AGRICULTURAL PRICE PROTECTION AND PRODUCTIVITY IN HIGH AND LOW INCOME COUNTRIES

by

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ABSTRACT

It is argued that agricultural pricing policies can have an effect on agricultural productivity through the effects that price expectations can have on the choice of technique by producers, on the incentives for discovering new knowledge and on investment in agriculture. It is hypothesized that there is a positive (negative) relationship between subsidy (tax), but this relationship depends on the degree of the subsidy or tax. The Nominal Protection Coefficient (NPC) is used as a proxy for agricultural policy, and is included as an explanatory variable in production function. Policy is also hypothesized to be an endogenous variable in the process of economic growth, so a simultaneous equations model is estimated consisting of an aggregate production function and a policy equation. Agricultural policy is found to have a positive and significant impact on agricultural productivity and this productivity effect is not the same for all countries. In particular, in the countries that subsidize or tax agriculture moderately, the response of productivity to the NPC is large with an elasticity greater than 2. The results imply that if the price interventions were to be eliminated, agricultural productivity would increase on average by more than 68% in developing countries and would on average by about 30% in developed countries. The results also suggest that it would be possible to reduce the adverse environmental impacts of agriculture caused by subsidies without significantly lowering agricultural productivity in developed countries.

CHAPTER 1

INTRODUCTION

In his volume Distortion of Agricultural Incentives, T. W. Schultz argued that the producer incentives play "the critical allocative role in attaining the optimum increases in productivity" and "interventions by government are the primary cause of the lack of optimum economic incentives" (Schultz, 1978).

Following his argument, the goal of this research is to utilize the aggregate cross-country production function to test the hypothesis that agricultural policy has a significant impact on aggregate agricultural productivity. The concept of a meta-production function, introduced by Hayami and Ruttan, is adopted here. Agricultural policy is measured by a country's nominal protection coefficient (NPC), defined here as the ratio of border prices to domestic prices.

There is also an important emerging literature which shows that agricultural policy is a function of a country's economic growth (Bates, Binswanger and Scandizzo, Anderson and Hayami, etc.). Thus, agricultural policy may be a function, in part, of a country's agricultural productivity. Therefore, in this research, the aggregate production function is estimated jointly with a political model that explains the country's NPC.

The econometric results strongly support the hypothesis that agricultural policy has a positive and significant impact on agricultural productivity. However this productivity effect is not the same for all countries. In countries that tax agriculture highly (NPC less than 0.7), the impact of marginally reducing the tax is relatively small, apparently because the high level of taxation has severely distorted incentives. At moderate to low levels of taxation or low to moderate levels of subsidy (NPC between 0.7 and 1.15), there is a large (elasticity greater than 2) response of productivity to the NPC. At high subsidy levels (NPC greater than 1.15), the evidence suggests that policy changes are associated with the smallest productivity response partly because of diminishing returns to subsidy incentives and because of the impact of other distorting policies on the sector.

The thesis is organized as follows: the first chapter of this thesis briefly reviews the aggregate production and political economy literatures. The second chapter gives some theoretical background on the relation between policy and productivity. The following chapters describe the data and equations to be estimated, present and interpret the results, and summarize the conclusions.

CHAPTER 2

LITERATURE REVIEW

Literature of Production Economics

In the past two decades, the application of Hicks' induced innovation theory and econometric tools have led to significant advances in productivity research. In a pioneering paper published in 1970, Hayami and Ruttan explored the sources of agricultural productivity differences among countries by estimating an aggregate production function based on cross-country data for 1960. Later, they extended their data to 1970 and 1980 (Hayami and Ruttan, 1985). Hayami and Ruttan described the cross country aggregate production function as the meta-production function, which they defined as the envelope of the production points of the most efficient countries. Output was regarded as a function of the country's resource endowment, modern technical inputs and human capital. Hayami and Ruttan found significant differences between less developed countries (LDCs) and developed countries (DCs): in particular, constant returns to scale in LDCs and increasing returns to scale in DCs. They also found that different factor price ratios induced different paths of technology progress in different countries.

Evenson and Kislev (1986) modified Hayami and Ruttan's model by including a variable measuring each country's investment in agricultural research and by relating research activity to agricultural productivity. The proxy used for the stock of research variable was the total number of agricultural research publications. They showed that increased investment in agricultural research and extension will achieve an expansion in agricultural supply.

Antle (1983) found a significant positive effect of infrastructure on agricultural productivity by adding a variable measuring the transportation and communication services produced by each country's infrastructure capital.

Estimates of some of the coefficients in Hayami and Ruttan's model seem implausible. The coefficients of land appear too small and the coefficients of general education seem too large and have the wrong sign for DCs. The year dummies which measure technological change are negative, contrary to expectation. Lau and Yotopulos (1989) tried to improve the specification by introducing country-specific effects. To do this, they estimated the Cobb-Douglas model in first-difference form, thus allowing for country-specific efficiency factors. The estimated coefficients for land in this transformed model are larger and significant. The estimates of technological change coefficients have the expected sign. They also estimated a flexible function form, the transcendental logarithmic production function, with country-specific effects. The estimated coefficients of all the factors other than land and machinery are similar to Cobb-Douglas model, but the coefficient of land is smaller and the coefficient of machinery is higher in the transcendental logarithmic model. This model may reduce the possibility of bias caused by country-specific effects productivity difference, but it is parameter-intensive, reducing by one third the number of observations.

Mundlak and Hellinghausen's research (1982) provided an alternative approach to the analysis of intercountry and intertemporal agricultural productivity differences. Based on induced innovation theory, they constructed a variable coefficients model for treating productivity growth as a process endogenous to state variables representing the physical and economic environment within which the firms operate. Changes in the state variables cause changes in the implemented techniques which are associated with changes in inputs and outputs. Compared to Hayami and Ruttan's model, they obtained higher values for land and labor elasticities and lower values for livestock, machinery and fertilizer.

Literature of Political Economy

In the political economy literature, the effect of agricultural pricing policy receives much attention. Review and critique of this literature can be found in Alston and Carter (1991), Tolley, Thomas, Nash and Snyder (in press) and Gardner (1992).

Recent attempts to explain policy focus on economic interest groups. Policies are hypothesized to be the result of redistributing income among groups in response to pressure from voters and lobbies. Different patterns of interventions exist in different economic conditions and political institutions around the world. It is observed that as a country becomes richer, it moves toward protecting agriculture instead of taxing the sector as poor countries do. Several theoretical models attempt to explain this observed fact. First, it has been recognized that in countries where agriculture is a large part of the economy, it provides a natural tax base for governments. Second, Olson (1965,1986), Peltzman (1976) and Becker (1983) explain these facts in terms of group size and free riding. In high income countries where farmers tend to be a relatively small homogeneous and well-educated group, it is easier for them to organize to protect their economic interests and to overcome the free riding problem than in low income countries.

Bates and Rogerson (1981,1983) provide another explanation for the pattern of taxation and subsidization of agriculture. They treat society as a collection of producer/consumer groups who specialize in production, but consume a common bundle of goods. Coalitions of some groups organize to lobby the government to increase producer prices. Although by assumption, a larger coalition can achieve a greater price, each coalition hesitates to include any group producing a good that accounts for a large share of the consumption bundle, since it will cause other existing coalition members to pay substantially higher prices of the goods they consume. In low income countries, food accounts for a large share of consumption. Thus in low income countries, farmers will tend not to be included in a coalition that obtains subsidies which lower the cost of food. In high income countries, where food only accounts for a small share of consumption, farmers are more likely to participate in coalitions to receive subsidies from the government.

Variations of different rates of protection from country to country provide a base for empirical analysis of agricultural policy. Using commodity-specific Nominal Protection Coefficients for 31 countries, including developed and developing countries, as a policy variable, Binswanger and Scandizzo (1983) found that the NPCs could be explained as a function of income level, resource endowment and stage and pattern of development. Their findings confirm the well known fact that countries with low incomes and large agricultural resource endowments tend to tax agriculture, but countries with high incomes and poor resource endowments tend to subsidize agriculture.

Anderson, Honma and Hayami (1986) confirmed Binswanger and Scandizzo's conclusion. Using a weighted average of nominal rates of agricultural protection for 12 commodities as an aggregate estimate of agricultural protection in 15 industrial countries, they found a positive relation between a country's protection and income. Their research also provided a study of the transition from taxing to subsidizing agriculture. As comparative advantage shifts from agriculture to industry, it can be expected that agricultural pricing policy will tend to protect agriculture. The experience of Japan, Korea and Taiwan showed this pattern.

In explaining intervention in U.S. commodity markets to aid farmers, Gardner (1987) used the data on 17 commodities over the period 1910 to 1980 to estimate a model to explain policy. The dependent variable used to measure intervention is an estimate of producers' price gains generated by farm programs as a percentage of observed market price for the commodity. Thus, the dependent variable he used was similar to the NPC in that it measured the percentage effect of policy on price. Independent variables associated with the cost to producers of generating political pressure and the social cost of redistribution are both found to be empirically important. Gardner found that greater costs reduce intervention. He also found that there is a nonlinear relationship between group size and political power, which indicates that there is an optimal size of group.

Krueger, Schiff and Valdes used data from World Bank studies of agricultural policy in eighteen developing countries to measure the effect of sectoral (direct) and economywide (indirect) policies. The direct effect is measured by the proportional difference between the producer price and the border price. The indirect effect has two components. The first is the impact of the unsustainable portion of the current account deficit and of industrial protection policies on the real exchange rate, and thus on the agricultural price relative to non-agricultural non-tradables prices. The second is the impact of industrial protection policies on the relative price of agricultural commodities to that of non-agricultural tradable goods. They found that indirect discrimination against agriculture through industrial protection and an over-valued exchange rate is quantitatively more important than direct policy intervention. They also found that direct and indirect intervention in combination yields net taxation of agricultural producers in these countries.

De Gorter and Tsur (1990,1991) presented a model to explain agricultural protection as the outcome of the interaction between self-interested politicians and citizens. The model was tested in terms of the level of the nominal protection coefficient for 18 developing countries studied by Krueger, Schiff and Valdes. The NPCs are used as a proxy for the level of transfers between the agricultural and non-agricultural sector. The explanatory variables include the difference in income between agricultural and non-agricultural sector, the ratio of agricultural to non-agricultural population and a dummy to capture the influence of trade.

They found an inverse relation between policy and relative income between agricultural and non-agricultural sectors. They argued that when farm income is relatively low, the subsidies to farmers are greater.

Antle (1988) described the theoretical issues in analyzing the impacts of production and price policy on productivity. On the demand side, relative product and factor prices influence farmers' demands for innovations. On the supply side, induced innovation theory implies price policies may influence research and development in both the public and private sectors.

To date there appear to be only two empirical attempts to estimate the impacts of agricultural policy on aggregate productivity. Fulginitti and Perrin (1991) used Mundlak's variable coefficients model to first estimate the impact of output price on productivity and productivity is found to be negatively related with the output prices. They used the NPC data to estimate the implicit productivity gains from policy liberalization and found out that agricultural productivity would have increase on average by about a third.

Schiff and Valdes (1991) used total price interventions, rather than just direct interventions, as a measure of policy impact. Comparing the average values of interventions and rate of agricultural growth of different groups, they found a negative correlation between agricultural growth rates and the rate of total taxation.

CHAPTER 3

THEORY AND HYPOTHESES

It has long been recognized that improved agricultural inputs and production techniques are necessary to increase agricultural productivity. But T.W. Schultz argued that the availability of superior seeds and fertilizers and other forms of new technology are not sufficient to achieve large increases in agricultural productivity. Producer incentives, which may be strongly influenced by government intervention, play a critical role in attaining the optimum increases in productivity (Schultz,1978). The interventions by governments change the economic opportunities in markets and cause distortions to agricultural incentives. According to Schultz, these incentives are the result of the comparison of farmers' expected costs, including risks, against the returns they expect to receive. Incentive plays a key role in the realization of the economic potential created by modern production processes. When incentives are suppressed, farmers are less likely to exploit investment opportunities or to discover new knowledge. Thus, government policy intervention can influence agricultural output and agricultural productivity.

The productivity measure used in this study is total factor productivity (TFP) based on comprehensive aggregates of outputs and inputs. Empirically, productivity change can be inferred from shifts in the production function. Let the production function be specified in Cobb-Douglas form

$$Q = b_0 X_1^{\alpha_1} \ldots X_n^{\alpha_n}, \tag{1}$$

where the X_i are inputs. Total factor productivity (TFP) is

$$TFP = Q / X_1^{\alpha_1} \ldots X_n^{\alpha_n} = b_0 \tag{2}$$

Note that this definition of TFP holds inputs quantities constant. More general measures of productivity allow inputs to vary (see Antle and Capalbo, 1988, Ch.2). Price distortions caused by government intervention have three effects. First, in the short run, with a given technology, changes in output price affect factor use on the intensive margin (variable inputs) and thus quantity supplied, where farmers produce along their supply curves. Second, in medium run, price distortions alter land use decisions on the extensive margin. Third, in the long run, price distortions alter physical capital investment on the farm, human capital investment, and may affect research and development through the induced innovation process described by Hayami and Ruttan. According to Hicks' induced innovation theory and the Hayami and Ruttan extension to public R&D, the output price can influence rate and bias of technological change by shifting the position of the production frontier. Under the assumption that production is efficient, technological change and productivity change are synonymous. Productivity, therefore, is expected to be affected by price distortions in the long run.

Thus, when agricultural pricing policy and other policies have the effect of subsidizing agriculture, both agricultural supply and agricultural productivity should increase and these impacts should be greater in the long run. Policies that tax agriculture should decrease supply and agricultural productivity. Hence, within the agriculture sector, protection of agriculture and aggregate agricultural productivity are expected to be positively related. An increase in protection and thus the incentive to produce will monotonicly increase agricultural productivity; conversely, taxation of agriculture should reduce productivity. This positive relationship between the subsidization of agriculture and agricultural productivity will be subject to two caveats, however.

First, when subsidies increase, the positive effects of subsidies on productivity could become small and high subsidies could even be associated with decreasing productivity. Technology constraints in the short run and resource constraints in the long run will limit the productivity response to incentives. High levels of subsidies could also lead to some problems, like overproduction. Some forms of supply control other than pricing policies, like acreage use limitation and supply quota often occur. These policies cause distortions in resource allocation across commodities and inputs in the agricultural sector, which could harm agricultural productivity. Hence, as illustrated in Figure 1, beyond some point, the slope of the curve could become smaller and even be negative. Second, when taxes become high, the negative effects on productivity could become small. Taxes on agriculture could reduce investment incentives to such a low level that, beyond some point, changes in tax rates have little or no impact on agricultural productivity. If this is the case, as Figure 1 illustrates, the slope of the curve will become smaller when the taxes on agriculture increase beyond some point.

These effects imply that the relationship between protection of agriculture and agricultural productivity could be nonlinear. The effects of policies are hypothesized to fall within three ranges. Policies which subsidize (tax) agriculture at a moderate level are hypothesized to have positive (negative) effects on productivity. Policies that highly subsidize agriculture are hypothesized to have smaller marginal positive or even negative effects on productivity. Policies that heavily tax agriculture are also expected to have small marginal effects on productivity. Figure 1 illustrates this relationship between Total Factor Productivity (TFP) and the pricing policy variable. The figure is drawn to represent the model that is estimated in

Chapter 5, where it is assumed that a piece-wise linear function is a reasonable approximation. In fact, the relationship would be expected to be a smooth, continuous one.

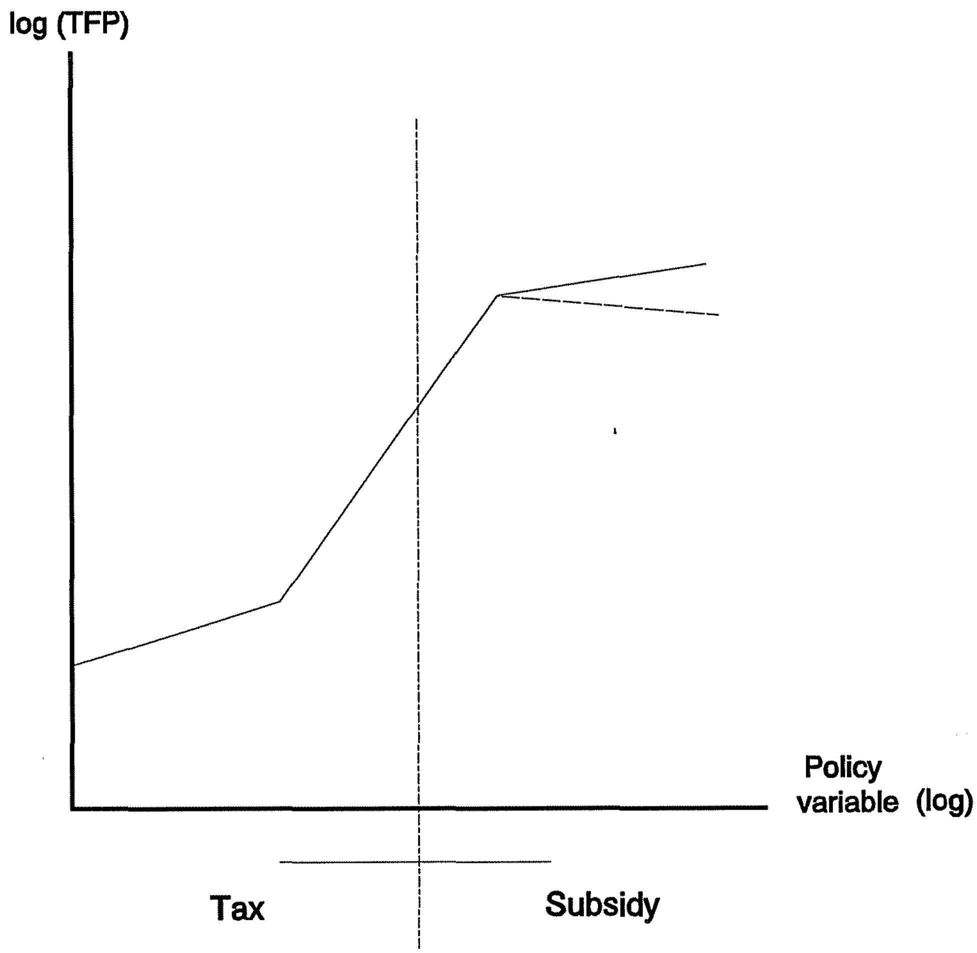

Figure 1. Hypothesized Relationship between TFP and Policy

CHAPTER 4

DATA

Both a production model and a policy model are estimated in this study. In the production model, in order to achieve comparability with other studies, the same input categories with exception of policy variable are used as those in the series of studies introduced by Hayami and Ruttan. Those inputs are Labor (L), Agricultural land (A), Livestock (S), Machinery (M), Fertilizer (F), General education (E). The data are for 1960, 1970 and 1980. In principle, the data for flow variables, such as agricultural land and fertilizer inputs, are measured, respectively, as 1957-62 average, 1967-72 averages and 1975-80 averages; and those for stock variables, such as agricultural land and number of farm workers, are measured for 1960, 1970 and 1980.

Agricultural output (Q), the dependent variable in the production models, is specified as the value of agricultural production, net of agricultural intermediate products such as seeds and feed. Since relative prices vary greatly across developed and developing countries, they may cause a serious bias in the measurement of the LDCs total value of agricultural production. Hayami and Ruttan generated three sets of wheat-relative price data in 1960 for the U.S., Japan and India which represent high, middle and low income country price patterns. To measure the series of 1957-62 average agricultural output in each country, the method is to use these prices to obtain three output values and to take their geometric mean. The other two series are extrapolated from these 1957-62 average using FAO's indices of agricultural production for each country.

Labor (L) is measured in thousands of participants in the economically active male population in agriculture as reported by FAO. Agricultural land (A) is measured in thousands of hectares of arable and permanent cropland and permanent pastures as reported by FAO. Livestock (S) is measured as a weighted average of various types of animals reported by FAO. The weights for aggregation are as follow: Camels, 1.1; buffalo, horse and mules, 1; cattle and asses, 0.8; pigs, 0.2; sheep and goats, 0.1; poultry, 0.01. Machinery (M) is measured as agricultural tractors and garden tractors (FAO) in thousands of horsepower units, aggregated according to formula: $M = h*N1 + 5*N2$, where h is average horsepower per riding tractor and 5 is average horsepower per garden tractor. Fertilizer (F) is measured as the sum of nitrogen, potash, and phosphate content of various fertilizers consumed and measured in thousands of metric tons as reported by the International Fertilizer Institute. Number of farm (N) is measured using data of the number of farms collected by FAO. Education (E) is measured as the adult literacy rate.

All of the conventional inputs, Labor (L), Agricultural land (A), Livestock (S), Machinery (M), Fertilizer (F), as well as Agricultural output (Q), are deflated by the Farm number (N) so that the production function is expressed in per-farm terms.

In the policy model, explanatory variables include income per capita (IC), agricultural land per capita (AC) and agricultural output (Q), which is specified the same as in the production model.

Income per capita (IC) is specified as GDP per capita adjusted for changes in the terms of trade using 1985 international prices for domestic absorption and current prices for net foreign balance as reported in The PENN World Table. Arable land per capita (AC) is agricultural land (A) in production function deflated by population data collecting from World Table, 1984.

The proxy variable used in this study to indicate the degree of government's protection provided to a country's agricultural sector is its aggregate nominal protection coefficient (NPC).

Every given commodity's nominal protection coefficient (NPC) is defined as the ratio of the price of this commodity received by agricultural producers in the domestic market, including government subsidy or tax, to the world price of the commodity if it were sold on the world market. World prices, which are measured at the country's border, represent the opportunity cost of tradable commodities for countries that are price takers in world market. These are the prices that would have prevailed domestically in the absence of government intervention. The aggregate nominal protection coefficient is used to represent the government's intervention in the sector as a whole. For each country it is measured as the weighted average of nominal protection coefficients for the commodities selected based on their importance in that production using domestic production valued at border prices as weights. If there is no price distortion in the sector, the NPC is equal to unity; if the economy subsidizes the sector and increases the prices received by domestic producers, the NPC is greater than 1; if the domestic sector is taxed, the NPC is less than 1.

The NPC used in this study is an aggregate measure for the agricultural sector. It should be noted that this aggregate measure does not capture the differences in policies across commodities and other aspects of polices such as input subsidies or supply control. Actually, the effective rate of protection (ERP) is a better proxy to indicate the degree of protection to agricultural sector since it takes account of the effects of government policies not only in final goods markets but also in input markets. However the data of ERP is not available for many countries and over time. NPC is the best measure of agricultural policy available for many countries over a long time period.

The data for NPCs is not available for many countries over the 1960-1980 period from one consistent source. NPCs for industrial countries for 1960, 1970 and 1980 are obtained from The Political Economy of Agricultural Protection by Anderson and Hayami(1986). Anderson and Hayami assumed that each country was unable to influence international prices and compared the domestic prices with the prices at each country's border for 12 commodities and 15 countries. Domestic prices are assessed as the average prices received by farmers including the effects not only of trade protection but also of more direct agricultural support policies such as deficiency payments. The domestic prices are converted to US dollars using the average exchange rates for each year.

Wholesale prices are compared with border prices since wholesale prices represent payments for approximately the same marketing services as are embodied in import or export prices. Since adjustments are not made for marketing costs from the farm gate to the wholesale level, the resulting NPCs underestimate the rate of producer protection in these industrial countries. However because this bias is similar across countries and over time, it should not bias the analysis. Border prices are measured by cif unit import values for the importing countries and by fob export values for the exporting countries. Commodities used to calculate aggregate NPCs are rice, wheat, barley, corn, oats, rye, beef, pork, chicken, eggs, milk and sugar. The countries used in this study are: Japan, Taiwan, Sweden, Switzerland, New Zealand, Denmark, France, West Germany, Italy, Netherlands, the United Kingdom, Australia, Canada, and the United State. When the sample is split according to income, following Hayami and Ruttan, Taiwan is included in the low income group.

The data on NPC's for developing countries are taken from the World Bank research project on the political economy of agricultural pricing policies. Estimates of sector-specific (direct) and economy wide (indirect) policies on agricultural incentives are both utilized. For each country, major export-competing and import-competing agricultural commodities are selected on the basis of their importance and the representativeness of the commodity specific policies. Most countries are assumed to be price takers in world market.

The direct nominal protection rate measures the proportional difference between the relative domestic price, related to the nonagricultural sector price index, and the relative border price of agricultural tradable. Border prices are adjusted for transport costs and other factors to make them comparable to producer prices. World market border prices are measured by cif unit import values for importables and by fob export values for the exportables. Direct NPC estimates measure the effects of price controls, export taxes or quotas and other policies affecting domestic producer prices.

The indirect nominal protection rate measures the proportional difference between border price, related to nonagricultural sector price index, both evaluated at the official nominal exchange rate, and the relative border price evaluated at the equilibrium nominal exchange rate. For each country, a country's equilibrium exchange rate is defined as the exchange rate that equilibrates the current account in the absence of tariffs, quotas, export taxes and other export restrictions. A simple three sector model (exportables, importables and nontradables) is constructed to estimate this equilibrium exchange rate. Indirect NPC estimates measure the effects of the official nominal exchange rate differing from the equilibrium nominal exchange rate and the effects on agriculture implicit in protection to industry.

The sum of the magnitude of the impact of direct and indirect policies on agricultural prices is the total nominal protection rate. A detailed discussion of their construction is presented in the appendix of The Political Economy of Agricultural Pricing Policy by Krueger, Schiff and Valdes (1991).

In their study, Krueger, Schiff and Valdes have shown that indirect policy intervention on agricultural production through overvalued exchange rates and industrial protection is quantitatively more important than direct policy intervention. Thus, in this analysis the total nominal protection rate is used for developing countries. Ten countries in Hayami and Ruttan's data base match the World Bank data: Argentina, Brazil, Chile, Columbia, Egypt, Pakistan, Philippine, Portugal, Sri Lanka and Turkey. The data include the three years, 1960, 1970 and 1980.

For Argentina, Egypt and Turkey, the 1960 data are not available. Using the available data, a log-linear model was used to generate estimates of these missing values. The explanatory variables include income per capita, agricultural labor, agricultural land, livestock, fertilizer, machinery, general education rate and technical education variable. The R2 is 0.77 for this model.

Thus, the sample consists of 24 countries, 11 of which are developing countries.

It should be noted that the methods of calculating NPCs used in these two studies are not consistent. The Anderson and Hayami NPC measure is comparable to the World Bank's direct measure. Anderson and Hayami did not measure the effects of economy wide policies for industrial countries. Generally in developed countries, however, the official exchange rate is close to the equilibrium value, so the indirect effects of industrial protection on agriculture are small. Thus, the effects of indirect policies on agricultural prices are less important in the high income countries compared to developing countries. Thus it is assumed that the Anderson and Hayami NPC measure is comparable to the total measure (direct plus indirect) for the developing countries produced by the World Bank.

Another measure difference between these two studies is that the adjustment for transport costs and other factors is included in the World Bank's measure but is not included in Anderson and Hayami's measure. This could lead to a bias in models estimated with the pooled sample, but will not influence the results of stratified samples.

CHAPTER 5

ESTIMATION PROCEDURE AND RESULTS

Four models are investigated in this study: a single-equation production model; a single-equation policy model; a simultaneous equations system model containing the production model and policy model; a simultaneous equations system identical to model(3) except that it includes dummy variable-NPC interaction terms to test the hypothesis presented in Figure 1.

The effect of the NPC on aggregate agricultural productivity is first estimated with an aggregate production function with NPC as an explanatory variable (model 1). Following the political economy literature cited above, it is assumed that policy is an endogenous variable. A policy model is set up with NPC as the dependent variable (model 2). Since it is suspected that there is joint dependence between policy and productivity, the production model and the policy model are estimated as a system of simultaneous equations (model 3). To test the hypothesis of a nonlinear relationship between NPC and productivity, a simultaneous equations model with NPC-dummy variable interaction terms is estimated.

Estimation of Model 1

The first step in the analysis is to add the policy variable to Hayami and Ruttan's meta-production function. Hayami and Ruttan utilized their meta-production function concept by pooling the data cross countries and over time. The functional form they used is the Cobb-Douglas model. As noted above, Lau and Yotopulos (1989) argued that Hayami and Ruttan failed to take account of intercountry differences. Lau and Yotopulos introduced an equation system Cobb-Douglas model in first-difference form which allowed for country-specific efficiency factors. If Lau and Yotopulos' model were used in this study, it would reduce the number of observations from 72 to 48. Therefore, the original Hayami and Ruttan specification is maintained in this study, with the addition of the NPC variable to explain country-specific efficiency differences.

The Cobb-Douglas production function model is specified as:

$$Q = b_0 L^{b1} A^{b2} S^{b3} M^{b4} F^{b5} e^{u}, \; u \sim (0, \sigma^2) \qquad (3)$$

where b_0 is assumed to be a function of education and policy variables:

$$\ln(b_0) = \ln(b_{00}) + b_{01}\ln(E) + b_{02}\ln(NPC) + b_{03}\ln(D7) + b_{04}\ln(D8) \quad \textbf{(4)}$$

The conventional input variables, labor (L), land (A), livestock (S), machinery (M), fertilizer (F), represent the country's agricultural resource endowments. The general eduction level (E) is used as proxy for human capital. D7 and D8 are dummy variables for the year 1970 and 1980 respectively. An agricultural research variable was constructed using annual research expenditure data developed by Pardey and Roseboom (1990). Apparently because of the high correlation between research and other modern inputs, this variable did not contribute to the model and was omitted. For the same reason, Hayami and Ruttan's technical education variable was omitted. The infrastructure variable was omitted because of measurement problems caused by high inflation rates in developing countries.

Models were estimated by OLS with the full sample and split into DC and LDC groups. The pooled data capture the wide variation in observed production conditions. The group data allow a test of the difference between DCs and LDCs. The results are reported in Table 2.

The NPC variable is not significant at the 90% confidence level in the pooled sample. This provides little support for the hypothesis that the policy variable contributes to the explanation of productivity differences. It is significant at the 99.5% confidence level in the DC group regression, but it is not significant at the 90% confidence level for the LDC group. The negative sign of the estimated coefficient for NPC indicates that increasing subsidies could harm the growth of productivity in DCs.

In the pooled sample, the estimates of the regression coefficients all appear satisfactory except agricultural land and the time dummies. The signs of those coefficients are negative. Similar results were obtained by Hayami and Ruttan. The low values of the agricultural land coefficient may occur because land quality differences are not measured. The estimated coefficients for the year dummies, which are assumed to act as proxies for technological change, are positive for the DC's but negative in the pooled model and for the LDCs. These results are not plausible since it seems unlikely for the level of the agricultural technology for the LDCs to have retrogressed about 15% over the two decades of the 1970's and 1980's.

It is apparent from the results in Table 2 that there is a substantial difference between the DCs and the LDCs. An F-test was used to test for a statistical difference. Calculation of F(10, 52) is 2.87, which is greater than the critical value, 2.7 at the 1% significance level, and suggests that there is a difference between high income and low income groups. As shown in Table 2, labor, livestock and machinery have greater effects in LDCs than in DCs. Fertilizer has a greater effect in DCs than in LDCs. The coefficients for land

and the two year dummies are estimated to be negative for LDCs, while they are positive in DCs, although the land coefficient is not significant in DCs. The general education coefficient is positive and significant for LDCs, while it is negative in DCs. But the variation in the general education (E) is narrow among DCs, as it is close to 100% in those countries. Thus this result is not meaningful.

Estimation of Model 2

The theoretical arguments drawn in Chapter 2 argued that policy is an endogenous variable in the process of economic growth. In order to explore these relationships, a model is specified to explain policy in terms of economic development characteristics: agricultural output (Q), income per capita (IC) and agricultural land per capita (AC). The model is:

$$NPC = \alpha_0 Q^{\alpha_1} IC^{\alpha_2} AC^{\alpha_3} e^{v}, \quad v \sim (0, \sigma^2), \tag{5}$$

where Q, the value of agricultural output per farm, is defined the same as in the production model. This model is interpreted as follows. A country's policy is assumed to be a function of its stage of agricultural development and its resource endowment. One of the best proxies for a country's agricultural development is the share of agriculture in national income. Thus, as agricultural output increases for a given per capita income, agriculture's share of production should be increasing. Political economy theory suggests that as agriculture's share decreases, agriculture becomes better organized, and thus less likely to be taxed or more likely to be subsidized. Similarly, the higher is per capita income, the more likely is agriculture to be a small and politically well-organized group. Hence, it is hypothesized that $a_1 < 0$ and $a_2 > 0$. Also, countries with larger agricultural resource endowments are more likely to tax agriculture more or subsidize it less. Thus, it is hypothesized that $a_3 < 0$. Models were estimated using OLS with the full sample and split into DC and LDC groups. Table 3 presents those results.

The levels of statistical significance of the regression coefficients are good in all three versions of the model. The positive sign of the estimated coefficient for income per capita and the negative signs of agricultural output and agricultural land per capita are as hypothesized. The results indicate that income per capita has a significant positive effect on agricultural policy, and agricultural output and agricultural land have significant negative effects on protection. The two year dummies show that from 1960 to 1980, NPC has tended to decrease which suggests countries have tended to subsidize less or tax more over time.

An F-test indicates some differences between the estimated models for the two groups. $F(6, 60)$ equals 3.65 which is greater than the critical value, 3.12, at 1% significance. The estimated elasticities of agricultural output are nearly the same in two groups. An increase in per capita income has a larger impact in LDCs than in DCs. The negative impact of agricultural land per capita is smaller in LDCs than in DCs. The signs of the estimated coefficients of these year dummies show that DCs have tended to move toward subsidizing agriculture more and LDCs have tended to move toward taxing agriculture more over these two decades.

The results for the policy model are consistent with the hypothesis and the empirical results of other studies, such as Binswanger and Scandizzo (1983) and Anderson and Hayami (1986).

Estimation of Model 3

As shown above, Q, the dependent variable in the production model, is assumed to be an exogenous variable in the policy model. NPC, the dependent variable in the policy model, is assumed to be the exogenous variable in the production model. It can be seen from Table 3 that Q is significant at the 90% confidence level in all three versions of the policy model. Although the NPC coefficient is not significant in the production model, it is possible that the NPC and Q are jointly determined. Because the NPC is assumed to be endogenous, the existence of a correlation between NPC and the error term in the production model leads to inconsistency of the OLS estimator of the regression coefficients. Thus the results of the production model could be biased and inconsistent and biased. By the same reasoning, the results of the policy model also could be biased and inconsistent.

To investigate this possibility, the production model and the policy model were estimated as a simultaneous system. The model is:

$$Q = b_0 L^{b_1} A^{b_2} S^{b_3} M^{b_4} F^{b_5} e^{u}$$
$$NPC = \alpha_0 Q^{\alpha_1} IC^{\alpha_2} AC^{\alpha_3} e^{v} \qquad \textbf{(6)}$$

where b0 is specified as in equation (2).

Model 3 was estimated by maximum likelihood (ML) methods for the full sample and for the DC and LDC groups. The ML estimates are known to be consistent and asymptotically efficient under the assumption that the errors u and v are independently and identically distributed. GAUSS is the program package used. Results are reported in Table 4.

In the pooled sample, the NPC coefficient is positive and significant at the 97.5% confidence level in the production function, while Q is significant and negative at the 90% confidence level in the policy function. The significance of both NPC and Q fails to reject the hypothesis that NPC is endogenous variable and both NPC and Q are jointly dependent. The explanatory power of NPC in the simultaneous system also fails to reject the hypothesis that NPC has a significant effect on productivity. The positive sign of the estimated coefficient for NPC indicates that as the level of NPC increases, which suggests that there is a higher subsidy or lower tax, agricultural output will increase. The NPC coefficient in DCs, which was negative in the single-equation policy model, is positive and significant in the simultaneous equations model. The NPC coefficient in LDCs is positive but insignificant in the simultaneous system.

Comparison of Tables 2, 3 and 4 shows the differences between the single-equation and system estimates. In the pooled sample, OLS appears to underestimate the coefficients of labor (L), land (A) and the year dummies (D7 & D8). The estimated coefficient for land is positive, but still insignificant. The coefficients of machinery (M) and general education (E) appear to be overestimated by OLS. The estimates of livestock (S) and fertilizer (F) are similar.

Estimating the model as a simultaneous system does not have much effect on the policy model. All the estimates of the regression coefficients for the policy equation in simultaneous system are similar to the OLS results. Income per capita has a significant positive effect on agricultural policy, and agricultural output and agricultural land have significant negative effects on protection.

A likelihood ratio statistic was calculated to test the difference between the two income groups. Minus two times the logarithm of the likelihood ratio between the pooled and unpooled models equals 115.2, greater than the critical value of 32 at the 1% significant level. This suggests substantial difference between these two groups. The way these two groups differ is similar to the differences in the OLS models: Labor, livestock and machinery have greater effects in LDCs than in DCs. Fertilizer has a greater effect in DCs than in LDCs. For LDCs, the coefficient of the year dummy for 1980 in the production equation becomes positive, while the coefficients of the year dummy for 1970 and land are still negative. In the simultaneous system, land is positive and significant in DCs. The general education coefficient is positive but not significant for LDCs, while it is still negative in DCs.

As in the pooled sample, in the stratified samples the coefficients of the policy equation in the simultaneous system do not differ much from the OLS estimates. The estimated elasticities of agricultural output are similar in the two groups. An increase in per capita income will have larger impacts in LDCs than in DCs. The negative impact of agricultural land per capita is smaller in LDCs than in DCs. The signs of the estimated coefficients of these year dummies for LDCs show that LDCs have tended to move toward taxing agriculture more over these two decades. DCs tended to subsidize agriculture more from 1960 to 1970 but have tended to subsidize agriculture less from 1970 to 1980.

Estimation of Model 4

In Chapter 3, it is hypothesized that not only is there a positive relationship between policy protection for agriculture and agricultural productivity, but also the relationship may differ according to the degree of subsidization or taxation. To test this hypothesis, a fourth model is specified. In this model, the NPC variable interacts with two dummy variables to test for different productivity effects according to the range of NPC. The model is specified as equation (6) except b_0 is specified as:

$$\begin{aligned} \ln(b_0) &= \ln(b_{00}) + b_{01}\ln(E) + b_{02}\ln(NPC) \\ &+ b_{021}*D0*\ln(NPC) + b_{022}*D1*\ln(NPC) \\ &b_{03}\ln(D7) + b_{04}\ln(D8) \end{aligned} \quad \textbf{(7)}$$

D0 is a dummy variable taking the value unity if NPC is in the low range (less than 1). D1 is a dummy variable taking the value unity if NPC is the high range (greater than 1). To determine the low, middle and high ranges, cutoff points were identified using a maximum likelihood criterion. A search procedure resulted in cutoff points of 0.7 and 1.15. The coefficient of b_{02} shows directly the effect of NPC in the middle range between 1.15 and 0.7. The sum (b_{02}+b_{021}) shows the effect of NPC in the low range which is less than 0.7. The sum (b_{02}+b_{022}) shows the effect of NPC in the high range which is greater than 1.15.

The use of the NPC-dummy interaction model allows the elasticity of NPC to vary according to the range of the NPC, as illustrated in Figure 1. Of the total observations in the sample, there are 15 observations in the low range, 28 observations in the middle range and 29 observations in the high range. Because of the number of observations, this model was estimated with the full sample. The results are reported in Regression (1) of Table 4.

The estimated NPC elasticity in the low range is 0.54 (t-stat = 2.29), is 2.17 in the middle range (t-stat=3.96), and is 0.111 in the high range (t-stat=0.364). The values of the NPC coefficients for the low and middle ranges are both significant at the 97.5% confidence level. The NPC coefficient for the high range is not significant. These coefficients fail to reject the hypothesis of a nonlinear relationship between NPC and agricultural output. As hypothesized, the NPC in the middle range has greater positive effect on agricultural output than NPCs in the other two ranges. The estimated effects of NPC in the low and middle ranges are much greater than the effect found in model 3. This suggests that at moderate to low levels of taxation or low to moderate levels of subsidy (NPC between 0.7 and 1.15), there is a large response of agricultural output to the NPC and the elasticity of production output with respect to NPC is greater than 2. The productivity responses to NPC are much smaller when the economy is highly taxed or highly subsidized.

Other coefficients in the model remain the same as in the previous simultaneous model except for land and the year dummies. The coefficient of land becomes negative. But the coefficients of the two year dummies are positive as one would expect and indicate that the level of the agricultural technology has increased over the two decades of the 1970's and 1980's. The estimates of the policy equation are similar to the previous system model, although the negative effect of agricultural output on NPC is larger and more significant (at 99% confidence level) in this model. The positive effect of income per capita is greater and the negative effect of agricultural land per capita is smaller in this model. The coefficients of year dummies remain the same as in the previous model, which still suggest countries tend to subsidize less or tax more in those two decades as compared to 1960.

Since the results of the above models also suggest there are substantial differences between DCs and LDCs, another version of the simultaneous system model was specified to capture this difference. In this model, interactions between inputs in the production function and an income dummy variable are introduced to allow structural change between low and high income countries. The model is specified as:

$$Q = b_0 L^{(b_1 + b_{11} * DL)} A^{(b_2 + b_{21} * DL)} S^{(b_3 + b_{31} * DL)} M^{(b_4 + b_{41} * DL)} F^{(b_5 + b_{51} * DL)} e^{u}, \quad u \sim (0, \sigma^2) \qquad \textbf{(8)}$$

$$NPC = \alpha_0 Q^{\alpha_1} IC^{\alpha_2} AC^{\alpha_3} e^{v}, \quad v \sim (0, \sigma^2) \qquad (10)$$

where DL is the dummy variable taking the value unity if the *where*

$$\ln(b_0) = \ln(b_{00}) + b_{01}\ln(E) + b_{011}*DL*\ln(E) + b_{02}\ln(NPC) + b_{021}*D0 *\ln(NPC) + b_{022}*D1*\ln(NPC) + b_{03}\ln(D7) + b_{04}\ln(D8) \quad (9)$$

country is an LDC and zero otherwise. The results of this model are reported in Regression (2) of Table 5. Adding the income dummy interaction terms does not change the estimated coefficient of the NPC significantly. This suggests that the model without DL is acceptable, as the effect of NPC is similar to the effect in the version with income interaction terms. Therefore, the version without income interaction terms is chosen to be the final version of this model.

CHAPTER 6

PRODUCTIVITY POTENTIAL

Previous theory suggests that agricultural productivity will be affected by agricultural price and related policies. In this chapter, the implications of the simultaneous model for evaluating the impact of NPC on agricultural productivity is examined.

As described in Chapter 3, total factor productivity (TFP) in this study is defined as:

$$TFP = Q/L^{b_1}A^{b_2}S^{b_3}M^{b_4}F^{b_5} = b_0 \quad \textbf{(11)}$$

Using the parameter estimates and the mean values of NPC, the productivity change caused by the elimination of price distortions can be estimated. From equation (7), the elasticities of total factor productivity with respect to NPC are $(b_{02}+b_{021})$, b_{02} and $(b_{02}+b_{022})$ when NPC is in low, middle and high ranges. The estimates of these elasticities are 0.544, 2.169 and 0.111 respectively (using the results of Table 5). This indicates that when NPC is in the middle range, a 10% increase of NPC will produce a 21.69% increase in productivity. When NPC is in low range, a 10% change of NPC will change productivity by only 5.4%. When the NPC is above 1.15, an increase in the agricultural subsidy of 10% will slightly increase agricultural productivity by only 1.1%.

The potential of agricultural productivity impact of policy liberalization can be obtained, following Fulginitti and Perrin, by multiplying the elasticity of total factor productivity by the amount of price distortion. The mean value of the NPC is 1.34 in DCs and 0.76 in LDCs in the sample used here. If the distortion caused by policy intervention were eliminated in LDCs in this sample, productivity would increase more than 68% on average. If DCs cut their NPCs from 1.34 to 1.15, agricultural productivity in these countries will only decease on average by about 1.5%. But if the DCs were to reduce subsidies from 1.15 to 1, productivity would decrease by 30% on average, according to these estimated responses in the middle range of the NPC.

It is useful to compare the results to those of Fulgnitti and Perrin. In their paper, they estimated the effect of expected prices on productivity for eighteen developing countries and then used the World Bank NPC data to estimate the effect of policy reform on productivity. The elasticity of total factor productivity with respect to past price expectation they obtained is 0.5 which indicates that a 10% change in past output price expectations (due to different policy choices) would produce a 5 percent increase in productivity. This result is close to the estimate for the NPC in the low range of this study. Since only developing countries are in the low range, these two results are quite consistent. They found that if the developing countries in their sample had eliminated their price interventions, agricultural productivity would increase on average by about a third, which is about half of the potential gain from price liberalization for all LDCs in both low and middle ranges found in this study.

CHAPTER 7

CONCLUSION

This study has examined the relationship between agricultural policy and agricultural productivity. The empirical results show that the nominal protection coefficient (NPC) has a significant positive impact on agricultural productivity in a sample of 24 countries including high and low income countries. The results also confirm the hypothesis that the relationship between agricultural productivity and agricultural policy varies according to the degree of taxation or subsidization. When NPC is in the middle range from 0.7 to 1.15, productivity is found to have the largest response to policies whose effects are reflected in the NPC.

The productivity potential of eliminating the price distortions is found to be large for the developing countries, which generally have the experience of taxing agriculture. In countries that are moderately taxing (up to 30 percent), the elasticity of total factor productivity with respect to the NPC is estimated to exceed 2. In those economies where agriculture is heavily taxed, the elasticity of total factor productivity with respect to the NPC is estimated to be around 0.5. For the high income countries, which have the experience of subsidizing agriculture, lower subsidies will decrease agricultural productivity. For the countries that are moderately subsidizing agriculture (up to 15 percent), the elasticity of productivity response to NPC is greater than 2. Higher subsidies beyond 15% are estimated to have only a small additional effect on productivity.

These findings have various implications. Elimination of trade protection in each country and free entry into the world markets could increase productivity by more than 68.% in LDCs and decrease productivity by about 30% in DCs. These large productivity changes could have significant impacts on the balance of world agricultural trade.

Another concern of high income countries is the suspected tradeoff between agricultural output and environmental quality. As Antle (1991) has suggested, higher farm output may reduce environmental quality. The results presented here suggest that in countries with very high subsidies, somewhat lower subsidies would be associated with very small productivity losses. Therefore, it may be possible to reduce the adverse environmental impacts of agriculture caused by subsidies without significantly lowering agricultural productivity.

These conclusions are subject to several important caveats. As noted in Chapter 3, the productivity concept used in this study is a narrow one, and does not account for changes in factor use in response to policy changes. Also, as explained in Chapter 4, there are numerous limitations to the data. Finally, future research could further explore the central hypothesis posed in this study, namely that the effect of policy on productivity depends on the degree of taxation or subsidization.

REFERENCES CITED

Anderson, K. and Y. Hayami
The Political Economy of Agricultural Protection: East Asia in International Perspective
Sydney: Allen and Unwin, 1986

Alston, J. and C. Carter
"Cause and consequences of farm policy"
Contemporary Policy Issues, January,1991: 107-121

Antle, J.
"Infrastructure and aggregate agricultural productivity: International evidence"
Economic Development and Culture Change 1983: 609-619

-----"Human capital, infrastructure and the productivity of Indian rice farmers"
Journal of Development Economics 14, 1984: 163-181

-----"Dynamics, causality, and agricultural productivity"
Agricultural Productivity: Measurement and Explanation S.Capalbo and J.Antle eds
Washington, D.C.: Resource for the Future, 1988

-----"Farm policy reform and the environment"
American Journal of Agricultural Economics, 1991

Bates, R.H. and W.P.Rogerson.
"Agriculture in development: A coalitional analysis"
Public Choice 36, 1981: 513-27

Becker, G.
"A theory of competition among pressure groups for political influence"
Quart. Journal of Economics 98, 1983: 371-400

Binswanger, H.P.and P.L. Scandizzo
"Patterns of agricultural protection"
discussion paper report No.ARU 15, 1983

Corden, W.M.
The Theory of Protection
Oxford: Clarendon Press, 1971

de Gorter, H. and Y. Tsur
"Explaining price policy bias in agriculture:The calculus of support-maximizing politicians"
American Journal of Agricultural Economics, Nov. 1991: 1244-1254

Evenson, R.E., and Y. kislev
Agricultural Research and Productivity
Yale University Press,New Haven,CT, 1975

Fulginitti and Perrin
"Price and Productivity in Agriculture"
unpublished paper, 1991

Gardner, B.L.
"Causes of U.S. farm commodity program"
Journal of Political Economy 95, 1987: 290-310

-----"Changing economic perspectives on the farm problem"
Journal of Economic Literature No.1, 1992: 62-101

Hayami, Y. and V.W. Ruttan
Agricultural Development: An International Perspective
John Hopkins University Press, Baltimore, MD,1985

Kawagoe, T., Y. Hayami and V.W. Ruttan
"The intercountry agricultural production function and productivity differences among countries"
Journal of Development 19, 1985: 113-132

Krueger, A.O., M.Schiff and A.Valdes
"Agricultural incentives in developing countries: Measuring the effect of sectoral and economywide policies"
The World Bank Economic Review,Vol.2,No.3, 1988: 255-271

Lau, L.J. and P.A. Yotopoulos
"The Meta-production function approach to technological change in world agriculture"
Journal of Development Economics 31,1989: 241-269

Mundlak, Y. and R. Hellinghausen
"The intercountry agricultural production function: Another view"
American Journal of Agricultural Economics 64,1982: 664-672

Olson, M.
The Logic of Collective action
Cambridge, Harvard University Press, 1965

Peltzman, S.
"Toward a more general theory of regulation"
Journal of Law and Economics, No.19, 1976: 211-240

Schiff, M. and A. Valdes
"Agricultural incentives and growth in developing countries: A cross country perspective" unpublished manuscript,1991

Schultz, T.W.
Distortion of Agricultural Incentives
Bloomington, Indiana University Press, 1978

Tolley, G., V. Thomas, J. Nash, and J. Snyder
"What we know about agricultural price: Policies, Politics, and Supply"
Essays on Agricultural Policy in Honor of D. Gale Johnson, J.M.Antle and D.A.Sumner, eds
Chicago, University of Chicago Press, in press

APPENDIX

Table 1. SUMMARY STATISTICS

NAME	N	MEAN	ST.DEV	MINIMUM	MAXIMUM
NPC-w*	72	1.076	0.40992	0.325	2.26
NPC-l	33	0.76064	0.26753	0.325	1.52
NPC-h	39	1.3428	0.30701	0.95	2.26
IC-w	72	6110.2	4023	542	15046
IC-l	33	2412.5	1294.6	542	4785
IC-h	39	9238.9	2628.4	3008	15046
AC-w	72	0.002873	0.008019	0.000048	0.045274
AC-l	33	0.001403	0.002101	0.000055	0.008323
AC-h	39	0.004117	0.010629	0.000048	0.045274
Q-w	72	55332	84170	4906	497440
Q-l	33	32549	32911	4906	150420
Q-h	39	74610	107200	6827	497440
A-w	72	66314	128910	871	493360
A-l	33	44773	66246	871	207720
A-h	39	84541	163120	2017	493360
L-w	72	2302.4	2697.2	97	11380
L-l	33	3690.5	3223.6	432	11380
L-h	39	1127.9	1324	97	5097
S-w	72	20793	28391	1061	117550
S-l	33	21869	28952	1061	111650
S-h	39	19882	28254	1864	117550
F-w	72	1355.8	2938.4	14	19147
F-l	33	309.09	491.22	14	2717
F-h	39	2241.6	3764.7	99	19147
M-w	72	19005	43575	13	264910
M-l	33	2459	4057.9	13	18501
M-h	39	33006	55633	652	264910
N-w	72	1777.8	1986.5	65	8715
N-l	33	2365.1	2175.1	174	8715
N-h	39	1280.9	1684.2	65	6057
E-w	72	83.724	22.26	15.4	100
E-l	33	66.345	22.836	15.4	93
E-h	39	98.428	1.5751	90.7	100

* w refers the whole sample, l and h refer low and high income groups

Table 2. ESTIMATION OF MODEL 1 : SINGLE-PRODUCTION EQUATION MODEL

	ALL COUNTRIES	LDCs	DCs
VARIABLE	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)
CONSTANT	1.1971 (2.2705)	0.83906 (1.0909)	4.7038 (0.86034)
LNL	0.25325 (2.0425)	0.61133 (2.4492)	0.26705 (3.2855)
LNA	-0.0094169 (-0.20743)	-0.23002 (-1.3308)	0.015228 (0.66452)
LNS	0.43667 (5.762)	0.5549 (2.5573)	0.40601 (8.2012)
LNM	0.13165 (3.3271)	0.22595 (2.6466)	0.11077 (2.9215)
LNF	0.18919 (4.8678)	0.063922 (0.66508)	0.1335 (2.7053)
LNE	0.27666 (2.3661)	0.35958 (2.1302)	-0.47064 (-0.39463)
LNPC	0.11828 (1.0022)	0.2397 (1.1013)	-0.31302 (-2.7889)
D7	-0.045758 (-0.61652)	-0.14735 (-0.88985)	0.16448 (3.3944)
D8	-0.015458 (-0.18309)	-0.15142 (-0.66651)	0.28739 (4.8083)
R-SQUARE	0.97	0.91	0.99
SSE	3.8	2.36	0.24

Table 3. ESTIMATION OF MODEL 2 : SINGLE-EQUATION POLICY MODEL

	ALL COUNTRIES	LDCs	DCs
VARIABLE	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)
CONSTANT	-4.8861 (-13.619)	-6.9217 (-6.141)	-1.8735 (-1.8051)
LNQ	-0.10272 (-2.3175)	-0.12013 (-1.4591)	-0.13979 (-3.6427)
LNIC	0.55697 (9.575)	0.78063 (5.5282)	0.25914 (2.2065)
LNAC	-0.095732 (-4.5348)	-0.16364 (-3.5064)	-0.053766 (-2.7275)
D7	-0.093046 (-1.5163)	-0.16974 (-1.5361	0.037892 (0.55105)
D8	-0.33099 (-5.2072)	-0.65386 (-4.9311)	0.013009 (0.15458)
R-SQUARE	0.76	0.6	0.68
SSE	2.85	1.50	0.59

Table 4. ESTIMATION OF MODEL 3 : THE SIMULTANEOUS SYSTEM MODEL

	ALL COUNTRIES	LDCs	DCs
VARIABLE	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)
PRODUCTION FUNCTION			
CONSTANT	1.452738 (2.5015)	1.354478 (0.762187)	8.383717 (1.551715)
LNL	0.316908 (2.391583)	0.724349 (1.25966)	0.306602 (3.083981)
LNA	0.016316 (0.250462)	-0.280021 (-0.80626)	0.07622 (2.524087)
LNS	0.432619 (4.044925)	0.635135 (1.454945)	0.462601 (8.045737)
LNM	0.107028 (1.971447)	0.230125 (1.170787)	0.043536 (1.12501)
LNF	0.186402 (4.197857)	0.027371 (0.182426)	0.162031 (2.903991)
LNE	0.201252 (1.439275)	0.216188 (0.528397)	-1.363913 (-1.15607)
LNPC	0.354634 (2.141785)	0.699931 (1.146088)	0.617903 (4.341596)
D7	0.055905 (0.633806)	0.01138 (0.034924)	0.268932 (2.697137)
D8	-0.028226 (-0.38037)	-0.1321 (-0.76995)	0.119308 (1.508972)
POLICY FUNCTION			
CONSTANT	-4.950732 (-9.2104)	-7.031944 (-4.23328)	-1.968463 (-1.50339)
LNQ	-0.119298 (-1.58609)	-0.138338 (-1.11525)	-0.122272 (-1.63852)
LNIC	0.575225 (6.052025)	0.801452 (3.412862)	0.257338 (1.80615)
LNAC	-0.091723 (-3.20148)	-0.164008 (-2.91211)	-0.059562 (-1.64963)
D7	-0.331197 (-5.23052)	-0.660664 (-3.87913)	-0.000738 (-0.00666)

Table 4. (continued)

D8	-0.093361 (-1.18113)	-0.173128 (-0.8722)	0.029706 (0.344062)
Likeli Log	19.4	3.01	74.02

Table 5. ESTIMATION OF MODEL 4 : SIMULTANEOUS SYSTEM WITH NPC-DUMMY INTERACTION

	REGRESSION 1	REGRESSION 2
VARIABLE	COEFFICIENT (t-STAT)	COEFFICIENT (t-STAT)
CONSTANT	0.972552 (1.565619)	0.583351 (1.06772)
LNL	0.315322 (2.133168)	0.195967 (0.645729)
LNA	-0.024283 (-0.31944)	0.003266 (0.042446)
LNS	0.500682 (4.306198)	0.44501 (2.210461)
LNM	0.072163 (1.25947)	0.111994 (0.775408)
LNF	0.153083 (3.281235)	0.175038 (0.925832)
LNE	0.321645 (2.184791)	0.398032 (2.812151)
LNPC	2.168632 (3.959597)	2.139699 (3.801456)
D0*LNPC*	-1.624735 (-3.13213)	-1.420546 (-2.96778)
D1*LNPC	-2.058002 (-3.0724)	-2.097537 (-2.50529)
D7	0.139337 (1.557281)	0.165179 (1.359439)
D8	0.043106 (0.557429)	0.038928 (0.419881)
DL*LNL		0.558926 (1.553488)
DL*LNA		-0.197446 (-1.2745)
DL*LNS		0.132696 (0.538424)
DL*LNM		0.024668 (0.155088)
DL*LNF		-0.153098 (-0.79867)
DL*LNE		-0.028665 (-0.28666)

Table 5. (continued)

CONSTANT	-5.186504 (-8.62001)	-5.159674 (-8.27827)
LNQ	-0.18445 (-2.64902)	-0.176589 (-2.57623)
LNIC	0.646957 (6.570228)	0.638338 (6.330825)
LNAC	-0.073399 (-2.66371)	-0.075794 (-2.89137)
D7	-0.331399 (-4.71494)	-0.331443 (-4.14134)
D8	-0.094203 (-1.04657)	-0.094143 (-0.97606)
LOG LIKELIHOOD	31.05	41.99

* The t-stat for (LNPC + D0 * LNPC) 2.287 and the t-stat for (LNPC + D1 * LNPC) is 0.3642