of labor and capital in the economy. If the factor intensities of the agricultural and other sectors differ, then Rybczynski's theorem (Rybczynski, 1955; Ethier, 1988) would lead us to expect that changes in factor supplies will induce changes in the output mix. In particular, if agriculture is more labor-intensive than the rest of the economy, then in a two-sector two-factor model, capital accumulation will cause agriculture's output to fall absolutely. It is obvious that the economy-wide supplies of different factors of production may accumulate at different rates. This fact has been central to the analysis of the process of economic development, as captured in trade-oriented models (Leamer, 1987), but its possible role has largely been ignored in the literature on the declining share of agriculture (Schultz, 1953).

The analytical basis for the Rybczynski effect is reviewed in the Appendix, using the standard two-good two-factor model for expositional simplicity. An intuitive explanation is also helpful. In this analysis, the *aggregate* economy-wide stocks of labor and capital and relative *commodity* prices are treated as exogenous, but the allocation of factors across sectors and relative factor prices are determined endogenously within the model. A central analytical point is that the factor proportions used in each of the two individual sectors will not change when the aggregate factor endowments change, holding relative commodity prices and technology constant. This is so because factor proportions in each sector depend on relative factor prices and on the production functions in each sector. Given the production functions, factor prices in turn depend on relative commodity prices (the Stolper-Samuelson theorem), but commodity prices and technology are each held constant throughout the Rybczynski analysis.

Capital accumulation causes the more capital-

intensive industry (non-agriculture) to expand. Its expansion draws on the newly augmented supply of capital, but also requires additional labor. This labor can only be obtained from agriculture, and to release labor, agriculture must contract absolutely, releasing the required labor and some additional capital as well. Therefore, not only must agriculture contract absolutely but non-agriculture must expand proportionately more than the amount by which the aggregate capital stock initially grew.

In reality, of course, the simplifying assumptions of the Rybczynski analysis – including fixed commodity prices and static technology – will not hold. A satisfactory empirical analysis of the causes of agriculture's decline must therefore allow for the changes in these variables. Nevertheless, the Rybczynski analysis does not suggest that when aggregate factor supplies accumulate at different rates, powerful effects on the sectorial composition of national output may result. It would seem *possible*, therefore, that changes in the composition of aggregate economy-wide factor supplies is one of the important contributory factor underlying the process of agriculture's long-term relative decline. At least, that possibility could not be dismissed a priori.

2.4. Adjustment costs

In addition to demand-side forces, technical change and factor accumulation, dynamic factors will also affect sectoral shares. In particular, they will influence the rate at which restructuring occurs. The relative decline of agriculture is almost certain to require the physical movement of factors. The rate of resource movement will depend upon physical adjustment costs (Mundlak, 1979; Cavallo and Mundlak, 1982) and psychic adjustment costs (Tweeten, 1979, p. 180). Higher rates of resource allocations will mean the movement of resources (e.g. labor) for which adjustment costs are progressively higher.

We have thus distinguished three major sources of agriculture's decline: changes in relative commodity prices; differential rates of technical change; and factor accumulation. The rate at which agriculture declines will also depend on

costs of adjustment, among other forces. During the process of economic development, all these forces presumably operate. But what is their relative importance?

3. Methodology

The economic process of structural change is fundamentally general equilibrium in character, depending upon both demand and supply-side influences. But since our interest is on the proximate determinants of agriculture's decline, as described above, the present paper focuses on the production side. This analysis treats output prices, technology and the aggregate economy-wide stocks of factors of production (as distinct from their sectoral allocation) as predetermined. We attempt to model the response of the agricultural sector to changes in these determinants.

Time series data are required to capture the dynamics of adjustment resulting from factors such as adjustment costs, information and implementation lags. Static models are unlikely to be adequate given the probability of lags in adjustment. However, since the major focus of interest is in the long-run structural parameters, an approach is required which readily allows estimation of these parameters. The methodology thus required consideration of both the long-run structure and the dynamic properties of the data. Each of these issues is now discussed.

3.1. Long-run structure

The analysis considers three major sectors – agriculture, manufacturing and services – utilizing capital, labor and a changing level of technical knowledge. This technology can be characterized by the implicit function:

$$J(A, M, H, K, L, T) = 0 \tag{1}$$

where A is agricultural output, M is manufacturing output, S is services output, K is the aggregate capital input, L is the aggregate labor input, and T is an index of technology. Given the focus of this study, the sectoral output variables must be treated as endogenous. By contrast, the aggre-

gate supplies of capital and labor can be treated as exogenous, or at least predetermined for statistical purposes.

Under the dual approach, technological parameters are inferred from the properties of a profit function subject to certain regularity conditions. Of the generally used dual functional forms (see Diewert and Wales, 1987), the translog function seems most suitable. It is the only one which does not impose input-output separability (Lopez, 1985) and it has the convenient property that its first derivatives with respect to output prices are the value shares of each output, the variables of prime interest in this study.

3.2. Dynamics

Because of adjustment costs, incomplete information and implementation lags, the economy will not necessarily be in long-run equilibrium at any particular time. Clearly, some mechanism is required to define how the economy deviates from its long-run equilibrium. One approach to doing this is to specify a general model containing lags on both the dependent and the independent variables. For this reason, a general autoregressive-distributed lag model, reparameterized into the transformed regression model discussed by Wickens and Breusch (1988) was employed in initial specifications of the analysis. This transformation allows direct estimation of the long-run coefficients and their standard errors within a model which is linear in the parameters. Wickens and Breusch show how the general model in (2) can be transformed:

$$Y_t = \sum_{i=1}^{m} Y_{t-i} C_i + \sum_{i=0}^{n} X_{t-i} D_i + U_t \qquad (2)$$

where Y_t is a vector of endogenous variables, X_t is a vector of exogenous variables, and U_t is a vector of disturbances.

To estimate the matrix of long-run multipliers directly, we first subtract $D_i X_t$ from each of the X_{t-i} terms on the right hand side, maintaining the equality by adding $D_i X_t$ to the $D_0 X_t$ term. Subtracting $C_i Y_i$ from both sides of (2) similarly leaves the equality undisturbed. The matrix of

long-run coefficients can then be obtained directly by estimating the following system of equations:

$$Y_t = \sum_{i=1}^{m} \Delta_t Y_t F_i + X_t \Phi + \sum_{i=1}^{n} \Delta_i X_t G_i + V_t \qquad (3)$$

where

$$R = \left(I - \sum_{i=1}^{m} C_i \right)^{-1}$$

and with

$$F_i = -C_i R \qquad G_i = -D_i R \qquad V_t = U_t R$$

and

$$\Phi = (\Sigma D_i)(I - \Sigma C_i)^{-1}$$

Because current endogenous variables appear on the right hand side of equation system (3), a simultaneous equation estimator is required. Examples are Three Stage Least Squares (3SLS) or Full Information Maximum Likelihood (FIML) for a system, or Two Stage Least Squares (2SLS) for a single equation. Direct estimation of the long-run parameters (Φ) in this way has two major advantages. First, the fact that it provides direct estimates of both the long-run coefficients and their standard errors avoids the need to solve for them after estimation. Second, it becomes straightforward to impose and test the restrictions which economic theory implies for the long-run parameters, but not the short-run parameters.

The estimation method used is a relatively simple linear-in-variables and linear-in-coefficients approach to estimation of the long-run coefficients, together with the dynamics of interest. The simultaneous estimation of the long-run coefficients and the dynamics should help to improve the quality of the long-run estimates by overcoming omitted variable bias. Since the dynamic specification can be interpreted in terms of adjustment costs and lags, it has an economic interpretation, as well as playing an important statistical function by improving the specification of the model.

4. Data sources

Thailand is an interesting country for this analysis because it has a relatively open market economy which has experienced rapid and sustained economic growth and structural change. Two major data sources were used. The World Bank's national accounts data were used to obtain estimates of the value and quantities of output from each sector, and the Summers and Heston (1987) data were used to obtain estimates of investment and population. The complete data set required was available for the period 1960 to 1985. Obtaining the variables actually used in the econometric analysis required some transformation of the available data. For each sector identified in the data set, an implicit price deflator was calculated by dividing the current price estimate of the value of output (in value added terms to avoid double counting) by the constant price estimate of output. Where aggregation of sectors was required, a Tornquist price index was calculated using

SHAZAM (White and Horsman, 1986) and an implicit quantity index was then calculated for the resulting composite sector.

The population estimates provided by Summers and Heston were used as a simple proxy for the size of the labor force. While some estimates of the labor force participation rate are available for the period from 1971, these are based on sample surveys with a significant margin of error and the incorporation of these errors may cause more problems than it overcomes. Some experimentation was undertaken using the available data from ILO and other sources, but the results were not encouraging.

The capital stock was estimated using the Summers and Heston data series on investment at constant prices beginning in 1950. A capital stock series was calculated using the perpetual inventory method:

$$K_t = (1 - h)K_{t-1} + I_t \qquad (4)$$
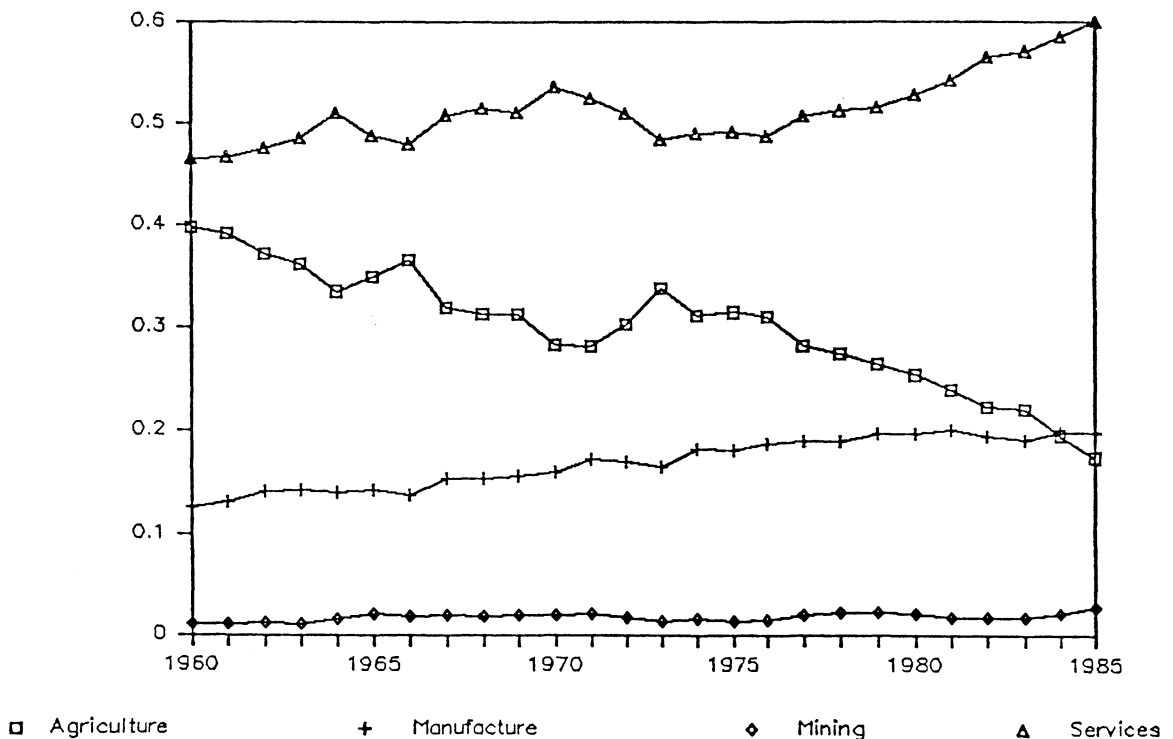
where K_t is the capital stock at the end of each

Fig. 1. Sectoral shares of GDP.

period, h is the depreciation rate, and I_t is a constant-price measure of the quantity of investment in each period. A value of 0.05 was chosen for h based on estimates surveyed in Limskul (1988). Some sensitivity analysis of the responsiveness of the results to this estimate was undertaken over a range from 0.035 to 0.06, but the results were not sensitive to this parameter.

Estimating the capital stock series using Eq. (4) requires an estimate of the unknown opening capital stock in the initial period. To minimize the effect of this unknown variable on the analysis, it was estimated for 1949, giving the opening value for the first year of the Summers and Heston data set (1950), which begins ten years before the start of the National Accounts data set. The estimate was obtained by first regressing the log of investment against time for the period 1950 to 1960 to obtain an average growth rate and a trend value for investment in 1949, designated I_0. Assuming the capital stock was in steady-state

equilibrium at that time allowed the opening capital stock to be estimated as:

$$K_0 = I_0 / (g + h) \qquad (5)$$

where K_0 is the opening capital stock in 1950, g is the estimated growth rate of real investment (and also of capital in the steady state), and h is the rate of depreciation. Since the capital stock series was estimated recursively over the entire period from 1950, any errors resulting from misestimation of the initial period capital stock are very unlikely to be important.

5. Estimation and results

Econometric results obtained using time series data appear to be influenced by the time series behavior of the data as well as the nature of the relationship between the variables of interest. Thus, it is desirable to examine the behavior of the data prior to estimation.
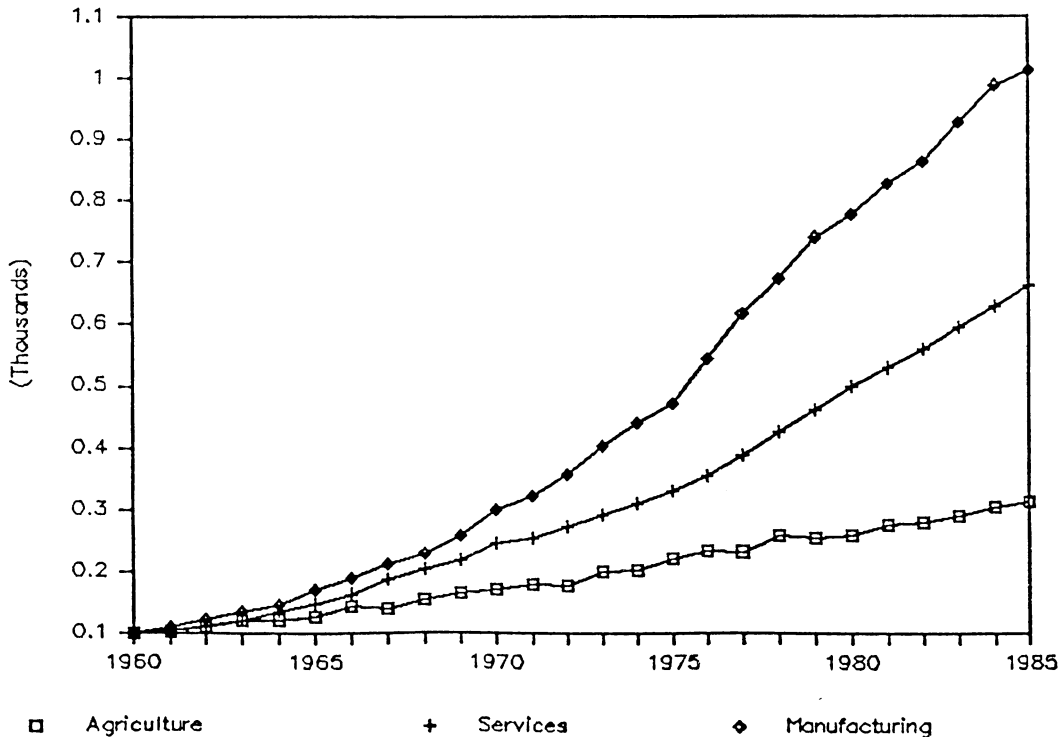
Fig. 2. Sectoral output trends.

5.1. Behavior of the data

The Thai economy grew rapidly over our study period of 1960 to 1985, with an average growth rate of real GDP of 6.9%. The GDP shares of agriculture, manufacturing, services and mining are shown in Fig. 1. The dominant feature is the decline in the share of agriculture, from over 40% in 1960 to around 17% in 1985. On average, the share of the agricultural sector declined by almost one percentage point per year during our study period. By contrast, the share of services grew from 47% to around 62%, an average increase of 0.5% per year. The manufacturing share rose, from a relatively small base, at 0.3% per year. The share of mining remained small.

Changes in the volume of output, as measured by value added at constant prices, are depicted in Fig. 2. These output indices are considerably less volatile than the corresponding value measures,

and their behavior appears to be dominated by relatively steady trends. The average rate of growth of output was highest in the manufacturing sector, at 9.5% per year, while services and agricultural output grew at 7.5% and 4.5%, respectively.

To focus attention on relative prices, the implicit price for each sector normalized by an economy-wide Tornquist index has been plotted in Fig. 3. It is clear that the price variables have been more volatile than the corresponding quantity variables. Over the period as a whole, the normalized prices of agricultural and manufactured goods trended downwards, by broadly similar amounts, while the price of services trended upwards. On average, the agricultural price index fell 0.4% per year relative to the manufactures price index. By contrast, the price index for services rose by an average of 0.9% per year relative to the price of manufactures. In contrast with the
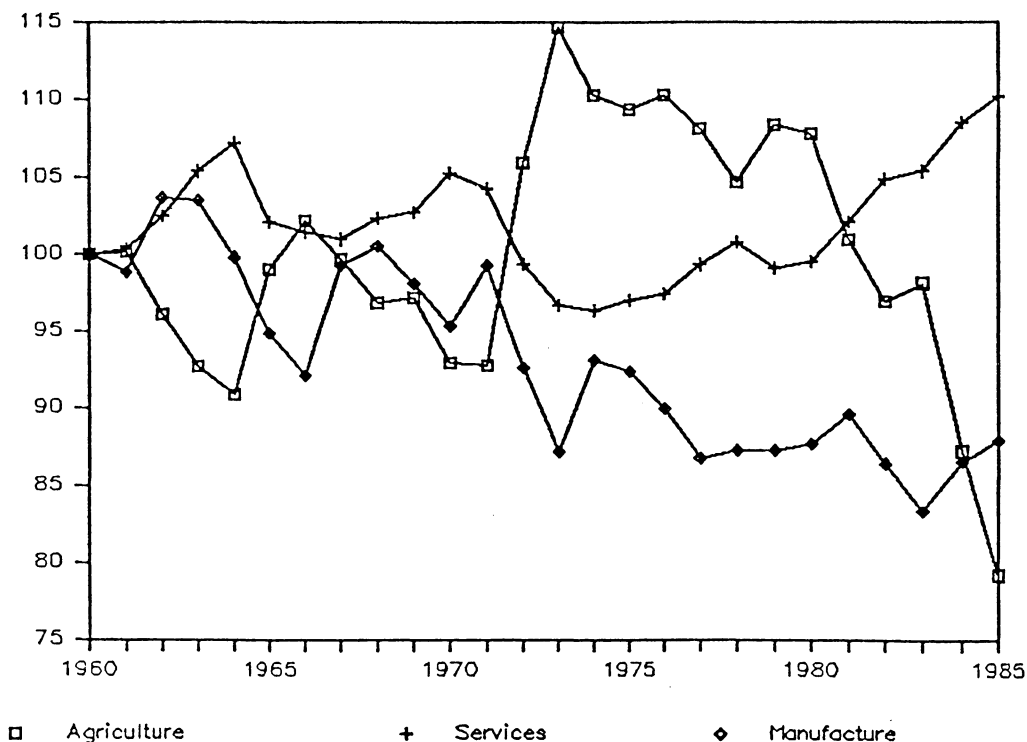

Fig. 3. Trends in deflated relative prices.

price indices, the indices of the capital stock and of population shown in Fig. 4 have increased relatively smoothly. The estimated real capital stock grew considerably faster than population – at an average annual rate of 9%, versus 2.6% for population.

All the series depicted in Figs. 1 to 4 trended up or down for sustained periods. For some of the series, such as population and the capital stock, these trends were not subject to major changes while for others, the trend varied markedly. The price series, in particular, did not trend smoothly, but rather appeared to 'drift', with persistent deviations from any underlying trend level of prices. This behavior can have major implications for inferences based on econometric analysis (Engle and Granger, 1987) and hence requires further consideration.

Most conventional econometric procedures and interpretations are intended for situations where the time series being analyzed have a constant underlying mean and variance, that is they are (mean-variance) stationary. In recent years, it has been recognized that these procedures must be carefully evaluated when the time series do not have a constant mean, but 'drift' in the sense that a shock in any one period changes the expected future value of the series in all subsequent periods. Such series are referred to as non-stationary or integrated.

The methodology used in this paper involved first testing the integration properties of the individual series used in the analysis. If all or most of the series were found to be integrated, then attention would be focussed on the cointegration properties of the estimating regressions. If all variables were found to be non-stationary, then standard regression theory would apply. The transformed regression model used is appropriate both for regressions on stationary data and for cointegrating regressions on non-stationary data since it creates stationary combinations of all variables.
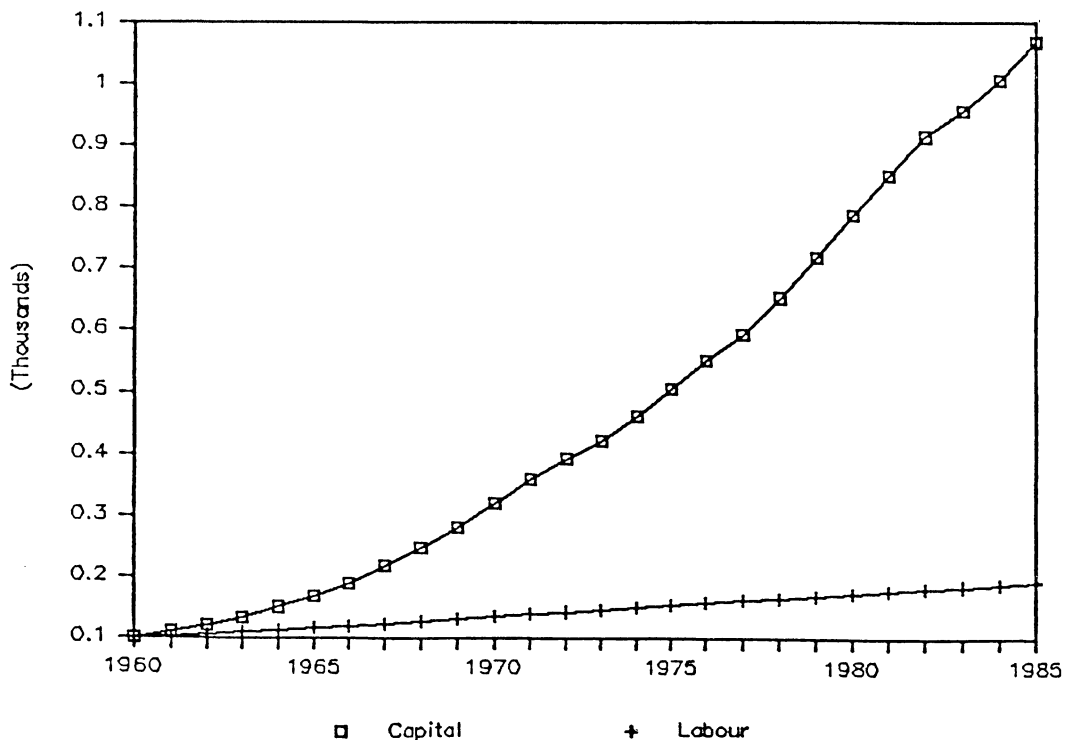
The results of the Dickey-Fuller and Aug-

Fig. 4. Trends in capital and labor.

Table 1
Dickey-Fuller and augmented Dickey-Fuller tests for variables used in the analysis

	Dickey-Fuller	Augmented Dickey-Fuller	Interpretation
ln p_A	−0.22 (−1.55)	0.03 (0.2)	Integrated
ln p_H	−0.10 (−0.93)	0.07 (0.79)	Integrated
ln K	−0.02 (−4.4)	−0.02 (−4.6)	Not integrated
ln L	−0.02 (−14.3)	−0.02 (−14.9)	Not integrated
S_A	−0.008 (−0.12)	0.04 (0.79)	Integrated
S_H	0.01 (0.13)	0.11 (1.4)	Integrated

ln p_A = log of the price of agricultural output deflated by the price of manufactures.
ln p_H = log of the price of services deflated by the price of manufactures.
ln K = log of the beginning of period capital stock.
ln L = log of the population.
S_A = share of agriculture in non-mining GDP.
S_H = Share of services in non-mining GDP.
Critical values: DF Test: −3.0 at 5%; −2.63 at 10%; ADF Test approximately −2.8.

Table 2
Single equation estimates of the translog share equations [a]

	Ordinary least squares		Two stage least squares [b]		
	S_A	S_H	S_A		S_H [c]
Constant	−3.9 (−1.11)	5.54 (1.57)	−5.10 (−1.08)	5.24 (1.07)	−2.15 (−1.00)
ln p_A	0.20 (11.6)	−0.20 (−11.6)	0.21 (9.56)	−0.22 (−9.6)	0.22 (11.1)
ln p_H	−0.17 (−3.2)	0.29 (5.4)	−0.17 (−3.09)	0.29 (5.06)	−0.18 (−3.47)
ln L	−0.20 (−2.6)	0.21 (2.65)	−0.23 (−2.47)	0.22 (2.24)	−0.19 (−2.66)
ln K	0.62 (1.49)	−0.69 (−1.69)	0.76 (1.40)	−0.68 (−1.21)	0.43 (1.57)
T	−0.003 (−0.78)	0.001 (0.22)	−0.004 (−0.70)	−0.0004 (−0.07)	
R^2	0.98	0.96	0.98	0.96	0.98
DW	2.21	1.69			
Diagnostics [d]					
Bera-Jarque	1.14	5.58			
RESET(2)	4.21	0.39			
B.P Hetero	0.69	0.43			
LM					
−1	−0.67	0.75			
−2	0.59	0.41			
DF	−1.13 (−5.46)	−0.85 (−4.13)			
ADF	−1.03 (−3.12)	−0.80 (−2.83)			

[a] Figures in parentheses are *t*-statistics.
[b] Instrument list for 2SLS: ln p_H; ln K; ln L; ln$(p_A)_{t−1}$; ln $H_{t−1}$; ln $K_{t−1}$; and ln $L_{t−1}$ where ln $A_{t−1}$ is the quantity of output in period $t − 1$ and ln $H_{t−1}$ is the corresponding quantity variable for services. All other variables are as defined in Table 1.
[c] Excluding the time trend variable.
[d] DW is the Durbin-Watson statistic. The Bera-Jarque test for normality of residuals is distributed as a Chi-Squared with 2 d.f. (Critical value at 5% = 5.99). The RESET(2) test is distributed as F(1, 19), with a critical value of 8.18 at the 1% significance level. The Breusch-Pagan test for heteroscedasticity is distributed as a Chi-Squared with 1 d.f. and a critical value of 3.84 at a 5% significance level. The LM *t*-statistics test for residual autocorrelation at each order of lag. The critical value for the D.F. test for co-integration is −3.0 at 5%. (For a detailed discussion of Diagnostic statistics, see Beggs, 1988.) A tabulated critical value for the A.D.F. test at this sample size was not available, but would be approximately −2.8 (see Fuller, 1976, p. 373; Engle and Granger, 1987).

mented Dickey-Fuller tests (Dickey and Fuller, 1979) for the variables appearing in the analysis are presented in Table 1. The results are generally consistent with the impression created by inspection of the data – that most of the data are integrated. For the share variables S_A and S_H which form the dependent variables in the translog estimating equations, we are unable to reject the null hypothesis of a unit root.

It should be noted that the agricultural output price and services output price are expressed relative to the manufactured output price. Thus, $p_A = P_A/P_M$ and $p_H = P_H/P_M$, where P_A, P_H and P_M denote the absolute prices of agricultural output, services and manufactured output. The factor endowment variables have not been deflated or, alternatively, constant returns to scale of the profit function in capital and labor has not been imposed. This restriction was tested in preliminary specifications and rejected. Constant returns to scale could still hold if all factors, including natural resources and human capital, were included in the model.

The formal hypothesis of a unit root is rejected for both the capital and labor variables. This could present problems given the apparent non-stationarity of the dependent variables since a stable long-run relationship cannot exist between a stationary and a non-stationary variable (Engle and Granger, 1987). In this case, however, the problem may lie more with the nature of the formal test than with the behavior of the time series. By the nature of these series, a shock in one period persists for a very long time. This is consistent with the very small estimated coefficients obtained in the tests. In practice, it seems likely that these variables will behave like integrated series.

5.2. Results

With the economy divided into three sectors, there are only two independent share equations to be estimated. The two chosen were the agriculture and services share equations. Two sets of single-equation estimates of the relevant equations are presented in Table 2. The first pair of equations shown was estimated by ordinary least squares (OLS), while the second group of three was estimated using a two-stage least squares estimator. The OLS equations allow an initial exploration of the properties of the relationship between the variables, and enable diagnostic tests on the regression residuals to be performed to ensure that the major underlying assumptions of the regression approach are not violated.

The OLS estimates are of particular interest given the apparent non-stationarity of the variables being analyzed. They allow simple tests for the existence of a stable long-run relationship between the variables (i.e. whether they are cointegrated). Further, if such a stable long-run relationship is found to exist, the estimators are known to converge and hence the OLS estimates may provide a reasonably good indication of the long-run relationship despite the omission of relevant dynamic variables.

The OLS regression for the share of agriculture in total output (S_A) presented in Table 2 yields coefficient estimates with signs consistent with expectations. As expected, the price of agricultural output has a positive impact on the value share of agriculture in non-mining output. Similarly, the price of services has a negative impact on agriculture's share. Consistent with the Rybczynski effect, an increase in the stock of capital relative to labor has a large negative effect on agriculture's share. Also as expected, an increase in the supply of labor raises the share of agriculture in total output.

The coefficient on the time trend variable used as a proxy for the effects of technical change is negative, consistent with relatively slow technical change in agriculture, although this coefficient is not statistically significant.

The coefficients in the S_H equation are also of interest. The positive coefficient on p_H and the negative coefficient on p_A are as expected. However, the positive coefficient on the capital variable, and the negative coefficient on the labor variable, are somewhat surprising. In terms of the Rybczynski effect, these results would be consistent with the service sector being relatively capital-intensive. This result may be reasonable given the inclusion of some relatively capital-intensive industries such as electricity and transport infras-

tructure in this aggregate, and the relatively heavy capital investment required for industries such as tourism. Technical change in services appears to occur at a similar rate to the weighted average of agriculture and manufacturing.

Diagnostic tests on the residuals of the OLS regressions are reported in Table 2. None of these test results provides statistical grounds to question the adequacy of the model. Even though indications of autocorrelation due to omitted dynamics would be acceptable, and even expected, given the simple, static nature of the specification, the test results provide virtually no indication of residual autocorrelation. The RESET tests for functional form and the Breusch-Pagan test for heteroscedasticity are particularly important since these problems would not be alleviated by the inclusion of additional dynamics. Neither of these tests provides cause for concern.

The final two tests reported in Table 2 are the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests for cointegration (Engle and Granger, 1987). When applied to the residuals of a potentially cointegrating regression, these tests provide an indication of whether a stable long-run relationship exists between variables which are themselves non-stationary. In conjunction with the Durbin-Watson test, these results are consistent with both of the reported regressions yielding cointegrating vectors.

In the estimation of the 2SLS estimates reported in Table 2, the actual value of ln p_A was replaced by an instrument formed using the relevant lagged price and quantity variables, and the relatively predictable capital and labor variables in order to mitigate the errors-in-variables problems arising from the use of actual, rather than expected, prices. A Wu-Hausman exogeneity test for statistically significant differences between the OLS and 2SLS estimators was performed by augmenting the OLS equation with the residuals from the first-stage regression of the 2SLS procedure (for a discussion, see Beggs, 1988). This variable was significant at the 10% level in the S_A equation and at the 5% level in the S_H equation. As can be seen from Table 2, the coefficients in the 2SLS equations are, in most cases, very similar to those in the OLS equations. However, the

Table 3
Estimated elasticities of agricultural output with respect to price

	Agriculture	Services	Manufacturing
A. From equation including technical change bias			
1961	−0.06	0.03	0.03
1965	−0.05	0.02	0.03
1970	0.03	−0.04	0.01
1975	0.0	−0.05	0.05
1980	0.07	−0.1	0.03
1985	0.4	−0.38	−0.02
Sample mean	0.01	−0.04	0.03
B. From equation excluding bias of technical change			
1961	−0.04	0.01	0.03
1965	−0.03	−0.01	0.04
1970	0.06	−0.09	0.03
1975	0.03	−0.09	0.06
1980	0.09	−0.15	0.06
1985	0.48	−0.46	0.02
Sample mean	0.04	−0.09	0.05

coefficient on ln p_A is noticeably larger in the 2SLS equations. The coefficients on both the labor and capital variables also increase in absolute value in the agricultural share equation.

Some of the key elasticities of output with respect to price shown in Table 2 do not satisfy the requirements of economic theory at all points in the sample. To illustrate this point, the estimated elasticities of agricultural output with respect to price obtained from the 2SLS equations are presented in Table 3 for selected points in the sample. A necessary condition for a translog profit or revenue function to be consistent with economic theory is that it be convex with respect to output prices, a necessary (but not sufficient) condition for which is that the elasticities of output with respect to own-price be positive. As can be seen from Table 3, this condition is satisfied at the sample means, but not at some early observations in the sample. The estimated own-price elasticities of supply of agricultural output increased noticeably over time.

It was thought that the low estimated elasticity of agricultural output with respect to its own price may have been due to the use of the less efficient single-equation approach to estimation. Accordingly, the two independent share equations in the system were next estimated as an

Table 4
Estimates of static and dynamic systems subject to symmetry constraint

	S_A	S_N	S_A	S_N
Constant [a]	−4.03 (−1.15)	5.65 (1.62)	−8.18 (−2.04)	14.06 (3.05)
ln p_A	0.20 (11.8)	−0.20 (−12.02)	0.185 (10.4)	−0.18 (−9.02)
ln p_N	−0.20 (−12.0)	0.31 (9.56)	−0.18 (−9.0)	0.27 (5.14)
ln K	−0.21 (−2.8)	0.21 (2.82)	−0.25 (−3.82)	0.29 (3.68)
ln L	0.64 (1.55)	−0.72 (−1.76)	1.09 (2.4)	−1.63 (−3.17)
T	−0.003 (−0.7)	0.0006 (0.13)	−0.01 (−1.59)	0.02 (2.19)
D ln p_A			−0.07 (−2.2)	0.06 (1.56)
D ln p_N			0.17 (1.51)	−0.08 (−0.57)
D ln K			−0.04 (−0.27)	0.06 (0.32)
D ln L			−1.31 (−0.84)	4.73 (2.62)
DS_A			−0.22 (−0.36)	−0.26 (−0.36)
DS_N			−0.63 (−0.78)	−0.18 (−0.19)

[a] The prefix D denotes the first difference of the relevant variable.

interdependent static system. Finally, the system was estimated when augmented with first-order dynamics to account for the major adjustment costs and delays in structural transformation. The systems approach to estimation did not overcome the apparent problem of low output supply elasticity identified in the original single-equation estimates. In general, the results from estimation of both the static and the dynamic systems were similar to those obtained using the single-equation approaches (see Table 3), although an unexpected consequence of the systems estimation was a decline in the estimated own-price coefficient in the share equation for agriculture.

The results of the general first-order dynamic model presented in Table 4 were of particular interest given that the static system did not satisfy the convexity condition at all points in the sample. As was discussed in Section 3, estimation of

the dynamic system leads to coefficients on the current explanatory variables which can be interpreted as long-run coefficients. Given this, it was expected that the coefficients obtained in this model would be larger in absolute value than those obtained using the static model. As is evident from the coefficients in Table 4, this was not the case for the price coefficients. The small average own-price elasticities obtained could reflect problems of aggregation, and the well known tendency for time series estimates of supply response parameters to be small in absolute value.

The single-equation 2SLS estimates satisfy the necessary condition of a positive own-price elasticity at the sample mean and at most points in the sample (see Table 4). These equations allow a simple decomposition of changes in the share of agriculture in the economy in response to the major determinants identified in the literature:

Table 5
Estimated sources of change in the share of agriculture in GDP

	Contribution to agriculture's relative decline [a]
Contributions of	
D ln p_A	10
D ln p_H	18
Total price change effect	**28**
D ln K	194
D ln L	−122
Total factor accumulation effect	**72**
Total	**100**

[a] From equation excluding T in column 5 of Table 2.

changes in relative prices, changes in relative factor endowments, and biases in technical change. The results of such a decomposition are presented in Table 5, based from the final column of Table 2. The decomposition presented in Table 5 draws out the importance of changes in aggregate factor endowments for the composition of output. Almost three quarters of the decline in agriculture's share was due to increases in the per capita endowment of capital. Price effects, by contrast, account for only 28% of the total decline of agriculture's share of GDP.

The coefficient on the time trend variable used to proxy the possible bias of technical change in agriculture relative to the rest of the economy presents particular difficulties. This variable is statistically insignificant and was deleted from the regression reported in Table 4. Nevertheless, there is widely believed to be such a bias in technical change, at least in the poorer countries (Dowrick and Gemmell, 1991; Chenery et al., 1986). When the measure for the potential bias of technical change is included, this effect is an important contributing factor to the overall decline in the share of agriculture in the economy. It contributes an estimated 49% of the reduction in agriculture's share. However, because the time trend is not statistically significant, a second set of estimates is presented based on the 2SLS equation with this variable set to zero. If the output price elasticities were higher, the effects of price on the value shares would obviously be higher, although this effect would not be greatly affected by an own-price elasticity in the 0.15 range which Peterson (1979) cites as typical for time series analyses.

6. Conclusions

Based on a survey of the literature on the role of agriculture in economic development, we identified three fundamental determinants of the ubiquitous decline in the economic role of agriculture as economies develop:

1. demand/supply forces, especially on the demand side, which lower the price of food relative to prices of all other goods;

2. a possible bias in technical change against agriculture; and

3. changes in factor endowments which can be expected to cause relatively labor-intensive sectors to contract.

The demand-side influences identified above operate on the structure of production solely through their effects on relative commodity prices. We have not attempted to explain these relative price movements. Our attention is focussed on the proximate determinants of agriculture's share: relative output prices; bias in technical change; and relative factor endowments.

A system of equations was formulated based on a translog profit function representation involving these three determinants of output. These equations were estimated for Thailand, a middle income developing country where structural transformation has been rapid. The preferred single-equation estimators yielded small positive own-price supply elasticities at the sample mean and at all but a few early years in the sample. Small absolute values of the own-price elasticities are not particularly surprising, since own-price elasticities at the aggregate level would be expected to be substantially smaller than estimates at the individual commodity level.

A decomposition of the total decline in the share of agriculture in GDP was undertaken using the preferred single-equation parameter estimates. Changes in the economy's stocks of capital and labor, and a possible bias against agriculture in technical change were found to contribute over three quarters of the total decline in the share of agriculture in the Thai economy. The relative price effects which have received the most attention in the literature were found to be minor. With both of the models used, the decline in the price of agricultural output relative to the price of manufactured output contributed around 10% of the measured decline in agriculture's share of GDP. The rise in the relative price of services contributed an additional 18%. Moreover, the mechanism through which these relative price changes affected agriculture's measured share of GDP was almost entirely through valuation effects alone – their effects on the value shares

used in measuring GDP – rather than through agriculture's quantity response.

Our overall conclusion is that, for Thailand at least, supply-side influences such as capital accumulation appear to be the most important determinants of the decline in agriculture's share of GDP. Demand-side factors, operating through relative commodity prices, seem to be much less important. These results are consistent with those from a related study of Indonesia (Martin and Warr, 1993) and together with that study provide, to the best of our knowledge, the first empirical evidence on the relative importance of these phenomena for changes in the size of the agricultural sector. If supported by further research, this conclusion has important implications for policies affecting economic development and structural change. It also suggests a reorientation of the literature on the causes of agriculture's relative decline during economic development towards a much greater emphasis on the role of supply-side influences, especially that of factor accumulation.

Appendix 1

Rybczynski effect

Since the operation of the Rybczynski effect is less obvious and less widely understood than that of demand-side forces, a brief review of its mechanism in a simple two factor model is helpful (see also Ethier, 1988). For expositional simplicity, we take the case of an open economy in which commodity prices are externally given and which contains two sectors, agriculture and non-agriculture. These sectors use two factors of production: capital and labor. The aggregate economy-wide stocks of each of these factors are given exogenously, but the factor prices and the allocation of factors across sectors are determined endogenously within the model.

Fig. A.1 shows agricultural output (A) on the vertical axis, and an aggregate of all non-agricultural output (N) on the horizontal axis. The diagram illustrates the shift in the production possibility frontier, from VV to WW, resulting from
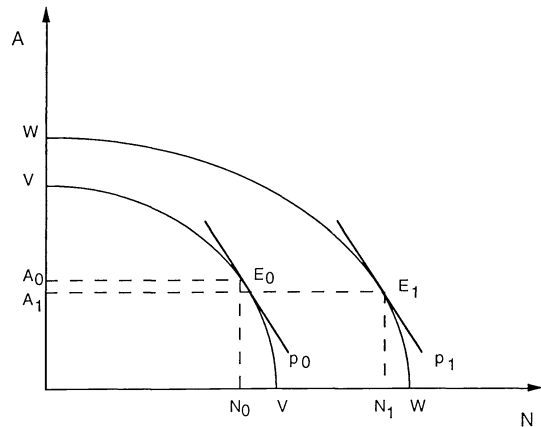

Fig. A1. Capital accumulation and the production possibility frontier.

capital accumulation with a given labor force. It is assumed throughout that agriculture is the more labor-intensive industry and that constant returns to scale apply. At constant relative prices ($p_0 = p_1$), the shift in the production possibility frontier causes non-agricultural output to rise from N_0 to N_1, while agricultural output falls from A_0 to A_1.

Fig. A.2 shows the mechanism by which capital accumulation causes the production frontier to shift, as illustrated in Fig. A.1. Employment of capital and labor are shown on the two axes. The analysis utilizes the Stolper-Samuelson theorem that relative factor prices are determined by relative commodity prices and technology, by which
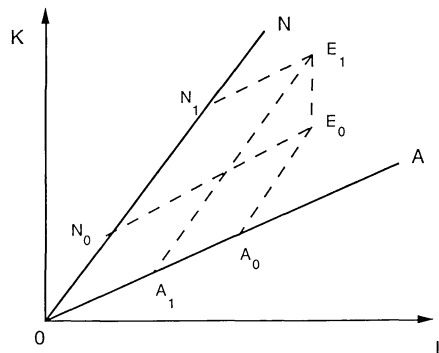

Fig. A2. Capital accumulation and sectoral outputs.

we mean the *production functions* faced by each industry (Ethier, 1988). Commodity prices are held constant in Figs. A.1 and A.2, and hence factor prices are also constant.

In Fig. A.2, the slopes of rays OA and ON show the proportions in which capital and labor are employed in agriculture and non-agriculture, respectively, at these given factor prices. Constant returns to scale implies that the output of each industry can be read from the diagram by looking at the distance from the origin at which factor employment occurs. The initial aggregate factor endowment is given by E_0, requiring outputs in agriculture and non-agriculture of A_0 and N_0, respectively, to achieve full employment with a total factor endowment of E_0.

Now assume that capital accumulation combined with a constant aggregate labor force moves the endowment point to E_1. Commodity prices and technology do not change. Thus, production continues to occur on the rays OA and ON, as before. For total factor employment to become E_1, employment of both factors in non-agriculture must rise to N_1, but employment of both factors in agriculture must *fall* to A_1. Agricultural output must also fall, in proportion to its decreased factor employment.

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