CHAPTER 3 REVIEW OF SELECTED LITERATURE ON SUPPLY RESPONSE

3.1 Introduction

Although industrialization is still the primary goal of economic development, agricultural production remains the main concern of the growing population in the world, especially in less developed countries (LDCs) (Askari and Cummings 1976). The agricultural sector not only contributes to food security of the developing economies, but it also provides the main sources of foreign exchange for economic development. To ensure food availability, many economists devote their efforts to studying the supply of agricultural products, particularly the supply of cereals and annual crops that are the most important food crops in the world.

Research on the supply response of agricultural production has become remarkably advanced since Marc Nerlove's seminal work in 1958. Most studies try to examine the responsiveness of farmers to price changes and other variables.

Various methods and assumptions have been applied to the supply response analysis depending on purpose of the studies and specific situations. Quantities produced and quantities marketed need not respond identically to various incentives. Some studies have concentrated on the supply of aggregate output or acreage and productivity, while others have considered the marketed quantities (or market surplus).

3.2 Supply Response of Aggregate Output

The study of quantity supplied or aggregate output is probably the most common type of supply analysis. The supply response of aggregate output can be undertaken using various approaches depending upon data availability, computing facilities and "the decision-making process which the estimates are intended to aid" (Coleman 1983, p. 224 quoted in Henneberry and Tweenten 1991, p. 51).

The common estimation methods for supply response can be divided into positive and normative approaches. While the positive approach mainly utilises regression analysis of time-series data, the normative approach involves derivations of commodity supply response functions from data and information relating to production functions and individual optimisation behaviour, which is not the interest of this study (Anderson 1974). A common objective in the positive approach is to estimate a behavioural structure for the supply response function and, given this structure, to predict future production levels. Since it focuses on time-series data, the results of this analysis are based on actual past changes and they are most likely to account for farmers' preferences and other considerations. Within this approach, various types of models are regularly used but frequently they involve time lags and assumptions about how price expectations are formed.

The exact formulation of these models is typically based on specific agricultural production problems. These agricultural production problems arise from Just (1993, p.12): (i) the nature of the production relationship; (ii) constraints due to resource availability, short-run asset fixity, and government restrictions; (iii) accounting relationships which describe constraints between market transactions and the variable input allocations among production activities; and (iv) characteristics of the producer, including beliefs, opinions, education, experience, and information held by the producer.

The common purpose of these models seems to be to examine the impacts of price variables on output supplied. Studies, which use these models usually, specify output to a function of only two variables in the first instance, while the others may be introduced at a later stage of the analysis. The simple aggregate output supply response of agricultural production can be expressed as (Ghatak and Ingersent 1984, p. 181):

$$Q = A \times Y \ldots \tag{3.1}$$

where:

Q = quantity of output supplied;

A = acreage as a proxy for price and exogenous explanatory variables; and

Y = yield, as another proxy for price and exogenous explanatory variables.

3.3 Area Response

Simple models which express aggregate agricultural output as a function of area and yield are often as being unable to estimate the reality of supply response. Tomek and Robinson (1981) argue that, by definition, production in a given time period equals yield per unit multiplied by the number of units (in the case of annual crop production, the number of the units is planted area). While analysts may try to estimate total production using only one equation, it may be more appropriate to consider planted area and yields separately in two equations. Ghatak and Ingersent (1984) mention that the acreage is generally under the direct control of the cultivator and, hence, it is usually accepted as the proxy variable for output and better explains the producers' behaviour.

In addition, Nerlove (1958) argues that the most striking characteristic of the output of a crop is that the farmer has so little control. Furthermore, Behrman (1968) and Tomek and Robinson (1981) add that observed agricultural output often differs considerably from the planned output because of important environmental factors which, due to the substantial expenditures that would be required for their regulation, remain beyond farmers' control. Behrman makes the further argument that the frequent large discrepancies between planned and actual agricultural production have led most econometric investigators of agricultural supply responses to approximate planned output not by actual output, but by area. The area actually planted to a particular crop is under farmers' control to a much greater degree than is the output so it is presumably a much better index of planned production. The area planted, therefore, is one focus of the present study.

The decision to focus on planted area rather than aggregate production is further justified as follows. Firstly, acreage is really a proxy variable since planned output (the variable to be explained) cannot be directly observed. It is, however, possible to use realised output as a proxy for planned output, the difference between the two being due to the impact of random factors on agricultural output. Planted area is generally under the direct control of the producers and hence it is usually accepted as the proxy variable for output (Ghatak and Ingersent 1984).

Secondly, land is one of the most important inputs in agriculture governing farmers' decisions about the production of a specific crop. Instead of considering only planted area as an indicator of planned output, one would prefer to utilise an index of all inputs devoted to the crop. In the construction of such an all-inclusive index, however, several problems are encountered. Behrman (1968) states that most non-land inputs are not unalterably committed to one crop at the start of the production period, but are varied throughout the production period in response to factors that are beyond farmers' control. Also, land devoted to a particular crop is not unchangeably committed to that crop at the time of planting, in the sense that the land need not be later cultivated and harvested. On the other hand, land differs from many other factors of production in that land is not substitutable over time within a production period. Therefore, a measure of the amount of factors actually devoted to a crop may reflect very poorly the originally planned allocation. Moreover, even for countries with the most comprehensive agricultural information available, data on quantities of non-land inputs actually devoted to specific crops on multi-product farms are often lacking. Thus unavailability of data precludes the construction of an all-inclusive index.

Finally, land is often far from a homogeneous factor. Behrman (1968) argues that if land is sufficiently heterogeneous and if other inputs constrain production, a situation is conceivable in which a farmer decides to increase the planned output of a specific crop by allocating less, but better, land to that crop. This suggests that separate area and yield equations may be preferable to a single output equation in supply response analysis.

A general and simple form of supply response can be expressed economically as a function of price variables and non-price variables, by:

$$A_t^* = f\left(P_t^*, Z_t^*\right) \tag{3.2}$$

where:

A_t^* = planned area;

P_t^* = vector of expected price variables; and

Z_t^* = vector of expected non-price variables.

Different studies identify and use various forms of these explanatory variables. Behrman (1968) emphasises that the degree of supply responsiveness is basically an empirical question depending upon the chosen explanatory variables in the models of estimation.

3.3.1 Price Variables

Price is probably the most important variable in supply estimation. Askari and Cummings (1977) suggest that whatever measure of output is used as the dependent variable in a supply model, it is reasonable to express the desired output level as a function of expected price. Behrman (1968) agrees that, in underdeveloped agriculture, farmers respond significantly and normally to price changes. He cites several studies that emphasise the importance of price changes in determining the level of agricultural supply:

> "Dantwala and Falcon, for example, emphasize that the

composition of output responds to relative price changes. J.W. Mellor suggests that short run responses may be greater in underdeveloped agriculture than in advanced agriculture because of greater flexibility in respect to factor inputs and in respect to distribution channels... In specific reference to Thailand, Brown and H. Platenius have joined Schultz in attributing the expansion of corn and kenaf to a remarkable price response". (Behrman, 1968, pp. 4-5).

(i) Own Price (Price of Rice)

The own price of an agricultural product is perhaps the most important factor influencing the quantity supplied (Cochrane 1955; Tomek and Robinson 1981).

The own price elasticity of an agricultural product is usually severely inelastic in the short run (Cochrane 1955). This means that the aggregate output of the agricultural product varies very little with a change (rise or fall) in the price of the commodity. Cochrane (1955), and Tomek and Robinson (1981) argue that the low short run elasticity of an agricultural product results from a number of interrelated and interacting causes. Firstly, the allocated resources - land, labour, drought animals and other capital - for agricultural production are treated as fixed in the short run so that they are fully employed in the production operation regardless of whether or not they are used. Secondly, during a period when product price is falling, land, labour and capital lack alternative uses and, therefore, they are still engaged in agricultural production. Thirdly, the present context showing that most of the rice productive areas in Cambodia (about 90 per cent) are flooded during the wet season so that rice is the only crop that is suitable for that land. Finally, the majority of Cambodian farmers are rice growers who lack alternative opportunities for employment, so they tend to view their occupation as a way of life, as well as a business, and do not respond readily to economic stimuli. Therefore, the total output of agricultural product varies only modestly with a change in price levels (Cochrane 1955).

(ii) Input Prices

The use of input prices in empirical studies of supply response is common. Since changes in the prices of inputs result in an increase or decrease in input levels and, therefore, the quantity of output, the inclusion of input prices in supply response analyses is inevitable. Tomek and Robinson (1981) point out that if factor prices increase with other variables held constant, the supply curve will shift to the left implying a decrease in quantity supplied.

Changes in the relative prices of outputs and inputs appear to be important in supply analysis. Tomek and Robinson (1981) argue that in some cases, if the price of a product increases relative to the prices of inputs used, the quantity supplied of the product increases as well. However, this is not always the case since the amount of inputs used in production may be small, and farmers may not be profit maximisers. Tomek and Robinson (1981) conclude that the use of price ratios in supply response analysis is an empirical question.

(iii) Prices of Competing Crops

Competing commodities are defined by Tomek and Robinson (1981, p. 84) as ones that can be produced with the same resources. In theory, if more profit can be obtained from producing other competing crops, production will decrease. Hence

Tomek and Robinson (1981) suggest that the prices of crops which compete for the same resources should be included in empirical analyses of supply response.

3.3.2 Non-Price Variables

Price is not the only variable that affects the acreage and output of annual crops like rice. Many other non-price factors also influence production. Climatic conditions, technological changes and risk are obvious and common factors influencing the production or supply of agricultural products.

(i) Climatic Conditions

A measure of weather variation seems to be the most commonly encountered non-price variable in studies of agricultural crop production. The supply studies surveyed by Askari and Cummings (1977) use a wide variety of methods to measure this variation: absolute value versus relative terms; indices of rainfall, humidity and frost; annual or seasonal measurements, and so on. 'In many cases, concepts essentially related to infrastructure seemed important and measurable to the researcher and thus were directly included in the statistical analysis of the basic model' (Askari and Cummings 1977, p. 261).

Because agricultural production in many developing countries is still predominantly rain-dependent, the inclusion of a rainfall variable in supply response models is inevitable. Rainfall variables have been included in many studies of supply response analysis.

The way in which rainfall is introduced into the supply response model varies from study to study. Lahiri and Roy (1985) initially introduced rainfall in a monotonic – either simple linear or logarithmically linear – fashion but eventually replaced it with a non-linear specification that recognised the detrimental impact of floods as well as droughts on the supply of rice in India during the autumn and winter months. They tested for all forms of rainfall effects – more rain is better, drought and floods have symmetric effects and droughts are worse than floods - and assumed adaptive expectations and partial adjustment in the Nerlovian tradition. They concluded that the detrimental impacts of excess rainfall and floods should not be ignored in supply estimation. Moreover, they suggest that it is possible to construct a crop-specific rainfall index to capture the pure effect of rainfall after accounting for the impact of changes in other variables such as prices and irrigation.

Francisco (1980) studies yield-rainfall relationships using two approaches. The first approach involves the calculation of yield-weather indices to be used either directly as estimates of the effects of weather on production, or indirectly as independent variables in regression analysis. The second approach utilises meteorological information directly in the regression analysis, with the yield of a crop as the dependent variable. Fisher (1978) also identifies two approaches to capture the effects of weather on the wheat supply in Australia: the use of the traditional multiple-regression approach; and the construction of weather indexes designed to estimate the effect of the weather on the crop yield in a given year.

To capture the real effectiveness of rainfall on crops, many analysts suggest that rainfall should be included in quadratic form. For example, Fisher (1978), Lahiri and Roy (1985), Francisco and Guise (1988), and Coelli (1992), explain that the rainfall pattern should be included in the supply model in quadratic form to capture too much rain (floods) and too little rain (droughts).

(ii) Technological Changes

Technological change is generally defined in terms of either a productivity index or the production function. The former refers to the production of a greater output with a given quantity of resources or, in other words, is a result of an increase in output per unit of input. The latter refers to a change in the parameters of the production function or the creation of a new production function (Ruttan 1957, quoted in Martin 1977, p. 498). These two definitions are entirely consistent with each other, both showing the relationship between technological change and production, and hence supply. Through technological changes, more output can be produced with the same total resources; alternatively, fewer resources are required to produce the same output.

Among the important technological changes which can increase the supply of agricultural products are the development of high-yielding varieties of crops, better fertilisers, better methods of insect, disease, and weed control; mechanization which makes it possible to plant and harvest more promptly; and better tillage techniques (Tomek and Robinson 1981). The identification and measurement of these changes is difficult due to the inability to precisely measure how much of a given change of output is derived from a particular technological change. Nevertheless, the effects of these types of changes are well known.

(iii) Risk

Risk in both forms, price risk and yield risk, plays an important role in agricultural production since the agricultural production process takes a long time - at least a few months for rice and other annual crops - from planting to harvesting. There seems to be a general recognition that risk does influence farmers' production decisions (Just 1993). Traill (1978) concluded that if risk does in fact have an important influence on farmers' production decisions, the inclusion of variables representing risk and uncertainty in aggregate supply response models may be desirable in order to predict production more accurately; to improve the estimates of other parameters in the model; and as an aid to quantifying the impact of government policies that affect uncertainty as well as prices.

Risk and uncertainty have been included in various forms by different authors. Behrman (1968) introduced price risk and yield risk separately in the supply estimation of the production of four major annual crops in Thailand between 1937-1963. He measured risk using a three-year moving average of the standard deviation of price. Just (1974), on the other hand, took into account all price risk and yield risk in a single variable by measuring risk in terms of variation around the expected price. He assumed that producers' risk expectations would be formed by geometrically weighting past observations of risk similar to the way in which price and yield expectations are formed. Traill (1978) used a three-year moving average standard deviation of past actual returns per acre as a risk variable.

These studies found that risk is an important factor in the decision-making process of farmers, and inclusion of risk variables into supply response model improves the quality of the supply estimates.

In conclusion, a large number of price and non-price variables should be included in any study of rice production in Cambodia. Since supply decisions in agricultural production are taken months before the actual products reach the market and prices are realised, the production decisions are taken on the basis of expected prices.

At this stage two questions arise: What price levels should be used in the estimation? And how is each explanatory variable measured and included in the models?

3.3.3 Price Expectations

Equation (3.2) expresses planned area as a function of the expected prices to be received by producers. Unfortunately, expected prices are unobserved. To overcome this problem, a number of methods have been suggested for expressing expected prices in terms of observed variables.

A common procedure has been to specify expected prices as some function of observed current and past prices. Fisher (1975) explained that the simplest models used in supply response analysis incorporate price variables with one or two period lags, while the more complex ones may incorporate, either implicitly or explicitly, a distributed lag of the price variables. Probably the most widely employed justifications for using a distributed lag on prices in agricultural supply response analysis are the naïve expectations (due to Ezekiel 1938[6]), adaptive expectations (Cagan 1956), and partial adjustment hypotheses (Nerlove 1958).

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[6] Tomek and Robinson (1981, p. 182) point out that Ezekiel wrote one of the first papers on the Cobweb model, while Waugh (1964) provided a more recent summary and bibliography, and Tomek and Robinson (1977) provides additional references.

Naïve expectations hypothesis. The naïve expectations hypothesis assumes that current supply decisions are taken solely on the basis of last periods' price. This is the well-known Cobweb model. Such a model is recursive because current year's supply is given by the previous year's price, and this supply then determines current price, given the market-clearing conditions. Naïve expectations imply

$$P_t^* = P_{t-1} \tag{3.3}$$

where:

P_t^* = expected price at time *t*; and

P_{t-1} = actual price in period *t-1*.

Adaptive expectations hypothesis. The adaptive expectations model was developed by Cagan (1956) in a study of the effects of hyper inflation. The general form of the adaptive expectation model can be written mathematically as:

$$P_t^* - P_{t-1}^* = \lambda\left(P_{t-1} - P_{t-1}^*\right) \tag{3.4}$$

where λ is a coefficient of adjustment ($0 < \lambda < 1$).

Equation (3.4) says that producers respond to past errors in price expectation formation by using a weighted average of the previous period's actual and expected prices to form the current period's price expectation. The expectation is revised each period by the proportion of the difference between the past value of the variable and its previous expected value, i.e. λ.

In linear models the adaptive expectations hypothesis means that expected price can be presented as a weighted average of past prices, where the weights are functions of the coefficient of expectation and decline geometrically:

$$P_t^* = \lambda P_{t-1} + (1-\lambda)\lambda P_{t-2} + (1-\lambda)\lambda P_{t-3} + \ldots \qquad (3.5)$$

Equation (3.5) is the Koyck (1954) distributed lag expressing expected price as an exponentially weighted moving average of past prices.

3.3.4 Planned Area

The development variable in equation (3.2), planned area, is also unobserved. It is possible to express planned area as a function of observable variables under the partial adjustment hypothesis. The partial adjustment hypothesis is based on the idea that there is a desired level of area to be allocated to a particular crop in period *t*, but adjustment to this desired or planned level is not complete in one period. Instead, only some fixed fraction (γ) of the desired adjustment is accomplished. In other words, the change in observed area is proportional to the difference between the desired area in the long-run equilibrium and the actual area in the last period. Mathematically:

$$A_t = A_{t-1} + \gamma\left(A_t^* - A_{t-1}\right) \qquad (3.6)$$

where γ is adjustment coefficient and lies between 0 and 1. If γ equals zero, the actual area is equal to last year's actual area. If γ equals 1 then actual area equals the desired or planned area. In practice equation (3.6) is usually rearranged as:

$$A_t^* = \frac{1}{\gamma} A_t - \frac{(1-\gamma)}{\gamma} A_{t-1} \tag{3.7}$$

Equation (3.7) can then be substituted into equation (3.2).

Many authors have used the naïve expectations and the partial adjustment hypotheses to estimate the supply of agricultural crops. For example, Powel and Gruen (1966) estimated supply functions for six rural commodities, including wheat, for aggregate Australia based on naïve price expectations and partial adjustment. Anderson (1974), Gunawardana and Oczkowski (1992), and Maji, Jha and Venkataramanan (1971), also apply combinations of naïve price expectations and the partial adjustment hypotheses in their studies of the supply of annual crops.

3.4 Yield Response

Yield equation is typically expressed as a function of price and non-price variables:

$$Y_t = f(P_t, Z_t) \tag{3.8}$$

where:

Y_t = yield in year t;

P_t = a vector of price variables; and

Z_t = a vector of non-price variables.

Dillon and Anderson (1990) give a thorough review of yield response modeling methods, for both aggregate and experimental data. This review discusses the main factors influencing crop yield; including price variables and non-price variables. It would be seen that the price variables which have the greatest effect on the yields of agricultural products are the prices of outputs and inputs. The price of output only has a marginally positive influence on the yield of a product because by harvesting time most resources have already been used in the production process. Input prices, on the other hand, seem to have a greater effect on yields, due to the fact that producers can vary their input use in accordance with variations in the prices of inputs which are known easily in the production process. Thus, both output and input prices should be included in a yield equation.

Non-price variables affecting the yields of agricultural crops include meteorological variables (rainfall) which are beyond producers' control, and variables which measure technological improvement. The weather variable is probably the most important non-price factor influencing the yield of crops. Little or too much rainfall during the growing period can severely damage crop productivity.

Measurement of the effects of technological changes on crop yield has been based on two points of view (Francisco 1980). Shaw (1964) claims that technological changes have a stepwise effect on the yield. To capture these stepwise effects, he suggests that one must first extract from the yield series the effects of weather, and then identify the relevant technological variables for use in subsequent analysis.

The following studies are examples of good empirical analyses which attempt to measure the effects of price and non-price variables on yield.

Fisher (1978) attempted to estimate both the yield and area supply response of wheat for a number of regions in south-eastern Australia. He provided an excellent discussion of the problems involved in yield estimation in Australian conditions. The most important explanatory variables were climatic factor, rainfall, and technological changes. He included the rainfall pattern in three forms: (i) prior sowing rainfall (summer and autumn) (ii) growing period rainfall; and (iii) grain filling period rainfall. These three rainfall variables were included in quadratic form. A time trend was also included in quadratic form.

Francisco and Guise (1988) estimated yield/rainfall equations for eight agricultural commodities, including wheat, in 14 regions in New South Wales. A time trend and six four-monthly rainfall aggregates from months both prior to and during the growing season were included in quadratic form. The results showed that the coefficients of a linear time trend and rainfall in February to May and June to September were statistically significant.

Gunawardana and Oczkowski (1992) estimated yield and area equations for rice production in Sri Lanka during 1952-1987. Nine explanatory variables were considered, including the current price of rice, proportional area under high-yielding rice varieties, a time trend, the subsidised price of fertilizer, the price of labour, the area under irrigation as a percentage of total rice area, total quantity of concession rice sales by the government, rainfall, and a weighted average price of alternative crops.

Coelli (1992) estimated both wheat yield and area functions for 64 shires in Western Australia from 39 yearly observations. Important variables included were monthly rainfall, a time trend and area planted. The rainfall variables during the growing period were included in quadratic form to capture the real effects of too little or too much rainfall on yield. A time trend was also included in quadratic form. It should be mentioned that the prices of inputs and outputs were included separately and as a ratio but were found to have no significant influence upon yields.

3.5 Supply Response of Marketed Surplus

Studies of marketed surplus are based on the assumption that, while farmers may be responsive to price changes, their planting and marketing decisions are primarily governed by traditional behavior patterns, thereby making price response of output of only secondary importance in explaining variation in quantities marketed (Askari and Cummings 1976). Some believe that farmers either do not respond to price changes at all or respond in an inverse way, marketing less as prices increase. Mathur and Ezekiel (1961) argued that farmers' cash requirements are relatively stable, so that the size of the marketable surplus varies inversely with price. In general, in subsistence economies, farmers have fairly steady annual cash requirements and what they market out of their production may vary inversely with price in a rather rigid fashion. Once cash needs have been met, any remaining production is utilised for household consumption and for livestock feed and seed.

However, Krishnan (1965), in a study of the marketed surplus of food grains, argued that the price responsiveness of marketed surplus depends on how close farmers are to a purely subsistence farming situation. He proceeded a rationale for various types of response of marketed surplus to price changes, including both negative, zero and positive responses. Once farmers produce more than the minimum subsistence requirement, they have flexibility in terms of how much is consumed at home.

Most of the studies of the supply of marketed surplus interpret the surplus in terms of a real income effect. Krishnan (1965) and Olson (1960) explained variation in the marketed surplus in terms of real income and concluded that, as prices for the crops rise, an income-consumption effect is likely to occur. Furthermore, Askari and Cummings (1976, p. 383) surmised that a price increase swells the real income of the peasantry, and the income effect on their demand for consumption of these goods counterbalances the influence that price increases might have on the amount they bring to the market.

Most of the studies of marketed surplus are based on primary data from various surveys. For instance, Bardhan (1970), Bhargava and Rustogi (1972), Mandal (1961), Mandal and Ghosh (1968), Misra and Sinha (1961), Rao (1965), Sharma and Gupta (1970), and Shastri (1961) based their studies on surveys at village levels. They found that there was no evidence that marketed surpluses were increasing; rather, the indications were that they had stagnated or even declined in the face of increases in food crop production (Askari and Cummings 1976).

Lack of data on home consumption precluded marketed surplus from being the focus in this study. However, according to one source Cambodian farmers mainly produce rice for their own consumption (Department of Planning and Statistics 1995).

3.6 Summary

Although, supply response studies often focus on the response of total output to price change having a single equation, the estimation of area and yield equations are often preferred in the case of annual crops. Area and yield are influenced by various factors which can be divided into price and non-price variables. The price variables include prices of output, input, and alternative crops, while non-price variables are rainfall and technological changes in the production. Commonly lagged prices and assumed models of how expectations are formed are involved in these models. In many cases it is more appropriate to focus on the responsiveness of marketed surplus but lack of data prevented this in the present study.

CHAPTER 4 MODEL SPECIFICATION, ESTIMATION PROCEDURES AND DATA

4.1 Introduction

This chapter transforms the generic area and yield equations described in Chapter 3 into an econometric model. Section 4.2 describes the functional form and stochastic assumptions required to make these area and yield equations empirically operationed. Section 4.3 explains the estimation procedures. Section 4.4 describes the data which will be used to estimate the parameters of the econometric model.

4.2 Model Specification

Following the discussion in the previous chapter, the supply response of rice in Cambodia will be estimated using area and yield equations.

4.2.1 Area Equation

Assuming a linear functional form for equation (3.2), naïve expectations (equation 3.3) and Nerlovian partial adjustment (equation 3.6) hypotheses, an equation expressing area response is obtained as a function of lagged area, the lagged price ratio of rice to fertiliser, the lagged price ratio of maize to fertiliser, and lags of rainfall and of the square of rainfall during the planting period:

$$\begin{aligned} A_{it} &= \alpha_{0i} + \lambda_1 DT_{it} + \alpha_1 A_{i,t-1} + \alpha_2 PRF_{i,t-1} + \alpha_3 DT_{it} PRF_{i,t-1} \\ &\quad + \alpha_4 PMF_{i,t-1} + \alpha_5 DT_{it} PMF_{i,t-1} + \alpha_6 RP_{i,t-1} + \alpha_7 RP_{i,t-1}^2 + e_{1it} \end{aligned} \tag{4.1}$$

where:

A_{it} = area sown to rice in province *i* in year *t*;

PRF_{it} = ratio of the price of rice to the price of fertiliser;

PMF_{it} = ratio of the price of maize to the price of fertiliser;

RP_{it} = rainfall during the planting period (April-July);

DT_{it} = dummy variable representing policy changes, which takes the value zero for 1980-1989 and one otherwise;

i = 1, 2, ..., 20 (number of provinces in Cambodia);

t = 1, 2, ..., 18 (time period); and

e_{1it} = disturbance term.

The rationale for this specification is three-fold. Firstly, the choice of a linear functional form means this equation is easy to estimate. Coelli (1992, pp. 16-17) states that "from a practical viewpoint, this model can be estimated using OLS, unlike the adaptive expectation model which requires maximum likelihood estimation". Secondly, it is believed that, prior to planting, most Cambodian rice growers base their estimate of the likely rice price at harvest time on the price received for the previous crop implying naïve expectations. Finally, the vast majority of rice productive areas are predominantly mono-cultural, other crops not being an alternative form of production.

Cambodian farmers, as well as farmers in other LDCs, can be expected to change their production decision in response to variations in the prices of agricultural products such as rice. As explained in Chapter 2, Cambodian peasants appeared to respond positively to increases in the price of rice during the 1920s, 1930s and 1960s by increasing rice acreage and, hence, production. Helmers (1997) confirms that Khmer farmers were probably responsive to rice market conditions in the 1920s and 1930s since they earned good incomes from rice sales. He adds that, in response to a high export market price of rice during the 1960s, farmers seemed to increase their production by expanding cultivated areas to the highest level ever reached in Cambodian history, around 2.5 million ha. Thus, our priory expectation is that α_2 will be positive.

The prices of agricultural commodities were freed up in 1989 as part of major government policy changes promoting a market economy. An attempt is made to account for this influence using the dummy variable DT_{it} which takes the value zero for 1980-1989 and one otherwise. This dummy variable is introduced in such a way that it allows both intercept and slope coefficients to vary. Note that policy changes were introduced in September 1989 and, therefore, any effects would have first been observed in 1990.

Economic theory suggests that the price of an alternative product may influence the area planted to rice in Cambodia. Maize probably does not compete significantly with wet-season rice for heavy flooded land. However, for some areas on which the water can be controlled or for which the quantity of water is likely to be limited, wet-season rice and wet-season maize, and dry-season rice and dry-season maize, are production alternatives. Although there is no clear evidence showing that maize competes for rice productive area, it is believed that some small-scale rice areas along the Mekong river and other small rivers could be used for maize production. Furthermore, rice and maize may compete for other factors of production, such as labour and inputs, during the planting season. For these reasons the price of maize was included in equation (4.1).

Fertiliser seems to be the only common purchased input used in rice production in Cambodia. The vast majority of rice growers keep their own seeds for next season's production, and use their own family labour or shared-labour in production operations. Therefore, only the price of fertiliser was used to represent non-land purchased inputs in equation (4.1). It is expected that a rise in the price of inputs would have a negative influence upon the area planted so, again, it is expected that α_2 to be positive. Note that equation (4.1) implies that the area responses to rice and fertiliser prices are opposite but equal. This constraint is needed to ensure that the area equation is homogenous of degree zero in prices. Finally, other inputs such as pesticides and herbicides are not commonly used in rice production in Cambodia, apparently because of low budgets and the unavailability of these inputs in remote areas.

Our prior expectation is that rainfall has a significant influence upon farmers' decisions to plant rice. Within the Cambodian ecosystem, rice-cropping systems predominate for rain-fed lowland rice. Among the rice varieties grown in Cambodia, around 90 per cent of production areas grow wet-season rice, which depends on monsoon rainfall between April and November (Nesbitt & Chant 1997). The rainfall distribution during this period is very important for both the cultivated area and the yield of rice.

Generally, rain-fed-rice farmers start to apply farmyard manure to the fields for land preparation and nursery preparation in April and May of each year. When there is sufficient rain to prepare the nursery, the soil is ploughed twice and harrowed once or twice to level the plot. Ploughing of the main field follows nursery bed establishment by 1 to 3 months, depending on the rainfall pattern. Land preparation and transplanting take place 3 to 4 months for the majority of the rice varieties relying upon rainfall patterns (Figure 4.1). Therefore, the rainfall pattern during the first four months of the rainy season, April-July, needs to be included in the wet-season area equation to capture the effects of rainfall on planted area. Rainfall is introduced using a quadratic functional form to account for the fact that either two much or too little rainfall may cause a reduction in wet-season area sown.

Each year approximately 5,000 ha of productive area is lost due to droughts and floods.

4.2.2 Yield Equation

Assuming a linear functional form for equation (3.8), yield equation can be written as:

$$\begin{aligned} Y_{it} = \delta_{0i} + \omega_1 DT_{it} + \delta_1 PFR_{it} + \delta_2 DT_{it} PFR_{it} + \delta_3\ T_{it} + \delta_4\ RG_{it} \\ + \delta_5\ RG_{it}^2 + e_{2it} \end{aligned} \quad (4.2)$$

where:

Y_{it} = yield of rice in province *i* in period *t*;

PFR_{it} = fertiliser/rice price ratio;

T_{it} = time trend;

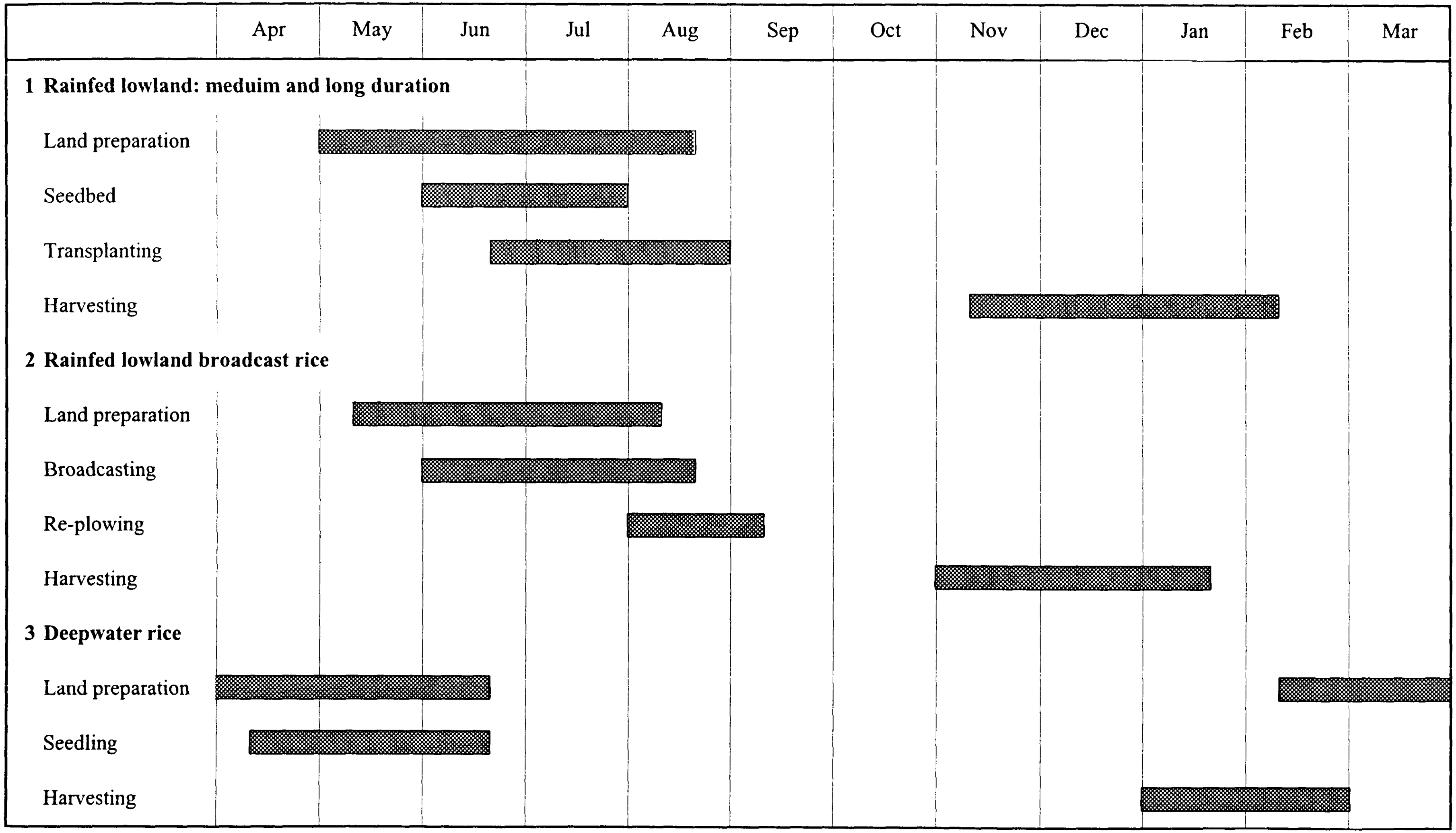
RG_{it} = rainfall during growing period (August-November); and

e_{2it} = disturbance term.

The price of fertiliser was included in the yield equation because it is hypothesised that it has a direct effect on the use of fertilisers and, therefore, rice productivity. The prices of fertiliser and rice were included in ratio form to maintain zero degree homogeneity in prices.

A post-civil war program of agricultural research and development appears to have led to substantial growth in farm productivity. Technological developments in the 1980s and 1990s in Cambodia include an expansion of the use of high-yielding varieties (IR varieties) and an increase in the use of farm inputs such as fertiliser and insecticides. An increase in rice production in recent years may be evidence of the effectiveness of such developments.

Figure 4. 1. **Rice Agroecosystems**



Source: Javier 1997, p. 34.

Although many analysts believe that technological change in rice production in Cambodia is slow it is a widely belief that the adoption of new technology has led to increase in rice production. As evidence, Mr. J.H. Nesbitt's letter dated 28th May, 1997 points out that since their introduction, around 100,000 ha of wet-season and dry-season area has been sown to high-yielding varieties. These IR varieties provide yields satisfactory productivity of around 3 t/ha. He also mentions that fertiliser is currently applied at 50 kg/ha in small-scale wet-season rice production and 100 kg/ha in small-scale dry-season rice production (mostly in high yielding varieties). Unfortunately, data on fertiliser usage and the area sown to IR varieties is unreliable or unavailable. In this study, technological improvements, productivity change and efficiency improvements over time are accounted for by the inclusion of a single time trend.

The factor which probably limits the productivity of rice in Cambodia more than any other seems to be rainfall. As explained earlier, rainfall pattern is expected to be the most important factor affecting rice productivity because farmers use a few other inputs and the irrigation system is limited. The growing period of most of the rice varieties extends only from August to the end of the wet season. The rainfall pattern during this period is very important for both the growing process and weed control (Nesbitt & Chan 1997). Since Cambodian farmers do not use chemicals to control weed populations, the water level during the growing period is used to control weeds and to improve production. Rainfall during flowering is likely to have a larger effect on yields than rainfall at other times of the growing period. For these reasons, the rainfall pattern during August to November is included in the yield equation for the wet-season rice.

Finally, an extra 10mm of rainfall in a growing period in which rainfall was already above average would be expected to have a much smaller effect upon yield than an extra 10mm of rainfall in a period in which rainfall was well below average. To permit a variable marginal influence of rainfall, note that from equation (4.2) that rainfall was included in quadratic form.

4.3 Estimation Methods

It is possible to estimate the parameters of equations (4.1) and (4.2) in a number of alternative ways. This study uses four different estimation methods corresponding to four different sets of assumptions on the intercepts and disturbance terms. Time constraints prevent considerations of other assumptions and estimation methods which appear in the literature.

4.3.1 Single Equation Ordinary Least Squares (OLS) Estimation

Note from equations (4.1) and (4.2) that the intercept terms area permitted to vary across i (provinces). These variations are assumed to be non-random in this section. Thus the intercept terms in equations (4.1) and (4.2) can be written:

$$\alpha_{0i} = \alpha_0 + \sum_{j=2}^{20} \lambda_j \, Dum_{jt}$$

and

$$\delta_{0i} = \delta_0 + \sum_{j=2}^{20} \omega_j \, Dum_{jt}$$

where: Dum_{jt} is a provincial dummy variable which takes the value 1 if $j=i$ and zero otherwise. Then

$$A_{it} = X_{1it}\alpha + e_{1it} \tag{4.3}$$

$$Y_{it} = X_{2it}\delta + e_{2it} \tag{4.4}$$

where:

$$\alpha = [\alpha_0, \lambda_1, \lambda_{0,2}, \lambda_{0,3}, \dots, \lambda_{0,20}, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7,]' \ is \ (28 \times 1)$$

$$\delta = [\delta_0, \omega_1, \omega_{0,2}, \omega_{0,3}, \dots, \omega_{0,20}, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5]' \ is \ (26 \times 1)$$

and the definitions of X_{1it} and X_{2it} are obvious, although it is worth pointing out that X_{1it} is (1×28) and X_{2it} is (1×26).

The models given by (4.3) and (4.4) are commonly known as *dummy variable models.* In this section it is assumed that e_{1it} and e_{2it} are i.i.d with

$$E(e_{jit}) = 0 \quad j = 1, 2 \tag{4.5}$$

$$E(e_{jit}^2) = \sigma_j^2 \quad j = 1, 2 \tag{4.6}$$

$$E(e_{1it}e_{2js}) = 0 \quad for\ all\ i, j, t, s \tag{4.7}$$

Equations (4.3) and (4.4) area, in fact, wet-season area and yield equations. Dry-season area and yield equations are special case of (4.3) and (4.4) obtained under the following restrictions:

$$\lambda_{0,12} = \lambda_{0,14} = \lambda_{0,16} = \lambda_{0,17} = \lambda_{0,18} = \lambda_{0,19} = 0$$

$$\omega_{0,12} = \omega_{0,14} = \omega_{0,16} = \omega_{0,17} = \omega_{0,18} = \omega_{0,19} = 0$$

and

$$\alpha_6 = \alpha_7 = 0$$

$$\delta_4 = \delta_5 = 0.$$

These restrictions reflect the facts that only 14 provinces (Phnom Penh, Kandal, Kompong Cham, Svay Rieng, Prey Veng, Takeo, Kompong Thom, Siem Riep, Tattambang, Pursat, Kompong Chhnang, Kom Pot, Kompong Speu, and Kratie) grow dry-season rice and, because of irrigation, dry-season area and yields area unaffected by rainfall. Thus dry-season rice area and yield can be represented by equations (4.3) and (4.4), although X_{1it} now has dimensions (1×20) and X_{2it} is now (1×18).

Since the disturbance terms are well-behaved and there is no correlation between them, the coefficients in both dummy variables equations (4.3) and (4.4) can be estimated separately by OLS.

4.3.2 Systems Estimation

Keeping the previous assumptions about the intercepts of both the area and yield equations, equations (4.1) and (4.2) can be estimated jointly under the assumption that there is correlation between the two error terms, e_{1it} and e_{2it}. Assumptions (4.5) and (4.6) are maintained but equation (4.7) is replaced with the assumption:

$$E\left(e_{1it} e_{2js}\right) = \begin{cases} \sigma_{12} \ for\ i = j\ and\ t = s \\ 0 \quad otherwise \end{cases} \tag{4.8}$$

At this point it is convenient to write equations (4.3) and (4.4) in shorthand form as:

$$Y = X\beta + e \tag{4.9}$$

where:

$$Y=\begin{bmatrix}Y_1\\Y_2\end{bmatrix},\quad Y_1=\begin{bmatrix}A_{11}\\A_{21}\\\vdots\\A_{NT}\end{bmatrix},\quad Y_2=\begin{bmatrix}Y_{11}\\Y_{21}\\\vdots\\Y_{NT}\end{bmatrix},\quad X=\begin{bmatrix}X_1 & 0\\0 & X_2\end{bmatrix}$$

and all other definitions are obvious, although it is worth pointing out that X is (2NT×54), Y and e are (2NT×1), and $\beta=(\alpha',\delta')'$ is (54×1). Moreover, assumptions (4.5), (4.6) and (4.8) imply that:

$$E(ee')=\Omega=\begin{bmatrix}\sigma_1^2 I_{NT} & \sigma_{12}I_{NT}\\\sigma_{12}I_{NT} & \sigma_2^2 I_{NT}\end{bmatrix}=\Sigma\otimes I_{NT} \tag{4.10}$$

where I_{NT} is an identity matrix of order NT and $\Sigma=\begin{bmatrix}\sigma_1^2 & \sigma_{12}\\\sigma_{12} & \sigma_2^2\end{bmatrix}$. The matrix Σ is symmetric, so that $\sigma_{ij}=\sigma_{ji}$. It is also nonsingular and thus has an inverse. All information about the error covariances is contained in the matrix Ω. If the disturbances are normally distributed, the most efficient estimator of β is the Generalised Least Squares (GLS) estimator:

$$\begin{aligned}\hat{\beta}&=(X'\Omega^{-1}X)^{-1}X'\Omega^{-1}y\\&=\left[X'(\Sigma^{-1}\otimes I_{NT})X\right]^{-1}X'(\Sigma^{-1}\otimes I_{NT})y\end{aligned} \tag{4.11}$$

with

$$Var(\hat{\beta})=(X'\Omega^{-1}X)^{-1}=\left[X'(\Sigma^{-1}\otimes I_{NT})X\right]^{-1} \tag{4.12}$$

GLS is best linear unbiased. In practice, the variances and covariances (element of Σ) are unknown and must be estimated, with their estimates being used in equations (4.9) to form an estimated generalised least squares estimator. To estimate the σ_{ij} each equation is first estimated by least squares to obtain the residuals $\hat{e}_{jit}$. Estimates of the variance, and covariances are then given by:

$$\hat{\sigma}_{ij} = \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{e}_{1it}\hat{e}_{2it} \qquad j \neq i \tag{4.13}$$

and

$$\hat{\sigma}_j^2 = \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{e}_{jit}^2 \qquad j = 1, 2 \tag{4.14}$$

If $\hat{\Sigma}$ is defined as the matrix Σ with the unknown σ_{ij} and σ_j^2 replaced by $\hat{\sigma}_{ij}$ and $\hat{\sigma}_j^2$ then the estimated generalised least squares estimator for β corresponding to equation (4.11) can be rewritten as:

$$\begin{aligned} \hat{\beta} &= \left(X'\hat{\Omega}^{-1}X\right)^{-1} X'\hat{\Omega}^{-1}y \\ &= \left[X'\left(\hat{\Sigma}^{-1} \otimes I_{NT}\right)X\right]^{-1} X'\left(\hat{\Sigma}^{-1} \otimes I_{NT}\right)y \end{aligned} \tag{4.15}$$

This estimator is the one that is generally used in practice and is known as Zellner's *Seemingly Unrelated Regression* (SUR) estimator. The estimated parameters can be easily obtained using SYSTEM command in SHAZAM.

4.3.3 The Cross-Sectionally Heteroskedastic and Timewise Autoregressive (CHTA) Estimator

In this section it is assumed that all individual provinces have the same intercept coefficients and further generalise the assumed properties of disturbance terms. If the intercepts are constant across provinces then our area and yield equations can still be written in the form of equations (4.3) and (4.4). However, $\alpha_{0,2} = \alpha_{0,3} = \cdots = \alpha_{0,20} = 0$ and $\delta_{0,2} = \delta_{0,3} = \cdots = \delta_{0,20} = 0$, so X_{1it} now has dimensions (1×19) and X_{2it}

now has dimensions (1×7). These restrictions in the dimensions of X_{lit} (and β) give us scope to relax some of our assumptions concerning the error terms. Since cross-section and time-series data will be used, the consideration of the usual cross-section assumptions concerning heteroskedasticity and the usual time-series assumptions concerning serial correlation should be made. Specifically, we maintain assumptions (4.5) and (4.7) and replace assumption (4.6) with:

$$E\left(e_{jit}^2\right) = \sigma_{ji}^2 \qquad j = 1,2 \qquad \text{(heteroskedasticity)} \tag{4.16}$$

The other assumptions are (j=1, 2):

$$E\left(e_{jit}e_{jkt}\right) = 0 \; for \; i \neq k \qquad \text{(cross-sectional independence)} \tag{4.17}$$

$$e_{jit} = \rho_{ji}e_{ji,t-1} + u_{jit} \qquad \text{(serial correlation)} \tag{4.18}$$

$$E\left(u_{jit}\right) = 0 \tag{4.19}$$

$$E\left(u_{jit}^2\right) = \sigma_{uij}^2 \tag{4.20}$$

$$E\left(u_{jit}u_{jkt}\right) = 0 \qquad for \; i \neq k \tag{4.21}$$

$$E\left(u_{jit}u_{jis}\right) = 0 \qquad for \; t \neq s \tag{4.22}$$

and

$$E\left(e_{ji,t-1}u_{jkt}\right) = 0 \qquad for \; all \; i, k \tag{4.23}$$

Under these assumptions, the model is known as the *cross-sectionally heteroskedastic and timewise autoregressive model (CHTA).* Techniques for estimating the unknown parameters of the error distributions are discussed in Kmenta (1986). Estimated GLS estimates can be obtained easily using the POOL command in SHAZAM (with no options).

4.3.4 The Cross-Sectionally Correlated and Timewise Autoregressive (CCTA) Estimator

A more general model is obtained by replacing assumptions (4.17) and (4.21) with (j=1, 2):

$$E\left(e_{jit}e_{jkt}\right)=\sigma_{jik} \qquad \text{(cross-sectional correlation)} \qquad (4.24)$$

and

$$E\left(u_{jit}u_{jkt}\right)=\phi_{jik} \quad for\ i\neq k \qquad (4.25)$$

This model is known as the *cross-sectionally correlated and timewise autoregressive model (CCTA).* Again, details concerning the estimation of the σ_{jik} and ϕ_{jik} can be found in Kmenta (1986). In practice, this model can be estimated easily using the POOL command in SHAZAM (with the requirement of FULL option).

4.3.5 Other Methods

The above models and estimators do not exhaust the alternatives for dealing with cross-sectional and time-series data. Other models include the well-known error components, based on the assumption that the α_{0i} and δ_{0i} are random variables. The coefficients of the error components model can also be estimated by a generalized least squares (GLS) procedure. However, due to time constraints, this model could not be considered. Nor was there time to estimate the CHTA and CCTA models in a systems framework.

4.4 Data

Data on Cambodian agricultural production is difficult to obtain. Most of the data on rice area and yield of all provinces in Cambodia have been obtained from various publications of the Department of Planning and Statistics, Ministry of Agriculture, Forestry and Fisheries. These publications include the Bulletin of Agricultural Statistics and Studies and Annual Statistical Reports. The data are originally collected by agricultural officials in the communes and reported to the provincial agricultural offices. The provincial agricultural offices gather and process data from each commune in the province and then report to the Ministry of Agriculture, Forestry and Fisheries on a monthly basis. At this stage of the data collection process the data are still subject to refinement by ministerial meetings, which are held annually at the end of the rice production season. The data used in this study are the final data. The data are officially endorsed and currently used by government institutions for policy analysis and other purposes.

Data on the prices of agricultural commodities were also obtained from the Bulletin of Agricultural Statistics and Studies. However, the collection procedures for these data are different. The prices of agricultural commodities were fixed by the Ministry of Agriculture, Forestry and Fisheries during the planned economy (1980-1989) and therefore represent the prices of agricultural commodities in the entire country. During the free-market economy (1990-1997), prices were collected monthly from only a few major markets in Phnom Penh and then average prices were calculated monthly and annually. These prices were officially published and referred to by all government institutions for various purposes. Therefore, only the average prices of agricultural commodities in the Phnom Penh market were used in this study.

The use of a single Phnom Penh market price of output is justified under the assumption that the provincial markets are integrated, so changes in prices in the Phnom Penh market reflect back to producers selling in other markets.

Fertiliser prices were taken from the same sources. Of course, fertiliser prices are subsidised by the government so they are uniform across all provinces.

The Ministry of Agriculture, Forestry and Fisheries sets the prices of fertilisers annually, while the Central Company of Agricultural Materials (COCMA) is responsible for transportation and distribution. The common fertilisers used in rice production in Cambodia are Ammophos, 16-20-0, Urea, 15-15-15, and 18-46-0. Average prices in Riel/kg were used in this study.

Meteorological data, including rainfall distributions, were obtained from the Bureau of Meteorology of the Ministry of Agriculture, Forestry and Fisheries. Rainfall data is collected daily from all meteorological stations and forwarded monthly to the Bureau of Meteorology in Phnom Penh. The data used in this study were obtained from the original unpublished records of the Bureau of Meteorology. Due to bureaucratic problems, monthly rainfall figures could not be obtained for all provinces. Only planting period rainfall (April-July) and growing period rainfall (August-November) in selected provinces were available. Rainfall figures for four provinces - Koh Kong, Preah Vihear, Ratanakiri and Mondulkiri - were not available because all meteorological stations in those provinces were destroyed during the war and have not yet been rebuilt. Thus for Koh Kong, Preah Vihear, Ratanakiri and Mondulkiri provinces, the rainfall figures of the neighbouring Kompong Som, Kompong Thom, Stung Treng and Kratie provinces were used.

4.5 Summary

The model of rice supply response used in this study is comprised of area and yield equations. The area equation was derived under the assumptions of naïve expectations and partial adjustment hypotheses. The explanatory variables in the area equation are lagged area planted, the ratio of rice to fertiliser price, the ratio of maize to fertiliser price, and rainfall during the planting period from April to July. Meanwhile, is specified as a function of the ratio of fertiliser to rice price, time trend to capture the effects of technological and productivity improvements, and rainfall during the growing period from August to November. Four methods - OLS, System, CHTA and CCTA - can be used to estimate the parameters. These four methods correspond to different assumptions concerning the intercepts and error terms.