AGRICULTURAL DEVELOPMENT PATTERNS

by

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ABSTRACT

A two-sector general equilibrium model of economic growth has been developed in conjunction with a political economy model of agricultural pricing policies. These theoretical models were used to both present arguments regarding the impact of economic and political forces on agriculture's share of GDP, as well as to provide guides towards specifying the econometric models. Empirical analysis was performed using two data sets. The first covered 81 countries for the years 1971-1981, but contained no explicit measure of policy. The second covered 22 countries for the years 1985-1989, and contained an explicit policy measure in the form of producer subsidy equivalents. Due to the lack of a policy measure in the large data set, a reduced form equation for agriculture's share had to be solved for in order to yield an operational statistical model. . Results from this model indicated that variations in agriculture's share could be explained by: level of development, world prices, natural resources, and the political economy variables. For the smaller data set, agriculture's share and producer subsidy equivalents were considered to be jointly endogenous, and so were estimated as a system. It was found that agriculture's share has a negative effect on producer subsidy equivalents, however, producer subsidy equivalents did not have a statistically significant effect on agriculture's share.

1. INTRODUCTION

Within the field of development economics, "structure" refers to a country's production, consumption, and demographic characteristics at a given level of development. On a commodity level production structure is the relative value of sectoral outputs in total production. However, production structure can also refer to technological relationships, such as input-output ratios. Consumption structure also has several dimensions. Most often it refers to the relative importance of individual commodities in consumer's consumption bundles. Sometimes consumption structure is expanded to include parameters representing an economy's marginal propensity to consume, which will affect its saving and investment ratios. Finally, structure can refer to a country's demographic characteristics.

Using the above definition of structure, development patterns are, "systematic changes in structure associated with rising income levels or some other index of development" (Chenery 1975, 4). Essentially general equilibrium in nature these patterns are the observed responses to movements along underlying demand and supply equations. For example, using income per capita as an index of development the structure of consumption will vary as income increases in accordance with relative income elasticities of demand. Sustained increases in real income per capita usually are caused by increases in human and physical capital per worker. A likely consequence of this increase in capital/labor ratios is a change in production structure as the economy adjusts to its new comparative advantage.

Much interest in the development economics literature has centered around these patterns because they are at the core of economic development, and it is thought that structural change and growth are strongly interrelated. In fact, some researchers have emphasized the importance of structural change as a determinant of growth. Kuznets writes, "some structural changes, not only in economic but also in social institutions and beliefs, are required, without which modern economic growth would be impossible" (Syrquin 1988, 208). Chenery also viewed structural change as a prerequisite for economic development when he described them "as a set of interrelated changes in the structure of an economy that are required for its continued growth" (1979, xvi). Structural change has been linked to growth through accumulation processes, such as increases in saving and investment ratios, which improve the long run productive potential of an economy. On a more short term basis, structural change can increase growth rates by reallocating resources to more productive sectors. Recently, structural changes in demographic variables and human capital have been given more attention, particularly the importance of education levels which are a necessary prerequisite for technology adoption.

Research on development patterns has uncovered a number of such processes that occur with such regularity they have been called the "stylized facts" of development (Syrquin 1988, 223). Providing a detailed analysis of all of these patterns is beyond the scope of this study. Instead, attention is focused here on production structure. The goal of this study is to explain the variability in agriculture's share of production observed across countries and over time.

Two models are developed to provide a theoretical foundation for this analysis. The main consideration in their development is they must be able to account for the major differences between countries, while at the same time remaining general enough to highlight transnational or uniform factors. The first is a two-sector general equilibrium model of economic development, and the second is a political economy model of agriculture pricing policy. These models are of interest in themselves, and also in conjunction because there might be an interaction between policy regimes and the level of agriculture's share. In this case both would work together to produce an equilibrium growth path.

Using intercountry data allows four sets of questions to be asked. First, holding country specific factors constant, does agriculture's share of production systematically vary as per capita income increases? That is, does the "stylized fact" of declining agricultural shares hold up with our data, and, if it does, what are its orders of magnitude? Second, holding the level of development constant, what effects will resources and policy have on agriculture's share? Third, are there any interactions between resources and income levels? We might expect that at different income levels the response of agriculture's share to different resource endowments will differ. Last, is it possible to detect any changes in the average pattern in response to changes in global economic conditions?

The rest of this paper is organized as follows. Chapter 2 contains a review of the literature used in the development of the theoretical models. In chapter 3 theoretical models of economic growth, and the political economy of agricultural pricing policy are presented. Chapter 4 presents the data, statistical models, and regression results of the empirical analysis. Finally, chapter 5 summarizes the results and suggests some areas for further research.

2. LITERATURE REVIEW

Reviewed here are three strands of literature which have been combined to produce a model of equilibrium growth paths. The review begins with the literature on development patterns, which consists of empirical work providing a unified description of these patterns, as well as theoretical work concerned with identifying their causes. Next, the literature on intercountry agricultural productivity is reviewed. Research in this area has been concerned with developing a general theory of agricultural development, and identifying factors causing productivity differences across countries. Concluding the review is a section on the political economy literature seeking to explain the observed policy structures across countries.

Development Patterns

One branch of literature on development patterns is mainly concerned with the identification of empirical regularities that typically accompany economic development. For the most part, this literature is more concerned with provviding an overall descriptionof the development process rather than a detailed description of a particular pattern. There is a long history in the search for these patterns, but some of the most notable studies using econometric techniques are Chenery (1960), Chenery and Taylor (1968), and Chenery and Syrquin (1975). In each paper the analysis is divided into two parts. The first part presents the average patterns or the "stylized facts" of development which emerged from regressions performed on the entire sample. The second part seeks to stratify the sample into more homogeneous country groups, and then compare the growth patterns between the groups.

Chenery (1960) used a more rigorous econometric approach than that which was used by previous researchers, such as Kuznets. He developed a model of sectoral growth functions which in a reduced form resulted in:

$$X_i = f(Y,N).$$

X_i = output of sector i

Y = per capita income

N= population.

For his regression equation he used a double log specification:

$$\ln V_i = \ln \alpha + \beta(\ln Y) + \gamma(\ln N)$$

where V_i is per capita value added in sector i.

Chenery and Taylor (1968) provide a uniform description of production patterns which is later expanded on in Chenery and Syrquin (1975) to include production, accumulation, and demographic patterns. While a formal theoretical model was not developed, there is an implicit general equilibrium model underlying the empirical analysis. The basic hypothesis underlying the set of statistical estimates is that development processes occur with sufficient uniformity among countries to produce consistent patterns of change in resource allocation, factor use, and other structural features.

The basic cross country regression specification used in Chenery and Taylor (1968) was:

$$\ln X_i = \alpha + \beta_1 \ln Y + \beta_2 (\ln Y)^2 + \gamma \ln N.$$

X_i = share of sector i in GNP

Y = per capita GNP (in 1960 dollars)

N = population

In contrast to Chenery (1960) the dependent variable in these regressions was always in a share form, which is how changes in production structure are typically measured. They divided the economy into three sectors which were hypothesized to have similar supply and demand characteristics. These sectors were primary (mining and agriculture), industry (manufacturing and construction), and services (all other sectors).

Chenery and Syrquin (1975) provide a uniform analysis of 10 basic processes. These processes were grouped into three main categories: accumulation processes, resource allocation processes, and demographic and distributional processes. Taken together they describe different dimensions of the overall structural transformation accompanying economic development. Two econometric specifications are used to measure all processes. These specifications are:

$$X = \alpha + \beta_1 \ln Y + \beta_2 (\ln Y)^2 + \gamma_1 \ln N + \gamma_2 (\ln N)^2 + \sum \delta_i T_i$$
$$X = \alpha + \beta_1 \ln Y + \beta_2 (\ln Y)^2 + \gamma_1 \ln N + \gamma_2 (\ln N)^2 + \sum \delta_i T_i + \varepsilon F$$

X = dependent variable measuring some dimension of structural change such as sectoral shares of production, or sectoral export shares as a fraction of GDP

Y= GNP per capita in 1964 U.S. dollars serving as an overall index of development as a measure of output

N = population in millions allows for the effects of economies of scale and transport costs on patterns of production and trade

T_i = time period.

F = net resource inflow (imports minus exports of goods and nonfactor services) as a share of total GDP

After finding the average development patterns for the entire sample, the next step in each of these papers was to look more closely at the sources of deviation. As can be seen, their regression equations contain no variables to account for the major sources of diversity between countries. Several of the most important are: differences in natural resource endowments, different social objectives, and different development strategies. The rationale for excluding these variables is the data are either not available or of poor quality. Instead, they developed several indexes which were then used to stratify the sample into groups of countries expected to be following more homogeneous development paths. The first index is population, to account for the effect of market size on development phenomena. The second index is derived from comparing actual versus expected trade levels on the assumption that the combined effects of a country's resource endowments and policy choices will be revealed in their trade patterns. Based upon these two indexes the sample was divided into: large countries; small, primary commodity-producing countries; and small, manufactured-commodity producing countries. Large countries were not divided into primary or manufacturing oriented because of the lack of observations for them

Although the results of these three papers are not identical since they came from different data sets and the regression equations are not the same, there are some common themes that emerge. In all cases, stratifying the sample into homogeneous groups greatly improved the efficiency of the regressions, and highlighted differences in the timing and magnitude of the various development processes. As theory would predict, countries classified as small, primary-commodity producing had significantly larger primary shares than the other two country groups for a given level of per capita income. Small, manufactured-commodity producing countries were at the opposite end of the spectrum with relatively large manufacturing shares early in the development process. The development paths for the large countries tended to lie in the middle, although somewhat closer to the countries classified as small, manufactured-commodity producing.

One of the most consistent of the "stylized facts" of development is that agriculture is a declining sector as measured by its share of production. Antle (1988) gives a detailed description of a two-sector growth model used to explain why this phenomenon occurs. A basic implication of the model is that given a closed economy and neutral growth agriculture will be a declining sector. This decline is caused by a lower income elasticity of demand for agricultural relative to non-agricultural commodities, which in turn causes a relative decrease in the production of agricultural versus non-agricultural commodities. However, in an open economy supply is no longer linked to demand. In this case the production path is determined by relative prices, and the shape of the production possibilities frontier. What then causes agriculture's share to decline with economic development in virtually all *open* economies?

According to Anderson (1987), part of the reason may lie in the presence of non-tradable goods. He also uses a two-sector model of growth, but instead of dividing the sectors into agriculture and non-agriculture, he divides them into tradable and non-tradable. Since in equilibrium, supply must equal demand for non-tradable goods the structure of demand will influence production much like the closed economy case. Given neutral growth, if the income elasticity of demand for tradable goods is less than for non-tradable goods the relative share of tradable goods produced will decline with growth. As evidence that this is the case he points out that:

> "given the non-tradable sector is roughly equivalent to services, and that services account for one third of expenditures in low income countries, and two thirds of expenditures in high income countries it is reasonable to assume that the income elasticity of demand for non-tradables exceeds one, and hence the corresponding income elasticity of demand for all tradables is less than one" (1987, 201).

He concludes, that since agriculture is for the most part tradable, and non-tradables are included in the non-agriculture sector, agriculture's share of GDP will decline with economic growth.

Antle (1995) develops a political economy model to use in conjunction with the two sector growth model described in Antle (1988) to "examine the properties of growth paths that correspond to both economic and political equilibria" (1995). His model, which is presented below, assumes policy and agriculture's share of GDP are jointly endogenous, interacting with each other throughout the development process.

$$SA = \alpha_0 + \alpha_1 \ln(GC) + \alpha_2 \ln(AC) + \alpha_3 \ln(NPC)$$
$$\ln(NPC) = \beta_0 + \beta_1 SA + \beta_2 \ln(AC) + \beta_3 \ln(UR)$$

SA = agriculture's share in GDP

GC = per capita GDP

AC = arable land per capita

NPC = nominal protection coefficient

UP = share of population in urban areas

LP = agricultural labor as a percent of total population

As with the other work on development patterns, his results indicate agriculture's share declines systematically with income. More importantly, however, his hypotheses of a joint dependency is also upheld. Antle's policy measures are NPC which measure the difference between domestic and border prices for agricultural commodities. Therefore, an increase in NPC means agricultural goods are being subsidized more heavily, and should result in an increase in SA. His results show NPC has a significant positive impact on agriculture's share of GDP. While, at the same time, agriculture's share is found to have a significant negative impact on NPC.

Intercountry Agricultural Productivity

Using intercountry data, researchers have estimated agricultural production functions in order to find factors explaining the great differences in agricultural productivity among countries. These differences come from two sources. First, productivity levels will change with increased capital and technology, sources of growth which by their nature are potentially open to all countries. Second, productivity levels depend upon country specific factors, such as land quality and quantity, and climate. This literature provides a guide towards the interpretation and specification of both production functions used in the two-sector growth model developed in this study.

According to Hayami and Ruttan (1985), agricultural development depends upon developing and adopting innovations which reduce the constraint imposed by the most scarce resource. Their theory of induced innovation postulates that this process will be determined endogenously by economic signals. For example, in the United States mechanical implements such as the thresher were developed in response to the constraint imposed by the relative lack of labor. Meanwhile, in Japan higher yielding seed varieties, requiring more labor input, but less land, were developed in response to the relative lack of land. This process was formalized in the specification of a meta-production function which can be interpreted as the envelope of all possible techniques available, or that will become available. Movement along the meta-production function is induced by changing input and input/output price ratios. According to this hypothesis, productivity levels will depend not only on conventional inputs, such as land and labor, but also on some non-conventional inputs which are thought to influence the producer's ability to move along the meta-production function. They interpreted the production function they estimated using intercountry observations as a meta-production function, representing the envelope of the most efficient production points in the world.

Craig, Pardey, and Roseboom (1994) also look at international agricultural productivity patterns. Like Hyami and Ruttan, they imposed some structure on the data through a meta-production function. However, they hypothesized that the conventional inputs were measured with error. Defining Z_i to be quality shifters, the relationship between observed input X_i and effective inputs X_i^* is $X_i^* = \alpha_i Z_i X_i$. Since growing conditions are not constrained by political boundries agro-ecological zones are included in their data set. In general, the coefficients for the agro-ecological zones were insignificant and of small size, suggesting that differences in growing conditions across countries can be reasonably explained by country-specific factors.

One of the assumptions of the meta-production function is that all countries produce on the same production function. Mundlak and Hellinghausen (1982) criticized this assumption, arguing that while all countries have access to the latest technology, adoption of a particular technique depends upon environmental and economic factors, which they defined as state variables. Changes in state variables cause a change in implemented techniques which, in turn, cause changes in input-output relationships. According to them, there is no reason why the parameters defining input-output relationships should remain constant. Instead, they specify a variable coefficient model where the parameter estimates for the conventional inputs depend upon the state variables.

Schultz (1978) emphasizes the role producer incentives play in increasing productivity levels. Farmers collect economic information to use in calculating expected costs versus expected returns. This calculation is the incentive farmers respond to in deciding what crops to plant, what inputs to use, and how much to invest in additional capital. Thus, to increase productivity levels it is not enough that better inputs and production techniques are available. Their must also be an economic incentive for producers to want to adopt them. He argues that one of the primary causes of low productivity levels in low income countries is that governments interventions have reduced economic incentives to the point that farmers are not making the necessary investments. According to Brown (1978), the most important long run effects of price incentives on production may be through price-induced shifts in the production function. Higher agricultural prices may stimulate production by inducing the discovery and adoption of new agricultural technologies.

Fulginiti and Perrin (1992) estimated a variable coefficients model similar to that of Mundlak and Hellinghousen. Included in their state variables are past prices to test the hypothesis that past prices will affect the rate of technological change, and, therefore, production levels. Once again, they define a technique as a particular combination of inputs producing a particular output. The collection of all techniques is the technology available at a point in time. Coefficients are determined at any one place and time by previous choices, and the current technological, natural, and institutional environment. Their results indicate that a 10% change in past output price expectations would produce a 1.3% shift of the production function, while increases in wages and fertilizer prices would shift the production function down by .9% and .3% respectively. It appears from this study that even after controlling for research, land quality, and schooling, past prices still have an effect on the level of production. This indicates prices influence innovations that cannot be conventionally measured.

Tolley, Thomas, Nash, and Snyder (1994) concentrate on supply response in a dynamic context. Like Fulginiti and Perrin, they build on induced innovation concepts to take into consideration the effects of price on technology. Their hypothesis is prices not only affect the level of supply in relation to some long term trend, which is determined by technological advances, but it also will affect the trend itself, through its effect on the rate of technological discovery and adoption. To test their hypothesis they performed a variety of regressions in which yield growth is a function of the growth of other inputs and on the level of a real price index. While the regression coefficients with respect to price were never highly significant, they were quite large, suggesting prices are potentially an important determinant of long run productivity.

Hu and Antle (1993) estimated an aggregate agricultural production function jointly with a political economy model to test the hypothesis that agricultural policy will affect agricultural productivity. Their results confirm this hypothesis, although the impact of policy on productivity occurs in a non-linear way. Higher levels of subsidization are associated with higher output levels after differences in resource endowments, input endowments, input levels, and general economic conditions have been accounted for.

Binswanger, Yang, Bowers, and Mundlak (1987) estimated aggregate agricultural supply responses based on the concept of a meta-production function. The optimization problem is to maximize profits subject to the constraint that the choice of technique is within the feasible technology set. Thus, supply depends on output and input prices as well as the level of implemented technology. Their results show strong supply responses to the shifters, defined as variables affecting which technology will be implemented, but own-price elasticities were negative. Since the shifters have such a strong effect on output, explaining long-run supply would require an analysis of the determinants of change of the shifters themselves, which is not done in this paper.

While there are some theoretical differences on how to draw statistical inferences from the data, the goal in all cases is to account for intercountry differences in agricultural productivity. To do this variables were divided into conventional inputs and non-conventional inputs. Table 1 contains a summary of the variables used in these studies.

Table 1. Conventional and Non-conventional Variables Used in Studies Estimating Intercountry Agricultural Production Functions.

Hayami and Ruttan	Craig, Pardey, Roseboom	Mundlak and Helling-hausen	Fulginiti and Perrin	Tolley, Thomas, Nash, Snyder	Hu and Antle
		Dependent Variable			
Output per farm	Output per worker	Total value in wheat units	Total value in 1980 international dollars	Average annual Growth rate	Output per farm
		Conventional Inputs			
Labor	Labor	Labor	Labor		Labor
Land	Land	Land	Land		Land
Fertilizer	Fertilizer	Fertilizer	Fertilizer	Fertilizer growth	Fertilizer
Livestock	Livestock	Livestock	Livestock		Livestock
Tractor hp	Tractor hp	Tractors	Tractor hp	Tractor growth	Tractors

Table 1, cont.

Non-conventional Inputs					
Literacy ratio	Adult literacy	Potential dry matter	School enrollment ratio	Growth rate of irrigated area per hectare	Literacy ratio
Technical education	Research expenditures	Water deficit	Research expenditures	Past output price	Infra-structure
	% Arable & Perm. Cropland		Peterson's land quality index		Policy
	% Irrigated		Past output price		
	Agro-ecological zone		Past fertilizer price		

Political Economy

Researchers on both development patterns and intercountry productivity have developed models to show the effects of policy. However, except for the case of Antle (1995) and Hu and Antle (1993), these models are not concerned with the underlying causes of an observed policy regime. Following the work of Antle (1995), this study also develops a political economy model to use in conjunction with the growth model. Reviewed here first are two theoretical political economy models which provided the structure for the one developed in this study. Second, the results of a World Bank study on the political economy of agricultural pricing policy in developing countries are summarized. This study does not develop an overall theory of political economy , but it does provide a comprehensive synthesis of the observed policy regimes, and the conditions under which they are found.

Becker (1983) develops a model where the observed policy regime represents a political equilibrium among pressure groups. Pressure groups compete for political influence by spending time, energy, and money on the production of political pressure. Any group able to increase its pressure is able to obtain a more favorable policy environment. However, since the total amount raised from taxes must equal the total amount available for subsidies, a more favorable policy environment for one group necessarily will hurt at least one other group. Consequently, pressure groups compete for political influence. A political equilibrium will be obtained when all groups have maximized the welfare of their members by spending the optimal amount on political pressure, given the productivity of their expenditures, and the behavior of other groups. The structure of this equilibrium will depend upon the relative ability of the different groups to generate pressure. Comparative statics results indicate that this ability will be greater for more efficient groups, for groups with intrinsically more influence, and for groups whose benefits are financed by a small tax on many persons (Becker 1983, 391).

Bates and Rogerson (1980) develop a model where the ability of particular interests to manipulate the state depends on their ability to form coalitions. Rather than a compromise, interest groups are divided into clear winners and losers. The winners are those interests which have been able to form coalitions, whereas, the losers are composed of all interests excluded from coalitions. Next, in their analysis was a discussion of group characteristics that make for attractive coalition partners. They assume all economic agents are both producers and consumers. Price increases will therefore have two effects upon the members of the coalition. First, they will raise their incomes in their capacity has producers. Second, they will force all members to pay more for their consumption bundles. Consequently, interest groups invited to join a coalition will be those who produce goods that comprise a small share of the total consumption budgets of the other members of the coalition. Tolley, Thomas, Nash, and Snyder add to this model by treating citizens as producer/consumer/taxpayers rather than simple producer/consumers. With this assumption the costs of adding a member to a coalition depend not only upon the increase in the prices of goods consumed, but also on tax increases. In this case, industries that produce goods which comprise a large portion of a country's GDP will not be attractive coalition members because of the large tax increase including them is likely to entail.

Recently, a comprehensive World Bank study on the political economy of agricultural pricing policy in less developed countries was conducted, and the results were summarized by Krueger (1992). She does not develop an overall "theory of political economy," but rather suggests some of the patterns and themes that emerged from the historical experiences of individual countries. In many instances the underlying political economy causes of these patterns may be partially explained by the theoretical models developed by Becker, Bates and Rogerson, and others.

She argues that the evidence strongly points toward the importance of ideology in contributing toward the discrimination against agriculture. In the past, development economics has been concerned with how to industrialize, as industrialization was seen as the key to economic growth. This widespread ideology, coupled with the belief that taxing agriculture was relatively costless, had such great credibility the agricultural interests were powerless to fight against them.

Krueger also asserts that the blanket statement "poor countries tax agriculture while rich countries subsidize agriculture" is somewhat misleading as even among poor countries there was considerable variation in rates of taxation. She attributes this to two factors. First, the degree of taxation partially depends upon where the main base of support for the governing party rests. Second, a more universal pattern is "exports are taxed while import competing products are not." This too might be ideologically based since it has been believed that world terms of trade are turning against agricultural products, and therefore agricultural exports are a poor source of growth. Tolley, Thomas, Nash, and Snyder offer a different theoretical explanation of this phenomenon by noting that in less developed countries any exported product is likely to be a large share of that country's GDP, which means the costs of including it in a coalition in terms of higher taxes would be very high.

3. THEORY

Developed in this section are a two-sector growth model, and a political economy model of agricultural pricing policy. Included with the growth model are comparative static results used to predict properties of an equilibrium growth path. The political economy model is considerably less rigorous and no formal comparative static results are derived. However, there is discussion of the predicted effects of the exogenous variables.

Organization of this section proceeds as follows. First, the basis for a comparative analysis is considered. Second, theoretical growth models for a closed and open economy are developed, and then combined to produce a final model specification for empirical analysis. Last, a political economy model of agricultural pricing policy is developed to be used in conjunction with the two-sector growth model.

Basis for Comparative Analysis

Intercountry comparisons allow a generalization away from the historical patterns of single countries, making it possible to identify both uniform patterns of development as well as sources of deviation between countries. Deviations result from the wide variety of policy regimes and resource endowments across countries, but what are the economic explanations for expecting any uniform patterns at all? If there are no reasons, and every country's patterns are determined by factors unique to that country, intercountry comparisons are meaningless. General models of structural change depend upon the following assumptions.

i) There is a common hierarchy of human wants and needs. When agriculture and non-agriculture are considered in the aggregate it is assumed that two countries at a given level of development will have similar demand structures. As an example, consider Engel's law which has held up over a wide range of demand studies. This law states that the income elasticity of food, when considered in the aggregate, is less than one. This means that as income grows, demand for non-agricultural commodities will increase relative to the demand for agriculture commodities.

ii) There are systematic relationships between the level of development and relative productivity between sectors. Economic growth is associated with increases of both human and physical capital at a rate exceeding the growth of the labor force. Therefore, an equilibrium growth path will depend upon the relative supply responses to the changing capital/labor ratios. If all sectors have identical production functions the production possibilities frontier will shift outward in a parallel manner. This means, holding prices constant, production shares will remain the same. However, if there are systematic differences between sectoral production functions the production possibilities frontier will shift out in a non-parallel manner, resulting in supply induced changes in production structure.

Two-sector growth models

One of the principle difficulties in developing a general growth model is accounting for all of the different country types. Within countries an increase in total resources, or a change in world prices, will have different effects depending upon their participation in the global economy. The strategy pursued here is to develop growth models for both closed and open economies, and then examine the properties of growth patterns implied by the two different sets of assumptions. Last, it is recognized that in reality a typical country will contain aspects of both models, so they are combined to produce a final specification used for empirical analysis.

Closed Economy

It is assumed that producers will maximize revenues subject to a given resource endowment. Intercountry production functions are specified for agriculture and non-agriculture. In these functions the same technologies are available to all countries, but the technologies implemented depend upon the state variables. Examples of state variables include levels of education, an effective extension service, infrastructure, political stability, and policy. In there most general form the intercountry production functions are:

(1)
$$Q_a = q_a(K_a, L_a, Z_a, R)$$
$$Q_n = q_n(K_n, L_n, Z_n, R)$$

Q_i = output in sector i, i,=a,n

K_i = capital in sector i, i = a, n

L_i = labor in sector i, i = a, n

R = natural resource endowments.

Z_i = state variables, i = a, n

Notice, some of these variables are specific to a particular sector while others are shared by both sectors. State variables are critical because a country's implemented technology depends upon them.

The Lagrangian for a restricted revenue max problem is:

(2) $$L = P_a Q_a(K_a, L_a, R, Z_a) + P_n Q_n(K_n, L_n, Z_n) + \lambda(K_t - K_a - K_n) + \gamma(L_t - L_a - L_n)$$

Where P_a, P_n denote the prices of commodities a and n, and L_t, K_t denote total labor and capital available at time t.

Setting the derivatives with respect to K_a, K_n, L_a, L_n, and λ equal to zero yields the following first order conditions.

(3)
$$
\begin{gathered}
P_a \frac{\partial Q_a}{\partial K_a} - \lambda = 0 \\
P_a \frac{\partial Q_a}{\partial L_a} - \gamma = 0 \\
P_n \frac{\partial Q_n}{\partial K_n} - \lambda = 0 \\
P_n \frac{\partial Q_n}{\partial L_n} - \gamma = 0 \\
K_t - K_a - K_n = 0 \\
L_t - L_a - L_n = 0
\end{gathered}
$$

From these first order conditions the resource allocation equations can be solved for.

(4)
$$
\begin{aligned}
K_a^* &= k_a(K_t, L_t, P_a, P_n, Z_a, Z_n, R) \\
L_a^* &= l_a(K_t, L_t, P_a, P_n, Z_a, Z_n, R) \\
K_n^* &= k_n(K_t, L_t, P_a, P_n, Z_a, Z_n, R) \\
L_n^* &= l_n(K_t, L_t, P_a, P_n, Z_a, Z_n, R)
\end{aligned}
$$

Substituting these back into the production functions will yield the supply equations for each sector.

(5)
$$
\begin{aligned}
Q_a^s &= q_a(K_t, L_t, P_a, P_n, Z_a, Z_{nt}, R) \\
Q_n^s &= q_n(K_t, L_t, P_a, P_n, Z_a, Z_{nt}, R)
\end{aligned}
$$

The consumer problem in this model is to maximize utility subject to a budget constraint. The Lagrangian for a resticted utility max problem is:

(6) $$L = U(Q_a, Q_n) + \lambda(M - P_a Q_a + P_n Q_n)$$

where M is income. Setting the derivatives with respect to Q_a, Q_n, and λ equal to zero yields the first order conditions:

(7) $$\frac{\partial U}{\partial Q_a} - \lambda P_a = 0$$
$$\frac{\partial U}{\partial Q_n} - \lambda P_n = 0$$
$$M = P_a Q_a + P_n Q_n$$

These equations can then be solved for the demand functions:

(8) $$Q_a^d = Q_a(P_a, P_n, M)$$
$$Q_n^d = Q_n(P_a, P_n, M)$$

Having obtained the supply and demand functions for both sectors the final step is to impose the market equilibrium conditions.

(9) $$Q_a^s(P_a, P_n, \ldots) = Q_a^d(P_a, P_n, M)$$
$$Q_n^s(P_a, P_n, \ldots) = Q_n^d(P_a, P_n, M)$$

It is assumed that prices are flexible, and will adjust within the relevant time period so as to equate demand with supply in both sectors.

The entire system is composed of four types of equations which can be solved simultaneously to determine the prices and quantities that will be observed given our behavioral assumptions and resource constraints.

Demand equations:

$$Q_a^d = Q_a(P_a, P_n, M)$$
$$Q_n^d = Q_n(P_a, P_n, M)$$

Supply equations:

$$Q_a^s = Q_a(K_a^*, L_a^*, T_a, A)$$
$$Q_n^s = Q_n(K_n^*, L_n^*, T_n)$$

Market equilibrium equations:

$$Q_a^s(P_a, P_n, \ldots) = Q_a^d(P_a, P_n, M)$$
$$Q_n^s(P_a, P_n, \ldots) = Q_n^d(P_a, P_n, M)$$

Income equation:

$$M = P_a Q_a + P_n Q_n$$

After solving for the equilibrium prices and quantities, agriculture's equilibrium share of GDP is:

(10) $$SA = \frac{P_a^* Q_a^*(\bullet)}{P_a^* Q_a^*(\bullet) + P_n^* Q_n^*(\bullet)}.$$

Comparative Statics for a Closed Economy

Economic growth in a closed economy, as represented by outward shifts in its production possibilities frontier, can only occur through increases in K_t, L_t, or Z_i. Since the comparative static results are the same for every variable we can arbitrarily choose one input and denote it as X_i. Also, since demand and supply equations must be homogeneous of degree zero in prices, P_n is chosen as a numeraire. Using this notation the system of supply, demand, and market equilibrium equations can be denoted as:

$$Q_a^s = Q_a(P, X_i, \ldots)$$
$$Q_n^s = Q_a(P, X_i, \ldots)$$
$$Q_a^d = Q_a(P, M(X_i, \ldots))$$
$$Q_n^d = Q_a(P, M(X_i, \ldots))$$
$$Q_a^s = Q_a^d$$
$$Q_n^s = Q_n^d$$

where $P = \frac{P_a}{P_n}$.

The first step is to change the form of the share equation by dividing through by the value of nonagricultural goods.

(11)
$$SA = \frac{P\frac{Q_a}{Q_n}}{P\frac{Q_a}{Q_n}+1}.$$

Taking the total differential of SA with respect to X_i results in equation (12).

(12)
$$\frac{dSA}{dX_i} = \frac{P\frac{d\frac{Q_a}{Q_n}}{dX_i} + \frac{Q_a}{Q_n}\frac{dP}{dX_i}}{\left(P\frac{Q_a}{Q_n}+1\right)^2}$$

As can be seen the sign of this differential depends upon the sign of $\frac{dP}{dX_i}$ and $\frac{d\frac{Q_a}{Q_n}}{dX_i}$.

Equating the supply and demand equations yields a system of two equations which can then be solved for the equilibrium price ratio, which will be a function of X_i and the other variables. Having solved for the price that satisfies market equilibrium conditions we can then form the identities:

$$(13)\quad \begin{aligned} &Q_a^s(P(X_i,\ldots),X_i,\ldots)-Q_a^d(P(X_i,\ldots),M(X_i,\ldots))=0\\ &Q_n^s(P(X_i,\ldots),X_i,\ldots)-Q_n^d(P(X_i,\ldots),M(X_i,\ldots))=0 \end{aligned}$$

The total differentials of this system with respect to X_i are:

$$(14)\quad \begin{aligned} &\frac{\partial Q_a^s}{\partial P}\frac{\partial P}{\partial X_i}+\frac{\partial Q_a^s}{\partial X_i}-\frac{\partial Q_a^d}{\partial P}\frac{\partial P}{\partial X_i}-\frac{\partial Q_a^d}{\partial M}\frac{\partial M}{\partial X_i}=0\\ &\frac{\partial Q_n^s}{\partial P}\frac{\partial P}{\partial X_i}+\frac{\partial Q_n^s}{\partial X_i}-\frac{\partial Q_n^d}{\partial P}\frac{\partial P}{\partial X_i}-\frac{\partial Q_n^d}{\partial M}\frac{\partial M}{\partial X_i}=0 \end{aligned}$$

which can also be expressed in the matrix form

$$(15)\quad \begin{bmatrix} \left(\frac{\partial Q_a^s}{\partial P}-\frac{\partial Q_a^d}{\partial P}\right) & -\frac{\partial Q_a^d}{\partial M}\\ \left(\frac{\partial Q_n^s}{\partial P}-\frac{\partial Q_n^d}{\partial P}\right) & -\frac{\partial Q_n^d}{\partial M} \end{bmatrix} \begin{bmatrix} \frac{\partial P}{\partial X_i}\\ \frac{\partial M}{\partial X_i} \end{bmatrix} = \begin{bmatrix} \frac{-\partial Q_a^s}{\partial X_i}\\ \frac{-\partial Q_n^s}{\partial X_i} \end{bmatrix}.$$

Using Cramer's Rule the partial derivative of price with respect to X_i can be solved for as below.

(16) $$\frac{\partial P}{\partial X_i}=\frac{\frac{\partial Q_a^s}{\partial X_i}\frac{\partial Q_n^d}{\partial M}-\frac{\partial Q_n^s}{\partial X_i}\frac{\partial Q_a^d}{\partial M}}{-\frac{\partial Q_n^d}{\partial M}\left(\frac{\partial Q_a^s}{\partial P}-\frac{\partial Q_a^d}{\partial P}\right)+\frac{\partial Q_a^d}{\partial M}\left(\frac{\partial Q_n^s}{\partial P}-\frac{\partial Q_n^d}{\partial P}\right)}$$

The denominator will always be less than zero, so any comparative static results will depend on the sign of the numerator. Without some additional structure (16) cannot be unambiguously signed, however, the following relationship will always hold:

(17) $$\frac{dP}{dX_i}<0 \text{ if } \frac{\partial Q_a^s}{\partial X_i}\frac{\partial Q_n^d}{\partial M}>\frac{\partial Q_n^s}{\partial X_i}\frac{\partial Q_a^d}{\partial M}.$$

With some algebraic manipulation (17) can be stated in the equivalent form:

(18) $$\frac{dP}{dX_i}<0 \text{ if } \frac{\varepsilon_{Q_a^s X_i}}{\varepsilon_{Q_n^s X_i}}>\frac{\theta_{Q_a^d M}}{\theta_{Q_n^d M}}$$

where $\frac{\varepsilon_{Q_a^s X_i}}{\varepsilon_{Q_n^s X_i}}$ is the ratio of supply elasticities, and $\frac{\theta_{Q_a^d M}}{\theta_{Q_n^d M}}$ is the ratio of income elasticities of demand.

To summarize, the effect on relative prices of an increase in resources depends upon the relative magnitudes of the ratio of supply elasticities as compared to the ratio of income elasticities of demand. If some additional structure is imposed in the form of neutral growth (equal supply elasticities), and an income elasticity of demand for agricultural goods less than the income elasticity of demand for non-agricultural goods, the conditions for (17) to hold are met, and relative prices will turn against agriculture.

Relative prices are only one half of the story. The total effect of an increase in X_i

depends not only upon what happens to relative prices, but also what happens to relative quantities. In order to look at the effect on relative quantities, we begin by taking the total differential of the quantity ratio which results in Equation (19).

$$\text{(19)} \qquad \frac{d\frac{Q_a}{Q_n}}{dX_i} = \frac{Q_n \frac{dQ_a}{dX_i} - Q_a \frac{dQ_n}{dX_i}}{Q_n^2}$$

Once again, the sign of the differential depends upon the sign of the numerator, and it can be shown the following relationship will always hold:

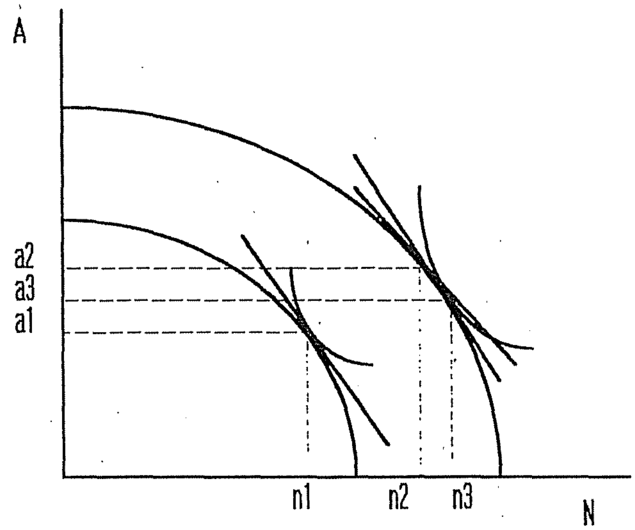
$$\text{(20)} \qquad \frac{d\frac{Q_a}{Q_n}}{dX_i} < 0 \text{ if } \frac{dQ_a^s}{dX_i}\left(\frac{X_i}{Q_a^s}\right) < \frac{dQ_n^s}{dX_i}\left(\frac{X_i}{Q_n^s}\right).$$

Solving for the total differentials of the supply equations, and then converting the differentials into an elasticity form yields the following two equations:

$$\text{(21)} \qquad \begin{aligned} \frac{dQ_a^s}{dX_i}\left(\frac{X_i}{Q_a^s}\right) &= \frac{\partial Q_a^s}{\partial P}\frac{\partial P}{\partial X_i}\left(\frac{X_i}{Q_a^s}\right) + \frac{\partial Q_a^s}{\partial X_i}\left(\frac{X_i}{Q_a^s}\right) \\ \frac{dQ_n^s}{dX_i}\left(\frac{X_i}{Q_n^s}\right) &= \frac{\partial Q_n^s}{\partial P}\frac{\partial P}{\partial X_i}\left(\frac{X_i}{Q_n^s}\right) + \frac{\partial Q_n^s}{\partial X_i}\left(\frac{X_i}{Q_n^s}\right) \end{aligned}$$

The terms $\frac{dQ_a^s}{dX_i}\left(\frac{X_i}{Q_a^s}\right)$ and $\frac{dQ_n^s}{dX_i}\left(\frac{X_i}{Q_n^s}\right)$ are the same in (20) and (21), and will be called growth elasticities, they represent the total % change of Q_a or Q_n supplied from a 1% change in X_i. Hypothetically, this change could be divided into two sources as is shown graphically in figure 1.

Figure 1. Effect of an Increase in X_i



Initially, this economy is in equilibrium at (a1, n1). Next, an increase in X_i shifts the production possibilities frontier outward. The second term on the right hand side of the growth elasticity equations represents the movement from (a1, n1) to (a2, n2), or the increase in supplies holding prices constant. However, if A has an income elasticity of demand less than N the economy will not be in equilibrium at (a2, n2). There will be an excess demand for N which will cause an additional adjustment to (a3, n3). This last adjustment corresponds to the first right hand side term in the growth elasticities.

With the same set of assumptions required for the relationship (17) to hold it follows that:

$$\frac{\partial Q_a^s}{\partial X_i}\left(\frac{X_i}{Q_a^s}\right) = \frac{\partial Q_n^s}{\partial X_i}\left(\frac{X_i}{Q_n^s}\right), \text{ and } \frac{\partial Q_a^s}{\partial P}\frac{\partial P}{\partial X_i}\left(\frac{X_i}{Q_a^s}\right) < \frac{\partial Q_n^s}{\partial P}\frac{\partial P}{\partial X_i}\left(\frac{X_i}{Q_n^s}\right).$$

Since these are all of the right hand side terms in the set of equations in (21), these conditions are sufficient for relationship (20) to also hold. In conclusion, under the assumptions of neutral growth, and an income elasticity of demand for agricultural goods which is less than the income elasticity of demand for non-agricultural goods, it is possible to show that both relative prices and quantities will turn against agriculture with an increase in X_i. Consequently, agriculture's share of production will also decline.

Open Economy

For a small, open country, the Lagrangian for a restricted revenue max problem is given by equation (22) which results in the same first order conditions as for a closed economy.

$$(22) \qquad L = P_a Q_a(K_a, L_a, R, Z_a) + P_n Q_n(K_n, L_n, Z_n) + \lambda(K_t - K_a - K_n) + \gamma(L_t - L_a - L_n)$$

Only now the equilibrium condition that domestic demand equals domestic supply need not hold since any excess demand or supply can be accommodated through trade. Thus, the market equilibrium conditions are now specified as:

$$(23) \qquad \begin{aligned} Q_a^s + I_a &= Q_a^d + E_a \\ Q_n^s + I_n &= Q_n^d + E_n \end{aligned}$$

I_j = imports of commodity j

E_i = exports of commodity i.

In this case prices are no longer determined within the system, but rather are exogenous, being determined by world supply and demand. Deriving two supply equations in the identical manner they were derived for a closed economy, sector share can then be defined as:

(24)
$$SA = \frac{P_a^w Q_a^s(\bullet)}{P_a^w Q_a^s(\bullet) + P_n^w Q_n^s(\bullet)}.$$

Comparative Statics of an Open Economy

The first result of interest is the effect of an increase in resources on SA. Dividing through by the share of non-agriculture results in the share equation:

(25)
$$SA = \frac{P\dfrac{Q_a^s}{Q_n^s}}{P\dfrac{Q_a^s}{Q_n^s}+1}.$$

Taking the total differential of SA with respect to X_i results in:

(26)
$$\frac{dSA}{dX_i} = \frac{p\dfrac{d\left(\dfrac{Q_a^s}{Q_n^s}\right)}{dX_i}}{\left(p\dfrac{Q_a^s}{Q_n^s}+1\right)^2}.$$

which will be less than zero if the elasticity of supply of Q_a with respect to X_i is less than the elasticity of supply of Q_n with respect to X_i.

Since prices are exogenous, the other result of interest will be the effect of a change in price on SA. Starting with the same share equation as above, the total differential of SA with respect to P is given in equation (27).

$$(27) \qquad \frac{d\,SA}{d\,P} = \frac{P\,\dfrac{d\left(\dfrac{Q_a^s}{Q_n^s}\right)}{d\,P} + \dfrac{Q_a^s}{Q_n^s}}{\left(P\dfrac{Q_a^s}{Q_n^s}+1\right)^2}.$$

With upward sloping supply curves $\dfrac{d\left(\dfrac{Q_a^s}{Q_n^s}\right)}{d\,P} > 0$ which means $\dfrac{d\,SA}{d\,P}$ will also be greater than zero.

Other Considerations in Models of Economic Growth

Non-tradable Goods

In the models above non-tradable goods are not considered as a separate sector. For the most part they will be included within the non-agricultural sector, as almost all agricultural goods can be considered as tradable. However, recognizing their presence some thought should be given to their effect on growth patterns. To do this we will proceed on similar lines as Anderson (1987).

Start by aggregating all tradables and non-tradables into two supersectors. The market equilibrium conditions will now be:

$$T_s+I_t=T_d+E_t \text{ and } NT_s=NT_d.$$

T_s = supply of tradable goods

NT_s = supply of non-tradable goods

T_d = demand for tradable goods

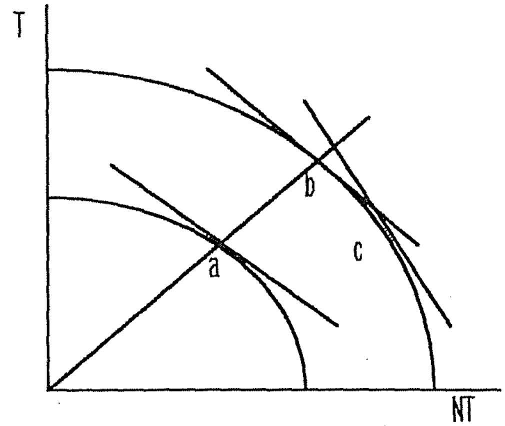
NT_d = demand for non-tradable goods

I_t = imports of tradable goods

E_t = exports of tradable goods.

Domestic prices of tradable goods are determined by world prices, but prices of non-tradable goods will be determined by domestic demand and supply. To see how this might affect growth patterns consider the diagram below.

Figure 2. Growth Patterns with Non-Tradable Goods



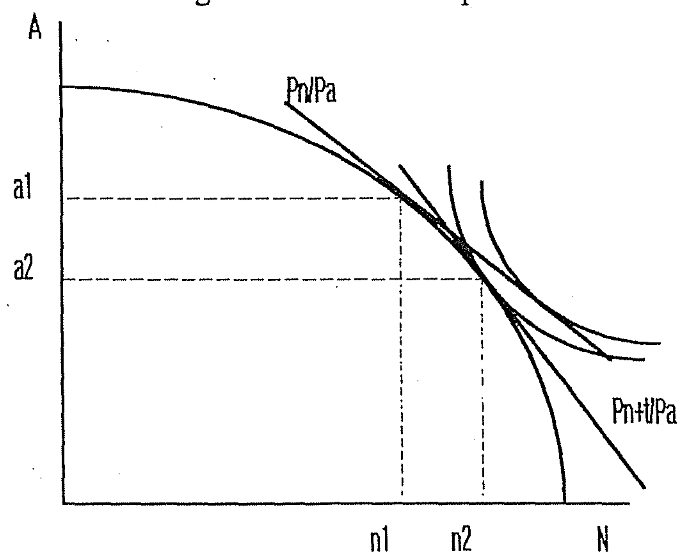
Initially this economy was in equilibrium at point a. Assuming neutral growth, the production possibilities frontier shifts out in a parallel manner, and if prices remained the same the new equilibrium would be at b. However, if the income elasticity of demand for non-tradable goods is greater than that for tradable goods there would be an excess demand for non-tradables at the old price ratio. In response, the price of non-tradables will rise relative to the fixed world price of tradables, and the economy will adjust to a new equilibrium at point c. Under this scenario, both relative prices and quantities turned against the tradable sector so its share will decline.

Agriculture's share would also decline since the agricultural sector is composed of all tradable goods, and the non-agricultural sector consists of a weighted average of tradable and non-tradable goods.

Effect of a Tariff

A per unit tariff will cause the domestic price of import competing goods to rise, which will cause resources to be drawn away from the unprotected sectors. For a two sector model the effect of a tariff is shown graphically below.

Figure 3. Tariff on Imports of N

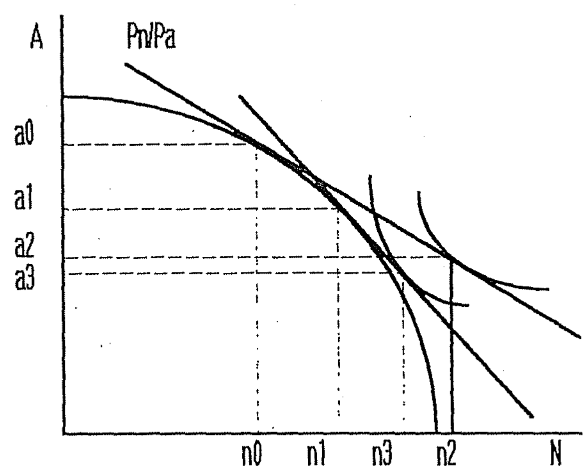


The imposition of a tariff raises the domestic price of sector N up to the ceiling of world price plus per unit tariff, causing the price ratio to increase from Pn/Pa to Pn+t/Pa In response to the change in relative prices, resources shift out of sector A into sector N. This results in a decline in output of sector A from a1 to a2, and an increase in output of sector N from n1 to n2. Since both relative prices and quantities have increased in favor of sector N its share of real income will increase. However, there are no quantity limits on imports so domestic price remains linked to world price, and supply in both sectors is determined separately from demand.

Effect of a Quota

Once again referring to the two-sector general equilibrium model, production levels, consumption levels, and trade status are depicted graphically below.

Figure 4. Quota on Imports of N



The point (a0, n0) depicts pre quota levels of production for A and N respectively, while (a2, n2) represents pre quota consumption levels of these two goods. A quota on N of amount $QT_n = n3\text{-}n1$ will result in an excess demand for N at the given price ratio. In response to this excess demand the price ratio Pn/Pa will increase, drawing resources out of sector A into sector N until a new equilibrium is reached. In the graph above (a1,n1) will be the new quantity combination produced under a quota of QT_n. Since both Pn/Pa and A/N have decreased the share of sector A will decrease. While the effects of a quota are similar to that of a tariff, the mechanisms are different which has important consequences upon the growth path that will be taken.

Quotas effectively close an economy in the sense that the new market equilibrium conditions will be:

$$A_s + I_a = A_d + E_a \text{ and } N_s + QT_n = N_d.$$

A_s = supply of A

N_s = supply of N

N_d = demand for N

QT_n = quota amount on import of N

I_a = Imports of A

E_a = Exports of A

As a result of the quota, relative prices depend upon domestic supply and demand so the closed economy comparative static results for an increase in resources now hold.

Long Run Effects of Pricing Policies

According to Schultz (1978) and Brown (1978) the development and adoption of new technologies depends in part upon economic signals. In a general equilibrium framework policies will not only cause a reallocation of resources along the existing production possibilities frontier, but also will affect its shape as it shifts outward. For example, in the above discussion the end result of imposing either a tariff or a quota on imports of commodity N was an adverse movement in the domestic terms of trade for commodity A. Holding the production possibilities frontier constant this caused a reallocation of resources into sector N which resulted in an increase in its share of production. In addition, the decline in commodity A's domestic terms of trade will cause a relative decrease in investment toward new technologies which could enhance its long run productivity levels. Also, companies involved in research and development will focus their attention towards developing new technologies for sector N where their profit potential is higher. As a result, the long run effect of these policies will be to cause a relative bias in the rate of technological change, and therefore growth rates, against sector A.

Adjustment Lags

In the models developed above growth patterns are caused by a movement from one equilibrium to another as an economy's production possibilities frontier shifts out. Strictly speaking, such a formulation only applies to a long run situation where enough time has passed to allow for resource reallocations. Following the arguments of other researchers, it is hypothesized here that intercountry variations at a point in time are representative of such long run equilibrium positions.

Within countries, there is a strong likelihood of some disequilibrium being present from year to year. Consider the case of neutral growth, or a parallel shift outward of the production possibilities frontier. Since the income elasticity of demand for agriculture is less than for non-agriculture there will be pressure for the share of agriculture to decline. This adjustment necessarily requires a change in the relative levels of inputs allocated to each sector. However, once in place, physical capital is relatively fixed, and capital proportions can only adjust to new equilibrium levels through depreciation of old capital and investment. This implies a time lag is likely before new equilibrium levels are reached. Also, due to disequilibrium there will be pressure for labor in agriculture to migrate towards other sectors. Because there are costs involved with switching employment- such as uncertainty of employment in another sector, additional training required, and relocation costs- labor will also require a period of time to adjust. It would be expected, therefore, that countries with high growth rates are experiencing a greater degree of disequilibrium, so they will be observed to have larger agricultural shares than countries at the same level of development and lower growth rates.

Final Form of Growth Model

The focus thus far has been on two-sector growth models for a price endogenous closed economy, and a price exogenous open economy. Comparative statics results were derived for both cases to show the effect of an increase in resources on agriculture's share of production. Additionally, comparative statics results for a change in relative prices were derived for a small, open economy. Next, while not explicitly given a separate sector it was recognized that included within the non-agricultural sector were non-tradable goods. Following the discussion on non-tradable goods, the effects of tariffs and quotas were examined. Finally, while no formal adjustment mechanisms are specified some of the consequences of adjustment lags were examined. With these factors in mind, the remaining task is to use these theoretical results to specify a realistic empirical growth model that will correspond to what is observed in the real world.

Typically, countries will fit neither the closed or open country models. The main purpose of these models is to provide a framework which can be used to examine causes of growth patterns under two sets of extreme assumptions. In order to correspond to what is actually observed, both of the models have to be combined.

First, all countries participate in international trade to some extent which means that world prices should have an effect on domestic production. Within each aggregate commodity there are individual commodities either not covered by a trade policy, or the policies are in the form of a tariff which preserve the link between world and domestic prices. Second, while all countries participate in international trade, due to the presence of non-tradable goods and quotas relative prices will in part depend upon the structure of demand. Last, while it is believed the major trends that can be picked up are caused by the variations across countries, which represent long run equilibrium positions, there will be adjustment lags which should be taken into account. For this reason the growth rate of per capita income will be included in the model. Combining all of the above, a final specification for the growth model in its reduced form is:

(28) $$SA = f(P, Pol, K_t, L_t, Z_a, Z_n, R, Grth).$$

P = Relative price of agricultural commodities.

Pol = Policy

K_t = Total capital

L_t = Total labor

Z_i = State variables, i = a, n

R = Resource endowments

Grth = Growth rate of per capita income.

Political Economy of Agriculture Pricing Policy

This section presents a model of policy choice similar to those developed in Antle

(1995) and Hu and Antle (1993). It is designed to provide some insights on the reasons behind observed policy measures across countries and over time. Necessarily this involves a considerable abstraction from detail, and as a result only trends are expected to be picked up.

Corresponding with the two-sector growth model there are two interest groups, one representing agriculture and one representing non-agriculture. These groups apply pressure by investing time, money, and energy into lobbying for political favors. These favors could take the form of a subsidy, or merely a reduction in the tax load for that group. The level of pressure each group is able to bring to bear depends on the efficiency of the group, its effect on other pressure groups, and characteristics of government which might give a group an intrinsic advantage. Political equilibrium will result when both groups have maximized the welfare of its members, subject to the above constraints. In this equilibrium, neither group has an incentive to invest more money to increase their political influence since the costs will exceed the benefits (for a more formal discussion of a model of this type see Becker, 1983).

With this model in mind, the next task is to identify group characteristics which are expected to be associated with its ability to engage in pressure producing activities. If, as economic development proceeds, there are relative changes in these characteristics between the two interest groups we can expect to see patterns in policy to go along with the patterns of production.

One such characteristic is group size which has been emphasized by Olson (1965). Because of the free rider problem, large groups will find it much more difficult to organize, and if they cannot offer some benefit to be given selectively to those who join the group they will not be able organize at all. Also, large groups typically have larger start up costs before even a minimal amount of pressure can be produced. Applied toward the present model, agriculture in less developed countries is composed of a large number of small producers, each growing a wide variety of products. Meanwhile, agriculture in rich countries is composed of a small number of producers, and perhaps even more important, these producers tend to be more specialized. Therefore, according to Olson's arguments, agriculture in the less developed countries will tend to be taxed while in rich countries the converse would be true.

It should be noted, however, that political economy models emphasizing the importance of voters would predict an opposite effect. These models assume that government officials are interested in maximizing the probability of staying in power. In this context it is the large groups which may be granted political favors since they represent a greater number of voters.

The relative value of a sector's production can also be expected to influence policy. As the value of a sector's production rises it becomes a more valuable source of tax revenue. Also, even if policy resulted in only a small per unit price increase the total value of the transfer would be large enough to significantly affect other interest groups. In both cases, the ability of a relatively large sector (in value of production terms) to produce political pressure is diminished due to the large effect any political favors granted to them will have on other interest groups. Since agriculture's share of output is greater in the poorer countries, the above reasoning would predict that once again poor countries would tend to tax agriculture while rich countries will tend to subsidize it.

Several studies have also included a measure for resource endowments. It is expected that a country's resource endowments will play a role in its overall development strategy. For example, a country richly endowed with agricultural resources will be more likely to tax agriculture to finance its other development objectives. Therefore, if two countries are at a similar level of development the one with a richer agricultural resource endowment will tend to discriminate more heavily against agriculture. This argument hinges on the fact that there is no unique path of development. Two countries which have succeeded in developing to a given level could have pursued very different strategies to get there.

While, in principle, factors expected to influence the political equilibrium can be identified, using intercountry data a final model specification will be limited by the few available variables. With this in mind the political economy model used in this study has the following specification:

(29) $$\text{Pol} = f(\text{Agshare}, \text{Urbpop}, \text{Arblndpcp}).$$

Pol = Policy

Agshare = Agriculture's share of GDP. Representing overall level of development as well as relative value of agricultural production.

Urbpop = % of population living in urban areas. Used to represent group size.

Arblndpcp = Arable land per capita. Controls for country specific differences in resource endowments.

4. DATA AND EMPIRICAL RESULTS

Data

The main advantage in using cross country observations is their greater variation in outputs, inputs, prices, and other key factors related to agricultural growth compared to individual countries' time series. Also, in the study of development patterns researchers have typically not had much of a choice as long time series for most countries are not available. However, a sample consisting of a large number of countries has some inherent weaknesses. Across countries, the data varies in quality, and in some cases the same variable is measured in different ways. There is also a very limited number of variables available, making it difficult to specify an empirical model. Below is a description of the variables used in the empirical analysis along with a discussion of what effects they are likely to be measuring.

Equation (28) reveals that agriculture's share depends, in part, upon the stock of physical capital and the state variables. There are measures of capital available, however, their quality varies so widely across countries that it is sometimes unclear what they are measuring. Also, variables such as infrastructure, educational levels, and research and development expenditures could be used as state variables. However, there are problems with finding such measures that cover the entire data set in a consistent manner, and there are other factors influencing productivity, such as social attitudes or market structure, which should also be taken into consideration. Due to these problems, a decision was made not to include direct measures of the stock of physical capital or the state variables in the regression equations. Instead, it is hypothesized that, given prices and resource endowments, per capita income will depend upon overall capital/labor ratios and the remaining state variables. Thus, per capita income can serve as a proxy for the combined effect of changing capital/labor ratios and state variables.

Relative prices have not been given much attention in intercountry work on development patterns. One rationale for excluding prices has been the assumption that in the long run prices have sufficient flexibility to not be a constraint on structural adjustment. Another reason is that at broad levels of aggregation price elasticities of demand between commodities are likely to be very low, with the principle changes in relative demand resulting from income changes. Thus, from a demand perspective relative prices have very little influence on broad consumption patterns. It is reasonable in a closed economy case to consider relative prices as endogenous, and, therefore, can be determined within the model without considering them explicitly. However, every country included in the data set constructed for this research engages in trade, which means they will be affected by world prices. With pooled data two options are available to deal with relative prices. First, the cross country sample could be estimated for each year separately, and the results would then be interpreted as a long term growth pattern holding world prices constant. The other option is to construct an index of relative world prices for each year included in the sample. While there are no intercountry price indexes by sectors, there are world export price indexes developed by the United Nations for different classes of primary commodities and manufactured goods. These indexes could be interpreted as the aggregate world price level for these commodities. It is recognized that these prices may not apply to individual countries because of policy distortions, and also because not all countries produce the same commodities. For example, different crops are produced in temperate versus tropical regions, and it might very well be the case that a decline in the world export price index for food is caused by a decline in one type of crops, while the other stayed the same, or may have even increased. Despite these shortcomings, a decision was made to use these indexes to see if there is any response in agriculture's share to some measure of global economic conditions, as well as to provide greater confidence in the use of the pooled sample.

Natural resources will affect growth patterns directly, as a production input, as well as indirectly, through their influence on the choice of development strategy. Rather than trying to directly account for the effects of natural resources, previous work by Chenery (1960, 1968, 1975, 1979) relied on a residual analysis to stratify their sample into more homogeneous groups of countries. Reasons cited for doing this are the poor quality of data available on resource endowments, and the difficulty of disentangling the effects of policy from its underlying causes (1975, 64). In this study, two resource measures are directly included in the regression equations. These variables are arable land per capita, and the share of arable land which is irrigated, both which have been used in the literature on intercountry agricultural productivity. Arable land per capita is included as a measure of total land resources, however, by itself it does not account for the great variations in land quality. Share of arable land which is irrigated is included to help control for variations in quality. Aside from the obvious direct effects irrigation share will have on land productivity, it might also give an indication of general agro-ecological conditions. Since there are costs to irrigating we would not expect to see much irrigation on marginal cropland. Also, an increase in the percentage of irrigated cropland is an indication of greater water availability, which in general will translate into better growing conditions. Last of all, in many countries large irrigation projects are undertaken by the government. In this case, the proportion of arable land which is irrigated may be a proxy for a policy environment more favorable to agriculture.

Unfortunately, for a wide range of countries no measure of policy is available. For a much smaller set of countries the USDA's Economic Research Service has calculated producer subsidy equivalents (PSE). In principle, the PSE gives an indication of the total amount of distortion caused by trade policies, income transfers, input subsidies, and in some cases macroeconomic policies. In order to be able to compare PSE across countries the version used here are percentage PSE which are defined as:

$$\frac{Q(P_d - P_w * X) + D + I}{Q * P_d + D}.$$

Q = Total quantity produced

P_d = Producer price in domestic currency units

P_W = World price in world currency units

X = Exchange rate conversion factor

D = Direct government payments

I = Indirect transfers through policies such as input subsidies, marketing assistance, or exchange rate distortions.

The PSE has an advantage over some other measures of policy in that it provides a quantitative measure of total policy distortion rather than just the distortion caused by certain policy types. This gives a more comprehensive description of the overall policy environment producers are working in. One limitation to the use of the PSE in this context is that in their calculation not all agricultural commodities are taken into account. Researchers picked the commodities covered according to their importance in the countries agricultural sector, and their importance to U. S. agricultural trade (USDA 1994, 3). Another limitation is PSE are not a measure of the relative policy differences between agriculture and non-agriculture which is what would ideally be had in the study of policy effects on growth patterns.

While there has been some improvement in the quality of labor statistics, they still are subject to large measurement errors, particularly in low income countries. In these countries women and children often are undercounted although they make up a substantial part of the labor force. In the regression equations specified here total population will serve as a proxy for total labor on the assumption they are roughly proportional.

Percent urban population is directly available from the World Tables. It is included to measure group size, and should give an indication of the relative size of urban versus rural interests. What it does not take into consideration is the fact that within either of these two groups there will be many subgroups. Accordingly, such an aggregate measure may be meaningless if the political process is carried out on a much more disaggregated level.

Table 2. Variable Definitions and Sources

Variable	Definition	Source
Agshare	Value added share of agriculture in total GDp	World Tables 1993 and OECD Economic Survey
Rgdpch	Real GDP per capita (1985 international prices; Chain index	Penn World Tables (Mark 5.5)
Relprice	World export price index for agricultural food products divided by world export unit price index for manufactured goods	United Nations statistical papers United Nations Monthly Bulletin of Statistics
Pop	Population in millions	World Tables 1993

Table 2, cont.

Urbpop	Percent of population living in urban areas	World Tables 1993
Lndpcp	Land under temporary or permanent crops (1000 ha) divided by population	FAO Production Yearbook 1975, 1988-1992
Irrshare	Irrigated land (1000 ha) divided by land under temporary or permanent crops	FAO Production Yearbook 1975, 1988-1992
Pse	Producer Subsidy Equivalent	Economic Research Service, USDA

Statistical Model Specifications and Empirical Estimates

Two data sets are constructed for empirical analysis. The first is for the entire sample of 81 countries through the years 1971 -1990, which gives a sample size of 1620 observations. The second data set is limited to those countries and years for which data on PSE's are available. This sample consisted of 22 countries for the years 1985-1989, giving a sample size of 110 observations. Developed below are econometric models for use with each data set, followed in each case with the regression results.

OLS Model Specification for Full Sample

As indicated above, there is no available policy measure covering all 81 countries. Substituting equation (29) for the policy variable in equation (28) will yield the reduced form:

(30) Agshare = f(Rgdpch, Grth, Relprice, Pop, Lndpcp, Irrshare, Urbpop)

which can be estimated with the available data.

Theory can provide quite a bit of guidance towards choosing a functional form. A unique equilibrium in production and consumption is obtained under the conditions of a concave production possibilities frontier and convex utility curves. These conditions suggest the response curves will have an upper and lower asymptote. Theoretically, the most satisfying functional form would probably be a logistics curve, however, following Chenery (1976) and Antle (1993) the model specification adopted for preliminary regressions is:

$$\text{(31)} \quad Agshare = A_1 + A_2Lnrgdpch + A_3Grth + A_4Lnrelprc + A_5Lnpop + A_6Lnlndpcp + A_7Lnirrshr + A_8Lnurbpop + A_9Time$$

Lnrgdpch = natural log Rgdpch
Grth = growth rate of Lnrdpch
Lnrelprc = natural log Relprice
Lnlndpcp = natural log Lndpcp
Lnpop = natural log Pop
Lnirrshr = natural log Irrshare
Lnurbpop = natural log Urbpop
Time = linear time trend

The tradeoff with using this form is it only allows for one asymptote, however, in the empirical work on this pattern using the more complex logistics form has not resulted in significant improvements (Chenery 1975, 17).

To see if there are additional non-linearities over the linear-log form, as well as identify possible interactions, three sets of regressions were run with the sample divided into low and high income countries. In these regressions the splits between low and high income countries were set at per capita income levels in international dollars of $2980, $4915, and $7332.

In these preliminary regressions, there were consistent differences between low and high income countries for the parameter estimates of Lnrgdpch and Lnlndpcp. In all cases the estimates for Lnrgdpch were significantly more negative for the poorer income group, indicating this group experiences more structural change due to an increase in income than does the richer group. Lnlndpcp represents a country's total land resources relative to its population, which means it should be positively associated with agriculture's share. The preliminary results indicated a somewhat more complex story, with the effect of Lnlndpcp varying according to income levels. For all of the low income regressions parameter estimates for Lnlndpcp were insignificant, and very small in absolute value. Conversely, for all high income groups they were positive. In order to account for these additional non-linearities two interaction terms were introduced into the empirical model. These terms are Lnrgdpch interacting both with itself and with Lnlndpcp.

While variables have been included which provide partial measures of resource endowments and policy regimes, it is likely there are additional country specific factors not being accounted for. For example, agricultural productivity depends upon land quality and climatic conditions, factors which vary greatly across countries, yet are poorly represented in the available data. Also, there is some question as to what extent the observed policy regimes can be explained with the available political economy variables. Development ideologies, social characteristics, and historical influences are not taken into consideration since they are so difficult to measure. It is reasonable to suspect, however, that these variables vary among countries and play a role in determining what policies will be adopted. To allow for possible country specific effects, country dummy variables are also included in the empirical model specification.

With the inclusion of the interaction terms and country dummy variables the final model specification for use with the full sample is:

(32) $$\text{Agshare} = A_1 + A_2\text{Lnrgdpch} + A_3\text{Gdpsq} + A_4\text{Grth} + A_4\text{Lnrelprc} + A_5\text{Lnlndpcp} + A_6\text{Lnpop} + A_7\text{Gdplndin} + A_8\text{Lnirrshr} + A_8\text{Lnurbpop} + A_9\text{Time} + \sum A_i\text{Dummy}_i$$

Lnrgdpch = natural log Rgdpch
Gdpsq = Lnrgdpch * Lnrgdpch
Grth = Growth
Lnrelprc = natural log Relprice
Lnlndpcp = natural log Lndpcp
Lnpop = natural log Pop
Gdplndin = Lnrgdpch*Lnlndpcp
Lnirrshr = natural log irrshare
Lnurbpop = natural log Urbpop
Time = linear time trend
Dummy_i = dummy variable for country i

Full Sample OLS Estimates

Table 3 presents the full sample OLS results of equation (32), along with OLS results obtained from estimating equation (32) without country dummy variables.

Table 3. OLS Estimates for Full Sample

Without Country Dummy Variables			With Country Dummy Variables		
Variable	Parameter Estimate	t-statistic	Variable	Parameter Estimate	t-statistic
Intercept	1.64	7.98	Intercept	3.56	9.95
Lnrgdpch	-.31	-8.14	Lnrgdpch	-.62	-9.02
Gdpsq	.02	9.69	Gdpsq	.02	5.78
Grth	.074	2.28	Grth	.07	4.67
Lnrelprc	.02	2.20	Lnrelprc	.02	2.18
Lnlndpcp	-.09	-5.08	Lnlndpcp	.20	4.60
Lnpop	-.001	-1.17	Lnpop	.02	.78
Gdplndin	.012	5.43	Gdplndin	-.02	-4.20
Lnirrshr	.01	7.34	Lnirrshr	.01	1.69
Lnurbpop	-.045	-8.03	Lnurbpop	.03	3.12
Time	-.003	-1.92	Time	-.001	-2.33
Adjusted R-Squared = .7755 Sample size = 1620 Regression F-statistic = 622.430			Sample size = 1620 Regression F-statistic = 404.74		

A visual examination of the residuals obtained when the model is restricted to a single intercept revealed that in almost all cases they were of the same sign for each cross section. In addition, when country dummy variables are included they are significantly different from zero for 55 of the 81 countries. Obviously, the country dummy variables belong in the model specification, however, including them does change the interpretation of the model somewhat. When the model is restricted to a single intercept, parameter estimates reflect both intercountry and within country effects. However, since the majority of the variation occurs between countries the intercountry effects will be weighted relatively more heavily. When each country is allowed a different intercept the slope parameters now represent only the within country effect of a change in the predetermined variable. This is equivalent to estimating a regression equation where deviations are computed from country means.

This distinction had the most dramatic effect on the parameter estimates for Lnlndpcp and its interaction term, both of which actually change signs.

When country dummy variables are not included Lnlndpcp has either no - or possibly even a negative - effect on Agshare at low income levels. As Lnrgdpch increases the situation reverses itself with Agshare becoming positively associated with Lnlndpcp. However, with the inclusion of country dummy variables results indicate a positive within country association between Lnlndpcp and Agshare for all values of Lnrgdpch included in the range of the data. Comparing the results it appears that the negative association between Lnlndpcp and Agshare at low income levels is the result of intercountry differences in Lnlndpcp.

A positive within country association between Lnlndpcp and Ashare is expected since an increase in Lnlndpcp requires a significant commitment on the part of agricultural producers. In order to increase land resources producers have to clear and develop previously uncultivated land. For some countries this could also entail draining swampland, or other land types previously covered by water. Like the construction of irrigation projects, increasing arable land per capita could reflect not only a direct commitment to increasing agricultural productivity, but also a policy environment favorable to agriculture. Since both can be expected to increase agricultural production the combined effect is to increase agriculture's share.

Intercountry variations in Lnlndpcp reflect not so much the actions of producers to increase arable lands, but rather inherited resource endowments. There are several possible explanations for the difference in the intercountry effect of land resources as income levels increase. First, in low income countries, farmers do not have the physical and human capital to increase the productivity of their marginal arable lands. For example, through crop rotations, fertilizers, pesticides, and specialized seed varieties agricultural producers in rich countries can obtain significant yields out of relatively poor land. In poor countries these methods are not used to the same extent, and as a result yields from the same land types are much lower. Therefore, an increase in land per capita between countries, without some better way of controlling for its quality, does not produce enough of a yield increase to significantly alter agriculture's share. Producers in rich countries can use technology to make the land more productive, resulting in much larger and consisten yields. Second, Lnlndpcp is an exogenous variable in both the growth and political economy models. In the reduced form estimated above the coefficient for Lnlndpcp will reflect not only the direct effect of land resources on production, but also the indirect effects resources have upon the countries policy regime. If countries well endowed with agricultural resources tend to tax agriculture to finance overall development objectives, increases in Lnlndpcp will be associated with movements in the policy environment unfavorable towards agriculture. The overall impact would be to reduce the parameter estimates for Lnlndpcp in the reduced form. However, there are reasons to expect the impact to be less in rich countries. Rich countries have a greater tax base, and do not need to focus as heavily on a specific sector for revenues. Therefore, policy will be determined more by other political economy variables such as group size. Also, in terms of an overall development strategy richer countries seem to exhibit a more balanced growth approach, as evidenced by their relatively constant sector shares.

GLS Model Specification for Full Sample

With pooled data one might suspect the presence of both autocorrelation and heteroscedasticity. Consequently, in this section a four stage estimation procedure is developed to test, and correct, for non-spherical errors. In the first stage, estimates are obtained for rho, the first order autocorrelation parameter. Next, in the second stage, these estimates are used to form a generalized difference form of the original model, which is then also estimated with OLS. The third stage consists of using the residuals obtained from estimating the model in its differenced form to estimate the relative variances of the error terms. Last, in the fourth stage of the estimation process the variance estimates are used to apply weighted least squares.

Since OLS parameter estimates of equation (32) are unbiased and consistent they can be used to obtain estimates of the autocorrelation coefficient (rho). Thus, for the first stage of the estimation procedure rho was calculated for each each cross section as:

$$\hat{\rho}_i = \frac{\sum_{t=2}^{T} \hat{e}_{it}\hat{e}_{i,t-1}}{\sum_{t=2}^{T} \hat{e}^2_{i,t-1}} \quad \text{for } i = 1,2,\ldots,N .$$

These estimates are reported in appendix C, in general, they were significant and ranged in value from .18 to .95.

For the second stage, the $\hat{\rho}_i$ were used to perform a generalized differencing transformation which was then also estimated with OLS. The equation estimated was:

$$AS^* = x^*\gamma_1 + u^* . \tag{33}$$

AS* = (N T x 1) vector of the transformed dependent variables, each entry defined as:

$$AS^*_{i,t} = AS_{i,t} - \hat{\rho}_i AS_{i,t-1} \quad i= 1,\ldots,81;\ t=2,\ldots,20$$

x^* = (NT x K) matrix of the transformed predetermined variables in equation (32). Each entry defined as:

$$x^*_{k,i,t} = x_{k,i,t} - \hat{\rho}_i x_{k,i,t-1} . \quad k=1,\ldots,90;\ i=1,\ldots,81;\ t=2,\ldots,20$$

u^* = (NT x 1) vector of transformed error terms each entry defined as:

$$u^*_{i,t} = u_{i,t} - \hat{\rho}_i u_{i,t-1} \quad i=1,\ldots,81;\ t=2,\ldots,20$$

Residuals obtained from estimating equation (33) are cleaned of autocorrelation, and can be used to test for heteroscedasticity, and correct for it if present. In order to provide a framework from which to estimate the relative error variances, a linear moment model (LMM) proposed by Antle (1983) was adopted. This approach provides a statistical methodology for specifying and estimating both mean agricultural share, and its variance about the mean, as a function of the predetermined variables. The LMM is composed of equations (34) and (35) which define the mean and the second moment functions respectively.

(34) $$AS^* = x^* \gamma_1 + u^*, E(u^*) = 0$$
$$\mu_1 = E(AS^*) = x^* \gamma_1$$

(35) $$(u^*)^2 = x\ \gamma_2 + \upsilon, E(\upsilon) = 0$$
$$\mu_2 = E\left[(u^*)^2\right] = x\ \gamma_2$$

All variables in the mean function are the same as equation (33). In the second moment function the (N x K) matrix X is the matrix of the untransformed predetermined variables defined in equation (32).

Antle (1983) proves that under the following conditions:

i) $E(u_j u_{j'}) = 0$ for $j \neq j'$.

ii) The x_j are bounded, and the matrix X of the x_j is such that the lim X'X/N = M_X is a positive definite matrix.

iii) Letting u and v_i be the (N X 1) vectors of the u_j and $v_{i,j}$, plim X'u/N = plim X'v_i = 0 for all i, and X'u/$N^{1/2}$ and X'v_i/$N^{1/2}$ converge in distribution to a well-defined limiting distribution.

one can obtain consistent estimators ($\hat{\gamma}_i$) of γ_i using least squares regressions with u_j^i replaced by $\hat{u}_j^i$ for i greater than or equal to two. A test for heteroscedasticy in the error terms for equation (33) would be to test the null hypothesis that all parameters except the intercept in $\hat{\gamma}_2$ are jointly equal to zero. However, it can be shown that the error terms in equation (35) are also heteroscedastic, with their variance a function of the predetermined variables. Consequently, parameter estimates for the second moment function must also be corrected for heteroscedasticity before a valid hypothesis test can be performed.

In light of these results, the following procedure was used test for heteroscedasticity in the error terms (u^*). First, OLS was performed on equations (36-38).

(36) $$AS^* = x^* \gamma_1 + u^*$$

(37) $$(\hat{u}^*)^2 = x\ \gamma_2 + \upsilon$$

(38) $$\hat{v}^2 = x\ \beta + \varepsilon$$

$$(\hat{u}^*)^2 = \frac{\left(AS_j^* - x_j^* \hat{\gamma}_1\right)^2}{\frac{1}{n}\sum_{j=1}^{n}\left(AS_j^* - x_j^* \hat{\gamma}_1\right)^2}, \quad \hat{v}_j^2 = \frac{\left((\hat{u}^*)^2 - x_j \hat{\gamma}_2\right)^2}{\frac{1}{n}\sum_{j=1}^{n}\left((\hat{u}^*)^2 - x_j \hat{\gamma}_2\right)^2}$$

The dependent variables in equations (36) and (37) were divided through by their sample means in order to increase their orders of magnitude. In their original form the calculated variances were so small that their use might have resulted in some loss of efficiency. The necessary information required to correct for heteroscedasticity is the relative magnitude of the error variances. Consistent estimates of the relative magnitudes of the individual variances in the vector v are provided by the predicted values ($x\ \hat{\beta}$), however, before they could be used a practical difficulty that had to be faced is some of these predicted values were negative. This problem was overcome by replacing all negative values in the vector $x\hat{\beta}$ with the smallest positive predicted value of .0036. After replacment, the weights $w = 1/\sqrt{x\hat{\beta}}$ were computed, and used to perform weighted least squares on equation (37) which resulted in the second round parameter estimates ($\tilde{\gamma}_2$). Results from this regression are reported in appendix D. Last, an F-test with a 99% level of confidence was performed under the null hypotheses that all parameters except the intercept in the vector $\tilde{\gamma}_2$ are equal to zero. The computed value of the F-statistic was equal to 10.62 which is greater than the critical value of 1.40 so the null hypotheses was rejected.

Since the null hypothesis of homoscedasticity in the error terms of equation (33) was rejected the fourth, and final, stage is to correct for heteroscedasticity. The predicted values ($x\hat{\gamma}_2$) provide estimates of the relative error variances of equation (33), but, once again, before they could be used all negative values had to be replaced with the smallest positive predicted value, which in this case was equal to .007. Next, the weights $h = 1/\sqrt{x\hat{\gamma}_2}$ were calculated, and used to perform weighted least squares on equation (33).

GLS Estimates

Table 4 presents the GLS parameter estimates for the full sample, as well as GLS estimates for the sample stratified into low and high income countries. The split between low and high income countries was set at per capita income levels of $2000. This stratification resulted in 43 countries classified as high income, and 38 classified as low income.

Table 4. GLS Estimates

	Full Sample		Low Income		High Income	
Variable	Parameter Estimate	t-statistic	Parameter Estimate	t-statistic	Parameter Estimate	t-statistic
Lnrgdpch	-.18	-2.75	-.10	-6.03	-.02	-4.10
Gdpsq	.000	-.24				
Grth	.02	4.64	.05	5.59	.015	2.81
Lnrelprc	-.001	-.51	-.02	-2.91	.001	.59
Lnlndpcp	.17	4.61	.043	1.25	-.01	-1.25
Lnpop	.04	3.17	-.18	-1.95	.03	3.51
Gdplndin	-.019	-4.63				
Lnirrshr	.003	.99	.003	.34	-.0002	-.11
Lnurbpop	-.0004	-4.15	-.001	-4.46	-.0002	-1.63
Time	-.002	-7.04	.004	1.91	.002	-8.96
R-Squared = .990			R-Squared = .992		R-Squared = .988	
Sample size = 1539			Sample Size = 722		Sample size = 817	
Regression F-statistic = 1696.90			F-statistic = 1855.35		F-statistic = 1326.69	

Note: All variables estimated in their differenced form. Dummy variables for all countries were included so the model was estimated with no intercept.

Parameter estimates for Lnrgdpch are significant and negative for all regressions, indicating a decling agricultural share as per capita income levels increase. This result is consistent with all other empirical work on development patterns. While Lnrgdpch does appear to have a smaller effect on agriculture's share for the high income countries this apparent non-linearity was not reflected in the quadratic term included in the full sample regression. In contrast, for the OLS regression results reported in table 3 this same term was very significant.

Consistent with the hypothesis of adjustment lags, parameter estimates for Grth are positive in all cases. There is some difference between high and low income countries, with Grth having a larger impact in the latter. This would be expected since high income countries are experiencing much less structural change, and generally have higher levels of investment and saving. These factors reduce the degree of disequilibrium, and the time needed for adjustment.

Lnurbpop entered into the reduced form as a political economy variable to capture the effects of group size. While very small in magnitude, the estimates are negative which goes against the free rider hypothesis. They do, however, correspond to political economy models which hypothesize that government officials will try to please the greatest number of constituents. Another explanation for the negative association could be Lnurbpop is serving as a proxy variable for a country's comparative advantage in industries relying upon large, concentrated work forces. Last, if size of labor force is proportional to population size, increases in urban population will correspond to a relative increase in the non-agriculture sector's labor force which would also decrease agriculture's share.

Resource variables included in the model are Lnlndpcp and Lnirrshr. GLS parameter estimates for Lnlndpcp are very similar to the OLS estimates, and their interpretation has been presented above. Estimates of Lnirrshr show no association between the percent of arable land which is irrigated and agriculture's share. One of the principle reasons for this lack of influence could be the inclusion of the country dummy variables which, along with Lnirrshr, serve to control for land quality differences between countries.

Temporal Stability

Over a long enough time period there is some question as to the temporal stability of the parameter estimates. In particular, their may have been additions to the technology set which may cause a structural change (in an econometric sense) of the parameter estimates. To test for temporal stability a test proposed by Chow was performed. This test involves computing the F ratio:

$$F = \frac{\frac{ESS_r - (ESS_1 + ESS_2)}{k}}{\frac{ESS_1 + ESS_2}{t-2k}}.$$

ESS_r = error sum of squares for restricted model

ESS_1 = error sum of squares for model estimated for the years 1972-1980

ESS_2 = error sum of squares for model estimated for the years 1981-1990

k = number of coefficients

t = number of total observations

The decision rule is to reject the null hypothesis of no structural change if the calculated F-statistic is greater than the critical value. For the full sample regression equation reported in table 4 the calculated F-statistic with 91 and 1357 degrees of freedom is equal to 1.67, which is greater than the critical value of 1.39, so the null hypotheses of no structural change can be rejected at a 99% confidence level.

System Specification for PSE Sample

For a limited group of countries a quantitative measure of policy is available in the form of PSE's. It is assumed that Agshare and Pse are jointly endogenous, simultaneously producing an equilibrium growth pattern. Accordingly, the two equations:

$$\text{Agshare} = A_1 + A_2\text{Lnrgdpch} + A_3\text{Gdpsq} + A_4\text{Grth} + A_5\text{Lnrelprc} + A_6\text{Pse} + A_7\text{Lnlndpcp} + A_8\text{Gdplndin} + A_9\text{Lnirrshr} + A_{10}\text{Lnpop} \quad (38)$$

$$\text{Pse} = B_1 + B_2\text{Agshare} + B_3\text{Lnlndpcp} + B_4\text{Lnurbpop}$$

were estimated as a system in order to obtain consistent parameter estimates. This system was also estimated with country dummy variables, however, including these variables resulted in all parameter estimates being insignificant so the the results are not reported.

System Estimates

Limited Information Maximum Likelihood estimates for the model presented above are reported in table 5.

Table 5. LIML Estimates

Dependent Variable = Agshare			Dependent Variable = Pse		
Variable	Coefficient	t-statistic	Variable	Coefficient	t-statistic
Intercept	1.294	1.39	Intercept	103.722	1.10
Lnrgdpch	-.512	-3.15	Agshare	-269.568	-3.78
Gdpsq	.037	4.41	Lnlndpcp	-10.935	-2.77
Grth	.342	1.45	Lnurbpop	-35.709	-1.78
Lnrelprc	-.023	-.12			
Pse	-.001	-1.34			
Lnlndpcp	-.201	-2.90			
Gdplndin	.021	2.74			
Lnirrshr	.003	.28			
Lnpop	.016	2.72			
Sample size = 110			Sample size = 110		
Regression F-statistic = 27.896			Regression F-statistic = 8.360		

At least for this small sample, the results suggest that while Agshare has a highly significant negative influence on policy, policy has relatively little effect on Agshare. One reason for this could be a more dynamic formulation of the effect of policy is needed. Because of a host of adjustment mechanisms, and expectations regarding future policy directions, it is possible that long run effects of policy are not being picked up. However, without a longer time series for PSE's it is difficult to say how well this argument holds. On one hand, if there are large variations in policy from year to year, then the short time period covered in the data set is apt to miss the long run response. On the other hand, if policy remains relatively stable for a number of years, adjusting only periodically with a sudden jump, the story could be different. In this case, the international policy structure observed at a point in time could be representative of a structure that has persisted for a number of years. What is observed across countries under this scenario is the long run responses to different policy regimes, and a more dynamic formulation is not needed. Another explanation for the lack of influence Pse has on Agshare could be that growth patterns are predominantly caused by economic factors more fundamental that policy. Policy may be able to alter growth patterns somewhat, but for the most part they will be determined by income levels and resource endowments.

Results from the Pse equation are somewhat mixed from what the political economy model would predict. As expected, Agshare and Lnlndpcp are both negatively associated with Pse. Lnurbpop is also negatively associated with Pse, providing evidence against Olson's arguments about the advantages of smaller groups, in favor of models emphasizing the importance of voter numbers. However, much care should be taken in interpreting Lnurbpop as a reliable measure of relative group sizes. Within rural and urban interests are a number of diverse subgroups, and aggregating them may not tell the true story. Another reason for the negative coefficient could be an additional feedback between Pse and Lnurbpop. Suppose a government was following a development strategy dedicated towards the development of urban based industry. This strategy requires a policy regime encouraging large scale migrations toward urban areas, a phenomenon which has actually been observed in several developing countries. Likely, one of the observed consequences of this policy regime would be negative values for Pse's, which would then be correlated with higher urban concentrations.

In the system specified above natural logs of the PSE's were not taken since some of their values were negative. It is very likely, however, that there is a non-linear relationship between agriculture's share and the PSE's. Hu and Antle (1993) found that the effect of policy on agricultural productivity depended upon the degree of policy distortion. Policy had a large and statistically significant effect on productivity in countries with moderate rates of taxation or subsidization. However, in countries that either taxed or subsidized agriculture at a high rate, the impact of marginally reducing the level of policy distortion was not found to be significant. They concluded that high levels of taxation or subsidization distort incentives to such a degree that, after a point, marginal changes in policy do not affect behavior.

To see if there was any evidence of a similar non-linear relationship between agriculture's share and the PSE's, the system was estimated with several different samples, stratified by predetermined levels of PSE. While the parameter estimates for PSE were never found to be statistically significant, their magnitude varied substantially, depending upon which values were included in the sample. Similar to the type of results obtained by Hu and Antle (1993), when only the middle range of the PSE were included the magnitude of the parameter estimate was the largest. As an example, when the sample was limited to those observations corresponding to values of PSE ranging between negative and positive 40 the parameter estimate was .097. In contrast, when the sample was limited to observations corresponding to only positive or negative PSE values, the estimate dropped to .00006 and .0002 respectively. These results suggest the relationship between agriculture's share and the producer subsidy equivalents could follow a logistics curve, and the real reason for Pse's lack of influence in table 5 is model specification error.

5. CONCLUSION

A two-sector growth model and a political economy model of agricultural pricing policy are developed in conjunction to explain the variability in agriculture's share of production across countries and over time. According to the models, this variability is caused by the interaction between transnational and country specific factors. Transnational factors include: a common hierarchy of human wants and needs, access to the same technology, and participation in the global economy. Due to the presence of these factors there will be certain uniform patterns of development. Country specific factors include resource endowments and the policy environment. These factors condition the impact of the transnational factors, accounting for the uniqueness among countries.

In the regression equations, the variables measuring transnational effects are income per capita, world prices, and growth rates. Results show that agriculture's share declines with increases in per capita income. This is caused by the interaction between demand and supply side forces as capital/labor ratios increase and state variables change. World prices are included to account for global economic conditions. Since all of the countries in the sample participate in the global economy, relative world prices should affect domestic production decisions. Results show some support of this hypothesis, however, their statistical significance varies from sample to sample. Growth rates serve to control for the degree of disequilibrium. It is hypothesized that, holding everything else constant, agriculture's share should be larger in countries with higher growth rates due to adjustment lags. For the most part results supported this hypothesis, although, in general they were more statistically evidence in support of this hypothesis. While the transnational variables represent factors affecting all countries, their effect on agriculture's share will be conditioned by resource endowments and policy. However, interpreting the results is complicated by the fact that policy often depends upon resource endowments, and many times it is difficult to disentangle the effects of policy from the underlying conditions which caused it. OLS results indicate that agriculture's share is positively associated with the share of arable land which is irrigated, however, like prices, there was no statistically significant relationship between the two in the GLS model. Holding the level of development and world prices constant, the intercountry effect of increasing land per capita depends upon income levels. At low income levels countries with greater land endowments do not have statistically significant higher agricultural shares. One reason for this may be producers in rich countries are better able to improve the quality of marginal land through the use of modern inputs. Another is, according to the political economy model, policy will be negatively associated with resource endowments. On the other hand, within countries land per capita is positively associated with agricultural shares for all income levels. PSE's are included in the regression equations for a subset of the data. At least in these regressions the effect of PSE on agriculture's share was very small, and only statistically significant when the growth equation was estimated by itself. The reasons for this could be that a more dynamic model formulation is needed, growth patterns are caused by factors more fundamental than policy, or a non-linear model is needed to capture the true relationship.

There is a noticeable lack of variables to account for supply conditions in the non-agricultural sector. One reason for this is the huge variety of industries lumped into this category, each requiring a different mix of inputs. Also, development of a manufacturing or service sector depends more upon human choices and policy decisions, factors which are very hard to quantify. No doubt countries that rely more upon development of non-agricultural sectors to stimulate growth do so in part to overcome natural resource limitations. However, the question remains as to why are some countries able to follow this development strategy, while others simply stagnate? There must be some country specific factors accounting for this phenomenon. Some possible examples could be location, preferential treatment by the developed nations, social characteristics, or a particularity adept government. Perhaps disaggregating into sectors with more homogeneous production and demand characteristics would allow some greater insights in this area.

Trade may also play a more significant role than it was given here. This study adopted a small, open country assumption where countries could sell all they wanted at given world prices. How well this holds is not clear as countries are going to have to expend some resources to find markets for their exports, and it could be the case they could only sell more at a lower price. Also, there is a literature concerned with the positive effects trade could have as a source of growth. The problem is trade is also an endogenous variable, determined in part by policy and the level of development. However, as transportation and communication costs decline, trade is apt to play a greater role in development patterns, and a closer examination of its interactions may become necessary.

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APPENDICES

A. COUNTRY LISTING AND SUMMARY STATISTICS OF LARGE SAMPLE

Table 6. Country Listing of Large Sample

Algeria	France	Norway
Argentina	Gambia	Pakistan
Australia	Germany, Fed. Rep.	Panama
Austria	Ghana	Paraguay
Bangladesh	Greece	Philippines
Belgium	Guinea-Bissau	Puerto Rico
Benin	Guyana	Senegal
Bolivia	Honduras	Sierra Leone
Botswana	Hungary	Somalia
Brazil	India	South Africa
Burkina Faso	Indonesia	Spain
Burundi	Italy	Sri Lanka
Cameroon	Jamaica	Sudan
Canada	Japan	Syrian Arab Rep.
Chad	Kenya	Tanzania
China	Korea, Rep.	Thailand
Colombia	Luxumberg	Togo
Congo	Madagascar	Trinidad and Tobago
Costa Rica	Malawi	Tunisia
Cote d' Ivoire	Mali	Turkey
Denmark	Mauritania	United Kingdom
Domincian Republic	Mauritius	United States
Ecuador	Mexico	Uruguay
Egypt	Morocco	Venezuela
El Salvador	New Zealand	Zaire
Ethiopia	Nicaragua	Zambia
Finland	Nigeria	Zimbabwe

Table 7. Summary Statistics for Large Sample

Variable	Agshare[1]	Rgdpch[2]	Grth[3]	Relprice[4]	Lndpcp[5]	Irrshare[6]
Min	.01	283	-.31	.66	.04	0
Max	.69	18399	.38	1.25	3.15	1
Mean	.22	3993	.02	.90	.42	.13
Std. Dev.	.15	4202	.06	.16	.16	.17

1. Agricultural value added divided by total GDP.
2. Real per capita GDP in 1985 international prices.
3. Growth rate of Rgdpch.
4. World export price index for food products divided by export unit price index for manufactured goods.
5. Hectares of land under temporary or permanent crops divided by population.
6. % of land under temporary or permanent crops which is irrigated.

B. COUNTRY LISTING AND SUMMARY STATISTICS OF PSE SAMPLE

Table 8. Country Listing for Pse Sample

Argentina	Jamaica	Senegal
Australia	Japan	South Africa
Canada	Kenya	Tanzania
China	Korea, Rep.	Turkey
Colombia	Mexico	United States
Egypt	New Zealand	Zambia
Hungary	Nigeria	Zimbabwe
India		

Table 9. Summary Statistics for Pse Sample

Variable[1]	Agshare	Rgdpch	Grth	Relprice	Pse	Lndpcp	Irrshare	Urbpop
Min	.019	452	-.145	.664	-116.2	.037	.005	19.7
Max	.627	18354	.133	.759	78.7	2.981	1.00	85.98
Mean	.169	5200	.018	.719	7.52	.496	.209	55.54
Std. Dev.	.139	5420	.041	.031	39.24	.653	.263	20.65

1. Variable definitions are the same as appendix A.

C. ESTIMATES OF FIRST ORDER AUTOCORRELATION COEFFICIENT

Table 10. Estimates of First Order Autocorrelation Coefficient

Country	Rho	t-statistic	Country	Rho	t-statistic
Algeria	.89	8.78	India	.63	3.85
Argentina	.45	2.14	Indonesia	.50	3.95
Australia	.56	2.92	Italy	-.07	-.29
Austria	.82	4.73	Jamaica	.89	9.08
Bangladesh	.80	5.24	Japan	.81	5.69
Belgium	.75	4.70	Kenya	.40	2.50
Benin	.62	3.29	Korea, Rep.	.93	11.82
Bolivia	.86	7.91	Luxumberg	.95	9.73
Botswana	.91	10.44	Madagascar	.58	3.07
Brazil	.37	1.98	Malawi	.73	4.80
Burkina Faso	.83	6.00	Mali	.62	3.28
Burundi	.62	3.93	Mauritania	.37	1.69
Cameroon	.41	1.86	Mauritius	.42	2.09
Canada	.79	8.53	Mexico	.55	2.75
Chad	.74	4.64	Morocco	.41	1.83
China	.83	6.34	New Zealand	.24	1.07
Colombia	.86	6.58	Nicaragua	.48	2.30
Congo	.82	5.58	Nigeria	.62	3.45
Costa Rica	.58	2.93	Norway	.82	4.75
Cote d'Ivoire	.18	.77	Pakistan	.58	3.37
Denmark	.69	4.02	Panama	.51	2.66
Dominican Republic	.25	1.10	Paraguay	.68	3.98
Ecuador	.64	3.97	Philippines	.91	8.08
Egypt	.76	5.01	Puerto Rico	.56	2.73
El Salvador	.93	7.31	Senegal	.37	1.72
Ethiopia	.83	6.39	Sierre Leone	.71	4.90
Finland	.35	2.34	Somalia	.64	3.59
France	.51	2.37	South Africa	.15	.63
Gambia	.39	1.68	Spain	.75	7.62
Germany	.89	6.72	Sri Lanka	.71	4.95
Ghana	.66	4.11	Sudan	.61	3.32
Greece	.44	2.22	Syria	.75	4.32
Guinea-Bissau	.27	1.17	Tanzania	.95	13.56
Guyana	.49	2.23	Thailand	.85	5.95
Honduras	.85	7.81	Togo	.51	2.44
Hungary	.82	5.73	Trinidad and Tobago	.32	1.48

Table 10. cont.

Country	Rho	t-statistic	Country	Rho	t-statistic
Tunisia	.09	.37	Venezuela	.66	3.81
Turkey	.91	10.13	Zaire	.83	7.86
United Kingdom	.96	10.35	Zambia	.68	3.89
United States	.82	5.83	Zimbabwe	.39	1.70
Uruguay	.66	3.68			

D. REGRESSION RESULTS OF VARIANCE EQUATION

Table 11. Results of Weighted Least Squares Estimation of Equation (35)

Variable[1]	Coefficient	t-statistic	Variable	Coefficient	t-statistic
Intercept	18.93	.93	Domdum	-.06	-.05
Lnrgdpch	-8.37	-2.11	Ecudum	.36	.37
Gdpsq	.36	1.68	Egydum	-2.27	-1.82
Grth	.63	.71	Slvdum	4.44	2.46
Lnrelprc	1.42	3.27	Ethdum	-4.72	-3.31
Lnlndpcp	.53	.24	Findum	1.48	1.18
Lnpop	.86	0.95	Fradum	-.90	-.62
Gdplndin	-.17	-.71	Gmbdum	2.84	.87
Lnirrshr	-.22	-1.07	Deudum	-3.02	-1.72
Lnurbpop	.98	2.38	Ghadum	-.06	-.05
Argdum	.016	.016	Grcdum	1.11	1.36
Ausdum	2.62	1.38	Gnbdum	1.57	.54
Autdum	-.33	-.25	Guydum	6.47	1.24
Bgddum	-.05	-.01	Hnddum	.49	.33
Beldum	-2.17	-1.25	Hundum	.67	1.06
Bendum	-.61	-.38	Inddum	-4.69	-1.49
Boldum	1.59	.42	Idndum	-2.80	-1.65
Bwadum	3.33	1.37	Itadum	-1.17	-.84
Bradum	-2.24	-1.30	Jamdum	.44	.17
Hvodum	1.59	1.29	Jpndum	-3.54	-1.63
Bdidum	.13	.08	Kendum	-2.34	-2.09
Cmrdum	-.32	-.34	Kordum	-2.29	-1.75
Candum	1.41	.78	Luxdum	4.75	1.38
Tcddum	-1.03	-.70	Mdgdum	.80	.78
Chndum	-4.42	-1.38	Mlidum	2.81	.30
Coldum	-1.47	-2.69	Mwidum	-1.36	-.91
Cogdum	.51	.18	Mrtdum	1.30	.45
Cridum	1.62	.76	Musdum	11.61	3.60
Civdum	2.33	2.28	Mexdum	-1.09	-.84
Dnkdum	1.51	1.19	Mardum	-.24	-.51
Nzldum	1.17	.58	Sdndum	1.21	1.57
Nicdum	2.75	1.54	Syrdum	4.04	5.44
Ngadum	-2.00	-1.49	Tzadum	-2.14	-2.21
Nordum	.47	.29	Thadum	-.07	-.06
Pakdum	-2.35	-1.67	Tgodum	1.77	.46
Pandum	1.28	.58	Ttodum	1.70	.58
Prydum	1.24	.79	Tundum	1.21	1.28
Phldum	-2.31	.85	Turdum	-.48	-.46