5. Data

5.1 Introduction

The main objective of this chapter is to describe the data sources used in this study of Thai agricultural production. Data sources are described and measurement of the input and output quantity and price variables is discussed.

5.2 Data Sources

The quantity of fertiliser used in agriculture is derived from *Chemical Fertiliser Statistics* (Ministry of Agriculture and Cooperatives 1977), *Fertiliser* (Thai Farmer Bank 1978), *Agricultural Facts in Thailand* (Ministry of Agriculture and Cooperatives 1985), *Important Information on Fertiliser and Future Fertiliser Requirement* (Ministry of Agriculture and Cooperatives 1988), and *Projection of Long-Term Demand for Chemical Fertilisers* (Kogapoon and Phanthian 1992). The price of fertiliser is published in *Chemical Fertiliser Requirement in Thai Agriculture during 1992-1997* (Ministry of Agriculture and Cooperatives 1992b).

Agricultural capital data, including farm machinery, water pumps and threshers, are collected from *Selected Economic Indicators Relating to Agriculture* (Ministry of Agriculture and Cooperatives 1984), *Utilization of Farm Machinery in Asia* (Mongkol 1991), and *Agricultural Statistics of Thailand Crop Year 1981/82, 1984/85, 1986/87, 1987/88, and 1990/91* (Ministry of Agriculture and Cooperatives 1992a). The import values and numbers of farm tractors, water pumps and threshers are obtained from the *Annual Statement of Foreign Trade Statistics* (Ministry of Finance 1991).

Quantities of hired labour, operator labour and unpaid family labour in persons are published annually by *Report of the Labour Force Surveys 1971-1990* (National Statistical Office 1993). Compensation of employees is published by *National Income of Thailand, New Series 1970-1987* (Office of the National Economic and Social Development Board 1988), and *National Income of Thailand, Editions 1989-1990* (Office of the National Economic and Social Development Board 1990a). Net farm income is obtained from *National Income of Thailand, New Series 1970-1987*, and *National Income of Thailand, Editions 1989-1990*.

Quantities and prices of crops are taken from *Agricultural Statistics of Thailand Crop Year 1974/75, 1977/78, 1981/82, 1984/85, 1987/88, 1990/91 and 1991/92* (Ministry of Agriculture and Cooperatives 1992a).

Agricultural land use data are available in *Agricultural Statistics of Thailand Crop Year 1981/82, 1986/87, and 1991/92* (Ministry of Agriculture and Cooperatives 1992a), and *Summary of Agricultural Statistics and Data* (Ministry of Agriculture and Cooperatives 1992c).

A 6 per cent real discount rate is assumed. This rate is derived from the nominal interest rates of agricultural long-run credit, published in the *Annual Report* of the Bank of Agriculture and Cooperatives (1991), deflated by the CPI (1986 = 100).

The Consumer Price Index (CPI) is published in *Group and Subgroup Indexes, Annual Average 1966-1979* (Office of the National Economic and Social Development Board 1980), *Thailand Social Indicators in Ten Years and 1987 Social Indicators* (Office of the National Economic and Social Development Board 1987), and *Thailand Social Indicators, 1990 Edition* (Office of the National Economic and Social Development Board 1990b).

5.3 Measurement of the Variables

The study involves Thai agricultural industry. Aggregate annual data from each of four regions of Thailand, namely the Central, Northern, Northeastern, and Southern regions, are used for the period 1971-90. The variables are classified into five groups: output supply, fertiliser, capital, labour and other exogenous variables, such as land and technology indicators. In addition to these variables, materials and services such as fuel and electricity, seed, insecticides and other costs have been important factors in Thai agricultural production. In addition, public capital, especially government investment in infrastructure such as roads and irrigation, has played an important part in agricultural production in the Thai agricultural sector for many years (Thailand Development Research Institute 1988, Ch. 3).[1] However, owing to no consistent data being available, both materials and services and public capital are not included in this study.

5.3.1 Index Number Methods

To reduce the number of variables in the model to a manageable number, a number of variables are constructed by aggregating two or more variables. The Tornqvist (1936) method has been used widely to construct price or quantity indexes which involve more than one commodity in many economic studies (e.g., Lawrence and McKay 1980; McKay, Lawrence and Vlastuin 1980, 1982, 1983; Warjiyo 1991; Luh and Stefanou 1991; Coelli 1996). The main advantage of the Tornqvist index is that it does not assume perfect substitution of all inputs of production as does the Laspeyres index. In other words, it does not assume linear production functions (Christensen 1975, p. 911). The Tornqvist index is 'exact for a homogeneous aggregator function which is capable of providing a second-order approximation to an arbitrary twice-continuously-differentiable aggregator function'. Thus, it is a 'superlative' index number (Diewert 1976, pp. 117, 136). However, there exist a few disadvantages. Caves, Christensen and Diewert (1982, p. 83) and Coelli and Rao (1995, pp. 67, 71) mentioned that it does not satisfy the transitivity test which requires that the set of all pairs of

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[1]See more detail on government agricultural policies in Chapter 2.

comparisons are consistent. Moreover, they also indicated that failure in the transitivity property is the primary disadvantage in the case of multilateral comparisons and, in particular, panel data. This, for example, is ignored by Warjiyo (1991), in his study involving a dynamic dual model of U.S. agriculture using time-series and cross-sectional data at state level. Nevertheless, Caves, Christensen and Diewert (1982, p. 83) indicated that it is possible to use the Elteto, Koves and Szulc (EKS) method to derive the transitive multilateral Tornqvist index from a Tornqvist index that is not transitive. This index has become known as the CCD multilateral index.

Recall that pooled data are used for this study, comprising annual time-series data for the period 1971-90 and for the four regions of Thailand. Thus, multilateral comparisons among the four regions are an important issue in this study. Thus, because of the disadvantage of the Tornqvist index in multilateral comparisons resulting from its failure in the transitivity property as discussed above, the CCD multilateral index is chosen to generate price indexes in this study. To the best of our knowledge, no dynamic dual study using the panel data has yet been undertaken which accounts for multilateral comparisons in the construction of data indexes.

Following Caves, Christensen and Diewert (1982, p. 79) and Coelli and Rao (1995, p. 72), the CCD multilateral price index in log change form for a pair of firms (s,t), for $s,t = 1,2,\ldots,M$, can be shown to be equal to

$$\ln P_{st} = \frac{1}{2}\left[\sum_{i=1}^{N}\left(v_i^t + \bar{v}_i\right)\left(\ln p_i^t - \overline{\ln p_i}\right) - \sum_{i=1}^{N}\left(v_i^s + \bar{v}_i\right)\left(\ln p_i^s - \overline{\ln p_i}\right)\right] \tag{5.1}$$

where $\bar{v}_i = \frac{1}{M}\sum_j^M v_{ij}$, $\overline{\ln p_i} = \frac{1}{M}\sum_j^M \ln p_{ij}$, p_i is the price of item i and v_i is the share of item i in total cost or revenue. In this study, M is equal to 80.

Following a number of studies (e.g., McKay, Lawrence and Vlastuin 1980, 1982, 1983; Wall and Fisher 1987; Ball 1988; Knopke, Strappazzon and Mullen 1995), implicit quantity indexes are obtained by dividing the current value of each input and output by its corresponding price index. One reason for using this approach is that Allen and Diewert (1981, p. 432) indicated that 'if there is less variation in the price ratios than in the quantity ratios, then the direct price indexes... are essentially share weighted averages of the price ratios... and will tend to be in closer agreement with each other than the implicit price indexes...'. In this case, they recommended '...the use of a superlative direct price index and the corresponding implicit quantity index...'. In this study, it seems price ratios are less varied than quantity ratios. This is because the average Whole Kingdom price of each crop and input is used due to lack of regional price data, as discussed below.

5.3.2 Computation of Index Numbers

Generally, the popular **TSP** (TSP International 1992) and **SHAZAM** (White 1993) computer packages have, respectively, the **DIVIND** and **INDEX** commands to calculate a few indexes such as Tornqvist and/or Fisher indexes. Unfortunately, they cannot calculate the CCD multilateral index. However, Coelli and Rao (1995, pp. 73-5) show that the CCD price index in equation (5.1) is easy to calculate by using **SHAZAM** commands. In this study, the programming in **SHAZAM** for constructing the CCD multilateral price and corresponding implicit quantities indexes of output supply and input demands is presented in Appendix B.

5.3.3 Output Quantity and Output Price

Thai agricultural output is aggregated into a single output index to conserve degrees of freedom and to avoid any further complexity in econometric modelling. The output measure includes the ten major crops: rice, kenaf, cotton, cassava, groundnuts, soybeans, mungbeans, sugarcane, corn and sorghum.

As discussed in Chapter 2, livestock is a sector which has been very important for Thai agriculture for a long time, particularly buffaloes and cattle. Based on 1990/91 crop year data, livestock and livestock products accounted for around 22 per cent of total agricultural production calculated at farm price. Around 41 per cent of livestock and livestock products is derived from buffaloes and cattle. Inclusion of the livestock sector in the econometric analysis would certainly enhance the understanding of Thai agriculture, and help policy makers choose the appropriate direction of economic development planning. Unfortunately, as indicated by Thailand Development Research Institute (1988, Ch. 5), there are no livestock product data available, even at the Whole Kingdom level. Thus, the livestock products are not included in this study. Particular regions have higher livestock output, and thus their low indexes reflect to some extent the problem of undervaluation.

Ball (1985, p. 476; 1988, p. 817) measured the total quantities of crops from the sum of quantities marketed, the farmer-owned inventory changes and farm household consumption. In this study, the ten major crops were measured in kilograms of actual harvested outputs.

The actual prices of the ten major crops are used. Due to lack of regional price data, the average Whole Kingdom farm price of each crop is used.

5.3.4 Fertiliser Quantity and Fertiliser Price

Fertiliser is considered to be a variable input. Chemical fertiliser used in Thai agriculture is divided into three main types: ammonium sulphate, urea and all other fertilisers. Due to lack of regional data of each type of fertiliser used, the quantity of all nutrient fertilisers (total mixing chemical fertiliser) used in agriculture is employed. Regional data on fertiliser usage are not available in ten of the years. The missing data are extrapolated from the whole Kingdom data.[2] Due to lack of regional price data, the average Whole Kingdom price of all nutrient fertilisers is used.

[2]Following Setboonsarng and Evenson (1991, p. 209), the missing data are acquired by multiplying the national numbers by an average share of numbers of each region to national numbers which is calculated from the data available.

5.3.5 Capital Quantity and Capital Price

Capital is classified as a quasi-fixed input. Like output, capital is aggregated into one group to conserve degrees of freedom and to avoid any further complexity in econometric modelling. Capital comprises farm machinery, water pumps and threshers. Farm machinery includes large farm tractors (more than 45 hp), four-wheel tractors (less than 45 hp) and two-wheel walking tractors. Breeding livestock and draft animals usually considered as capital goods are not included in this study because no data are available.[3]

The values of investment and the outlay on capital services, proposed by Christensen and Jorgensen (1969) and applied subsequently by Vasavada and Chambers (1986), Ball (1985, 1988) and others, have been widely used to compute the quantity of capital input data. Due to lack of information on these values at the regional level, the physical unit numbers of all sizes of farm machinery, water pumps and threshers are used. However, six years of regional capital data are missing. As for fertiliser, missing data on capital are extrapolated from the Whole Kingdom data.[4]

Capital, like land, is usually defined as a 'durable' input which provides a service flow into the production process over a few years. Lawrence and McKay (1980, p. 50) stated that the initial purchase price of capital is not appropriate to measure the cost of annual capital service flow. In a perfectly competitive market, the rental price of capital can be a measurement of the capital service price, as mentioned by Wall and Fisher (1987, p. 87). However, the rental price is not available. Lawrence and McKay (1980, p. 56) and Coelli (1996, p. 10) indicated that the price of the capital service comprises three main components: depreciation, maintenance and opportunity cost.

In this study, owing to no such data being available, the purchase price of capital is used. Because of a lack of both the Whole Kingdom and regional price data, the

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[3]In Thai agriculture, draft animals, particularly buffaloes and cattle, have been a very important source of energy for many decades, as mentioned in Chapter 2.
[4]Setboonsarng and Evenson, op. cit.

average import prices of all sizes of farm tractors, water pumps and threshers are used to construct an index of the price of capital.

5.3.6 Labour Quantity and Labour Wage

The labour input is disaggregated into three groups: hired labour, operator labour and unpaid family labour. Since hired labour can be easily adjusted in the short term, it is classified to be a variable input. Operator labour and unpaid family labour, on the other hand, are much more difficult to adjust in the short run; thus, they are treated as quasi-fixed inputs.

The National Statistical Office (NSO) has annually conducted a labour force survey since 1963, except in 1970. However, Tinakorn and Sussangkarn (1994a, p. 15) indicated that, between 1963 and 1969, the timing of the survey in each round was inconsistent. During 1971 to 1983, the labour force was surveyed twice yearly. The first round was conducted during January to March, and the second round during July to September, except for the 1980 labour force survey for which only the second round was done. Since 1984, the NSO has annually had three rounds of the labour force survey. The first, second and third rounds of the surveys have been conducted in February, May and August, respectively.

Tinakorn and Sussangkarn (1994a, pp. 15-16) indicated that the second round labour force surveys during 1971 to 1983 and the third round labour force surveys during 1984 to 1990 are the most appropriate to use to measure labour input. There are three factors influencing this choice. First. the period during July to September is in the peak production period, and the agricultural population is at its most active. Secondly, the timing of surveys of both periods is consistent. Finally, due to inconsistency in data series, it is impossible to calculate the average employment between the wet and dry seasons. Note that these figures may therefore overstate the true employment figures.

Since 1971, the NSO has changed definitions, methodologies and sampling procedures several times as mentioned in many studies (e.g., World Bank 1983, Poapongsakorn

1985, Tinakorn and Sussangkarn 1994a). The changes in the definitions of labour force, employment and unemployment have been the most important issues. The study by World Bank (1983, p. 174) reported that, during the period 1971 to 1973, all unpaid family labourers were classified as employed workers but, from 1974 to 1976, only those unpaid family labourers who worked at least 20 hours per week were defined as employed. Between 1977 and 1981, due to the adoption of a new labour utilisation framework, unpaid family labourers who worked less than 20 hours per week and wanted to work more hours were included as employed. Moreover, since 1982, those waiting for the agricultural season have been classified as unemployed but unpaid family labourers waiting for the agricultural season have been counted as labour force since 1983 because of cancellation of the labour utilisation framework, indicated by National Statistical Office (1993) and Poapongsakorn (1985, p. 56). In addition, unpaid family labourers and those who worked at least 1 hour per week and did not want to work more have been defined as employed since 1983. Finally, following the new system of compulsory education, population aged from 11 to 12 years old has been excluded from labour force data since 1989 (National Statistical Office 1993, Tinakorn and Sussangkàrn 1994a). These changes have affected the numbers in the labour force, employment, unemployment and, in particular, unpaid family labour from time to time.[5] Unfortunately, it is impossible to adjust the data series by relying only on the published labour force survey reports without access to data magnetic tapes which are not available in many years.

Due to lack of labour data in terms of number of hours worked by each group, the quantities of hired labour, operator labour and unpaid family labour in persons are used.[6] Because of a perceived difference in the productivity of men and women, a weighting of 0.8 for female labour, as recommended by Nakajud (1972), is employed.

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[5]Poapongsakorn (1985, p. 61) found that the changes in definitions of employment and unemployment in 1983 had a large effect on unemployment and employment figures in the dry season but had little influence on the rainy season labour figures.

[6]Because the numbers of persons employed during peak season are used in this study, these numbers do not account for the underemployment problem mentioned in Chapter 2.

Because of a lack of consistency in data on agricultural wages for both the Whole Kingdom and the regions,[7] following Howard and Shumway (1988), agricultural wage per person per year is computed by dividing compensation of employees by the numbers of persons hired. Following Tyrchniewicz and Schuh (1969), net farm income per operator per annum is employed as a proxy for the wage of operator labour. As indicated by Tyrchniewicz and Schuh (1969, pp. 772, 786), by definition, there is no fixed wage for unpaid family labour. They suggested that hired labour wage can be used as a proxy for unpaid family labour wage. However, multicollinearity problems are likely to occur due to the use of hired labour wage for the prices of both hired labour and unpaid family labour.

In this study, a proxy for unpaid family labour wage is constructed by combining the above hired and operator labour wage series, using the CCD price index in equation (5.1). To do this, the programming in **SHAZAM** commands is constructed and also presented in Appendix B.

5.3.7 Land Quantity

Land has been one of the most important factors of Thai agricultural production, as mentioned in many studies (e.g., Thailand Development Research Institute 1988, among others). Because of lack of data on the price of land, a unit value function is employed by maintaining constant returns to scale with respect to land. Therefore, all quantity variables are expressed on a per hectare basis by dividing the quantity variables by agricultural land use.

Land use, in this study, comprises land under rice, field crops, fruit trees and vegetables, grass land, idle land, other land and housing areas. Four years of regional land use data are missing. Thus, missing data on land use are extrapolated from the Whole Kingdom data.[8]

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[7]The wage of private employees has been collected in the labour force survey since 1977 (World Bank 1983, p. 159) but published in *Report of the Labour Force Survey* since 1984. In addition, agricultural wage was collected in many studies (e.g., Poapongsakorn 1981, 1989; among others) but too little to be used in this study.
[8]Setboonsarng and Evenson, op. cit.

Lawrence and McKay (1980, p. 57) indicated that though land, which is an inexhaustible input, has no depreciation, it needs maintenance such as fertiliser, erosion management, etc. to conserve its productivity. In this study, fertiliser input is included as a variable input, as mentioned above. Other maintenance costs are excluded because there are no data available. There also exist differentials of land quality in Thai agriculture. Unfortunately, like many studies (e.g., Lawrence and McKay 1980; Ball 1985), no data are available on these differentials. Thus, homogeneity in the quality of land is assumed. Estimated results in this study are conditional on its validity.

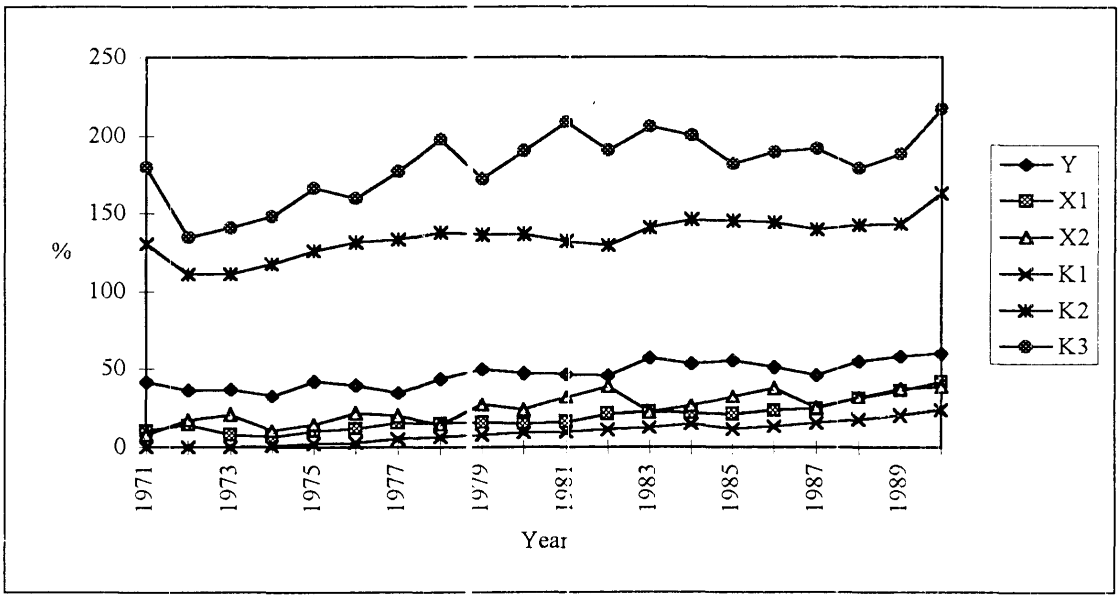
The CCD multilateral price indexes, the corresponding implicit quantity indexes and their descriptive statistics for each region are presented in Appendixes C to D.

Note that both the quantity and price variables are normalised by dividing all variables by the 1986 observation of the Central region as base for the CCD multilateral indexes.

Recall that all quantity variables are expressed on a per hectare basis by dividing the quantity variables by agricultural land use. Figures 5.1 to 5.4 show that although output indexes of all regions have been increasing, except the Southern Region, they are different among regions. The highest output index is obtained in the Central Region followed by the Northern Region. The lowest is obtained in the Southern Region. These output index differences are due primarily to the differences in soil quality, irrigation and climatic conditions, as discussed in Chapter 2. Most parts of the Northeastern and, in particular, Southern Regions are not irrigated, while large areas in the Central and Northern Regions are irrigated. In addition, livestock products are not taken into account in the construction of the output index in this study due to lack of data. As discussed earlier, particular regions have higher livestock output, and thus their low indexes reflect to some extent the problem of undervaluation.

The fertiliser index has been increasing in all regions; the highest fertiliser index is in the Central Region. As mentioned in Chapter 2, almost 44 per cent of fertiliser was used in the Central Region in 1987.

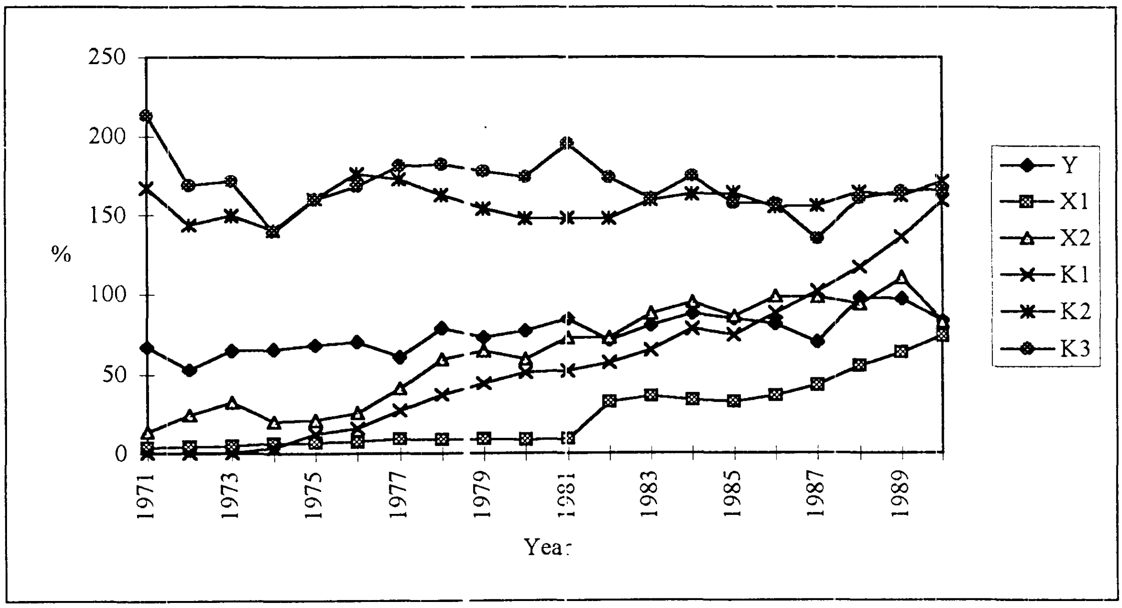
Figure 5.1: Implicit CCD multi ateral quantity indexes of the Northeastern Region of Thailand, 1971 to 1990



Note: Y is output, X1 is fertiliser, X2 is hired labour, K is capital, K2 is operator labour, and K3 is unpaid family labour.

Source: Table C.1.

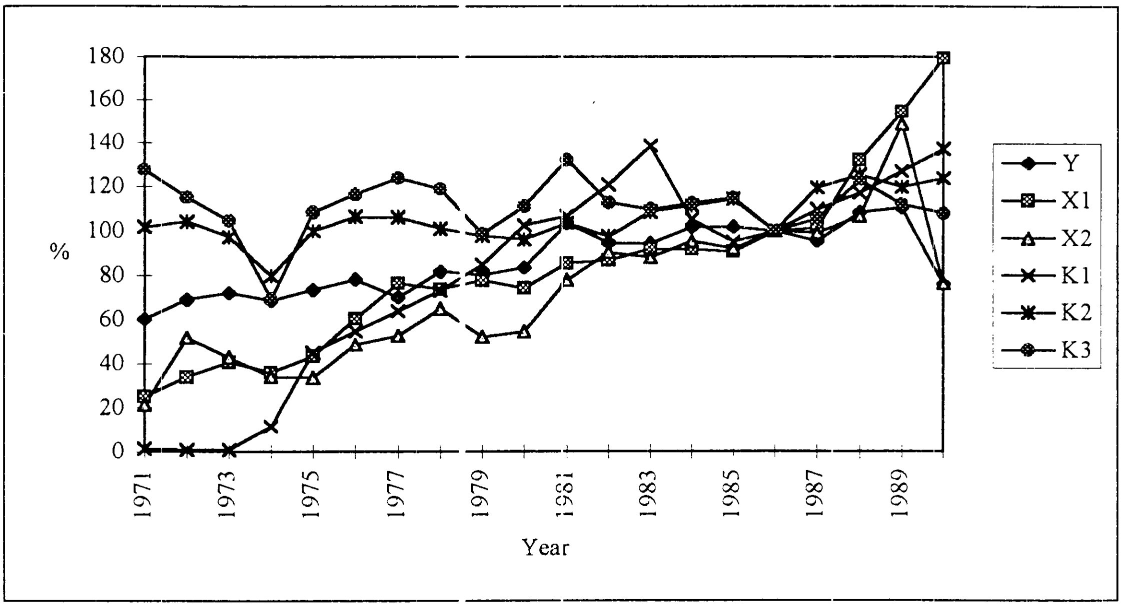
Figure 5.2: Implicit CCD multilateral quantity indexes of the Northern Region of Thailand, 1971 to 1990



Note: Y is output, X1 is fertiliser, X2 is hired labour, K1 is capital, K2 is operator labour, and K3 is unpaid family labour.

Source: Table C.2.

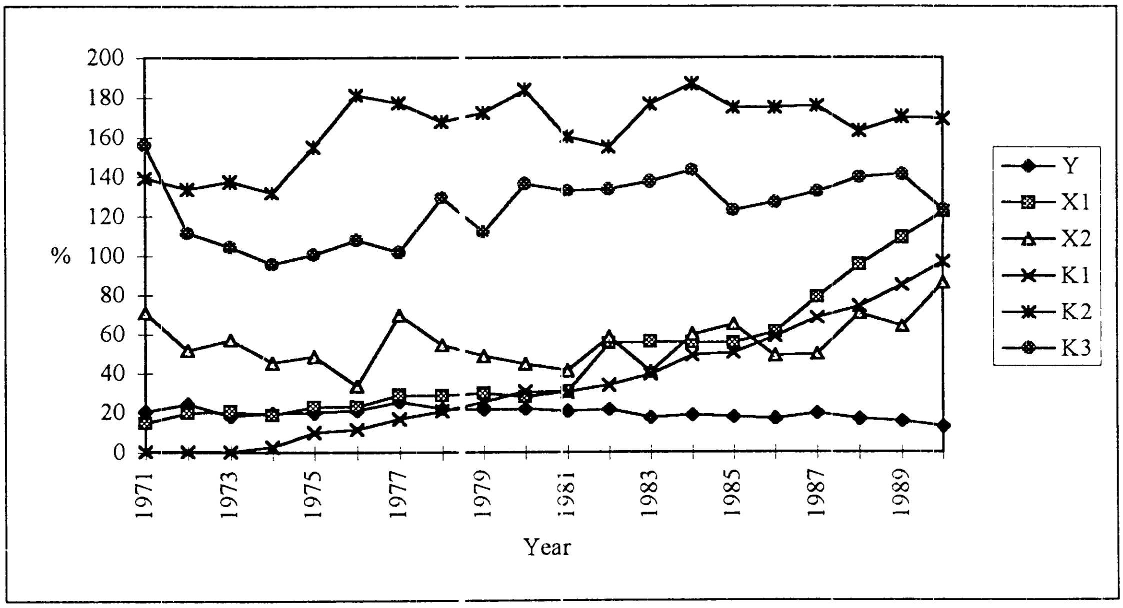
Figure 5.3: Implicit CCD multilateral quantity indexes of the Central Region of Thailand, 1971 to 1990



Note: Y is output, X1 is fertiliser, X2 is hired labour, K1 is capital, K2 is operator labour, and K3 is unpaid family labour.

Source: Table C.3.

Figure 5.4: Implicit CCD multilateral quantity indexes of the Southern Region of Thailand, 1971 to 1990



Note: Y is output, X1 is fertiliser, X2 is hired labour, K1 is capital, K2 is operator labour, and K3 is unpaid family labour.

Source: Table C.4.

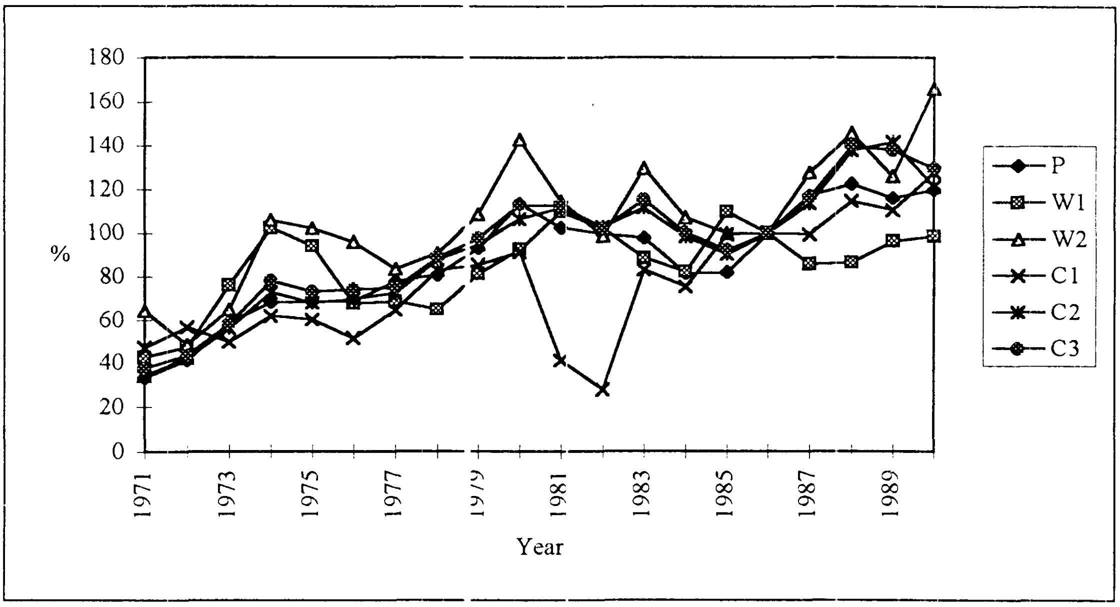
The capital index comprising tractors, water pumps and threshers has been increasing in all regions. The highest capital index is generally obtained in the Central Region followed by the Northern Region. This can be explained by the fact that in 1990, based on 1990/91 crop year data, around 34 per cent of the tractors, 55 per cent of the water pumps and 57 per cent of the threshers used in agriculture were in the Central Region, while around 41 per cent of the tractors, 26 per cent of the water pumps and 29 per cent of the threshers were in the Northern Region.

Recall that the labour input is divided into three categories: hired labour, operator labour and unpaid family labour. Hired labour is classified to be a variable input, while operator labour and unpaid family labour are treated as quasi-fixed inputs since hired labour can be easily adjusted in the short run but operator labour and unpaid family labour cannot. Figures 5.1 to 5.4 show that hired labour indexes of all regions have been increasing, while those of operator labour and unpaid family labour have been marginally increasing, and are rather steady in some cases. However, definitions, methodologies and sampling procedures have been changed several times, as mentioned earlier, which should be kept in mind when interpreting these labour indexes here and the analysis results in next chapter.

CCD multilateral price indexes do not differ a lot among regions because of the use of the Whole Kingdom price for each region. Thus, only price indexes of the Central region, whose 1986 observation is the base, are plotted here in Figure 5.5.

Figure 5.5 shows that all price indexes of output supply and inputs have been increasing, except for the fertiliser price index since 1981 (the fertiliser import tax was abolished in April 1978, as discussed in Chapter 2). The price index of capital is quite low in the period of 1981-82 because the average import price of tractors was very low in that period.

Figure 5.5: CCD multilateral price indexes of the Central Region of Thailand, 1971 to 1990



Note: P is the price of output, W1 is the price of fertilise·, W2 is the price of hired labour, C1 is the price of capital, C2 is the price of operator labour, and C3 is the price of unpaid family lal our.

Source: Table C.3.

5.3.8 Technology Indicators

A time trend has been used as a p·oxy for technical change in a number of studies (e.g., Taylor and Monson 1985, Vasavada and Chambers 1986, Howard and Shumway 1988, Luh and Stefanou 1991), though Norsworthy and Jang (1992, p. 63) pointed out that other specifications, such as ·esearch and development expenditures, may be preferable, if available.

In this study, because of lack cf consistent data on agricultural research and development expenditures, the simple time trend variable is employed as an indicator of disembodied technical change in Thai agriculture.

The quality of labour and capital may change from improved education and construction, respectively. Howard and Shumway (1988, p. 841) and Weersink (1989, p. 68) suggested that these embodied technical changes could be taken into consideration by adjusting labour and capital quantities by quality indexes. However, due to no data being available, embodied technical change in Thai agriculture is not accounted for in this study.

5.4 Conclusions

Aggregate annual data from each of the four regions of Thailand are used for the period 1971-90. Inputs are classified into five groups: fertiliser, hired labour, capital, operator labour and unpaid family labour. Output is aggregated into one category to conserve degrees of freedom and to avoid any further complexity in econometric modelling.

Some years of regional data are missing. Then, the simple extrapolation from the national data is employed. In the case of the data involving more than one commodity, CCD multilateral methods are used to construct any price indexes and implicit quantity indexes.

Because of lack of data on the price of agricultural land, the assumption of constant returns to scale with respect to land is applied. All quantity variables are divided by agricultural land use. Then, all price and quantity variables are normalised by the 1986 central region (the base year).

A 6 per cent real discount rate is assumed and a time trend is used as an indicator of technical change.

The primary data limitations are that data were not available for: livestock output, livestock input and capital data in the form of depreciation and maintenance or rental cost.

6. Empirical Results

6.1 Introduction

The primary objective of this chapter is to report the empirical results of the dynamic and static models applied to Thai agricultural production. As discussed earlier, one of the primary advantages of the dynamic model over the static model is that the static model assumes that all inputs are variable (in other words, there is no disequilibrium in the production process in the short run), implying that the actual level of quasi-fixed input stocks is equal to the desired level, while the dynamic model allows quasi-fixed inputs to adjust partly in the short run and fully in the long run. Thus, the dynamic model is preferred to the static model in this study. However, one of the main objectives of this study is to compare the empirical results using the two different models and to illustrate the consequences of ignoring dynamics in the estimation of production characteristics. Hence, following this introduction, the empirical results of the dynamic model are described. Then, those involving the static model are discussed and compared. The last section provides conclusions.

6.2 The Dynamic Model

This section is divided into four subsections. First, the model estimation is described. Then, tests of hypotheses are reported. The last two subsections cover elasticity calculations and the measurement of biases in technical change. Note that, when comparing these estimates with those in previous studies, the various results could occur due to a combination of the differences in methods, data and functional forms being used.

6.2.1 Model Estimation

The system of equations (4.19) to (4.24) is a non-linear, simultaneous equation model. Recall that, due to the recursive nature of the simultaneous equation model, the non-linear seemingly unrelated regression estimation provides consistent parameter estimates and has been used to estimate the dynamic dual models in past studies (e.g., Vasavada and Ball 1988; Luh 1990; Luh and Stefanou 1991, 1993). The non-linear seemingly unrelated regression routine, **NL** procedure in **SHAZAM** (White 1993), is used to estimate the unknown parameters of the model. The Davidon-Fletcher-Powell algorithm is the numerical optimising method used. The programming in **SHAZAM** used in parameter estimation is presented in Appendix B.

As discussed in Chapter 4, lagged output price is used in this study because the prices that farmers receive in the current period are unknown to them at the beginning of the period, when many production decisions are made. Current period input prices are employed in this study because they approximate prices that farmers pay at the beginning of the current period when the production decisions are made.

Furthermore, $\dot{K}_t$ is approximated by $K_t - K_{t-1}$ (e.g., Howard and Shumway 1988, 1989a; Luh and Stefanou 1991). This is because there is no information at all about the depreciation rate of capital nor the number of labourers retiring from the agricultural sector.

The parameter estimates of the system of equations are reported in Table 6.1. Almost 90 per cent of estimated parameters are at least twice their corresponding asymptotic standard errors. This is quite a favourable result when compared with other estimated modified generalised Leontief models which applied the non-linear seemingly unrelated regression estimator to dynamic dual models (e.g., Luh 1990; Luh and Stefanou 1991, 1993). The estimated R^2 values for output supply and input demand for fertiliser, hired labour, capital, operator labour and unpaid family labour are, respectively, 0.94, 0.92, 0.84, 0.97, 0.89 and 0.75.[1] This implies that the model explains a large proportion of the variation in the dependent variables. The Durbin-Watson (DW) values for output supply (1.66), demand for fertiliser (1.69), hired labour (1.68), capital (1.42), operator labour (1.83) and unpaid family labour (1.93), suggest autocorrelation is not a problem. In addition, because regional data were used in this study, a test of heteroscedasticity was conducted by using the Breusch-Pagan test (Breusch and Pagan 1979). The test values for output supply and input demand for fertiliser, hired labour, capital, operator labour and unpaid family labour are, respectively, 18.43, 23.08, 25.53, 24.56, 26.45 and 24.70. The results show that heteroscedasticity is a problem for demand for fertiliser and hired labour equations, while it is not for output supply, demand for capital, operator labour and unpaid family labour equations (given the critical chi-square values, at the 5 per cent significant level, of 22.36 for output supply, demand for fertiliser and hired labour and of 35.17 for demand for capital, operator labour and unpaid family labour). The presence of heteroscedasicity could be an indication of mis-specification or may be due to data problems. To overcome this issue, the two-step weighted least squares (WLS) procedure, illustrated by Maddala (1989, Section 5.4), could be applied to the dynamic model. However, due to considerable work involved, there is no attempt to solve the problem in this study. Therefore, empirical results of this study should be interpreted cautiously.

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[1]To be able to compare the estimated R^2 values of the dynamic model to those of the static model in Section 6.3, $\dot{K}$ predictions from equations (4.22)-(4.24) were converted into K predictions. Then, the R^2 values were obtained from the square of the correlation between the observed K and predicted K.

Table 6.1: Non-linear seemingly unrelated regression parameter estimates of output and input demand equations in the dynamic model[a]

Parameter	Unrestricted mode	Parameter	Unrestricted model
a_{11}	-12.1030 (1.2641)	e_{33}	1992.3000 (58.5730)
a_{12}	16.3050 (1.5007)	f_{11}	102.5700 (69.8080)
a_{13}	-5.8891 (0.5271)	f_{12}	887.9700 (73.8130)
a_{21}	66.3780 (3.2009)	f_{13}	548.3300 (112.1600)
a_{22}	-88.6950 (4.1862)	f_{22}	-642.6900 (30.8050)
a_{23}	30.8520 (1.4228)	f_{23}	-2482.2000 (113.5100)
a_{31}	57.5290 (3.6746)	f_{33}	-1383.6000 (90.8620)
a_{32}	-76.9800 (4.4556)	g_{11}	1506.9000 (117.3900)
a_{33}	27.1120 (1.5756)	g_{12}	49.0540 (116.4600)
b_{11}	-0.0920 (0.0214)	g_{13}	-285.0500 (161.8800)
b_{12}	-0.2135 (0.0244)	g_{22}	-372.0400 (76.7440)
b_{13}	-0.0275 (0.0226)	g_{23}	-486.1700 (102.7300)
b_{21}	-0.1709 (0.0150)	g_{33}	895.5800 (107.3900)
b_{22}	-0.1699 (0.0305)	h_1	138.7200 (26.5550)
b_{23}	-0.3188 (0.0220)	h_2	-788.7000 (120.1500)
b_{31}	-0.2780 (0.0371)	h_3	-653.2100 (116.2000)
b_{32}	-0.0302 (0.0654)	h_4	-1663.4000 (245.9200)
b_{33}	-0.8521 (0.0512)	h_5	592.3000 (43.2240)
e_{11}	261.5900 (113.1300)	h_6	504.1500 (137.0700)
e_{12}	1894.7000 (262.3100)	h_{1d}	-120.1700 (23.6580)
e_{13}	-1843.8000 (202.2600)	h_{2d}	714.3500 (96.4650)
e_{21}	-766.2800 (114.6100)	h_{3d}	599.2900 (95.1800)
e_{22}	-320.2000 (65.9860)	h_{4d}	1546.5000 (180.6800)
e_{23}	1338.1000 (151.2500)	h_{5d}	-608.4200 (24.5600)
e_{31}	-1173.2000 (127.2900)	h_{6d}	-502.6800 (115.9900)
e_{32}	-2572.3000 (115.5700)		

[a] Coefficients of dummy variables are presented in Appendix E.

Note: Standard errors of estimates are in parentheses.

The adjustment matrix obtained from the estimated parameters is of particular interest. The adjustment rate of demand for capital, equal to $(b_{11}+r)$, is estimated as -0.03, given a 6 per cent real discount rate. This implies that capital adjusts 3 per cent per year towards the desired level, or takes around 33 years to reach the long-run level. This is a surprising result because the estimate of length of adjustment is indeed longer than expected and it is difficult to explain, given the length of life of the capital components included in this study. However, this adjustment coefficient is not significantly different from zero, with a t-value of 1.50 (while t-values of operator and unpaid family labour adjustment coefficients are 3.60 and 15.47, respectively). This suggests that capital may be a fixed rather than a quasi-fixed factor. As compared with other studies using dynamic duality, this estimated adjustment rate of capital in Thai agriculture is much lower than those estimated for U.S. agriculture, such as -0.554 (Taylor and Monson 1985), -0.118 (Vasavada and Chambers 1986), -0.121 (Warjiyo 1991) and -0.15 (Luh and Stefanou 1991). This contrast may be a result of the differences in the components of capital used to construct the capital index. In this study, capital comprises farm tractors, water pumps and threshers, while, in other studies, it generally includes durable equipment (i.e., automobiles, motor trucks, farm tractors and agricultural machinery), breeding livestock and inventories.

The adjustment coefficient of operator labour is -0.11, implying that operator labour adjusts 11 per cent a year and takes around 9 years to reach the desired level. The adjustment coefficient of unpaid family labour was estimated to be -0.79, which is quite different from the value of one-fourth obtained for unpaid family labour by Tyrchniewicz and Schuh (1969) estimated for U.S. agriculture. This may be due to the differences in methodologies used and the agricultural economies under study. However, the results are in general quite similar to Tyrchniewicz and Schuh's results in that the absolute value of adjustment rate of unpaid family labour is much higher than the rate for operator labour. These results indicate that the extra effort involved in specifying a model in which operator labour and unpaid family labour are different inputs does appear to be warranted in this instance.

A study of the Thai labour market by Sussangkarn (1987), using data from the July-September 1984 Labour Force Survey, indicated that it could be divided into two sectors: an informal sector and a formal sector. In the formal sector, wages are high. Job opportunities in this sector are generally hard to find. This sector comprises the government sector and the larger private firms. In the informal sector, wages are low and work is easy to find in this sector. This study may provide further evidence that, due to the constraints on mobility of these two labour inputs, mentioned above, the Thai labour market is unlikely to be fully integrated within a decade.

6.2.2 Tests of Hypotheses

Tests of Competitive Behaviour

The dynamic model was estimated maintaining homogeneity and symmetry in prices and concavity in quasi-fixed inputs. Monotonicity and convexity conditions were checked following estimation. The results showed that the monotonicity condition was not satisfied with respect to the wages of operator labour and unpaid family labour at some data points and the convexity condition was violated with respect to capital price at most data points. These violations could be a result of data problems or may be a consequence of the intervention by the government in both output and input markets in Thai agriculture. This issue could be tested by applying the shadow price approach of Atkinson and Halvorsen (1984) to the dynamic duality but this is beyond the scope of this study. Furthermore, the violations of these curvature conditions are not limited to this study, but also occurred in many past studies in both the dynamic and static models (e.g., Shumway 1983; Lopez 1984; Taylor and Monson 1985; Vasavada and Chambers 1986; Vasavada and Ball 1988; Weersink 1989; Burrell 1989).

Structural Tests

Hypothesis test results are presented in Table 6.2. Wald Chi-Square tests (using the **SHAZAM TEST** command) were used in all cases. The null hypothesis that adjustments in the three quasi-fixed factors are independent of each other is rejected. Following this, we consider the independence of pairs of quasi-fixed factors separately. The null hypothesis of independent adjustments between capital and operator labour, capital and unpaid family labour and operator labour and unpaid family labour are all rejected by these individual tests also. This indicates that the adjustment of a quasi-fixed input affects the adjustment decisions regarding the other two quasi-fixed inputs, and *vice versa*.

Instantaneous adjustments of all quasi-fixed inputs and individual quasi-fixed inputs are clearly rejected. These test results imply that there are adjustment costs of capital, operator labour and unpaid family labour. In other words, capital, operator labour and unpaid family labour are not variable inputs.

In sum, the above findings suggest that the use of the dynamic model in which quasi-fixed inputs are included as separate inputs provides more information on speed and independence of adjustment of quasi-fixed inputs than the static model in which all inputs are modelled as variable inputs in this instance (static results are presented in the next section).

Note that the test values of the above hypotheses are quite high.[2] This is not a surprising result because, under the null hypothesis, quasi-fixed inputs are forced to adjust not only instantaneously to their optimal levels but also independently from others when prices change, while they actually do not. In other words, we try to force capital, for example, to adjust completely in one year instead of 33 years and without any effects on operator and unpaid family labour, whereas it cannot.

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[2] Warjiyo (1991) also obtained very high Chi-Square values when testing instantaneous adjustments of quasi-fixed inputs.

Table 6.2: Testing hypotheses in the dynamic model

Hypotheses	Test Values	Critical Values (5 %)	Results
1. Independent adjustment of all quasi-fixed inputs	641.38	$\chi^2(6) = 12.59$	Rejected
2. Independent adjustment between capital and operator labour	132.12	$\chi^2(2) = 5.99$	Rejected
3. Independent adjustment between capital and unpaid family labour	65.75	$\chi^2(2) = 5.99$	Rejected
4. Independent adjustment between operator labour and unpaid family labour	211.18	$\chi^2(2) = 5.99$	Rejected
5. Instantaneous adjustment of all quasi-fixed inputs	0.42E+08	$\chi^2(9) = 16.92$	Rejected
6. Instantaneous adjustment of capital	0.15E+06	$\chi^2(3) = 7.81$	Rejected
7. Instantaneous adjustment of operator labour	0.25E+06	$\chi^2(3) = 7.81$	Rejected
8. Instantaneous adjustment of unpaid family labour	0.13E+05	$\chi^2(3) = 7.81$	Rejected
9. No differences in technical change parameters	1413.52	$\chi^2(6) = 12.59$	Rejected
10. No difference in technical change parameter in output supply	25.80	$\chi^2(1) = 3.84$	Rejected
11. No difference in technical change parameter in fertiliser	54.84	$\chi^2(1) = 3.84$	Rejected
12. No difference in technical change parameter in hired labour	39.64	$\chi^2(1) = 3.84$	Rejected
13. No difference in technical change parameter in capital	73.26	$\chi^2(1) = 3.84$	Rejected
14. No difference in technical change parameter in operator labour	613.71	$\chi^2(1) = 3.84$	Rejected
15. No difference in technical change parameter in unpaid family labour	18.78	$\chi^2(1) = 3.84$	Rejected
16. No technical change	2083.44	$\chi^2(12) = 21.03$	Rejected
17. No technical change in output supply	27.31	$\chi^2(2) = 5.99$	Rejected
18. No technical change in fertiliser	64.22	$\chi^2(2) = 5.99$	Rejected
19. No technical change in hired labour	46.81	$\chi^2(2) = 5.99$	Rejected
20. No technical change in capital	141.56	$\chi^2(2) = 5.99$	Rejected
21. No technical change in operator labour	620.45	$\chi^2(2) = 5.99$	Rejected
22. No technical change in unpaid family labour	55.65	$\chi^2(2) = 5.99$	Rejected

Tests of Technical Change

Hypothesis test results regarding technical change are also presented in Table 6.2. Wald Chi-Square tests were used in all cases. To begin with we consider a hypothesis regarding differences in rates of technical change between the two sub-periods of 1971-77 and 1978-90. The null hypothesis of no differences in the technical change parameters in output supply and input demands between the two sub-periods is rejected as a composite hypothesis. When they are considered separately, the null hypotheses of no difference in the technical change parameters between the two sub-periods in output supply and in all input demands are all individually rejected. This indicates that the reduced availability of new land (in the latter sub-period) appears to have affected the rates of technical change in output supply and all input demands in Thai agriculture.

The null hypothesis of no technical change in output supply and input demands is rejected as a composite hypothesis. When they are considered separately, the null hypotheses of no technical change in output supply and demand for individual inputs are also all rejected. The estimated results show that there exists technical change in output supply and all inputs in Thai agriculture during the study period.

Note that the result of technical progress in output supply in this study is consistent with other studies of Thai agriculture (e.g., Mittelhammer et al. 1980; Patamasiriwat and Suewattana 1990; Tinakorn and Sussangkarn 1994a, 1994b).

6.2.3 Elasticity Calculations

Recall that the net investment demand equations (4.22) to (4.24) permit gradual adjustment in the quasi-fixed inputs. Therefore, if relative prices change, there exist short-run (i.e., $\dot{K} \neq 0$) and long-run (i.e., $\dot{K} = 0$ or $K = \overline{K}$) impacts on output supply and input demands. In addition, due to the recursive nature of the simultaneous system of equations (4.19) to (4.24), changes in relative prices can have both direct and indirect effects on output supply and variable input demands (as discussed in Chapter 4).

Tables 6.3 and 6.4 present direct, indirect and total elasticities for the short run and the long run, evaluated at the sample means of the data by using the formulae in Appendix A. Before discussing these estimates, some important points should first be made. Treadway (1970, pp. 345-6) indicated that in an intertemporal optimisation process, short-run own-price elasticities of quasi-fixed input demands are not necessarily negative, but that the long-run elasticities should be negative; that short-run and long-run own-price elasticities of variable input demands are not necessarily negative; and that in the short run, the output supply curve may be negative to reflect the penalty of quasi-fixed input adjustment. Furthermore, cross-price elasticities are not generally symmetric. Thus, it is generally hard to appraise whether the relations among inputs are complementary or substitute (Warjiyo 1991, p. 100). Finally, long-run elasticities are not necessarily larger than the short-run elasticities.

In the short run, the own-price elasticities (i.e., direct, indirect and total elasticities) of output supply have a positive sign, as one would expect, but are quite inelastic. In the long run, the direct own-price elasticity of output supply is positive, although its indirect own-price elasticity (i.e., via adjustments in quantities of quasi-fixed inputs) is negative. Therefore, the slow adjustment of quasi-fixed inputs results in a negative slope of the output supply function in the long run. Although this negative own-price elasticity of output supply is not consistent with the static maximisation theory, it is very small and insignificant. Caputo (1990, p. 695) pointed out that it is possible that the behaviour of output supply may contradict static theory at a particular point of time if the adjustment cost framework is applied to the firm. In addition, Treadway (1970, p. 343) also indicated that an internal adjustment cost can behave in such a way that the firm will have a determinate scale and will increase output in response to a fall in price even in the long run and even if it faces competitive markets'. Moreover, this result also occurred in past studies (e.g., Luh 1990; Warjiyo 1991; Luh and Stefanou 1993).

Table 6.3: Short-run elasticities of quantities with respect to prices in the dynamic model

Quantities		Output	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
Output	Direct	0.069	0.0255	-0.1656	0.0645	0.5117	-0.5055
		(0.1872)	(0.0802)	(0.1696)	(0.0655)	(0.4773)	(0.5051)
	Indirect	0.078	-0.0596	-0.1050	-0.0479	0.2269	-0.0927
		(0.0729)	(0.0312)	(0.1453)	(0.0326)	(0.7731)	(0.8957)
	Total	0.147	-0.0341	-0.2706	0.0166	0.7386	-0.5982
		(0.1903)	(0.0803)	(0.2010)	(0.0581)	(0.8747)	(1.0197)
Fertiliser	Direct	-0.034	-0.2195	0.3751	0.2509	0.1148	-0.4871
		(0.1077	(0.1834)	(0.2174)	(0.1829)	(0.3681)	(0.2649)
	Indirect	-0.070	-0.0604	-0.0839	-0.1694	0.0045	0.3791
		(0.1429	(0.1102)	(0.2639)	(0.1344)	(1.2139)	(1.3699)
	Total	-0.104	-0.2799	0.2912	0.0815	0.1193	-0.1080
		(0.1556	(0.1724)	(0.2779)	(0.0964)	(1.1866)	(1.3551)
Hired Labour	Direct	0.143	0.2425	-0.8064	0.2777	0.6668	-0.5243
		(0.1471	(0.1405)	(0.3311)	(0.1445)	(0.7498)	(0.8281)
	Indirect	0.087	-0.1239	-0.1982	-0.1635	0.3525	0.0456
		(0.0933	(0.0724)	(0.1662)	(0.1040)	(0.6912)	(0.7810)
	Total	0.231	0.1186	-1.0046	0.1142	1.0193	-0.4787
		(0.1370	(0.1375)	(0.2827)	(0.0910)	(0.4130)	(0.4269)
Capital		-0.123	0.0349	0.2192	-0.0857	-0.3446	0.2992
		(0.1068	(0.0565)	(0.1936)	(0.0555)	(1.0025)	(1.1463)
Operator Labour		0.021	-0.0228	0.0036	-0.0400	0.0465	-0.0088
		(0.0338	(0.0164)	(0.0648)	(0.0188)	(0.3245)	(0.3782)
Unpaid Family Labour		0.140	-0.0867	-0.1363	-0.0554	0.3571	-0.2191
		(0.1383	(0.0535)	(0.2816)	(0.0426)	(1.5338)	(1.7810)

Note: Standard errors are in parentheses.

Table 6.4: Long-run elasticities of quantities with respect to prices in the dynamic model

Quantities		Outpu	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
Output	Direct	0.0694	0.0255	-0.1656	0.0645	0.5117	-0.5055
		(0.1872	(0.0802)	(0.1696)	(0.0655)	(0.4773)	(0.5051)
	Indirect	-0.0746	0.0171	0.0927	-0.0478	-0.1794	0.1920
		(0.0779	(0.0387)	(0.1369)	(0.0383)	(0.7476)	(0.8514)
	Total	-0.0052	0.0426	-0.0729	0.0167	0.3323	-0.3135
		(0.2233	(0.0946)	(0.2399)	(0.0683)	(0.9254)	(1.0086)
Fertiliser	Direct	-0.0342	-0.2195	0.3751	0.2509	0.1148	-0.4871
		(0.1077	(0.1834)	(0.2174)	(0.1829)	(0.3681)	(0.2649)
	Indirect	-0.4253	0.0590	0.5196	-0.3376	-0.9943	1.1687
		(0.4484	(0.2376)	(0.7870)	(0.2469)	(4.2775)	(4.8598)
	Total	-0.4595	-0.1505	0.8947	-0.0867	-0.8795	0.6816
		(0.4435	(0.2054)	(0.7693)	(0.1570)	(4.2134)	(4.8181)
Hired Labour	Direct	0.1437	0.2425	-0.8064	0.2777	0.6668	-0.5243
		(0.1471	(0.1405)	(0.3311)	(0.1445)	(0.7498)	(0.8281)
	Indirect	-0.3192	0.0589	0.3912	-0.2365	-0.7528	0.8584
		(0.3360	(0.1742)	(0.5893)	(0.1780)	(3.2096)	(3.6494)
	Total	-0.1755	0.3014	-0.4152	0.0412	-0.0860	0.3341
		(0.4280	(0.2234)	(0.7698)	(0.1649)	(3.8529)	(4.4059)
Capital		-1.0716	0.4424	1.6629	-0.3260	-2.9525	2.2448
		(1.0061	(0.4573)	(1.7703)	(0.3838)	(9.7823)	(11.1740)
Operator Labour		-0.1734	0.0525	0.2978	-0.1089	-0.4810	0.4130
		(0.1618	(0.0853)	(0.2794)	(0.0795)	(1.4842)	(1.6823)
Unpaid Family Labour		0.2997	-0.1593	-0.3629	-0.0307	0.7878	-0.5346
		(0.3051	(0.1193)	(0.5479)	(0.0958)	(3.0845)	(3.5465)

Note: Standard errors are in parentheses.

In the short run, the total effects of the prices of fertiliser, hired labour and unpaid family labour on output supply are negative, as one would expect. However, capital and operator labour price changes have an unexpected positive influence on output supply. In the long run, only hired labour and unpaid family labour prices have unexpected positive effects on output supply where the other input prices have an expected negative effect. Although the positive effects of input prices on output supply are inconsistent with the static maximisation theory, this is not a great concern as they are insignificant.

Direct own-price elasticities of fertiliser and hired labour demands have the expected negative signs, while indirect own-price effects of fertiliser and hired labour demand are negative because of slow adjustments in quasi-fixed inputs in the production process. In the long run, indirect own-price elasticities of fertiliser and hired labour are positive. The total own-price elasticities of fertiliser and hired labour have the expected negative signs but these are lower in the long run due to the above positive effects of slow adjustments of quasi-fixed inputs. This result is surprising and difficult to explain why it is found in Thai agriculture. However, it may be partly due to a consequence of the intervention by the government in both output and input markets in Thai agriculture. In addition, although these lower magnitudes of own-price elasticities in the long run are inconsistent with the static maximisation theory, Treadway observed that it is quite normal in an intertemporal optimisation process, as mentioned above.

The own-price elasticities of demand for capital and unpaid family labour have expected signs, while that of the demand for operator labour has an unexpected positive sign in the short run. Treadway noted that, in the short run, it is possible that the investment demand curve has a positive slope, but in the long run it should be negative. In the long run, all own-price elasticities of demand for capital, operator labour and unpaid family labour have negative signs consistent with the static maximisation theory and the above observation by Treadway. In addition, the magnitudes of own-price elasticities of quasi-fixed inputs are higher than those in the short run. This result is consistent with other studies using a generalised Leontief function (e.g., Howard and Shumway 1988, 1989a; Luh 1990).

In the short run, the total elasticities of demand for fertiliser with respect to hired labour, capital and operator labour prices are positive, while those with respect to output supply and unpaid family labour prices are negative. In the long run, the total elasticities of demand for fertiliser with respect to capital, operator labour and unpaid family labour prices take the opposite signs to their short-run signs.

In the short run, the total elasticities of demand for hired labour with respect to the prices of fertiliser, capital and operator labour are positive, while that with respect to the price of unpaid family labour is negative. In the long run, the elasticities of demand for hired labour with respect to operator labour and unpaid family labour prices change to opposite signs. So, only operator labour is a complement to hired labour in the long run.

The elasticities of demand for operator labour with respect to the fertiliser, capital and unpaid family labour prices are negative, but its elasticities with respect to the prices of output supply and hired labour are positive. In the long run, all cross-price elasticities change sign, except for hired labour and capital prices.

The cross-price elasticities of unpaid family labour with respect to fertiliser, capital and hired labour prices are negative, whereas the elasticities with respect to other prices are positive in both the short run and long run.

Note that the above findings show that cross-price elasticities are not generally symmetric. This is not a surprising result because it is consistent with the comments of Treadway, as mentioned earlier, and also found in past studies using a generalised Leontief functional form (e.g., Weersink 1989; Luh 1990). In the case of changing the signs of cross-price elasticities, Berndt, Morrison and Watkins (1981, cited in Howard and Shumway 1988, p. 846) and Luh (1990, p. 87) observed that 'the changing of signs from the short run to the long is not theoretically inconsistent or empirically uncommon'. However, since the t-values of cross-price elasticities are not very significant, this result should not be a great concern in this study.

Comparing Table 6.3 with Table 6.4, the long-run own-price elasticities of output supply and demand for fertiliser and hired labour were less than their short-run own-price elasticities in absolute value. Therefore, Le Chatelier's principle, that the long-run own-price elasticities should be at least as large as the corresponding short-run elasticities in absolute value, is not satisfied in this study. Nonetheless this is consistent with the above observation by Treadway that long-run elasticities are not necessarily larger than short-run elasticities. However, this study may provide further evidence that the slow adjustment effects of quasi-fixed inputs (i.e., via indirect own-price elasticities) cause the failure of Le Chatelier's principle in the total own-price elasticities of output supply and variable input demands.

When comparing the magnitudes of the own-price elasticities of output with those in previous studies, short-run and long-run own-price elasticities of output are 0.15 and -0.01, respectively. The short-run and long-run own-price elasticities of output computed by Vasavada and Chambers (1986, pp. 957-8) using a normalised quadratic value function for aggregate U.S. agriculture are 0.3828 and 0.5362, respectively. Warjiyo (1991, pp. 101, 104), who classified U.S. agricultural output into crop and livestock categories, and also used the quadratic value function, obtained estimates of short-run and long-run own-price elasticities of crops of 0.0097 and 0.0136, respectively, and of livestock of -0.0714 and 0.2037, respectively. Thus, the magnitudes of the elasticities in this study are lower than those in Vasavada and Chambers' study but higher than those in Warjiyo's study in the short run.

Vasavada and Chambers (1986, p. 957) and Warjiyo (1991, p. 101) classified inputs into capital, land, labour and intermediate inputs. They found that the short-run own-price elasticities of labour and capital demands are 0.0185 and 0.0530, respectively. In contrast, Warjiyo obtained labour and capital own-price elasticities of -0.0050 and -0.0191, respectively. Because labour is decomposed into hired, operator and unpaid family in the current study, it is hard to compare results with other studies. This study found that short-run own-price elasticities of hired, operator and unpaid family labour demands are -1.00, 0.05 and -0.22. In absolute value, they are higher than those computed by Vasavada and Chambers (1986, p. 957) and Warjiyo (1991, p. 101) for their aggregated labour variable and capital.

The long-run own-price elasticities of labour and capital demands calculated by Vasavada and Chambers (1986, p. 958) are -0.5066 and 0.1160, respectively. Those of the labour and capital demands computed by Warjiyo (1991, p. 104) are -0.0544 and -0.1581, respectively. Results in this study (refer to Table 6.8) are, in absolute value, lower than those studies, except capital and unpaid family labour.

In sum, this study provides a few contributions of elasticity estimates relative to previous studies in Thai agriculture. First, in this study, the magnitudes of the own-price elasticities of output supply and input demands in the long run are generally lower in absolute value than those from previous studies. Second, in this study, the magnitudes of the cross-price elasticities between operator labour and unpaid family labour are quite different in absolute value in both the short run and long run. This indicates that these labour groups are different inputs. Thirds, the changing the signs of cross-price elasticities from the short run to the long run is observed in this study. This implies that relations among output supply and input demands in the short run may be opposite from those in the long run Fourth, as mentioned earlier, this study provides further evidence that the slow adjustment effects of quasi-fixed inputs result in the failure of Le Chatelier's principle in the total own-price elasticities of output supply and variable input demands.

6.2.4 Measurement of Biases in Technical Change

As for elasticity calculations, there are short-run and long-run biases in technical change due to gradual adjustment in quasi-fixed inputs permitted in the dynamic model. In addition, biases can be both direct and indirect due to the recursive nature of the simultaneous equation system, as discussed in Section 4.3.5. However, to facilitate comparison of these results with the static model results, total long-run biases are of interest in this study.

The measures of biases in technical change defined by equation (4.27) are presented in Tables 6.5 and 6.6. They are estimated at the sample means of the periods of 1971-77 and 1978-90, because of the findings that the rates of technical change are different between the two periods. Recall that a positive coefficient of B_{ij} implies that technical change is Hicks-saving in input i relative to input j.

In the period 1971-77, the bias coefficients in the capital column are all positive. This indicates that technical change in Thai agriculture was capital saving relative to the other inputs. In contrast, all bias coefficients in the unpaid labour column are negative, implying that technical change was unpaid family labour using relative to the other inputs. This may be partly because labour is plentiful and cheap. The remaining estimates indicate that technical change was fertiliser saving relative to the other inputs, except that in relation to capital, while it was hired labour using relative to the other inputs, except that in relation to operator labour and unpaid family labour. Technical change was operator labour using compared with fertiliser, hired labour and capital but operator saving in relation to unpaid family labour. In the 1978-90 period, the bias coefficients were generally similar to those of the 1971-77 period.

Note that, when comparing Table 6.5 with Table 6.6, the long-run biases are higher than their short-run biases in absolute value. This implies that, due to the slow adjustment in quasi-fixed inputs, farmers cannot quickly adjust their production processes in the short run when there exists technical change, while, in the long run, farmers can fully adjust their production processes. This supports the use of the dynamic model which provides more information on biases in technical change than the static model.

Table 6.5: Measurements of sho·t-run biases in technical change (B_{ij}'s) in the dynamic model

		Input *i*				
Input *j*	Periods	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
Fertiliser	1971-77		-0.0278	0.0271	-0.0450	-0.0412
			(0.0245)	(0.0340)	(0.0236)	(0.0242)
	1978-90		-0.0403	-0.0472	-0.0497	-0.0533
			(0.0111)	(0.0095)	(0.0096)	(0.0100)
Hired Labour	1971-77	0.0278		0.0549	-0.0172	-0.0134
		(0.0245)		(0.0311)	(0.0140)	(0.0147)
	1978-90	0.0403		-0.0070	-0.0094	-0.0130
		(0.0111)		(0.0095)	(0.0084)	(0.0092)
Capital	1971-77	-0.0271	-0.0549		-0.0721	-0.0683
		(0.0340)	(0.0311)		(0.0270)	(0.0285)
	1978-90	0.0472	0.0070		-0.0024	-0.0060
		(0.0095)	(0.0095)		(0.0055)	(0.0064)
Operator Labour	1971-77	0.0450	0.0172	0.0721		0.0038
		(0.0236)	(0.0140)	(0.0270)		(0.0033)
	1978-90	0.0497	0.0094	0.0024		-0.0036
		(0.0096)	(0.0084)	(0.0055)		(0.0033)
Unpaid Family Labour	1971-77	0.0412	0.0134	0.0683	-0.0038	
		(0.0242)	(0.0147)	(0.0285)	(0.0033)	
	1978-90	0.0533	0.0130	0.0060	0.0036	
		(0.0100)	(0.0092)	(0.0064)	(0.0033)	

Note: Standard errors are in parentheses.

Table 6.6: Measurements of long-run biases in technical change (B_{ij}'s) in the dynamic model

		Input i				
Input j	Periods	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
Fertiliser	1971-77		-0.0913	0.2585	-0.1306	-0.1492
			(0.0401)	(0.3184)	(0.0895)	(0.0956)
	1978-90		-0.0687	0.0514	-0.1536	-0.1927
			(0.0162)	(0.0611)	(0.0634)	(0.0747)
Hired Labour	1971-77	0.0913		0.3497	-0.0393	-0.0580
		(0.0401)		(0.3531)	(0.0543)	(0.0607)
	1978-90	0.0687		0.1201	-0.0849	-0.1240
		(0.0162)		(0.0713)	(0.0531)	(0.0643)
Capital	1971-77	-0.2585	-0.3497		-0.3890	-0.4077
		(0.3184)	(0.3531)		(0.4050)	(0.4117)
	1978-90	-0.0514	-0.1201		-0.2050	-0.2440
		(0.0611)	(0.0713)		(0.1208)	(0.1331)
Operator Labour	1971-77	0.1306	0.0393	0.3890		-0.0187
		(0.0895)	(0.0543)	(0.4050)		(0.0127)
	1978-90	0.1536	0.0849	0.2050		-0.0390
		(0.0634)	(0.0531)	(0.1208)		(0.0235)
Unpaid Family Labour	1971-77	0.1492	0.0580	0.4077	0.0187	
		(0.0956)	(0.0607)	(0.4117)	(0.0127)	
	1978-90	0.1927	0.1240	0.2440	0.0390	
		(0.0747)	(0.0643)	(0.1331)	(0.0235)	

Note: Standard errors are in parentheses.

When comparing biases in technical change with those in past studies, results in this study contradict those derived by Luh (1990, pp. 142, 150) who used a generalised Leontief value function for aggregate U.S. agriculture. She found that technical change was labour saving, capital using and intermediate and material inputs using. In addition, Vasavada and Ball (1988, p. 134), who used a normalised quadratic function for aggregate U.S. agriculture, reported that technical change was family labour saving, durable equipment using and intermediate materials (including hired labour) using. Taylor and Monson (1985, p. 7) indicated that technical change was labour, materials, capital and land using in Southeastern United States agriculture.

If we consider the increases in quantities of capital and chemical fertiliser used in Thai agriculture at the aggregate level over the study period (refer to Figures 5.1 to 5.4), it is surprising, on the surface, that technical change has been saving in these inputs in both sub-periods. Yet there is a plausible explanation of this result. In the case of fertiliser, disembodied technical change in fertiliser implies that farmers have developed their knowledge of fertiliser use over time. In other words, farmers use fertiliser better, making its use more profitable, and thus they use more fertiliser input in the production process. Furthermore, due to a decline in soil fertility and loss of topsoil from erosion, additional fertiliser has had to be used to sustain the productivity of the soil. In addition, the declining availability of new land may have induced farmers to use more fertiliser because it is a land-augmenting input, consistent with the induced innovation process as the price of land increased relative to the price of fertiliser.

The result that technical change is capital saving may be explained by the embodiment of more advanced technologies in tractors and other capital items over time. These items have become more productive; yet, being measured in physical units unadjusted for quality changes (see Chapter 5), the technologically superior capital items that were increasingly adopted over the study period are treated as equivalent to the less technologically advanced items existing early in the study period.[3] As capital items have become more productive, it has become more profitable to use them in the

[3] That is, capital has probably been undervalued as a factor of production in this study. If it had been possible to measure capital accurately to incorporate quality improvements, it is likely that the measure of capital saving technical change would have been less.

production process; the capital index has therefore risen even though technical change has been capital saving.

6.3 The Static Model

This section is divided into four subsections. First, the model estimation is described. Then, tests of hypotheses are reported. The last two subsections cover elasticity calculations and the measurement of biases in technical change. Again, when comparing these estimates with those in previous studies, the various results could be due to a combination of different methods, data and functional forms being employed.

6.3.1 Model Estimation

The model defined in equations (4.3) and (4.4) is a system of linear equations. The seemingly unrelated regression routine **(SUR)** in the **TSP** computer package (TSP International 1992) is employed to estimate the unknown parameters of this model.[4] The Gauss algorithm is used in estimation. Again, lagged output price is used in this study and current period input prices are employed, as discussed earlier. The programming in **TSP** used in parameter estimation is presented in Appendix B.

The parameter estimates of the system of equations defined by equations (4.3) and (4.4) are reported in Table 6.7. Approximately two-thirds of the estimated parameters are at least twice their corresponding asymptotic standard errors, which is quite a favourable result when compared with other estimated generalised Leontief models (e.g., Lopez 1984; Villezca-Becerra and Shumway 1992). The estimated R^2 values of output supply, demand for fertiliser, hired labour, capital, operator labour and unpaid family labour are 0.93, 0.85, 0.76, 0.83, 0.89 and 0.85, respectively. This indicates that the static model explains a large proportion of the variation in the dependent variables.

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[4] The **SHAZAM SYSTEM** procedure can also be used to estimate unknown parameters of the seemingly unrelated regression model. However, the primary advantage of using the **TSP SUR** procedure over that of **SHAZAM** is that the symmetry condition can be directly imposed on the estimating equation system without an additional option, while in **SHAZAM** it cannot.

However, we note that these R^2 values are less than those of the dynamic model, except operator labour and unpaid family labour. Given estimated Durbin-Watson (DW) values for output supply (1.02), demand for fertiliser (0.40), hired labour (0.88), capital (0.20), operator labour (1.01) and unpaid family labour (1.25), autocorrelation appears to be a problem. Again, the Breusch-Pagan test (Breusch and Pagan 1979) was applied to test for heteroscedasticity. The test values for output supply and input demand for fertiliser, hired labour, capital, operator labour and unpaid family labour are, respectively, 31.26, 19.21, 26.37, 17.05, 25.01 and 14.90. Given the critical chi-square value (at the 5 per cent significant level) of 18.31 for all equations, heteroscedasticity is a problem for all output supply and input demand equations, except capital and unpaid family labour. As for the dynamic model, the WLS procedure, as mentioned earlier, could also be used to correct this problem but no attempt is made in this study. The presence of autocorrelation and heteroscedasticity could be an indication of mis-specification or may be due to data problems. Thus, empirical results of the static model should be also interpreted cautiously.

Figures 6.1 to 6.6 show the comparison between the predictive performance of the static model and the dynamic model for all regions. Note that the % on the vertical axis means quantity indexes. In addition, the predicted values in some figures are negative.[5] This may be a consequence of data problems, as mentioned earlier. The results indicate that the dynamic model gives better predictions of output supply and input demands, except operator labour and unpaid family labour. This can be confirmed by comparing the root mean squared errors (RMSE) of the two models. The estimated RMSE from the static model for output supply and input demand for fertiliser, hired labour, capital, operator labour and unpaid family labour are, respectively, 7.50, 14.40, 13.83, 18.62, 8.61 and 12.84, while those from the dynamic model are 7.02, 10.65, 11.56, 7.23, 8.63 and 18.09, respectively. When these results are added to the observations on R^2 values and Durbin-Watson and Breusch-Pagan test results discussed above we conclude that the dynamic model is one the whole more compatible with the Thai agricultural data being used in this study.

[5] Warr (1994) also obtained negative predicted values when comparing the prediction of two models.

Table 6.7: Seemingly unrelated regression parameter estimates of output and input demand equations in the static model[a]

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
β_{1t}	0.5299	β_{6d}	1.4991	β_{26}	32.0541
	(0.2670)		(0.8947)		(13.3280)
β_{2t}	-4.8323	β_{11}	149.6050	β_{33}	39.1379
	(0.4287)		(25.8519)		(28.0644)
β_{3t}	-2.8421	β_{12}	2.1168	β_{34}	-20.5650
	(0.4148)		(9.0635)		(10.3239)
β_{4t}	-5.4760	β_{13}	-26.6705	β_{35}	-102.9460
	(0.5159)		(15.3007)		(35.3675)
β_{5t}	-1.5506	β_{14}	7.3306	β_{36}	94.8953
	(0.2956)		(7.3688)		(41.6082)
β_{6t}	-0.2159	β_{15}	2.0683	β_{44}	-20.4349
	(0.4023)		(22.3667)		(11.6646)
β_{1d}	-1.0391	β_{16}	-44.3115	β_{45}	-5.2626
	(0.5607)		(28.7233)		(7.9311)
β_{2d}	-0.8148	β_{22}	-46.9324	β_{46}	29.0713
	(0.9478)		(14.2450)		(10.8043)
β_{3d}	0.3287	β_{23}	-38.6968	β_{55}	-586.7290
	(0.9505)		(13.7393)		(204.6840)
β_{4d}	0.5306	β_{24}	-13.0932	β_{56}	572.118
	(1.2230)		(7.8784)		(232.5650)
β_{5d}	-1.5117	β_{25}	33.7903	β_{66}	-790.2420
	(0.6458)		(10.4753)		(267.4350)

[a] Coefficients of the dummy variables are presented in Appendix E.

Standard errors of estimates are in parentheses.

Figure 6.1: Comparison of observed and predicted output supply of all regions of Thailand

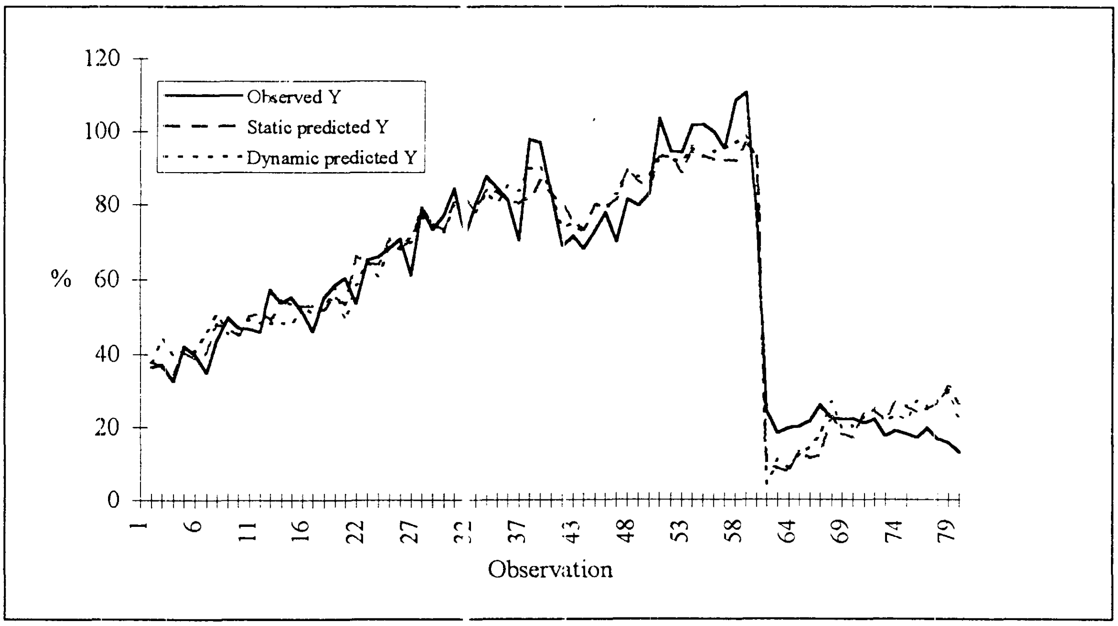


Figure 6.2: Comparison of observed and predicted fertiliser of all regions of Thailand

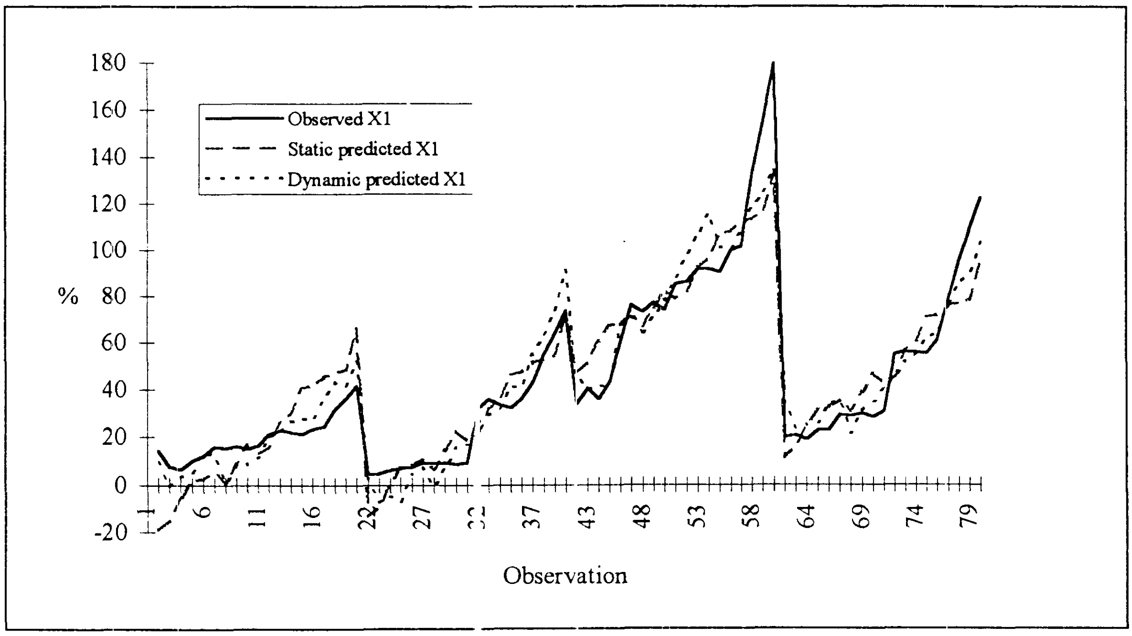


Figure 6.3: Comparison of observed and predicted hired labour of all regions of Thailand

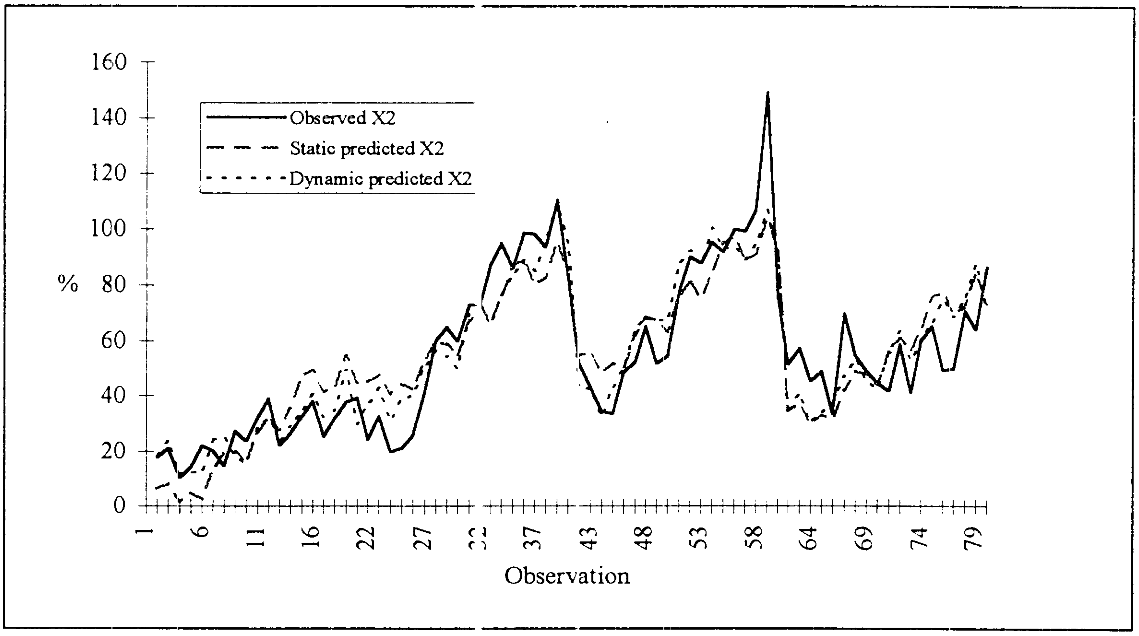


Figure 6.4: Comparison of observed and predicted capital of all regions of Thailand

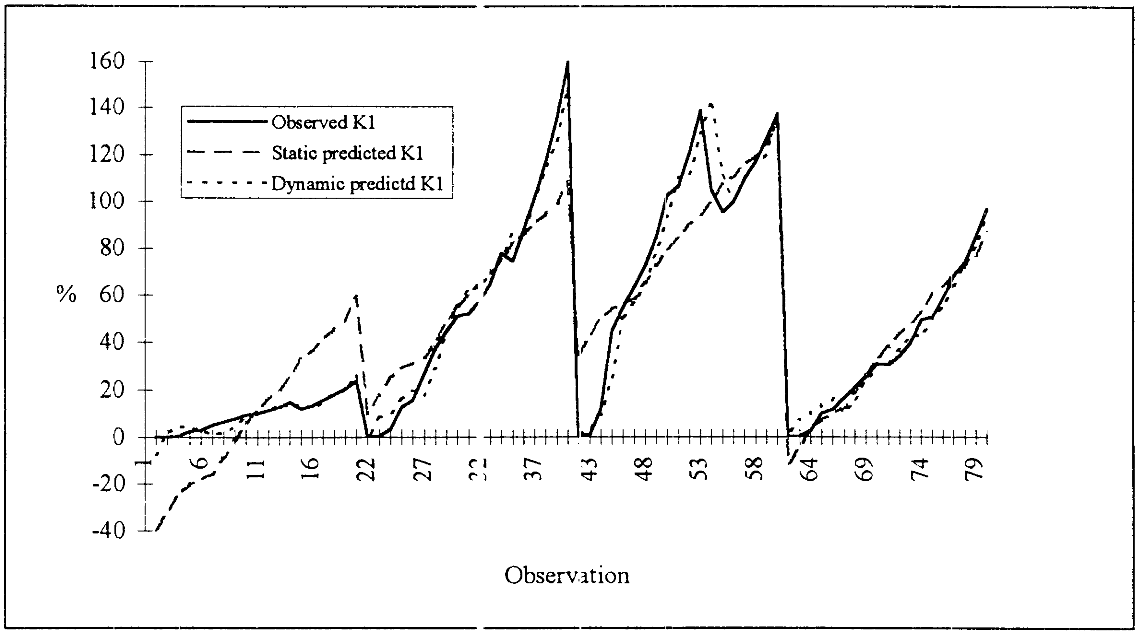


Figure 6.5: Comparison of observed and predicted operator labour of all regions of Thailand

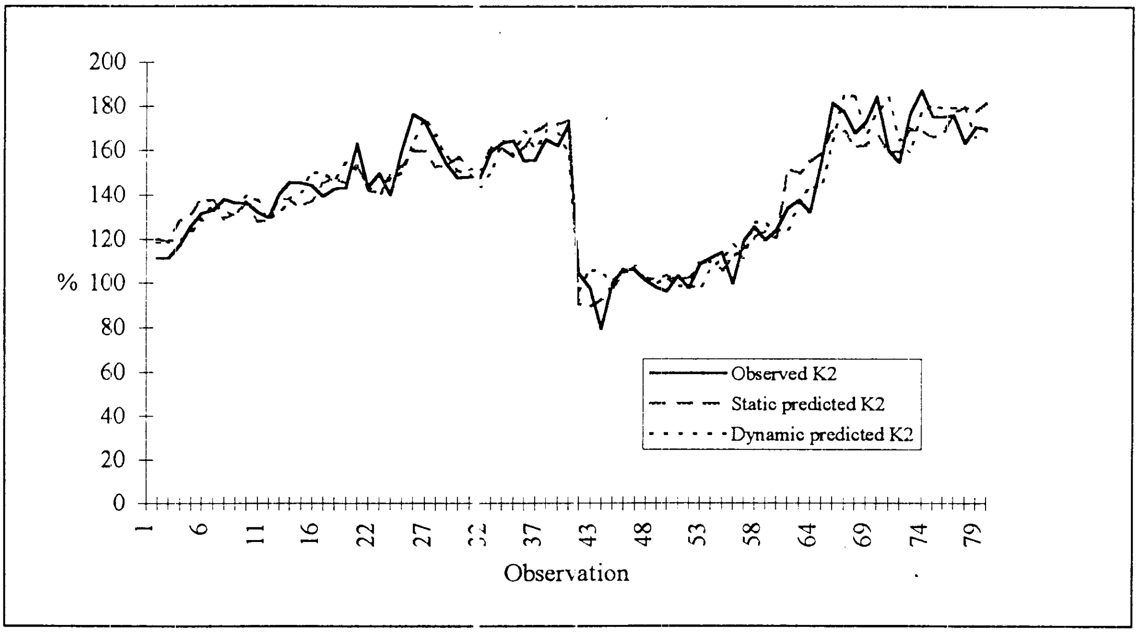
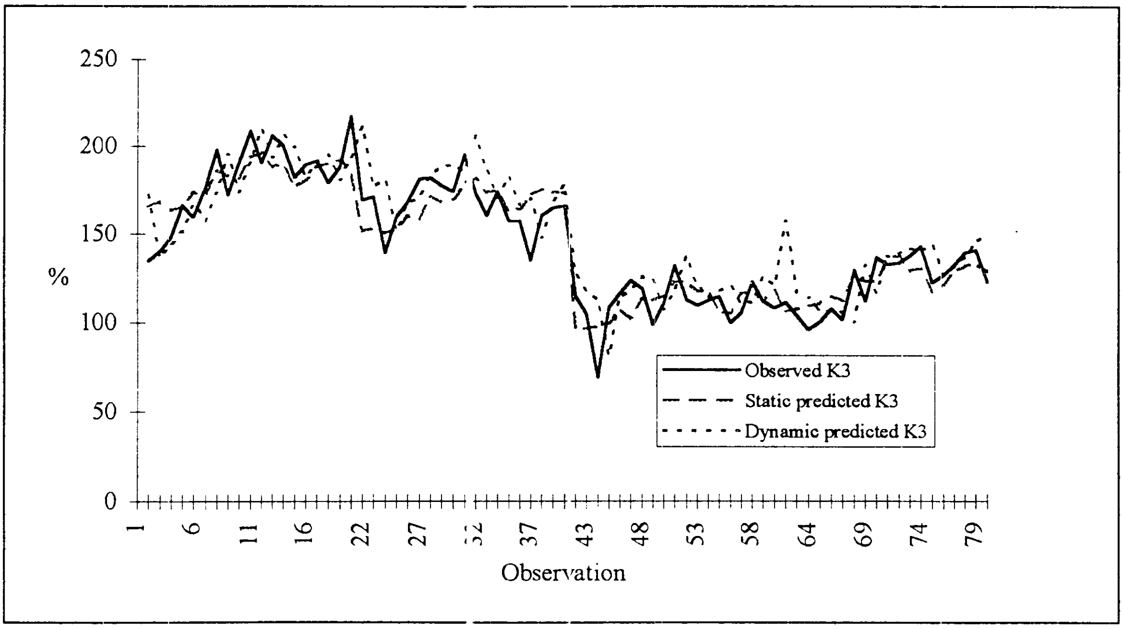


Figure 6.6: Comparison of observed and predicted unpaid family labour of all regions of Thailand



6.3.2 Tests of Hypotheses

The model was estimated maintaining homogeneity and symmetry in prices. Monotonicity and convexity in prices were checked following estimation. The monotonicity condition was found not to be satisfied with respect to the prices of fertiliser and capital at a few data points, suggesting that these violations are not a serious problem. However, the convexity condition was not satisfied with respect to the price of fertiliser and the wages of operator labour and unpaid family labour for almost all data points. As for the dynamic model, the reasons for these violations could be due to data problems, or may be a consequence of imperfect competition in output and input markets, as a result of intervention by the government in Thai agriculture, as mentioned in Chapter 2.

Hypothesis test results regarding technical change are presented in Table 6.8. Wald Chi-Square tests are used in all cases. Recall that the tests of hypotheses related to technical change are divided into two stages. First, the hypothesis is tested that the availability of new land does not affect the rate of technical change. Second, the hypothesis of no technical change in Thai agriculture is tested.

The estimated results are mainly similar to those of the dynamic model. Both models indicate the presence of technical progress in output supply which is consistent with previous studies, as mentioned earlier. The main difference in the results for the static model compared with those for the dynamic model is that no significant differences are found in the technical change parameters in fertiliser, hired labour and capital demands; results for the dynamic model show differences in the technical change parameters between the two sub-periods in output supply and all input demands. These contrary results may be due to the difference in model specification between the static model and dynamic model.

Table 6.8: Testing hypotheses in the static model

Hypotheses	Test Values	Critical Values (5 %)	Results
1. No differences in technical change parameters	19.9889	$\chi^2(6) = 12.59$	Rejected
2. No difference in technical change parameter in output supply	3.4344	$\chi^2(1) = 3.84$	Not rejected[a]
3. No difference in technical change parameter in fertiliser	0.7390	$\chi^2(1) = 3.84$	Not rejected
4. No difference in technical change parameter in hired labour	0.1196	$\chi^2(1) = 3.84$	Not rejected
5. No difference in technical change parameter in capital	0.1882	$\chi^2(1) = 3.84$	Not rejected
6. No difference in technical change parameter in operator labour	5.4801	$\chi^2(1) = 3.84$	Rejected
7. No difference in technical change parameter in unpaid family labour	2.8072	$\chi^2(1) = 3.84$	Not rejected[a]
8. No technical change	513.3789	$\chi^2(12) = 21.03$	Rejected
9. No technical change in output supply	15.9973	$\chi^2(2) = 5.99$	Rejected
10. No technical change in fertiliser	172.3759	$\chi^2(2) = 5.99$	Rejected
11. No technical change in hired labour	70.6661	$\chi^2(2) = 5.99$	Rejected
12. No technical change in capital	195.2945	$\chi^2(2) = 5.99$	Rejected
13. No technical change in operator labour	27.7295	$\chi^2(2) = 5.99$	Rejected
14. No technical change in unpaid family labour	5.7820	$\chi^2(2) = 5.99$	Not rejected[a]

[a] Rejected at 10 per cent critical value.

6.3.3 Elasticity Calculations

Applying equations (4.5) to (4.9), Table 6.9 presents elasticities calculated at the sample means of the data from the static model parameter estimates reported in Table 6.7. Note that the long-run static profit function is used in this study. Its elasticities can be compared only with the long-run elasticities of the dynamic model.

The analysis indicates that the supply elasticity is positive, inelastic and significantly different from zero. This result contradicts the results of the dynamic model and the study of Thai agriculture by the Thailand Development Research Institute (1988) using a single static equation which failed to find a statistically significant result. In addition, Adulavidhaya et al. (1979, p. 85), using a normalised quadratic profit function applied to the farm-level data of Thai agriculture in 1973, reported that the magnitude of own-price elasticity of output was greater than one.

The impacts of the prices of hired labour and unpaid family labour on output supply are negative, as one would expect, while the prices of fertiliser, capital and operator labour have a positive influence on output. The latter results are not theoretically consistent but, as for the dynamic model, this is not a great concern as their t-values do not appear to be significantly different from zero.

The own-price elasticities of input demands calculated from the static model are generally larger in absolute value and more statistically significant than those computed from the dynamic model. However, the dynamic model provides more signs that accord with expectations than the static model.

Table 6.9: Elasticities of quantities with respect to prices in the static model

Quantities	Output	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
Output	0.5660	0.0183	-0.2583	0.0603	0.0186	-0.4050
	(0.2062)	(0.0785)	(0.1482)	(0.0606)	(0.2014)	(0.2625)
Fertiliser	-0.0246	0.[illegible]770	0.4976	0.1429	-0.4040	-0.3890
	(0.1054)	(0.1573)	(0.1767)	(0.0860)	(0.1252)	(0.1617)
Hired Labour	0.2241	0.[illegible]217	-0.7652	0.1622	0.8896	-0.8324
	(0.1286)	(0.1[illegible]42)	(0.2561)	(0.0814)	(0.3056)	(0.3650)
Capital	-0.0864	0.1527	0.2683	-0.0405	0.0638	-0.3579
	(0.0869)	(0.0919)	(0.1347)	(0.0879)	(0.0962)	(0.1330)
Operator Labour	-0.0071	-0.1154	0.3930	0.0171	1.7737	-2.0613
	(0.0772)	(0.0[illegible]58)	(0.1350)	(0.0257)	(0.7263)	(0.8379)
Unpaid Family Labour	0.1449	-0.1037	-0.3433	-0.0893	-1.9240	2.3154
	(0.0939)	(0.0[illegible]31)	(0.1505)	(0.0332)	(0.7821)	(0.9136)

Note: Standard errors are in parentheses.

When comparing the magnitudes of the own-price elasticities of input demands in this study with results in previous studies, the results in this study range from -0.04 for capital to 2.32 for unpaid family labour. The own-price elasticities of input demands computed by Chotigeat (1981, p. 131) using a translog production function for aggregate Thai agriculture over the 1953-72 period range from -0.19 to -0.39 for labour, -0.35 to -0.60 for capital and -1.42 to -6.29 for fertiliser.[6] Warr (1994, p. 17) also used a translog production function for each commodity over the 1977-89 period and obtained estimates of own-price elasticities of labour demand ranging from -0.014 to -0.957, tractor demand ranging from -0.639 to -0.943 and fertiliser demand ranging from -0.460 to -0.992.[7] Setboonsarng and Evenson (1991, p. 211) employed a normalised quadratic profit function and reported own-price elasticities of labour, fertiliser and capital of -0.0630, -0.4176 and -0.6862, respectively. Adulavidhaya et al. (1979, p. 85) found own-price elasticities of seed-fertiliser, capital and labour demands of -1.112, -1.123 and -1.574, respectively. Jieamanugulgit (1989, p. 22) used a generalised Leontief profit function for Agro-Economic Zone 5 over the 1967-86 period and found own-price elasticities of capital, labour and fertiliser demands of -0.000, -0.028 and -0.514. This study separated labour into hired, operator and unpaid family labour, making it difficult to compare with the results from other studies. Generally, the magnitudes of the own-price elasticities of input demands in this study are lower than those from the other studies, except for operator and unpaid family labour demands.

The cross-price impact between fertiliser and hired labour is positive, while those between fertiliser and operator labour and between fertiliser and unpaid family labour are negative. Therefore, an increase in fertiliser price increases the demand for hired labour but decreases the demands for operator and unpaid family labour.

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6 Note that Chotigeat (p. 122) estimated the elasticities of input demand i with respect to input price j (ε_{ij}) by using the relation:

$\varepsilon_{ij} = \sigma_{ij} . S_j$,

where σ_{ij} is the Allen elasticity of substitution between input i and j; and S_j is the share of input j in total cost.

7 Note that Warr (p. 10) used the same formula as Chotigeat to estimate the price elasticities of input demands.

Substitutability between fertiliser and hired labour may not be impossible in Thai agriculture. The studies of Thai agricultural production by Chotigeat (1981, pp. 128-9) and Warr (1994, p. 17) found that fertiliser was substituted by aggregated labour (hired labour and family labour). In addition, a study of U.S. agriculture by Villezca-Becerra and Shumway (1992, p. 24), applying the generalised Leontief profit function, confirmed that hired labour (including capital) was substituted by materials where fertiliser was included. These results are consistent with a study of Philippine agriculture by Evenson and Quizon (1991, p. 201) who found substitutability between fertiliser and aggregate labour by using a normalised quadratic profit function. However, the more fertiliser is used, the more operator and unpaid family labour are required for maintenance, harvesting and threshing. That is why fertiliser is expected to be a complementary input to operator labour and unpaid family labour.

The cross-price elasticities between fertiliser and capital show that fertiliser input is a substitute for capital input, and *vice versa*. This result contradicts the findings of Chotigeat and Adulavidhaya et al. but is consistent with those of Warr and Setboonsarng and Evenson.

The cross-price elasticities between hired labour and capital and between hired labour and operator labour are positive. The result of substitutability between hired labour and capital is in line with the studies by Rijk (1986, p. 30) and Rijk (1989, pp. 116-7), while substitutability between hired labour and operator labour is consistent with the findings by Tyrchniewicz and Schuh (1969, p. 785). In addition, the estimated results show that capital substitutes for operator labour while it complements unpaid family labour.

Relations between operator labour and unpaid family labour are one of the primary issues in this study. The estimated results indicate that the cross-price elasticities between operator labour and unpaid family labour are negative. This implies that operator labour cannot be substituted by unpaid family labour, and *vice versa*. This is inconsistent with the results obtained by Tyrchniewicz and Schuh, probably due to the differences in the ways in which labour resources are used in U.S. agriculture compared with Thai agriculture.

Note that the above findings show that cross-price elasticities are not generally symmetric in size. This is consistent with past studies using a generalised Leontief functional form (e.g., Lopez 1984; Jieamanugulgit 1989; Villezca-Becerra and Shumway 1992).

There are some differences between the cross-price elasticities of input demands estimated from the static model and those from the dynamic model. First, almost all cross-price elasticities in the static model are significantly different from zero, while those in the dynamic model tend to be insignificant. Second, because of the recursivity of the simultaneous equation system, the dynamic model can estimate both direct and indirect cross-price elasticities of variable input demands, and thus provide more information than the static model in this instance. Third, some signs of cross-price elasticities differ between models. For example, the cross-price elasticities between operator labour and unpaid family labour in the static model are negative, while those in the dynamic model are positive. Finally, in general, although the cross-price elasticities in the two models are similarly inelastic, some cases are quite different in size such as the cross-price elasticities between operator labour and unpaid family labour, for example.

In sum, there are a few primary contributions of elasticity estimates in the static model relative to estimates in previous Thai studies. First, the magnitudes of the own-price elasticities of inputs demands in this study are generally lower than those from past studies. Second, as mentioned above, this study indicates that the cross-price elasticities between operator labour and unpaid family labour are negative. This means that operator labour cannot substitute for unpaid family labour, and *vice versa*. Third, in this study, relations between operator labour and hired labour and capital are opposite to those between unpaid family labour and hired labour and capital. As for the dynamic model, the last two contributions confirm that these two labour are different inputs.

6.3.4 Measurement of Biases in Technical Change

The measurements of biases in technical change defined by equation (4.12) are presented in Table 6.10. They are estimated at the sample means for the periods of 1971-77 and 1978-90, due to the hypothesis test findings that the rates of technical change are different between the two periods. Recall that because all inputs in the static model are treated as variable (i.e., no slow adjustments of quasi-fixed inputs are permitted), only long-run biases are measured and compared with those in the dynamic model. As for the dynamic model, a positive coefficient of B_{ij} implies that technical change is Hicks-saving in input i relative to input j.

In the period 1971-77, technical change in Thai agriculture was capital saving relative to the other inputs, while technical change was unpaid family labour using relative to the other inputs. This may be partly due to data problems (changes in employment definitions, methodologies and sampling procedure in the labour force survey of the National Statistical Office, as discussed in Chapter 5). These results are similar to those in the dynamic model.

In the 1978-90 period, the bias coefficients are smaller than those of the 1971-77 period but the biases are generally similar. The main difference between the two periods is that the technical change in the 1978-90 period was fertiliser saving relative to the other inputs. This result slightly contradicts that of the dynamic model where technical change was capital saving relative to the other inputs in both sub-periods. These contrary results may be due to the misspecification by the static model in that it ignores the adjustments of quasi-fixed inputs. The coefficient of the time trend in the static model might pick up something that should have been included in the model through the adjustment process.

Table 6.10: Measurements of biases in technical change (B_{ij}'s) in the static model

		Input i				
Input j	Periods	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
Fertiliser	1971-77		-0.1977	0.2066	-0.2486	-0.2810
			(0.0624)	(0.1367)	(0.0617)	(0.0617)
	1978-90		-0.0427	-0.0011	-0.0761	-0.0853
			(0.0090)	(0.0084)	(0.0085)	(0.0087)
Hired Labour	1971-77	0.1977		0.4043	-0.0509	-0.0833
		(0.0624)		(0.1418)	(0.0384)	(0.0398)
	1978-90	0.0427		0.0416	-0.0334	-0.0427
		(0.0090)		(0.0080)	(0.0073)	(0.0078)
Capital	1971-77	-0.2066	-0.4043		-0.4552	-0.4876
		(0.1367)	(0.1418)		(0.1565)	(0.1579)
	1978-90	0.0011	-0.0416		-0.0750	-0.0843
		(0.0084)	(0.0080)		(0.0089)	(0.0094)
Operator Labour	1971-77	0.2486	0.0509	0.4552		-0.0324
		(0.0617)	(0.0384)	(0.1565)		(0.0082)
	1978-90	0.0761	0.0334	0.0750		-0.0093
		(0.0085)	(0.0073)	(0.0089)		(0.0027)
Unpaid Family Labour	1971-77	0.2810	0.0833	0.4876	0.0324	
		(0.0617)	(0.0398)	(0.1579)	(0.0082)	
	1978-90	0.0853	0.0427	0.0843	0.0093	
		(0.0087)	(0.0078)	(0.0094)	(0.0027)	

Note: Standard errors are in parentheses.

6.4 Conclusions

An intertemporal generalised Leontief value function and static generalised Leontief profit function were applied for dynamic and static dual models in Thai agriculture. The dynamic model comprises a system of output supply, two variable input demand and three quasi-fixed input demand equations, while the static model consists of a system of output supply and five input demand equations. The parameters in these two equation systems were estimated using seemingly unrelated regression for the static model and non-linear seemingly unrelated regression for the dynamic model.

Autocorrelation appears to be a problem for the static model, while heteroscedasticity is a problem (in some equations) for both the static and dynamic models. The presence of autocorrelation and heteroscedasticity could be an indication of mis-specification or may be due to data problems. However, we observe that the dynamic model provides better predictive performance than the static model and also suffers much less from the above mentioned problems.

The results indicate that the quasi-fixed inputs in the dynamic model (capital, operator labour and unpaid family labour) could not adjust fully, in the short run, to price changes, and that adjustments were not independent of the quantities of other quasi-fixed factors.

We note that the validity of the results may suffer from the observed violations of monotonicity and convexity conditions. These suggest that the assumption of competitive product and factor markets may have been false or, alternatively, that the data may not be without problems. As a result, some estimated elasticities have unexpected signs.

Both the dynamic and static models report a few similar results. First, price elasticities are generally inelastic. Second, there exist substitutabilities between fertiliser and hired labour and between hired labour and capital. Third, there is significant technical change and an observed change in technical change parameters (hypothesised to be due to the declining availability of new land in Thai agriculture over the latter half of the sample period), and technical change which was capital saving and unpaid family labour using in the 1971-78 period.

The results also show a few differences in the results of elasticity estimates between the static and dynamic models. First, the dynamic model is superior to the static model in that it provides more information on both short-run and long-run elasticities, while the static model shows only long-run elasticities. Second, in the dynamic model, results indicate that operator labour is a substitute for unpaid family labour, and *vice versa*. In the static model, operator labour is a complementary input for unpaid family labour, and *vice versa*. Third, the static model provides more significant elasticity estimates than the dynamic model, while the dynamic model gives more consistent own-price elasticities.

The dynamic model indicates differences in technical change parameters between sub-periods in output supply and all input demands, while the static model reports differences in technical change parameters only in output supply and operator labour demand. In addition, the static model reports technical change was fertiliser saving in relation to other inputs in the 1978-90 period, while the dynamic model indicated technical change was capital saving. Moreover, the static model gives lower magnitudes of bias measurements in 1978-90 than in 1971-77, whereas the dynamic model does not. Finally, the dynamic model provides information on both short-run and long-run biases in technical change, while the static model does not.

The main conclusion to be drawn from these results is that the dynamic model is preferred over the static model. There are a few reasons. First, as mentioned before, the dynamic model gives more predictive power than the static model and has less problems with autocorrelation and heteroscedasticity. This implies that the dynamic model is more compatible with the data being used in this study. Second, the dynamic model provides information on dynamic effects, while the static model does not. Third, the dynamic model gives more valuable information than the static model on short-run and long-run price elasticity estimates and short-run and long-run biases in technical change in Thai agriculture. Therefore, the results of the dynamic model are of greater relevance, providing information that should help policy makers choose the appropriate direction of economic development planning.

7. Summary, Policy Implications and Conclusions

7.1 Introduction

The main objective of this chapter is to provide a summary, policy implications and conclusions of this study. Following this introduction, a summary of the study is given. Then, some policy implications are introduced. The last two sections provide the contributions of the study and suggestions for further research.

7.2 Summary of the Study

The agricultural sector is still very important for the Thai economy despite rapid economic growth and government policies which have favoured other sectors in recent years. It has continued to be a major source of GDP and export earnings, and to be an important source of employment when compared with other sectors and other Asian countries.

The future role of agriculture in employment is of particular concern, for three primary reasons. First, in the past, the relatively high growth rate of Thai agriculture was achieved by means of an expansion of cultivated area. In recent years, this pattern of growth could not continue because Thailand reached its land frontier (i.e., no new agricultural land was available) a decade ago and hence new technology inputs have been widely used. Second, most of the 'poor' are farmers, most of them small farmers, and agricultural workers in rural areas. Third, there has been a worldwide decline in prices of primary commodities which has been reflected in Thailand domestic markets. A question has been raised about the impacts of the above events on rural employment.

The general objective of the study is to develop an appropriate analytical model for understanding the relationships between agricultural inputs and outputs and the nature of dynamic adjustment of labour demand in Thai agriculture over 20 years from 1971 to 1990. It involved investigating the structural characteristics of demand for labour, the impacts of prices on demand for labour, output supply and other input demands, and the nature of the impact of technical change on labour demand, other input demands and output supply. Then, some agricultural development policies were to be suggested for planning purposes.

Most past studies have estimated a labour demand equation system associated with output supply and other input demands of Thai agriculture. No study has yet been undertaken which accounts for the dynamic nature of farm production and, in particular, the quasi-fixed nature of operator and unpaid family labour in Thai agriculture. In this study, a full dynamic dual approach, in which all inputs are not forced to adjust fully and immediately to the desired level in the short run, was used to derive an analytical model of a labour demand system incorporating output supply and other input demands of Thai agriculture. However, since one of the primary objectives of this study is to compare the empirical results of using the static and dynamic approaches (and hence to demonstrate the consequences of ignoring dynamics in the estimation of production characteristics), the static dual approach was also proposed to provide an alternative method to estimate the labour demand system for Thai agriculture.

An intertemporal modified generalised Leontief value function (dynamic model) and a generalised Leontief profit function (static model) were specified for Thai agricultural production. In the dynamic model, a system of six equations was derived, consisting of one output supply equation, two variable input demand equations of fertiliser and hired labour and three quasi-fixed input demand equations of capital, operator labour and unpaid family labour. In the static model, a system of one output supply equation and five input demand equations of fertiliser, hired labour, capital, operator labour and unpaid family labour was derived.

Non-linear seemingly unrelated regression estimation was used to estimate the unknown parameters of the dynamic model, while seemingly unrelated regression was employed to estimate the static model.

Pooled aggregate annual data were used for the study, comprising annual time-series data for the period 1971-90 for each of the four regions of Thailand. Output, comprising rice, kenaf, cotton, cassava, groundnuts, soybeans, mungbeans, sugarcane, corn and sorghum, was aggregated into one category to conserve degrees of freedom and to avoid any further complexity in econometric modelling. As mentioned earlier, five input groups were used including fertiliser, hired labour, capital, operator labour and unpaid family labour. Due to lack of data on the price of agricultural land, constant returns to scale in relation to land were assumed in the study.

Because of the need to construct the above aggregate variables in order to reduce the number of variables to a manageable number, an index number method was required. In addition, due to the use of regional data in this study, a transitive indexing method was required. Thus, the CCD multilateral index is used to form the various aggregate variables. A transitive index number method was preferred because it ensures the consistency of all direct and indirect comparisons.

The empirical results indicate that capital, operator labour and unpaid family labour do not adjust to price changes fully and immediately in the short run. The adjustment coefficient of capital was -0.03 and insignificantly different from zero, indicating that it might be a fixed rather than a quasi-fixed input. The adjustment coefficients of operator labour and unpaid family labour were -0.11 and -0.79, respectively, implying that it takes around 9 years for operator labour and less than 2 years for unpaid family labour to reach their desired levels. This indicates that they are different inputs. In addition, it was found that the adjustment of a quasi-fixed input was not independent of other quasi-fixed input quantities.

The dynamic model was estimated maintaining homogeneity and symmetry in prices and concavity in quasi-fixed inputs, while the static model was estimated imposing homogeneity and symmetry in prices. Monotonicity and convexity conditions were checked following estimation. It was found that the monotonicity and convexity conditions were violated in both models, suggesting that these violations might be due to data problems or due to violations of the assumption of competitive product and factor markets in Thai agriculture. This resulted in unexpected signs of some estimated elasticities.

The empirical results of both the dynamic and static models showed that, in general, price elasticities were relatively low and hired labour was a substitute for fertiliser and capital. In addition, it was found that there was significant technical change and that there was a difference in the rates of technical change due to the reduced availability of new land between the period 1978-90 versus the period 1971-77. Technical change was capital saving and unpaid family labour using in relation to fertiliser, hired labour and operator labour in the period 1971-77.

The two models also provided a few differences in both elasticity estimates and technical change parameters. For elasticity estimates, the dynamic model provided both short-run and long-run elasticities, while the static model provided only long-run elasticities. The results of the dynamic model showed that unpaid family labour was a substitute for operator labour, and *vice versa*, while those for the static model indicated that they were complements. Finally, we observe that, in general, the dynamic model provided more theoretically consistent own-price elasticity estimates (i.e., elasticities with the expected signs) relative to the static model, while the static model gave more statistically significant elasticity estimates.

For technical change measures, the dynamic model provided both short-run and long-run biases in technical change, whereas the static model did not report short-run biases. In addition, the dynamic model indicated differences in technical change between the two periods in output supply and all input demands, while the static model showed differences only in output supply and operator labour. Moreover, the dynamic model indicated technical change was capital saving in relation to other inputs in the period 1978-90, while the static model reported technical change was fertiliser saving. Finally, the static model provided lower magnitudes of bias measures in 1978-90 versus 1971-77, while the dynamic model did not indicate large differences.

In sum, this study concluded that the dynamic model was superior to the static model in that it provided more valuable information on the speed and independence of adjustment of quasi-fixed labour inputs, short-run and long-run price elasticities and short-run and long-run biases in technical change in Thai agriculture. Furthermore, the differences in the estimates obtained from the two approaches suggest that misleading information may be obtained when one attempts to model a dynamic process with a static tool.

7.3 Policy Implications

The primary purpose of this section is to explore some policy implications derived from this study. As summarised above, the study indicates that there were slow adjustments of capital, operator labour and unpaid family labour (although unpaid family labour adjusted more quickly than the other two factors), dependent adjustment between these quasi-fixed inputs, low price-responsiveness of output supply and input demands and substitutability between hired labour and fertiliser and between hired labour and capital in Thai agriculture. In addition, it was found that there was technical change in output supply and input demands and technical change was capital and fertiliser saving. Therefore, the agricultural development policies should take into account this empirical evidence. A few policy recommendations are now introduced below.

First, the empirical results indicate that there was a difference in the speed of adjustment between operator labour and unpaid family labour, implying that they are different inputs. Policy makers should treat them as different inputs in the agricultural policy decisions. This means that the impacts of a policy on these labour inputs may not be in the same way. In addition, they should realise that the magnitudes of the effects of a policy on demand for operator labour and unpaid family labour are different and, due to the slow adjustments of these quasi-fixed labour inputs, the policy takes a few years fully to achieve the desired effects. Thus, to assure that the appropriate direction of economic development planning is attained, a policy should be designed particularly for a labour group.

Second, as discussed in Chapter 2, agricultural development policies in Thailand in the past have been designed separately for each input or output. The results of this study indicate that there was dependent adjustment between the quasi-fixed inputs, implying that the effects of one policy have tended to be countered by the impacts of policies for other inputs. For example, while capital policy has affected the investment demand for capital, fertiliser policy has also indirectly affected the demand for capital through the stocks of labour due to relative price changes [refer to the system of equations (4.22) to (4.24)]. Therefore, to assure that there is no contradiction between these policies, a policy package for the whole agricultural economy should be considered and designed.

Third, the results of this study indicate low responsiveness of output supply and labour demand in Thai agriculture, both in the short run and long run. This implies that a price policy, such as a price guarantee program which is intended to increase farming incomes, would have little impact on output supply and labour demand in Thai agriculture. In addition, due to the slow adjustments of quasi-fixed inputs in Thai agriculture, any price policy requires some years fully to achieve the desired impacts. A long-term program is needed, if at all, but a price policy alone would not be sufficient. Because of this, a non-price policy which is possibly more effective - such as a direct intervention to alter key technical coefficients - should be considered.

Fourth, the empirical results indicate that there was technical change in output supply and input demands in Thai agriculture. One of the implications of this result is that an improvement of agricultural productivity, which increases farm income and, particularly, sustains employment, can be achieved through technological progress which results in better use by farmers of the modern inputs of fertiliser and capital. As mentioned in Chapter 2, the government encouraged farmers to use more capital and fertiliser by allocating a budget to agricultural mechanisation credit via the Bank of Agriculture and Cooperatives and by providing a fertiliser subsidy, implemented by the Marketing Organisation of Farmers, respectively. Note that any subsidy is not of necessity a good thing because it may cause distortions in resource allocation. However, to ensure further technical change in agricultural production and an improvement of income distribution in Thailand, the government should focus these policies on the poor small farms.

Fifth, in general, the empirical results indicate that technical change was labour using relative to the other inputs. This may be partly because labour is plentiful and cheap, relative to other inputs such as fertiliser and capital on which tariff and quota restrictions have been imposed for decades. Following Binswanger (1974b), a labour-using bias is likely to be accompanied by a fall in real wage rates. This is in contrast to minimum wage policy in Thailand where the minimum wage has been set higher than the market rate in the Northern and Norteastern Regions but lower than that in Bangkok, indicated by Charsombut (1990, p. 149) and Biggs et al. (1990, p. 106). This may hinder investment in those regions and encourage workers to engage in rural-urban migration (Biggs et al. 1990, p. 106). Thus, to solve those problems and to enable employers to keep with the law in Thailand, the minimum wage rate should be the same as the market rate. This is consistent with a policy recommendation by Charsombut (1990).

Sixth, the empirical results indicate the constraints on mobility of operator labour and unpaid family labour, as mentioned earlier. This may be because farmers are not able to easily adjust their labour skills to other occupations or may be due to adjustment costs in agriculture such as search cost, relocation cost and reorganisation costs (Vasavada and Ball 1988, pp. 125, 133). To facilitate the mobility of these two labour categories, the government should develop programs to upgrade skills, provide job entry and management training, recommended by Charsombut (1990) and Biggs et al. (1990), and improve the labour market information system, outlined by Sussangkarn (1993).

However, as mentioned above, to obtain the desired effects, they should be long-term programs.

7.4 Contributions of the Study

The primary contribution of this study is the provision of information on short-run and long-run price elasticities and technical change in Thai agricultural production. This is achieved using the dynamic dual approach which is theoretically more consistent than approaches followed in previous studies of Thai agricultural production.

The second contribution of this study is that, to the best of our knowledge, the dynamic dual approach has not been applied in any developing countries, although it has been used in U.S. and German agricultural studies, as mentioned earlier. Thus, it may be concluded that this is the first study applying the dynamic dual approach to developing countries, including Thailand. The results indicate that there may be important differences in the nature of adjustment processes in the agricultural industries in developed versus developing countries.

The third contribution of this study is the use of the (transitive) CCD multilateral index in constructing the aggregate variables used in the econometric analysis of Thai agriculture. No other dynamic dual study using panel data could be identified which accounts for the consistency of multilateral comparisons in the construction of their aggregate data indexes. This study is possibly the first dynamic dual study to use the CCD multilateral index in this way.

The fourth contribution of this study is that agricultural labour is divided into three groups: (variable) hired, and (quasi-fixed) operator and unpaid family labour. This degree of disaggregation has not been conducted in any other study of this type. This enables a better understanding of the nature of labour demand and interactions between the various components of labour in Thai agriculture.

The fifth contribution of this study is that the empirical results help policy makers better understand and choose appropriate development policies to solve current Thai agricultural problems. Three policy issues where decision making should be enhanced by the empirical results in both the short run and long run are research policy and its implications for the adoption of new technologies, technical change and rural employment policies.

7.5 Suggestions for Further Research

Although the primary objectives of this study have been achieved, a number of areas of further research should be considered in order to test the robustness of the empirical results. In addition, the empirical results of the study could be strengthened by the support of evidence obtained from further research. First, the use of alternative functional forms should be considered. Howard and Shumway (1989a, p. 24) and Weersink (1990, p. 15), who compared the empirical results obtained from the modified generalised Leontief and normalised quadratic functional forms in the U.S. dairy industry, indicated that there exists a lack of robustness of empirical results across functional forms. Therefore, it may be inadequate for policy makers to outline agricultural development planning based on the empirical results obtained from only one functional from.

Second, as mentioned in Chapter 6, the empirical results indicated violations of monotonicity and convexity conditions. One of primary reasons for these violations could be a consequence of intervention by the government in both output and input markets in Thai agriculture. This issue could be investigated by specification of formal hypothesis tests of the effects of government policies on the effective prices of inputs and output in a manner similar to Atkinson and Halvorsen (1984).

Third, as mentioned earlier, the CCD multilateral index was used in this study to construct aggregate variables due to its superiority on the transitivity property over other indexes such as the Tornqvist method. However, the use of alternative index numbers, which do not satisfy the transitivity property, would be more interesting in two respects. First, it enables an investigation of the influence of the transitivity property on the empirical results. Second, the robustness of empirical results using different index methods can be examined.

Fourth, as discussed in Chapter 5, the unpaid family labour wage variable employed in this study was proxied using an index constructed from the hired and operator labour wage series. However, this unpaid family wage does not reflect the migrant decisions whether to move out of the agricultural sector to urban areas. To overcome this problem, the unpaid family wage rate could be adjusted to reflect these decisions by using the following formula which is based on the Todaro model (Todaro 1971):

$$W = \frac{W_r}{W_u \times \rho} \tag{7.1}$$

where ρ is probability of gaining an urban job (i.e., $\rho = 1/(1-\mu)$ where μ is unemployment rate), W_r is rural wage rate (i.e., unpaid family labour wage used in this study) and W_u is urban wage rate. The above adjusted unpaid family labour wage would reflect not only the price of unpaid family labour but also the prospects for gaining greater remuneration from moving to urban employment. In addition, it is also a possibility for the hired labour wage to be adjusted by applying the above formula.

Various criticisms have been made of this original model, leading to more sophisticated versions which entail a number of extensions to it. It would have been a major task to include the various factors influencing the off-farm migration decisions which are incorporated in these more sophisticated versions of the model. Because of the considerable extra work involved, it was resolved not to attempt to account for all factors influencing off-farm migration decisions in the models used in this study.

Fifth, as mentioned earlier, this study was conducted using a panel of only 80 observations, comprising annual data from 1971 to 1990 for four regions in Thailand, because the annual data are limited due to delays in publications. Due to the constraint of observations in this study, the empirical results should be interpreted with caution. It is suggested that if more annual data become available, this study can be improved by disaggregating output supply into at least two groups: for example, rice and other crops. This would be consistent with the characteristics of multi-input, multi-output production in Thai agriculture. In addition, the relationships between output groups could then be investigated.