# AGRICULTURAL PRODUCTIVITY AND SUPPLY RESPONSES IN GHANA

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## Abstract

The importance of Agricultural Supply Response (ASR) modelling cannot be over emphasised. Knowledge of its size provides a roadmap for designing a tailored agricultural policy based on suppliers' responses to price and non-price incentives. In spite of its policy importance, limited amount of studies exist for Ghana. This study seeks to fill the gap and also sheds some light on how future agricultural policies in Ghana should be formulated.

This study is conducted on a regional (*ecological*) group basis and at a crop-level. Apart from price and non-price factors, we have also accounted for technical inefficiencies, a problem that impedes the growth of agricultural production in Ghana. We employed the duality modelling technique (based on the profit function). This technique provides a more intuitive way of modelling and interpreting ASRs. We used the fourth wave of the Ghana Living Standard Survey (GLSS4), a cross-sectional dataset collected between 1998 and 1999. The analysis is based on six crops, grouped into industrial (cocoa and groundnut), food (maize, rice and cowpea) and staple (sorghum and millet combined and termed *migso* in the study). A sensitivity analysis is carried out to check the robustness of results.

We found high national and ecological technical inefficiency scores. Nationally, technical inefficiency is in the neighbourhood of 53%. At the ecological levels, groundnut (industrial crop) farmers in the Coastal zone recording the highest inefficiency (83%) with the least inefficiency score coming from cowpea (food) farmers in the Savannah zone (30%). In a related outcome we found that technical inefficiency estimates and patterns are sensitive to the structure and composition of the dataset.

Our supply elasticities support claims that farmers in Ghana will respond to both market (price) and non-price incentives. In terms of price incentives we found that, with or without technical inefficiency, farmers of food crops in the Coastal zone will respond the most to changes to outputs prices. Farmers in the Savannah zone for all crops but staples will be the least to respond to output price change. We found, however, that with production inefficiency accounted for, supply responses were relatively lower, reinforcing the arguments that earlier supply response estimates from other studies could have been inaccurately estimated especially where analysis failed to account for non-price factors. Moreover, the study

estimates revealed that farmers in Ghana are would record a larger output supply responses to changes in inputs prices than output prices.

Besides price, the study also found that all four non-price incentives - plot size, animal capital, family labour and education of household head - are important to the development of an effective agricultural policy regardless of whether technical inefficiency is accounted for or not. In some cases, output supply responses from non-prices factors outweighed price elasticities, again supporting the argument that ASR estimates are likely to be biased if non-price factors are omitted.

These findings provide two policy signposts for the design of Ghana's future agricultural policies. Firstly, the policy - aimed at increasing output and/or improving the sector's competitiveness - must identify and address technical inefficiencies among smallholder agricultural farmers. Failure to address such inefficiencies would lead to suboptimal performance - operating on a lower production frontier. Secondly, the differences in crop-level ecological supply elasticities support regional-based agricultural policies rather than a one-size-fits all centralised agricultural policy.

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# CHAPTER 1: GENERAL INTRODUCTION

## 1.1 Background, Motivation and Research Focus

### 1.1.1 Economic Performance

Agriculture is Ghana's most important economic sector, employing more than half the population on a formal and informal basis and accounting for almost half of GDP and export earnings. The sector's growth rates have been impressive and its contribution to national output has, on average, exceeded industry and services growth rates (see Table A1.1 at chapter appendix). The country produces a variety of crops in various climatic zones ranging from dry savannah conditions to a wet forest climate. Besides the GDP contribution, the sector is a forerunner in export revenue. It is no doubt exports, of which agricultural exports[1] form a large proportion that have fuelled Ghana's economy (Table 1.1). The agricultural exports, to which the country has comparative advantage, has seen steady growth topping the 20% (nominal) rate between 1960 and 1987 (Fosu, 1992). The strong correlation between total merchandise and agricultural exports (Table 1.1) suggests that any policy geared at growing the export sector must incorporate strategies of making the primary sector more productive and competitive.

Except for the early part of the 1970s, the economic performance of Ghana worsened in the late 1970s and early 1980s, as evidenced by worsening key economic trends. Real GDP per capita substantially declined, mainly due to the poor performance of the agriculture sector, which declined at an annual rate of 0.3% in the 1970s and fell precipitously in the drought years of 1982 (6.7%) and 1983 (1.5%). Food self-sufficiency index dropped to a record low of 60%, aggravated by the droughts of the early 1980s. The major export commodities experienced a significant decline in production; severely limiting the country's import capacity. Stryker (1990), in his contribution to the study led by Kruger, Schiff and Valdes (1988, 1991), noted that Ghana's agricultural distortions played a key role in the disintegration of the economy. In particular, cocoa prices were falling, and the overvaluation of the cedi (national currency) meant cocoa farmers were being paid less relative to their

[1] Ghana's agricultural exports could be disaggregated into traditional and non-traditional commodities. The traditional exports are commodities including cocoa, coffee and sheanuts which have been exported since the turn of the 20th century. The non-traditional exports have only recently begun to be exported. The traditional commodities represent a greater proportion of total agricultural exports than do the non-traditional commodities.

counterparts in neighbouring countries, where producer prices were much higher at the black market exchange rate. Stryker (1990) concludes that the overall effect of this was a steadily deteriorating economic situation and widespread rent-seeking, which increasingly undermined institutions and the society. The country's ability to finance overall economic growth was hampered by depleted national savings, export earning, and capital inflows. Financing huge budget deficits through borrowing from domestic banking system contributed to rapid growth in money supply and high rate of inflation. The depths of despair were reached in 1983. In addition to the already serious economic and political situation including the annual inflation rate reaching a height of 122.8%, the country experienced the worst ever drought and bushfires, as well as the forced repatriation of one million Ghanaians from Nigeria.

Table 1.1: Selected macroeconomic and agricultural indictors (averages)

| Selected Indicators | Average (1961-1983) | Average (1984-1989) | Average (1990-1999) | Average (2000-2009) |
|---|---|---|---|---|
| GDP growth (annual %) | 0.90 | 5.74 | 4.27 | 5.48 |
| Trade (% of GDP) | 33.73 | 34.82 | 62.72 | 89.14 |
| Merchandise exports (% of GDP) | 46.05 | 35.75 | 53.29 | 68.91 |
| Agricultural Exports (% of merchandise exports)* | 81.27 | 69.89 | 69.37 | 66.43 |

*Source: Calculated from World Development Indicators 2010 (online version)*
*Note: * this comprises agricultural raw materials and food exports*

In response to deteriorating macroeconomic imbalances (fiscal, monetary and trade) and worsening living conditions, the Government of Ghana (GOG) launched an Economic Recovery Programme (ERP) in 1983 in two phases. The first phase was to correct macroeconomic imbalances and influence macroeconomic prices (i.e., interest rate, exchange rate, and inflation) in 1984-86. The second was aimed at addressing structural weakness in major sectors of the economy, with agriculture topping the agenda (1987-89).

Following the success of stabilizing the macroeconomic environment and boosting economic growth in its first phase of implementation (1983-86), the GOG embarked on the second phase with emphasis on market-based, agriculture-led economic growth. Within the agriculture sector, the GOG instituted agricultural policy reforms aimed at self-sufficiency in food and industrial crops, improvement in fishery and livestock production, and agricultural diversification. The main agricultural policy instruments included decontrolling prices of most outputs and inputs, removal of input subsidies, and the liberalization of output and input markets. The policy was also aimed at rehabilitating physical infrastructure, strengthening the operational capacity of the Ministry of Food and Agriculture (MOFA), improving the delivery of agricultural support services, and promoting participation of the private sector as the main vehicle for agricultural transformation in Ghana. The reforms were designed to set the economy on a sound growth path.

Ghana’s economic performance after the reforms is best described as a qualified success, with national output growing at an average rate of 4% annually, increasing per capita incomes by a total of 30% between 1986 and 2004. The steady rising of incomes has culminated in a 10 percentage point reduction of the incidence of food poverty between the period 1991-92 and 1998-99 (Ghana Statistical Service, 2000). Agriculture has been the catalyst for Ghana’s post-reform economic growth ever since, growing at an average rate of 5% in the last ten years. It is therefore no surprise to see the sector at the forefront of Ghana’s medium-term development policy framework - the Ghana Shared Growth and Development Agenda 2010-2013. The policy development is part of the main growth strategy agenda for Ghana to become a middle-income country by the year 2015. Key to this (medium-term framework) is the modernisation of the agricultural sector through a dynamic and competitive private sector. It is believed that this strategy would deliver accelerated growth in the sector with much emphasis on food security (domestic policy) and enhancement of (agricultural) export competitiveness (external policy).

### 1.1.2 Summary of Agricultural Policies over the Years

Ghana’s agricultural policies have been outward-biased, emphasising the production of export commodities (cocoa, oil palm, coffee, etc.) and paying less attention to non-commercial cultivation of staple (food) crops for domestic consumption. Those policies included price controls, input and credit subsidies, obligatory credit allocations, and heavy government involvement in production, distribution and marketing (Stryker, 1990).

The first phase of the economic policy reforms ushered in a completely new approach to agricultural policies. Among other important reforms, state farms were privatised by the government, price controls abolished and input subsidies were gradually reduced. A new agricultural policy, 'Ghana Agricultural Policy: Action Plan and Strategies 1986-88', was launched. This time, attention was turned to securing domestic self-sufficiency in cereals, staples and animal protein foods. The action plan was aimed at addressing food price stabilisation and improved institutional facilities with emphasis on research, credit and marketing. There was no provision, however, to address any inefficiency practices. The implementation of the policy was met with many challenges partly due to the weak institutional capacity of the sector in particular and the country as a whole.

To help strengthen the country's institutional framework, the GOG, in collaboration with the World Bank, embarked on the 'Agricultural Services Rehabilitation Project (ASRP)'. The 4-year period of ASRP (1987-1990) succeeded in strengthening the capacity of agricultural research, extension, irrigation and policy planning institutions. This success was later to be followed by other medium-to-long term programs. The 10-year (1991-2000) 'Medium Term Agricultural Development Programmes (MTADP)' was subsequently adopted with the aim of increasing productivity and competitiveness in Ghana's agricultural sector.

There was much improvement in the agricultural sector in the second half of the 1990s (after MTADP implementation) although yields were short of reaching their potential targets. The gap was explained by structural weakness in the country, including inadequate roads, poor access to markets, inappropriate agricultural/farm practices (what we refer to as inefficiencies in the study), and low technology (Stryker, 1990). These factors are not only growth-resisting but also fight against poverty reduction strategies (ADB, 2002).

Poverty reduction and small scale industrialisation became the focus of the country from the year 2000. On a broader platform, Ghana developed the first phase of a pro-poor growth strategy, 'Ghana poverty Reduction Strategy' (GPRS1). The blueprint was to be a sectoral-led growth strategy with the main focus on agriculture, to be followed by manufacturing (industry sector development). To eschew past failures linking the two sectors, a small scale industrialisation strategy was adopted. In 2003 as a variant policy, the Ministry of Food and Agriculture (MOFA) developed a 'Food and Agriculture Sector Development Policy'

(FASDEP). The objective of FASDEP included achieving food security, poverty reduction, supplying raw materials to industry and enhancing the growth of the agricultural sector towards its contribution to the overall GDP, foreign exchange and government revenue. By this an attempt was made to link the agricultural and industrial sectors. FASDEP was to contribute its quota to the attainment of GPRS1 in the areas of infrastructure development, promotion of appropriate (agricultural) technologies and improvement of extension services.

FASDEP was faced with few problems of its own. A Poverty and Social Impact Assessment (PSIA) of the strategic objectives for agricultural policy criticised FASDEP as a one-size-fit-all policy that does not take account of the diverse needs of different stakeholders in the agricultural sector, particularly the very poor (food crop farmers according to the fourth wave of the Ghana Living Standard Survey) and women. Consequently, FASDEP II, a broader version of the initial policy was adopted. The new 6-year policy ending 2008 was drawn up by consensus among stakeholders (including donors) with a view to implementing a new sector-wide policy. FASDEP II became the backbone for subsequent agricultural policies, especially at the national level with the two most essential policies being the second phase of GPRS - 'Growth and Poverty Reduction Strategy' (GPRS II) - and the Millennium Development Goals (MDGs) project, of which goal one (eradicating extreme poverty and hunger) is vigorously pursued.

### 1.1.3 Motivation and Research Focus

There is considerable evidence supporting the positive correlation between (agricultural) exports and economic growth, with the former supposed to boost the latter. This is evident in the "success" stories of Hong Kong, Singapore, South Korea, Taiwan, Australia, the United States of America and China, who adopted the export promotion hypothesis as a development strategy. The basic hypothesis of such a strategy is that growth in real exports leads to growth in real GDP. It could therefore be conjectured that most developing countries' economic growth has been influenced by their dependence on primary commodities exports. The relevant economic theory underlying this primary export-led growth is the 'staple theory of growth', which emphasizes three kinds of benefits to a country - improved utilization of existing resources, expanded factor endowments and linkage effects.

Agriculture's central role in Ghana's economy suggests that growth in the sector could stimulate both greater general economic expansion and poverty alleviation. Both the Economic Commission on Africa (ECA, 2010) and World Development Reports (WDR, 2008) recommend that countries that have comparative advantages in agricultural commodities should rely on the sector as the engine of overall economic growth. Urey (2004) also contends that agricultural growth is a fundamental pre-requisite for widespread poverty reduction in poor economies. Ghana seems to have taken this development path - economic growth spearheaded by growth in the agricultural sector. The sector has seen more interventions over the years with the hope of increasing the sector's output and enhancing its competitiveness.

The emphasis on agriculture is justified. A greater proportion of poor people in Ghana live in the rural areas (39.2% according to 2010 World Bank estimated figures, compared to only 10% of the urban population living below the poverty line) and agriculture is the major economic activity in this part of the economy, employing more than half of the rural labour force. In fact it is an essential part of the livelihoods of many poor people in Ghana. Sustaining agricultural growth therefore has the potential not only to stimulate national economic growth but also reduce severe poverty, usually caused by malnutrition. Agricultural development in Ghana also has the potential to increase the earning base of farmers through exports.

Both history and theory suggest a pre-eminent role for agricultural growth in poverty reduction in poor agrarian economies. Johnston and Miller (1961) has argued that in the early stages of development in agrarian dominated countries the primary (agricultural) sector generates export earnings, labour, capital and domestic demand to support growth in other sectors and agricultural goods meet rising domestic demands from increasing populations with high income elasticity of demand for food.

Data from Ghana appears to support the agricultural export growth paradigm. As the figures show in Table 1.1, Ghana's agricultural exports have grown in keeping with merchandise trade (exports). Each year, from 2003 through 2006, agriculture had accounted for 45 to 60% of annual export revenues and over 36% of national income (GDP). The growth of agriculture in Ghana has a direct impact on poverty reduction. Poverty among export and food crop farmers has reduced from 49.6% and 51.8% in 1991/92 to 19.4% and 45% respectively in 1998/99, accounting for 62% improvement in the economic activities of export farmers. This in part has contributed to the overall improvement in rural poverty in Ghana, reducing by 27% between 1991/92 and 1998/99 (Ghana Statistical Service, 2000).

Half of Ghana's population reside in rural regions (the Word Bank 2010 estimates about 48%). Apart from rural headcount poverty ratio reaching almost 40% in 1999 and with a greater proportion of the rural poor deriving their total annual income from farming, the development of a sustainable agricultural growth remains one of the few pro-poor policies aimed at reducing severe poverty rapidly.

Recent literature strongly supports agricultural growth-poverty reduction correlation (see Timmer, 1997 and Datt and Ravallion, 2000). One medium of a direct linkage comes from farm activities, which is believed to offer opportunities for broadly based expansion in tradable activities with direct and indirect employment and income opportunities for the poor. In fact Delgado and Hopkins (1981) argue that in many poorer rural areas, increasing productivity of farm activities (usually called farm-based growth paradigm) will have greater potential for stimulating pro-poor rural and overall economic growth than promoting productivity increase in non-farm activities. This view is also shared by Fafchamps, Teal and Toye (2001) based on Africa.

Judging from the above theoretical and empirical evidences, it is not surprising that Ghana has embarked on an agricultural-led economic growth. Ever since, the sector has seen more interventions with the hope of increasing the agricultural output (to ensure domestic food security) and enhancing its competitiveness.

Despite the strong arguments in favour of pro-poor agricultural-led economic growth in Ghana, output has not seen a major increase. Food imports continue to rise. Clearly productivity is struggling in spite of many sectoral interventions.

The agricultural sector currently falls far short of its potential targets to secure incomes, employment and the food supply, and thus to reduce poverty among the rural population. The gap is attributed to distortions in the sector. Brooks et al. (2009) contend that although agriculture distortions in Ghana had reduced substantially, specific distortions still afflict the growth-dominant sector. These distortions include government protection of import-competing sectors among other factors. Lower productivity remains the greatest challenge to the development in this sector. The reasons for this are numerous. Producers have little access to financial resources and modern technologies and their organisational structures are weak. Unresolved land usage rights prevent people from making long-term (agricultural) investment commitments. A lack of technology and infrastructure, particularly in rural areas, makes it difficult to process primary agricultural products, and also causes high post-harvest losses. Additionally, smallholder farmers are seldom able to offer their produce to local markets, let alone the more demanding international markets (ADB, 2002). Investment in the sector has dried up. There is little private investment injected into the agricultural sector. Government's agricultural spending remains low, at constantly less than 2% of all public spending (Block, 2010). The 2004 share of just 1.3% contrasts with the target of 10% of all budgetary expenditures established in the Maputo Declaration in 2003.

Low productivity in Ghana's agricultural sector has been of great concern to policy makers over the years. Block (2010) traces the time path of the sector's productivity. His study found that the first 10 years of independence saw small gains in crop yield combined with declining output per worker. In the 1970s, the general decline of the economy was reflected in the rapid deterioration of both land and labour productivity. The lower than expected productivity in crop yields is to a greater extent related to (farmer) inefficiency (ADB, 2002). Inefficiency creates a wedge between actual and potential yield. Comparing actual against potential yields, Block (2010) found a substantial gap of about 40% in maize production in Ghana. A similar order of magnitude was established for other staple grains, with the yield gap for cassava reported around 57.5% (Breisinger et. al., 2008). The challenge, however is to identify the constraints on reducing these yields gaps. The two major 'gap factors' identified to have been contributing to Ghana's agricultural lower productivity are heterogeneity (Block, 2010) and price incentive distortions (Brooks et al, 2009). There is a recent third - a potential Dutch disease due to the discovery of oil in the country.

Urey (2004) grouped the above anti-agricultural growth factors into three - local conditions, global conditions and policy conditions. Local conditions are mainly supply-sided problems, not limited only to soil fertility constraints, inadequate fertilizer usage, information constraints, dried out government investment coupled with low level private sector involvement due to greater risks and lower returns to investment associated with the sector. Another crucial local constraint to agricultural growth has to do with the high post-harvest deterioration. These local challenges are further aggravated by low levels of human capital and inadequate infrastructure. Global conditions are mainly demand-sided. They include the improvement in technologies and indeed the demand for technological products, dynamics of population trends, and composition of global markets. These combined factors culminate in the downward trend in real prices for primary agricultural commodities. Policy conditions have to do with policy failures to the detriment of agricultural development in developing countries. Policy conditions are blamed on market failure and state failure. The large reduction of state funded agricultural research and investment is the major source of falling trends in agricultural productivity. This is further exacerbated by the shrink in private sector involvement arising from market failure. This argument is usually referred to as the ‘new institutional argument’. There is also the liberalisation agenda argument which stems from market failure.

Agricultural efficiencies are major factors responsible for explaining low productivity in the sector. Urey (2004) classifies this as a local agricultural development challenge. We focus more on production or technical efficiency. We inferably define technical inefficiency as a typical farmer not using best farming practices and thus end up operating on a suboptimal production frontier, according to the neoclassical school of reasoning. The ability to identify and measure this gap would prove essential for carrying out an agricultural supply response study.

However, not too many studies have done this - incorporating inefficiencies into supply responses. This is a typical omitted variable problem or better still classical measurement error of supply variable. Kumbhakar (1996) explains that the difficulty in measuring technical efficiency could be one reason for its being treated outside supply response models. In recent years, however, the measurement of efficiency scores has become less cumbersome through the use of more sophisticated statistical software like STATA, LIMDEP and FRONTIER.

Aside from the computational problems, another reason for assuming technical efficiency in many agricultural supply response models has to do with its complexity in modelling, estimation and interpretation. The study by Arnade and Trueblood (2002) provided an opening. In spite of this breakthrough, many agricultural response models still treat technical efficiency as given. Such innovation in modelling is still limited in Africa as a whole and Ghana in particular. The study by Abrar et al (2004a) remains the only exception we know of at the time of writing this thesis.

Aside from the complexity of modelling agricultural supply responses, it is a fact that not many of such studies have been carried out in Ghana. Of the few studies into this area of research, many concentrate on single crop analysis. A few of them have considered multiple crops analysis although the dominant method of analysis has been time series and aggregated data has been used mostly. The study by Ocran and Biekpe (2008) is a typical example. This study provides a different dimension. We employ a disaggregated dataset at the ecological levels. This is very relevant to Ghana as far as reducing spatial poverty is concerned. Although national head count poverty has been reducing, it has been rising for some regions and economic groups, with food crop farmers hit the most. With the success implementation of the decentralisation (local government) policy in Ghana, findings based on ecological levels would help policy makers at the various local units to target areas of agricultural growth and poverty reduction rather than a one-size-fit-all agricultural policy that is usually the case. The study on cocoa supply response by Hattink et al (1998) is another example.

A related supply-sided (local) constraint to agricultural productivity is the operation at sub-optimal efficiency levels by farmers. This is technically inefficient in production economics under the neoclassical school of thought. A farmer who is technically inefficient would not be operating at the highest possible production frontier (what we refer to as potential frontier) and thereby reaping suboptimal outputs. Not even the supply of extra inputs would move the typical farmer to a higher production frontier. Any such improvement would occur if the technically inefficient gap (difference between farmer's actual and potential production frontiers) is bridged. We found out, through the review of Ghana's agricultural policies, that no attention is given to this important policy ingredient, which we believe is one of the fundamental state failures in Ghana, needing policy redress.

Many factors account for these efficiency disparities. Country-specific constraints (specific to both home and partner countries), mainly originate from differences in institutional and political structures prevailing between the countries (Rodrik, 2000; Levchenko, 2004). They form the basis for production, consumption, distribution and trade. In this study, we give attention to production (or technical) inefficiency, one of such inefficiencies that are not factored into the conventional gravity analysis.

In fact Urey (2004) and Rodrik (2000) argue against any economic policy in developing countries without first acknowledging the structural obstacles to which technical inefficiency is key. In a policy direction for agricultural transformation, Urey (2004) recommends three phases, of which the first - establishing the basics - concerns restructuring of productivity factors. Most agricultural supply response studies assume technical efficiency for a number of reasons. We incorporated it in our analysis. We address its impact on agricultural supply responses in Ghana at the most disaggregated unit - ecological levels. The effect of that was noticeable to neglect.

This study is different from the earlier studies on Ghana in that it uses the (profit) duality approach, a popular technique used in many agricultural studies but rarely used in studies on Ghana. Hattink et al (1998) is the only study known to have used this technique to analyse the cocoa industry in Ghana. In this sense, this study adds to the literature (methodology) but on a multiple crop analysis, which has never been done - at least at the time of writing this thesis. What is also different from the study by Hattink et al (1998) is that this study incorporates technical inefficiency into duality modelling, a recent framework introduced by Arnade and Trueblood (2002).

The success of agricultural policies will, however, depend to a large extent on farmers' responsiveness to both price and non-price policy elements (World Bank, 2008). Any price response will signal the workability of market systems within a country. Although the debate on agricultural supply responses is usually divided between the relative importance of price (incentives) and non-price factors, many studies focus more attention to price incentives to which the study by the World Bank (Krueger et al., 1988) has been influential. Recent studies, however, have found non-price factors to be more effective supply reactors than getting prices 'right' (Mamingi, 1997).

It has also been shown that both sets of factors - price and non-price - mutually reinforce each other (Schiff and Montenegro, 1997). The bias towards price incentive is not dissimilar to case studies on the supply responses on the Ghanaian economy. We seek to augment the scarcity of studies in this area of research. This consideration also happens to be the thesis' second major contribution. In particular we investigate farmers' supply responses to both price and non-price policies. Unlike the usual production estimation techniques, this study adopts the duality concept for modelling the relationship between inputs and outputs. In practice, this is done by estimating the profit function and applying the Hotelling's conditions to which we obtain both the output supply and input demand functions respectively.

Also relevant to the promotion of agricultural development in achieving food security and enhancing export competitiveness is the issue of technical efficiency. Apart from natural constraints limiting agricultural development in Africa, such as drought and uncertainty of rainfall, the issue of technical inefficiency had been cited as a possible agricultural growth constraint (Bloom and Sachs, 1998). Technical inefficiency in this context comes through lack of best farming practices, which in itself have deeper roots in the institutional structure of a country. An effectual agricultural policy, in part, must address any inefficiency in farming systems. We surmise that when production inefficiencies are accounted for in any given supply response analysis, supply elasticities are likely to decline in most cases.

Up until recently, however, much of the empirical studies on agricultural production have either been centred on estimating price response of output supply and input demand by assuming (technical) efficiency on one hand or focusing on the estimation of production inefficiencies on another and thereby ignoring price responses. Output supply and input demand elasticities from either strand of studies have been shown to be biased unless inefficiency estimates are incorporated into the analysis (Kumbhakar and Lovell, 2000 and Arnade and Trueblood, 2002).

We adopt a modified version of a recent model developed by Arnade and Trueblood (2002) to incorporate technical inefficiency scores into duality profit functions. The approach requires fewer assumptions and follows a two-step approach. Unlike Arnade and Trueblood, however, we utilised the stochastic frontier technique to compute the levels of technical inefficiency scores rather than the DEA technique, a non-parametric method.

The estimation of a (technically) inefficient supply response model would be the third and final core contribution of this thesis. We use the stochastic frontier technique to estimate technical inefficiency scores at a disaggregated crop level for the three ecological zones in Ghana - Coastal, Forest and Savannah. The objective here is to investigate the impact of technical inefficiency on the response of small-holder (peasant) farmers in Ghana.

### 1.2 Dataset

The empirical chapters of the thesis – 4, 5 and 6 - use the fourth round of the Ghana Living Standard Survey (GLSS4-1998/99) dataset, obtained from the Ghana Statistical Service, the authoritative body that collected and processed the data. The survey was conducted over a twelve month period. The GLSS4 is a multi-topic household survey designed to provide comprehensive information on the living standards of Ghanaian households. The main objective of the survey was to provide information on patterns of disaggregated household consumption and expenditure.

Each of the ten regions in the country was represented in the survey using a two-staged sampling technique. At the first stage, 300 enumeration areas (EA) were selected using systematic sampling with probability proportional to size method where the size measure is the 1984 number of households in the EA. At the second stage, a fixed number of 20 households were systematically chosen from each selected EA to give a total of 6,000 households. An additional 5 households were selected as reserve to replace missing households. Out of the selected 6,000 households, 5,998 were successfully interviewed representing 99.7% coverage. Overall, some 25,694 eligible household members were covered in the survey. Because the focus of the thesis is concerned with the estimation of agricultural supply responses, we utilized sections 1, 2, 4(A-E), 8(A1-G), and 12(B-C) of the GLSS4 dataset. These sections capture information on household demographics, education, employment status (including agriculture) and household assets respectively.

We also complemented the information contained in the GLSS4 dataset with other primary/secondary datasets. As part of the GLSS4 survey, a price questionnaire, known as

Community Price Survey, was designed to collect prices of most if not all essential commodities used in the local communities. These commodities are commonly used in the country too. In that survey, each cluster had at least two visits to record the prevailing local price of outputs and some inputs. This was done to account for seasonality and variation.

It should be noted, however, that although both surveys provide only cross-sectional data, there are considerable variations in the data, allowing us to carry out meaningful estimations. The GLSS4 survey categorises Ghana's ten regions into three agro-ecological zones by the use of enumeration areas: Coastal, Forest, and Savannah. It was difficult to work with the original zone classifications as six of the ten regions (forming the zones) had some enumeration areas (EAs) in more than a single zone. In other words, it was not easy to know which EA, hence zone, a typical farm belongs to with the existing categorisation. The original situation not only makes analysis difficult in terms of the geographical demarcations of the regions, but may also affect inferences on domestic agricultural policy targeting.

We attempted to re-categorise the zones with the help and advice from the Ghana Statistical service, GLSS secretariat. The new zones are based on the enumeration allocations used in the original survey. The new classifications still maintains the three zones. There are three regions each representing the Coastal (Gt. Accra, Central and Volta regions) and Savannah (Upper West, Upper East, Northern regions) zones respectively and four (Western, Ashanti, Eastern, Brong-Ahafo regions) making up the Forest zone.

Out of the three making up the Coastal zone, the Greater Accra and Central regions are cited near the Gulf of Guinea (i.e. by the coast). The Volta region is also home to the second man-made lake (the Volta Lake) in the world. All three regions are located in the southern parts of the country (see figure A3.1 in chapter 3). Regions making up the Forest zone are predominantly located in the middle belt of the country and also characterized by favorable agro-climatic conditions. Ghana's major cash crop, cocoa, performs remarkably well in this zone. The regions in the Savannah zone are among the poorest in Ghana according to the GLSS4. The three regions are all located in the northern part of Ghana. In terms of total land size, the Savannah zone is the biggest (see figure A3.1 for map). This zone is home to very harsh agro-climatic conditions including extreme weather (rainfall, and sunshine) conditions.

## 1.3 Summary of Main Results

The plan of the thesis is to estimate supply responses for six crops categorised into industrial or export (cocoa and groundnut), food (maize, rice and cowpea) and staples (millet and sorghum referred to as *migso* in the thesis). We use both the translog and quadratic forms in our estimations. In the translog functional form, we assumed technical efficiency. Technical inefficiency was, however, controlled for in the quadratic profit function. In the last empirical chapter - chapter 6 - we conducted a sensitivity analysis of chapters 4 and 5 using used profit functional forms.

A number of key conclusions from our estimations were highlighted. Firstly, we can conclude that farmers in Ghana do actually respond to both price and non-price output supply and input demand incentives. At least farmers responded to what followed from the implementation of the Structural Adjustment 'price' measures in the agricultural sector and any following up 'price' measures. Potential adjustments to future output price changes are likely to be high in the Coastal zone compared with other zones for three out of the six crops (groundnut, maize and rice). Also revealed was the fact that crops that are highly concentrated in a particular zone ended up producing the highest output supply elasticity estimates. For example, the regions in the Savannah zone are likely to record the least output supply price adjustments to all the crops except staples (*migso*), which the region specialises in cultivating. Similarly, the own-price elasticity of cocoa in the Forest zone (where 83% of farms produced at least 70% of its output) was the highest of the three zones.

Secondly, and drawing from the first conclusion, our results run counter to the common pessimism regarding the Savannah zone agriculture's ability to respond to output incentives, particularly in the case of price incentives. We also found that farmers are most likely to respond positively to three non-price factors - farmland size, animal capital (proxy for mechanisation), and farmers' improvement of human capital (education and experience of household head). In the case of some crops (maize, groundnut and cowpea), non-price output supply elasticity estimates exceeded their price elasticities, confirming the imperativeness of non-price incentives in Ghana's agricultural development. The effect of family labour changes on output supply was mixed, and in some cases providing marginal values. We could statistically, however, not drop family labour from our model suggesting its importance to the overall output supply response. Further research of its importance is needed.

Third, our results confirmed the significance of essential inputs - seeds and fertilizers - to the success of any agricultural progress in Ghana, like the green revolution in Asia. As such farmers will react strongly to changes in the prices of seeds and fertilizers. Unlike the case of output price changes, potential responses to input price changes are mixed. What was, however, unambiguous was that farmers in both the Forest and Savannah zones were likely to react more to changes in fertilizer prices than that of their counterparts in the Coastal zone. Amazingly this trend followed a similar path of average zonal prices for chemical fertilizers. It is cheapest in the Coastal zone (border point) and dearest in the poorest zone (Savannah). A similar trend - the dominance of fertilizer over seeds - was also established for each of the crops. These conclusions impose two new development policy challenges. Firstly, and in the short term, a 'price variation narrow gap policy' is needed. This calls for a sort of 'price' reform but its design and implementation needs to be pro-poor. The second way forward, and one of medium-to-long-term, is to develop hybrid - fertilizer-resistant - seeds. This would need both public and private sector investments.

Finally we attempted to estimate Ghana's technical inefficiency (based on the six crops used for the study) as well as ecological inefficiencies. Average production inefficiency in the country is estimated to be in the neighbourhood of 56%. The figure dropped by 3 percentage points when we conducted a sensitivity analysis based on (output and input) shares estimation. In terms of crops and ecological performances, cowpea farmers in the Forest zone recorded the least inefficient score (30%). Groundnut farmers in the Coastal zone were the most inefficient (87%). Overall, farmers in the Savannah zone registered relatively the lowest production inefficiency on average. The reasons behind these scores were not the scope of this study. Undoubtedly these scores suggest a problem that needs policy attention either at the ecological levels or nationally.

## 1.4 Structure of Thesis

The thesis is structured into seven chapters of which this forms the first. In chapter 2, we review both theoretical and empirical literature on agricultural supply responses with particular emphasis on theoretical modelling and empirical estimations. Duality estimation also takes centre stage in this chapter. Chapter 3 presents a descriptive summary of the entire data used for the empirical estimations in chapters 4, 5 and 6 respectively. In chapter 4, we estimated agricultural supply responses using the duality profit functions. A similar line of estimation is carried out in chapter 5, except that we estimated and accounted for national and regional technical inefficiency scores. We employed the Stochastic Frontier technique in estimating the technical efficiency scores. Robustness analysis is carried out in chapter 6, where the emphasis was on shares estimations. The final chapter summarizes the results and the main conclusions drawn from the research, pointing out relevant policy implications. We also spell out the limitations of the thesis and identify areas for future research opportunities.

## Chapter 1 Appendix

Table A1.1: Ghana's sectoral shares (% of GDP) and their growth rates: 1997-2009

| Year | Sector | | |
|---|---|---|---|
| | Agriculture | Service | Industry |
| 1997 | 40.4 (4.3) | 31.6 (6.5) | 28.0 (6.4) |
| 1998 | 40.6 (5.1) | 32.1 (6.0) | 27.4 (3.2) |
| 1999 | 40.5 (3.9) | 31.9 (5.0) | 27.6 (4.9) |
| 2000 | 39.6 (2.1) | 32.7 (5.4) | 27.8 (3.8) |
| 2001 | 39.6 (4.0) | 33.0 (5.1) | 27.4 (2.9) |
| 2002 | 39.5 (4.4) | 33.0 (4.7) | 27.5 (4.7) |
| 2003 | 39.8 (6.1) | 32.8 (4.7) | 27.4 (5.1) |
| 2004 | 40.3 (7.5) | 32.6 (4.7) | 27.2 (4.8) |
| 2005 | 39.5 (4.5) | 32.9 (5.4) | 27.6 (7.7) |
| 2006 | 39.3 (4.5) | 32.9 (6.5) | 25.9 (9.5) |
| 2007 | 38.0 (4.3) | 33.4 (8.2) | 26.0 (7.4) |
| 2008 | 33.6 (5.1) | 31.8 (9.3) | 25.9 (8.1) |
| 2009 | 34.1 (6.2) | 31.8 (4.6) | 25.7 (3.8) |

*Source: Budget Statement and Economic Policy of the Government of Ghana and Ghana Statistical Service.*
*Notes: Sectoral shares won't add up to 100 where the proportion of Net Indirect Taxes has been deducted.*
*Figures in parentheses are the corresponding sectoral growth rates.*

# CHAPTER 2: GENERAL LITERATURE REVIEW

## 2.1 Introduction

Schultz (1964) argues that if farmers in developing countries did not respond much to changes in (price and non-price) incentives, it was not so much due to their inability to adapt to changing circumstances but rather to the constraints they are facing, and that the potential for a significant supply response did exist if the constraints were relaxed. This assertion calls for the investigation of farmers' responsiveness to agricultural incentives. Supply response is therefore a tool used to evaluate the effectiveness of price and non-price incentive policies and enables producers to allocate their resources.

In this chapter, we survey the literature on agricultural supply responses (ASR). In particular, we discuss the theoretical underpinnings of the ASR, followed by some estimation techniques of ASR. We then explain the duality framework of modelling ASR (what we used in our empirical chapters - 4, 5, and 6). We then discuss some auxiliary issues related to ASR and finally review the scant literature on ASR.

## 2.2 Agricultural Supply Response: Theoretical Review

Given that past and recent agricultural supply response models are based on the Nerlove Model, it would be essential to present, in simple terms, the basic framework of the model. In the next section, we have discussed the estimation techniques of not only the basic Nerlove model but also for other recent models. In what follows, we explain the basic structure of the Nerlove model in its simplest form.

The Nerlove model basically consists of three equations (Navayana and Parikh, 1981):

$$X_t^* = \theta_0 + \theta_1 P_t^* + \theta_2 Z_t + \mu_t \tag{2.1}$$

$$P_t^* = \gamma P_{t-1} + (1-\gamma) P_{t-1}^* \qquad 0 < \gamma \leq 1 \tag{2.2}$$

$$X_t = (1-\tau) X_{t-1} + \tau X_t^* \qquad 0 < \tau \leq 1 \tag{2.3}$$

where

$X_t^*$ is the long-term desired (equilibrium) acreage of the crop in period $t$

$X_t$ is the actual acreage

$P_t^*$ is the expected 'normal' price

$P_t$ is the actual price

$Z_t$ is any other relevant variable to be controlled for (say agro-climatic factors)

$\mu_t$ is the random residual

$\gamma$ is the price expectation coefficient

$\tau$ is the acreage adjustment coefficient

Nerlove (1958) distinguishes three essential ideas, posit by the three equations above. Firstly, farmers, over time, keep adjusting their output towards a desired output level in the long run, but the adjustment is based on expected future prices. This is the meaning of equation (2.1). The following equation asserts that current prices affect output only to the extent that they alter expected future prices. Equation (2.3) implies that short-term adjustments in output may fall short of the long-term desired output level because constraints on the speed of acreage adjustment may exist.

The restriction in equation (2.2) means that the current expected price $P_t^*$ is revised in proportion to the difference between actual and expected prices. By this restriction, if $\gamma = 1$, then the present time period's expected price is always equal to the previous time period's actual price. The restriction is very important as a $\gamma > 2$ or $\gamma < 0$ would end up in a moving away of the price expectation pattern from the actual price movement. The restriction in equation (2.3) also implies a similar acreage adjustment process.

It should be noted that the three equations contain the long-run equilibrium and expected variables that we do not observe. An attempt to measure them as they are would either lead to the classical-error-in-variables (CEV) and/or omitted variable biased, which would only render OLS estimates biased and inconsistent, as well as invalidating their inferences. For estimation reasons, a reduced form containing only observable variables may be written (Navayana and Parikh, 1981).

The final reduced model is shown below.

$$X_t = \theta_0\gamma\tau + \theta_1\gamma\tau P_{t-1} + (1-\gamma+1-\tau)X_{t-1} - (1-\gamma)(1-\tau)X_{t-2}$$
$$+\theta_2\tau Z_t - \theta_2(1-\gamma)\tau Z_{t-1} + \tau[\mu_t - (1-\gamma)\mu_{t-1}] \quad (2.4)$$

Both Fisher and Temin (1970) and Krishna (1963) are among many studies to have used the Nerlove model. Presently, the basic Nerlove model has been adopted in many studies. It has also seen many extensions and revisions to the basic model.

It should be noted that the Nerlove model is designed to handle single agricultural crop in supply responses. In contrast a modified version - the Griliches Model - is designed to accommodate multi-crop cases. The next section reviews the estimation procedures of agricultural supply models.

## 2.3 Agricultural Supply Response: Basic Framework and Estimation Approaches

In terms of econometric estimation of agricultural supply responses to price and non-price incentives, there are three major approaches - direct reduced form approaches (based on the Nerlove and Griliches models), co-integration and error correction analyses and dynamic general equilibrium approach. There are also cross country regressions. In what follows, we review both the theoretical and empirical literature on these estimation techniques in detail.

### 2.3.1 Direct Reduced Form Methodology

This approach directly estimates the partial supply models based on aggregate or single crop, and it uses time-series data. Under this approach, two models - the Nerlove (1958) model – developed for individual crop analysis or the model developed by Griliches (1960) to handle aggregated dataset – are prominent. Both models begin by estimating a single equation independently for each agricultural produce or group of commodities. Both approaches are modelled in a partial equilibrium framework as they do not account for non-agricultural sectors and thus assume no correlation between the two sectors. There is a difference between the two models too. The Nerlove model involves a one-stage procedure and directly regress production on prices and other essential factors, whilst the other model involves a two-step procedure with the supply function being derived from the profit marginal conditions of a Cobb-Douglas production function (Colman, 1983).

The majority of older researched supply response studies fall in this category and the Nerlove model has gained much attention in empirical literature. As we have discussed the detailed derivation of the Nerlove model in the immediate section above, we only assess the estimation of the model here.

Nerlove's partial adjustment model is used to capture agricultural supply response to price incentives. The general static supply functional form is presented econometrically as:

$$Q_t = \alpha + \gamma P_{t-1} + \theta T + \varepsilon_t \tag{2.5}$$

Where $Q_t$ denotes expected long-run equilibrium output level at time $\boldsymbol{t}$, $\boldsymbol{\gamma}$ is the long-run supply response with $P_{t-1}$ capturing lagged output. The parameter $\theta$ represent a linear deterministic time trend coefficient whilst $\boldsymbol{\varepsilon_t}$ is the error term satisfying the Gauss-Markov properties and is identically independently distributed (i.i.d.). The time trend variable usually serves as a proxy for the impact of technological change on output.

We then assume that the dynamics of supply is driven by price expectations - Nerlove's hypothesis. In the Nerlove model, price expectations are generally assumed to be adaptive, meaning that each year farmers revise the output level they expect to prevail in the coming production year to the error they made in predicting the output level of the current period. Mathematically, this assumption is presented equation (2.6) below:

$$Q_t^* - Y_{t-1}^* = \delta(Q_t - Q_{t-1}^*), \qquad \textit{where } 0 > \delta > 1 \tag{2.6}$$

From equation (2.6), $Q_t^*$ is expected or desired output at time $\boldsymbol{t}$, and $\boldsymbol{\delta}$ denotes coefficient of expectation about price or elasticity if variables are in logarithm.

If we substituting equation (2.6) in (2.5), we rewrite a new model as follows:

$$Q_t^* = \delta\alpha + \delta\gamma P_{t-1} + (1-\delta)Q_{t-1}^* + \delta\theta T + \delta\varepsilon_t \tag{2.7}$$

From equation (2.7), the short-run price elasticity of supply is captured by the parameter of the lagged Price (i.e.). The long-run price elasticity is captured by the parameter $\boldsymbol{\gamma}$. In the Nerlove model, in the event of producers having a static expectation and that if supply depends on expected normal prices or lagged prices, then the expectation coefficient in equation (2.6),$\boldsymbol{\delta}$, is unitary (one). This is an extreme case, where producers do not instantaneously adjust production decisions to changes in prices observed in period *t*. If this was to occur, equation (2.7) would reduce to:

$$Q_t^* = Y_t = \alpha + \gamma P_{t-1} + \theta T + \varepsilon_t \tag{2.8}$$

If $\boldsymbol{\delta}$ is less than 1, the fluctuation in expected output level is less than the fluctuation in the observed output level, such that the actual change in output level in the periods ***t*** or ***t-1*** is only a small part of the change required to achieve the expected output level. In this case the only condition for observing significant differences between short-run and long-run elasticities are the initiation of non-static assumptions (Olubode-Awosola, Oyewumi & Jooste 2006).

The majority of the regressions based on the Nerlovian partial adjustment model have found low values or even zero long-run price elasticities of agricultural supply (Thiele, 2000 and Bond, 1983). Bond (1983) reported 0.34 and 0.16 elasticities for Ghana and Kenya, respectively. Chhibber (1989) found elasticity of the range 0.39-0.43 for India whilst the study by Gafar (1997) produced a 0.23 for Jamaica.

The constant low supply elasticities produced for developing economies has thrown caution for the efficacy of the Nerlove model. The key criticism stems from its fundamental methodological weakness. Peterson (1979) provides a reason behind the low supply elasticities outcome. He argues against using time-series data in estimating long-run elasticities, because only short-run fluctuations are observed. This implies that output responsiveness to annual variations is therefore likely to be low, even after full adjustment. This is because farmers would respond strongly to price changes only if they are perceived to be permanent. He concludes that the long-run supply elasticities from time-series data are biased downward.

Schiff and Montenegro (1995) also criticised supply responses based on time-series estimates. They cited the ‘Lucas critique’ as the major cause. This means that the estimates from time-series dataset are specific only to a given policy period, implying it would be practically impossible to make forecasts from them.

The estimation of the Nerlove model, based on OLS approach, may implicitly assume that each series of the dynamic specification is stationary, a condition that warrants the use of OLS for time-series data. In practice, however, most economic data, including agricultural time-series, tend to be non-stationary. If not differenced before OLS is applied, its estimates would be spurious. Differencing the series also means that some essential data would be lost, and thereby affecting long-run supply elasticities.

In summary, the Nerlove (and Griliches) partial adjustment model faces three limitations. It does not distinguish between short-run and long-run elasticities, the model’s use of integrated (non-stationary) series poses the danger of spurious regression results, and the assumption that production adjusts to a fixed target of supply, towards which actual supply adjusts is considered unrealistic under dynamic conditions.

It can be concluded that the partial adjustment model was used as a framework by many previous studies on supply response analysis but, due to its limitations and the improvement of methods, the method also lacks the capacity to measure the effect of non-price factors influencing supply.

### 2.3.2 Alternative Time-Series Estimation Techniques

As a response to the limitations to the Nerlove and Griliches models, more sophisticated time-series techniques have emerged. The two widely used are the co-integration and error correction models and the dynamic general equilibrium models. We briefly explain these approaches.

#### 2.3.2.1 Error Correction Model and Co-integration Analysis

Supply response empirical dynamics can also be approached by Error Correction Models (ECM). The ECM allows a way to reincorporate levels of variables alongside their differences, even if short-run non-stationary exists. All that needs to be established is a long-run relationship of the dependent and explanatory variables. In this case, one can model long-run and short-run relationship between integrated series. There are two key merits in using these estimation techniques.

Firstly, they overcome the spurious estimates obtained from applying OLS to non-stationary data series under both the Nerlove and Griliches models. This is because the first differences of the series and the linear combination of both the dependent and explanatory variables are usually integrated of order zero (i.e. they become stationary - constant means and variances - after their first differences). In fact it is argued that the most straightforward way to overcome the restrictive dynamic specification of the Nerlove model is to conduct a co-integration analysis. This is because this approach does not impose any restrictions on the short-run behaviour of prices and quantities (Thiele 2000). All it requires is a co-movement of the two variables in the long-run. Thus, ECMs offer a means to incorporate the levels of the series (variables) alongside their differences. This unique approach means that ECMs communicate information on both short and long-run dynamics. This is the core advantage of the ECM over the partial adjustment model in that the ECM is consistent with forward-looking behaviour. As Nickell (1985) has revealed, the ECM can be derived from the minimisation of an intertemporal quadratic loss function.

The possibility of an ECM is always preceded by a co-integration analysis or test - to establish the long-run co-movement (long-run equilibrium) between the series to be used in the supply response modelling.[2] Co-integration analysis is carried out with either the Engle-Granger or Johansen test approaches. We only discuss the former test owing to the fact that it is popular among applied economists and widely used in the literature.

The theorem of Granger is presented in its simplified form. If we assume two variables - quantity ($Q_t$) and price ($P_t$) at time t are I(1) - only their first difference would render the variables stationary - and if their linear combination, denoted by the Gauss-Markov error term $\vartheta_t$ in equation (2.9) is stationary [i.e. I(0)],

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[2] For detailed discussions on the requirements of co-integration and ECMs, the reader is referred to Granger and Newbold (1994) - for theoretical justification - and Mackay et al. (1997) for explicit summary and application to supply response modelling.

$$\vartheta_t = Q_t - \gamma P_t \tag{2.9}$$

then Q and P are each said to be cointegrated of order 1 [i.e. (1,1)] and there exists a long-run relationship between them, calling for a possibility of ECM. If we assume that price 'granger cause' quantity, then we can write an ECM as:

$$\Delta Q_t = \alpha + \sum_{i=0}^{p} \beta_i \Delta Q_{t-p} + \sum_{j=0}^{q} \emptyset_i \Delta P_{t-q} + \theta T - \delta \vartheta_{t-1} + \mu_t \tag{2.10}$$

where Δ = difference operator such that $\Delta Q_t = Q_t - Q_{t-1}$

$\vartheta_{t-1} = Q_{t-1} - \gamma P_{t-1}$

T = our usual time trend capturing any technological changes

From equation (2.10), the first two terms on the right-hand side capture the short-run dynamic adjustment of both quantities and prices. The fourth term, usually referred to as the error correction mechanism, determines the speed at which the system restores itself to the long-run equilibrium relationship, with the lagged residual of the co-integrating regression in equation (2.9) representing the divergence from equilibrium.

In fact, the above can be said to be true only if all the coefficients of the differenced variables – $\beta_i$ *and* $\emptyset_i$ - turn out to be significant and also the adjustment parameter, $\delta$, must be non-positive to permit any adjustment back to its steady state from any short-run deviations. Where the coefficients $\beta_i$ and $\emptyset_i$ turn out to be insignificant, the ECM reduces to a partial adjustment model.

Recent studies on supply responses have adopted this approach of estimation. Studies by Abdulai and Rieder (1995), Townsend (1996), McKay et al. (1999) and Ocran and Biekpe (2008) - for Ghana - are just a few. Using the co-integration analysis, for example, Mackay et al (1999) obtained a long-run price elasticity of supply close to unity for both food crops (0.78) and export crops (0.93) for Tanzania.

Thiele (2000) is quick to point out that the cointegration and ECMs as well as the partial adjustment models (Nerlove and Griliches) share a major drawback, although the former models appear to solve the limitations of the latter models. They argue that both sets of modelling rely on a partial equilibrium framework where only the agricultural sector is considered, neglecting the non-agricultural sectors, which could render the estimates not robust. This is because in the long-run, the dynamics of agricultural supply, they contended, are likely to depend on the ability of the sector to attract additional production factors from other sectors, an effect that cannot be captured within the partial equilibrium structure. This called for a more sophisticated modelling. The dynamic general equilibrium models were introduced.

#### 2.3.2.2 Dynamic General Equilibrium Models[3]

The dynamic general equilibrium model (DGEM) has been structured to account for the effects of intersectoral factor movements on agricultural supply. DGEMs explicitly specify how production factors - labour, capital and land - are accumulated over time and how the factors of production are allocated among different sectors of the economy (Coeymans and Mundlak, 1993). The model assumes capital stock at present time t, $K_t$, available for the agricultural production is equal to the lagged capital stock, reduced by a given rate of depreciation at present time, $\sigma_t$, and augmented by the proportion ($\rho_t$) of present time total investment, $I_t$ , that goes to agriculture. This relationship is shown by equation (2.11).

$$K_t = K_{t-1} + \rho_t I_t - \sigma_t K_{t-1} \tag{2.11}$$

The model further assumes that the share of agriculture in total investment is determined by the past allocation of investment, $\rho_{t-1}$, and the differential rate of return between agriculture and non-agriculture (assuming a 2-sector model), $R_A/R_{NA}$. Thus, $\rho_t$ = ($\rho_{t-1},$ $R_A/R_{NA}$). It is expected that:

$$\begin{cases} cov(\rho_{t,}\rho_{t-1}) > 0 \\ \\ cov(\rho_{t,} R_A/R_{NA}) > 0 \end{cases} \tag{2.12}$$

Next, the model assesses the movement of labour force. Changes in the agricultural labour force at present time, $L_t$, comes from a growth in population and off-farm migration.

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[3] This section draws heavily from Thiele (2000)

$$L_t = L_{t-1} + g_t L_{t-1} - w_t L_{t-1} \quad (2.13)$$

where $g_t$ and $w_t$ are the population growth rate (determined exogenously) and the share of the labour force that migrate from agriculture in present time period. The migration from agriculture follows the model of Harris-Todaro where

$$\begin{cases} cov\left(m_{t,}U_{NA}\right) < 0 \\ \\ cov(m_{t,}\, W_{NA}/W_A > 0 \end{cases} \quad (2.14)$$

Equation (2.14) asserts that the labour force from agriculture, $m_t$, is determined and correlates negatively by urban employment rate in the non-agricultural sector (off-farm enterprises), ($U_{NA}$) and positively by the intersectoral differential in income, $W_{NA}/W_A$.

The final equation tries to specify a relationship for land, the last of three production factors considered by this model. The land size of the cultivated area, given by $A_t$, is specified to include the real price of land (PA/P) and the agricultural terms of trade, measured by the intersectoral differential rate of return ($R_A/R_{NA}$), and their first derivatives shown by equation (2.15) below:

$$\begin{cases} cov\left(A_{t,}\, P_A/P\right) > 0 \\ cov(A_{t,}\, R_A/R_{AG} > 0 \\ \qquad R < 0 \end{cases} \quad (2.15)$$

where $R$ represents a vector of constraints that limit the size of the area cultivated.

The *DGEMs* also *endogenises* the choices of techniques. It assumes that at any given time period, not all producers adopt the best available technology. Thus, the implemented technology depends on the available technology ($T$), incentives such as prices and non-prices ($C$), and constraints that needed to be controlled for, such as agro-climatic conditions ($G$). It is further assumed that these variables - $T$, $C$, $G$ - are exogenously given to farmers.

Given the above equations, a well-defined production function (exact function usually dictated by theory and empirics) is specified as

$$Q_t = \tau_0(T, C, G) + \tau_1(T, C, G)K_t + \tau_2(T, C, G)L_t + \tau_3(T, C, G)A_t + \omega_t \quad (2.16)$$

Equation (2.16) is a system of equations and must be estimated either by iteration or step-wise techniques. If the second approach is utilised, then the parameters in equations (2.12) and (2.16) must be estimated.[4] The parameters estimated can then be used as inputs for simulations of changes in the effect of agricultural prices. The studies by Mundlak et al (1989) and Coeymans and Mundlak (1993), for Argentina and Chile respectively, are along the lines of the second approach.

As a variant of time-series modelling, DGEMs also suffers from the 'Lucas-critique' explained earlier. This means that all estimations based on time series would end up understating the true agricultural supply elasticities. Schiff and Montenegro (1995) conclude that DGEMs are poor instruments for forecasting the impact of a price reform - the reason based on the 'Lucas-critique'.[5]

### 2.3.3 Cross-Country Regressions

A second most important response, besides the sophisticated time-series approaches described above, to the flaws of the partial equilibrium models is to estimate supply responsiveness for a cross section of countries rather than for a single country over time. This could be done using either different cross-sectional data for a given time period (pooling) or over a range of time (panel).

Cross-country supply response modelling usually leads to relatively higher long-run elasticity estimates than time-series analyses (Peterson, 1979 and Thiele, 2000). Using an instrumental variable estimation technique with a sample of 53 developed and developing countries,

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[4] For specific and detailed DGEM for supply response, the reader is referred to Chambers and Lopez (1983).

[5] It must be noted that both Schiff and Montenegro (1995) and Quiroz and Chumacero (1993) have been dealing with models free from the 'Lucas-critique' but they are not relevant in this study.

Peterson (1979) obtains a relatively large and statistically significant aggregate price elasticity of supply that lies above unity. His findings opened a new way of estimating supply responses especially in developing countries which hitherto was based on the Nerlove model. His regression was, nevertheless, criticised from the beginning. The centre of the disapproval was his omission of non-price variables such as irrigation, infrastructure, credit and agro-climatic variables including rainfall and soil fertility. Elementary econometrics would suggest that if there is a positive correlation between these omitted variables and any of the price variables used in the regression, then estimates would be biased upwards. Chhibber (1989) tested this claim, by conducting a sensitivity analysis of Peterson's estimation. Chhibber included two non-price control variables - research and irrigation - and rather found a less than unity long-run supply elasticity estimate. This tends to confirm the major drawback of cross-country studies - heterogeneity arising from different characteristics of pricing and production regimes of countries included in the estimations. Schiff and Montenegro (1995) have argued that correcting for omitted variables in cross-country estimation does not correct all the problems caused by heterogeneity. The study by Bond (1983) is yet another cross-country study involving many developing countries.

The problem of heterogeneity could be overcome by panel estimation techniques. In the event of no time-ordered multi-country dataset, one could also model agricultural supply response using the pseudo-panel or cohort estimation techniques.

## 2.4 Agricultural Supply Response: Duality Modelling

### 2.4.1 Justification of Duality Modelling

Until the use of duality models, Agricultural economists resorted to the modelling of crop production decisions in terms of acreage responses rather than output supplies. The justification of this approach was that acreage planted is essentially independent of subsequent weather conditions and hence may provide a closer proxy to planted production than does observed output (Coyle, 1993). Many of the studies attempting to measure acreage responses relied on the basic Nerlove partial adjustment framework and sometimes, on adaptive expectations models. Aside the discussed limitations of the partial adjustment models, Coyle (1993) further explains that for the reason that those models fail to integrate acreage demands into an economic framework, acreage response models are inferior to output supply models that are based on the duality theory.

Undoubtedly, a duality approach to a specification of a system of output supplies and factor demands has an added advantage over estimation of a single output supply or acreage response equation. Coyle (1993) and Arnade and Trueblood (2002) discuss three major merits of the duality modelling approach. Firstly, the dual system approach permits incorporation of contemporaneous covariance of disturbances across equations. This is akin to the estimation of a Seemingly Unrelated Regression (SUR); a technique that cannot be applied under acreage response modelling. Secondly, duality estimations permit specification of symmetrical restrictions of coefficients across equations implied by hypotheses of competitive profit maximisation (or minimisation of costs). Finally, estimations based on duality permits the recovery of the underlying technology.

We briefly explain the general form of the duality methodology. The starting point of duality models is the profit function (as opposed to a production function under a primal condition). The formal set up of the duality model is presented in what flows:[6]

### 2.4.2 Production Estimation: Primal Versus Dual Approaches

A production function describes all possible ways of transforming inputs into outputs via a set of technology. The technology here may be described as the production transformation set, where its boundary is described by equation (2.17)

$$G(Y, X; Z) = 0 \tag{2.17}$$

where

*Y* is a vector of non-negative outputs

*X* is a vector of non-negative variable inputs, and

*Z* is a vector of non-negative quasi-fixed inputs

[6] The derivation of this model follows closely from the study by Coyle (1993).

The production transformation set stated by equation (2.17) must possess the regularity properties of (a) domain, (b) continuity, (c) boundedness, (d) smoothness and twice differentiability, (e) convexity, and (f) monotonicity. Usually in practice, the property of convexity and monotonicity are assumed to hold mainly because we assume that the objective of the farm family is the maximisation of short-run profit and that the farm family is a price-taker in the output and variable input markets.

The primal model starts from a production function, which has the usual properties outlined above. With profit maximisation given, the primal approach is to estimate the production equation (2.17) subject to a set of inputs, and by setting the lagrangian function and later obtain the first order conditions. With this routine, a set of output supply and input demand equations can be obtained. The approach, however, encounters some problems. Firstly, direct estimation of any functional form of equation (2.17) using OLS produces simultaneity bias as input levels are endogenous. Equally the estimates of the output supply equations are inefficient as the residuals are most likely to be correlated contemporaneously (Thijssen, 1991). The second problem of the primal approach lies in the difficulty of deriving output supply and input demand equations from primal approach (Wall and Fisher, p.11) as this process involves solving a complex constrained optimisation.

In contrast the dual approach is not subject to the aforementioned problems of primal. Unlike the first approach which starts from the production function, the starting point for a duality approach is the profit function. The profit function deals only with prices of outputs and inputs and quantity of quasi-fixed inputs. The merit in this is that prices and quantities escape the endogeneity problem.

Given a well behaved profit function, duality principle assures that there is a well behaved technology corresponding to the profit function. If we assume that a rational producer aims at maximising variable profits constrained by production transformation set - equation (2.17) - then the economic problem facing the producer is set up by equation (2.18).

$$\Pi(P, W; Z) = Max\{P^n Y - W^n X; G(Y, X; Z) \leq 0\} \qquad (2.18)$$

where

$P^n$ is a vector of *m* output prices normalised by a chosen *numeraire*

$W^n$ is a vector of *n* variable input prices normalised by a chosen *numeraire*

$\Pi$ is the normalised variable profit, given the vector of prices and quantities

The inequality permits output inefficiency

McFadden (1978) has shown that equation (2.18) must possess all the properties listed under equation (2.17) plus that of homogeneity. The normalised profit function is sometimes referred to as restrict profit (Lau, 1978). If the restricted profit function is differentiable, it satisfies the Hotelling Lemma theorem (Ball, 1988).

To obtain output supply and input demand from the profit function, we ought to apply the Hotelling Lemma theorem. This is done by taking the first derivative of the profit function with respect to both output prices (for supply function) and input prices (for demand function). The behavioural derivations for the respective equations are shown by equation (2.19).

$$\frac{\partial \Pi(P,W;Z)}{\partial P_i} = Y_i(P,W;Z) > 0 \quad for \quad i = \overline{1,m} \quad and \tag{2.19}$$

$$-\frac{\partial \Pi(P,W;Z)}{\partial W_j} = X_j(P,W;Z) < 0 \quad for \quad j = \overline{1,n} \tag{2.20}$$

Equations (2.19) and (2.20) are the output supply and input demand functions. It should be noted from equation (2.17) that the non-negativity of all the variables - $X$, $Y$ and $Z$ - indicate that profit is expected to monotonically increase with output prices and quasi-fixed inputs, and to monotonically decrease with price of variable inputs, respectively (Saez and Shumway (1985)).

With profit maximisation assumed, it can be proved that duality models satisfy the properties of convexity and monotonicity on one hand, and symmetry on the other. The properties of convexity and monotonicity are demonstrated by assessing the sign of the first derivative of equations (2.19) and (2.20):

$$\begin{cases} \dfrac{\partial Y_i(P,W;Z)}{\partial P_i} = \dfrac{\partial}{\partial P_i}\left(\dfrac{\partial \Pi(P,W;Z)}{\partial P_i}\right) = \dfrac{\partial^2 \Pi(P,W;Z)}{\partial P_i^2} & (2.21) \\ \dfrac{\partial X_i(P,W;Z)}{\partial W_j} = \dfrac{\partial}{\partial W_j}\left(-\dfrac{\partial \Pi(P,W;Z)}{\partial W_j}\right) = -\dfrac{\partial^2 \Pi(P,W;Z)}{\partial W_j^2} & (2.22) \end{cases}$$

Since the restricted profit equation is a convex function, it only implies that the slopes of both the output supply and input demand function are respectively positive and negative, hence establishing monotonicity property.

Symmetry property is best proved by working out the cross-price effects from equations (2.19) and (2.20).

$$\begin{cases} \dfrac{\partial Y_i(P,W;Z)}{\partial P_j} = \dfrac{\partial}{\partial P_j}\left(\dfrac{\partial \Pi(P,W;Z)}{\partial P_i}\right) = \dfrac{\partial}{\partial P_i}\left(\dfrac{\partial \Pi(P,W;Z)}{\partial P_j}\right) = \dfrac{\partial Y_j(P,W;Z)}{\partial P_i} & (2.23) \\ \dfrac{\partial X_i(P,W;Z)}{\partial W_j} = \dfrac{\partial}{\partial W_j}\left(-\dfrac{\partial \Pi(P,W;Z)}{\partial W_i}\right) = \dfrac{\partial}{\partial W_i}\left(-\dfrac{\partial \Pi(P,W;Z)}{\partial W_j}\right) = \dfrac{\partial X_j(P,W;Z)}{\partial W_i} & (2.24) \end{cases}$$

The above relationships show that the cross-price effects of output supply and input demand are symmetric. The last property, homogeneity, has an intuitive meaning and that is if the prices of outputs and inputs are doubled, it would have no effect on output supplies and input demands as the proportionate increase would offset each other. This means the duality function is homogenous of degree one. In practice, homogeneity and symmetry properties are imposed, but could be statistically tested as well.

The final part of duality modelling is to calculate the output supply and input demand elasticities. Many studies follow the classic demonstrations by the studies of Weaver (1983) and Wall and Fisher (1987) in this regard. This study is not an exception. In that case, the price elasticity of output supply is computed as:

$$\eta_{ik} = \frac{\partial Y_i(P, W; Z)}{\partial P_k} \cdot \frac{P_k}{Y_i} = \vartheta_{ik} \cdot \frac{P_k}{Y_i} \quad for\ all\ i, k = \overline{1, m} \tag{2.25}$$

and the price elasticity of variable input demand is computed as:

$$\lambda_{jv} = -\ \frac{\partial X_j(P, W; Z)}{\partial W_v} \cdot \frac{W_v}{X_j} = -\ \zeta_{jv} \cdot \frac{W_v}{X_j} \quad for\ all\ j, v = \overline{1, n} \tag{2.26}$$

The two sets of elasticities are commonly termed Marshallian elasticities owing to the fact that they are only derived from an unconstrained output supply and input demand functions. Finally, the signs of the elasticities above reveal the appropriate terminologies - either gross complements ($\eta_{ik} < 0, \lambda_{jv} > 0$) or gross substitutes ($\eta_{ik} > 0, \lambda_{jv} < 0$).

### 2.4.3 Duality Modelling: Estimation

The starting point of estimating a duality supply response model in any case, is to decide on which functional form to use. There are usually four functional forms (translog, generalised Leontief, generalised Cobb-Douglas, and the quadratic forms) of the profit function that have been used in the literature. A choice of a particular functional form, in practice, depends on the fit of the dataset available, assuming the regularity properties can be satisfied.

The appropriate functional form, empirically, is a compromise between theoretical underpinnings and econometric feasibilities - a good fit of the dataset. A commonly used form, and the one adopted in this study, is the transcendental logarithmic functional (Translog) form by Christensen et al., (1973). The Translog functional form appears to fit our dataset very well too, hence we would only review the translog form here (the reader should refer to the appendix of chapter 4 for the full treatment of the remaining functional forms).

The translog form has been found to be more sensitive to micro-level data than the quadratic specification. Indeed our goodness-of-fit check confirmed the suitability of the translog specification, based on the dataset used (see Table A4.1 in appendix). An added merit of the translog form, as opposed to the quadratic form is that, the choice of a *numeraire* in the translog specification does not drastically affect the final estimates (Kumbhakar, 1996). On the basis of better fit and conformity to regularity properties, Wall and Fisher (1987) has shown that the translog functional form stands out.

The following is a summarised discussion of the Translog functional form.

It begins with the specification of the restricted profit in a logarithmic form, which is expressed as

$$ln\Pi^n = \psi_0 + \sum_{i=1}^{M} \phi_i lnF_i + \sum_{h=1}^{H} \psi_h lnZ_h + {}^1/_2 \sum_{i=1}^{M}\sum_{j=1}^{M} \psi_{ij} lnF_i lnF_j$$
$$+ {}^1/_2 \sum_{h=1}^{H}\sum_{k=1}^{K} \rho_{hk} lnZ_h lnZ_k + {}^1/_2 \sum_{i=1}^{M}\sum_{h=1}^{H} \psi_{ih} lnF_i lnZ_h \qquad (2.27)$$

where

$$F_i = \begin{cases} P_i(price\ of\ outputs) for\ all\ i = \overline{1, M} \\ W_i(price\ of\ inputs) for\ all\ j = \overline{1, N} \end{cases}$$

$Z_i$ is the quantity of quasi-fixed for $i^{th}$ input

The translog function is viewed as a second-order Taylor’s expansion about the unit point. When the Hotelling theorem is applied to equation (2.27), we obtain output supply and input demand functions, which we have not included as we have explained the process in equations (2.23) and (2.24).

In order for the model to meet the theoretical standards, it must satisfy the four conditions discussed above. The following symmetry restrictions are usually imposed by the equality of cross-partial derivates in a quadratic expansion

$$\psi_{ij} = \psi_{ji}, \phi_{hk} = \phi_{kh} \qquad (2.28)$$

Also homogeneity of degree one in prices requires that

(i) In prices

$$\sum_{i=0}^{M} \phi_i = 1, \sum_{i=0}^{M} \psi_{ij} = 0, \qquad (2.29)$$

(ii) In quasi-fixed inputs

$$\sum_{i=0}^{M} \rho_{hk} = 0, \qquad (2.29)$$

As mentioned earlier, homogeneity is assumed through the normalisation of output and input prices. In a similar manner, homogeneity in quasi-fixed inputs can be obtained by normalising quasi-fixed inputs with one of its own.

If the output supply and input demand elasticities are positive and negative respectively then the property of monotonicity is established. Convexity is satisfied when the Hessian displays a positive semi-definite.

Once an appropriate functional form has been chosen, the parameters of the equations are empirically estimated together within a system. The suitable estimation choice has been the Seemingly Unrelated Regression (SUR), which is able to efficiently handle systems of equations. The estimated coefficients are then used to derive the elasticities that describe the production relations of multiple-input, multiple-output farms. The derived elasticities are the output supply and input demand responses.

## 2.5 Agricultural Supply Response: Data Issues

### 2.5.1 Aggregate Data versus Farm-Level Data

There are usually two sets of data used for estimating supply response models - aggregate and farm-level dataset. The former had gained much attention in the literature but recent studies have begun using farm-level data. Rao (1989) contends that if supply response studies are meant for policy purposes, then aggregate data may be sufficient to measure supply elasticities. One reason why farm-level data is rarely used is that it is either not available or has small sample size to affect policy. However, conducting supply responses based on farm-level dataset has some merits. Firstly, farm-level data allows disaggregation by regions, farm size, income and other essential factors which may affect supply responses. By this Rao

(1989) and Schiff and Montenegro (1995) argue that such disaggregation can be used to fine-tune policy to the needs and potentialities of different types of farms, crops and regions. Another advantage of micro studies is that they allow better tests of some hypotheses regarding farmer motivation that can provide a deeper understanding of supply behaviour. Macro studies on supply responses would not always pick up the specific role of price and non-price incentives from the effects of contextual factors due to methodological constraints.

Schiff and Montenegro (1995) reveal that much of the controversy occurs with the use of aggregate data for the estimation of supply responses for Sub-Saharan Africa (SSA). The claims are that SSA agriculture exhibits low aggregate supply responses especially with respect to price incentives (Bond, 1983; Deldago and Mellor, 1984 and De Janvry, 1986). This claim is refuted by Schiff and Montenegro (1995) who argue that the claim is only justified when price and non-price incentives (what they called public goods) are considered as substitutes rather than complementary. They favoured the latter classification, and hence their disagreement. They also contested the use of time series estimates, which could be one of the reasons behind the low supply responsiveness in SSA. Instead they argue for the use of dynamic general equilibrium models.

### 2.5.2 Agricultural Supply Response: Price versus Non-Price Factors

Factors responsible for higher outputs in the agricultural sector are mainly grouped into price and non-price responses (Binswanger, 1990; Mamingi, 1997), although natural conditions and excessive sectoral taxes have been cited as other casual factors constraining the sector's growth, especially in developing countries (Chhibber, 1989; Bloom and Sachs, 1998). However, it is the two main factors, prices and non-prices, which have received much attention in the literature. Only a few of these studies have utilized farm dataset due to the scarcity of such surveys. It is therefore no surprise to witness volumes of agricultural supply response studies employing time series methodologies to model aggregate farm responses. Using farm dataset will give a more accurate reflection of famers' responses (Binswanger, 1990) but aggregate analysis is useful for investigating the effect of agriculture terms of trade on agricultural output (Rao, 2005).

Price related studies focus solely on 'getting prices right' (World Bank, 1990; Krueger et al., 1992). Supporters of this ideology, usually the extreme market economists, prefer price policy choices to input subsidies towards the development of the agricultural sector. Farm prices are seen to be the most important determinant of farm incomes which, in turn, affect farmers' ability to increase the quantity and improve the quality of resources available to them (Rao, 1999). The study by Askari and Cummings (1977) was the first to provide a comprehensive study on this branch of the analysis, involving over fifty different studies in this area of work. Using the typical Nerlove model, a greater part of the works found high price elasticities for the crops used. All of the three different anticipated output prices (actual, expected and weighted) used in the studies did not heavily alter the price sensitivity of the crops.

A greater part of the price-weighted supply response studies are based on time series analyses dividing elasticities into short-run and long-run. The pioneering work of Askari and Cummings (1977) once again is the most cited in this category. Most of these studies report positive output elasticities with respect to relative price changes. Usually long-run (output) price elasticities are found to be relatively higher than short-run responsiveness. Supply elasticities in the short-run ranges between zero and 0.8 while long-run sensitivities tend to be between 0.3 and 1.2. Initial supply responses of SSA countries have been biased also towards price stabilization and elasticities recorded have been relatively low with the average ranging from 0.18 (short run) to 0.21 in the long-run (McKay et al., 1998). Adopting the Johansen's multivariate Cointegration approach, Thiele (2002) recorded comparatively higher long-run supply elasticities (0.20-0.50) for ten SSA countries.

Beside the application of more sophisticated time-series approaches, the second major response to the limitations of the Nerlove approach has been to estimate supply elasticity on a cross-country basis. Usually cross-country elasticities tend to be relatively higher than time-series responses owing to the use of different price regimes. In the most widely cited empirical cross-country study, Peterson (1979) clearly confirms this proposition. For a sample of 53 developed and developing countries, he obtains an aggregate price elasticity of supply that lies significantly above unity (between 1.27 and 1.66). Most SSA countries, not surprisingly responded highly to price factors agricultural policies largely due to the phase of economic reform to which 'pricism versus structuralism' was hotly contested. Price stabilization policy swept throughout the continent (Bond, 1983) where the focus was more on adjustment. Explaining these high price responses, Schiff and Montenegro (1995) attribute this to the imperfect market conditions in developing countries and rigid price systems.

It has for some time been clear that Africa needs to move beyond adjustment to development, and agricultural commercialization has to play a crucial part in this process if it is to result in poverty alleviation and improved food security (Cornia and Helleiner, 1994) and towards competitive exports (WDR, 2008). As such, studies lining heavily towards price-related supply responses have been criticized mainly on the ground of methodology, for which aggregation issues and omission variable bias top the list. This culminates in either under- or over-estimating supply responsiveness (McKay et al, 1998; Schiff and Montenegro, 1995). There are also issues with measurement problems, such as whether to use output per yield or acreage as the dependent variable or which appropriate price variable (expected, lagged, present or weighted) should be used. The literature though reports minimal sensitivities from these sources, especially in cross-sectional data (Schiff and Montenegro, 1995). Chhibber (1989) led the criticisms against long-term supply elasticities based on time series data. Using Peterson's own data and adding what he calls shifters (non-price factors such as irrigation variable), he found a relatively lower elasticity (nearly 30% lower than Peterson's 1.27).

A growing literature also argues that output supply responds more to non-price factors than 'getting prices right', especially in developing countries where markets are either in disequilibrium or non-existent (Askari and Cummings, 1976; McKay et al, 1997; Mamingi, 1997; Abrar, 2002). Both Delgado and Mellor (1984) and De Janvry (1986) argue vehemently that farmers, especially those in developing countries, respond more to non-price factors (now known in the literature as public goods) than price factors.

Four major non-price/public factors usually cited in the literature includes inadequate capital (physical and human), sub-optimum technology, low levels of investment and agro-ecological factors such as soil quality (or fertility) and the amount and timing of rainfall. Analysis of non-price supply responsiveness has even been more useful if carried out at crop- or regional-levels or both, as this provides information on which crops are to be targeted if the agricultural sector is to be used to target poverty reduction. However, lack of farm data has constrained micro-economic agricultural supply response studies in developing countries, especially in Sub-Saharan Africa. Studies by Abrar (2002) on Ethiopia for selected food crops and the work of Hattink et al. (1998) on cocoa for Ghana are a few exceptions.

Studies that have argued public goods are more effective than prices in raising aggregate output have based their argument on the fact that the price elasticity is smaller than the elasticity with respect to non-price factors. As Chhibber (1989) states:

*"If farmers cannot respond sufficiently to higher prices because of constraints due to inadequate irrigation, unimaginative and inefficient research and extension services or poor transport facilities, then improvement of these goods and services may do more for agriculture than a policy of higher prices"* (p.55).

The dichotomy between prices on the one hand and public goods on the other has been criticized. Prices and public goods are to be treated as complements rather than substitutes and hence a typical study should include both for any lucid agricultural supply response analysis (Oyejide, 1984; Schiff, 1987). Schiff (1987) justifies the complementarity arguing that a higher level of public goods raises the impact of prices on output, and vice versa, that higher agricultural prices raise the impact that investments in public goods have on output. Chhibber (1989) summarizes the empirical literature and finds evidence on this complementarity. He states that the long-run aggregate supply elasticity in the poorer LDCs with inadequate infrastructural facilities is 0.3 to 0.5. On the other hand, in the more advanced LDCs with better provision of public goods, the elasticity is 0.7 to 0.9.

Schiff and Montenegro (1995) formerly tested the complementarity hypothesis. Eighteen countries were selected from Africa, Asia, the Caribbean, Europe and the Middle East (Turkey, which is now a member of the European Union). They created an index for the public goods variable which they call GIB, defined as the ratio of the share of public investment expenditures on agriculture relative to total public investment expenditures and the share of agriculture's GDP in total GDP. When the value of GIB is (smaller than) one means that the share of public investment funds going to agriculture was equal to (smaller than) the share of agriculture in GDP. A price index variable was also created, which was the ratio of a country’s agriculture's domestic terms of trade to its non-agricultural prices. Providing evidence for the complementarity hypothesis in his findings, he argues that growing a country's agricultural sector (increase output and making it competitive) should be based on a policy mix of both price and non-price interventions rather than treating them as substitutes. By this evidence, he disagreed with Chhibber's assertion (given by the quotation above). Supporting their disagreement, the authors argued that there is no one-to-one relationship between the relative size of the two elasticites (price and non-price) and the relative budgetary cost of achieving a given output increase of a particular country and as such that comparison is of no benefit. What is missing from the elasticity comparison is the unit cost of public goods versus the price of the relevant agricultural products. For given elasticities, the higher the price of agricultural products relative to the unit cost of public goods, the more attractive the public goods option becomes.

Other studies have also held up the complementarity argument and have called for, in addition to price reform, an investment in market failure public goods, accompanying tax reform for countries whose agricultural export taxes forms a greater percentage of government revenue, a marketing and distribution of inputs and outs. All of these will allow any price to reflect the true opportunity cost of agricultural outputs (Krueger, 1992; Schiff and Montenegro, 1995; Abrar et al., 2002).

## 2.6 Agricultural Supply Response: Ghana Literature

Not many studies on the subject matter exist for Ghana. Bond (1983) is one of those few. In cross country studies, based on the Nerlove model, the studies found, inter alia, a short-run elasticity of 0.20 and a long-run sensitivity of 0.34. Frimpong-Ansah (1992), Abdulai and Rieder (1995) and Hattink et al. (1998) have all carried out cocoa supply responses for Ghana employing different estimation methodologies. Short-run elasticities from these three studies range from 0.18-0.29. A higher value range was found for the long-run, 0.42-0.72. A recent time series study by Ocran and Biekpe (2008) employed a cointegration technique to analyse a multiple product and multiple input supply response for Ghana. After aggregation, they divided the commodities into food and export. They found that producers in Ghana, unlike the findings by Bond (1983) and Mackay et al. (1999) do not respond to short-run prices but only in the long-run. Long-run average aggregate supply elasticity was found to be 0.8, a relatively higher figure than Bond's 0.34. Food commodity supply elasticity was estimated at 0.76. This figure is slightly lower than the estimate by Mackay (0.78). What is missing from these Ghanaian empirical studies is the method and type of estimation used in this study. The study by Hattink et al. (1998) is the only exception, albeit it focuses solely on a single crop (cocoa) analysis. What makes this study unique is that, unlike the focus of their work (only cocoa supply response), we model multiple outputs and multiple inputs within the framework of duality.

## 2.7 Conclusion

We have evaluated the theoretical underpinnings of agricultural supply response modelling beginning with the Nerlove model. Although a partial equilibrium model, it has been used in many studies until recently. Together with the model by Griliches, the Nerlove model is limited mainly on methodological grounds, especially when it comes to estimating the long-run supply elasticity (for developing countries). The key criticism levelled against these partial equilibrium models is that they specify the dynamics of supply in a too restrictive way. These limitations appear to have been overcome by alternative time-series models, notably co-integration and error correction models as well as general equilibrium models. It must be noted that aside from the partial equilibrium models, the remaining approaches do not offer a definite ranking in terms of superiority because all of them have their unique demerits.

They suffer from the “Lucas-critique”, biasing estimates downwards.

Cross-country regressions provide alternative estimation approach to the partial adjustment modelling and standard time-series analyses. This approach also provides a major response to the drawbacks of both the Nerlove and Griliches models. This involves more than just estimation for more than one country’s supply response. Studies by Bond (1983) and Chhibber (1989) are two leading studies along this estimation path. Cross-country studies also suffer from heterogeneity emanating from unobserved country characteristics. This causes upward bias to supply response estimates.

Most of the papers reviewed were biased towards output price supply responses. Very little consideration was given to relevant non-price incentives, which have been argued to be essential especially when conducting agricultural supply responses for developing countries. This study helps to bridge that gap for Ghana by accounting for some non-price factors.

We also reviewed alternative supply response modelling technique - the duality modelling. This is alternative to the primal approach used by all the estimation techniques described above. Unlike primal estimation, duality supply elasticities are derived. Profit function, rather than output, is the starting point for duality modelling. The approach is also tractable. In particular we amended the basic framework by incorporating technical inefficiency to carry out our empirical analysis in chapter 4 and the remaining chapters that followed.

We did not find many studies on the subject matter for Ghana. Of the few that existed, many of them adopted one of the two major time-series approaches described above. There is only one study - Hattink et al. (1998) - that had adopted the duality framework. Our work is, however, different on two fronts. Firstly, we model the duality within a multiple output-input framework, compared to a single crop (cocoa) approach used by Hattink's work. Secondly, we accounted for production inefficiency, a major problem facing many developing countries. Technical efficiency was assumed by Hattink's study.

# CHAPTER 3: DATA AND VARIABLES MEASUREMENT

## 3.1 Introduction

In an ideal scenario, to be able to estimate the models described in chapter 2, one would require a time series data. Panel data would even be preferable if the key objective is policy intervention. The above dataset was not available to Ghana regarding this sort of study - multiproduct supply response analysis. We used a cross-sectional dataset, the GLSS4.

This chapter begins by explaining the fourth wave of the Ghana Living Standard Survey (GLSS4), the main data used for the next three empirical chapters in examining the supply responsiveness of farmers in Ghana to price and non-price factors. Because the study employs the dual approach in modelling supply responses for each of the three ecological zones in Ghana, a set of outputs, inputs, quantities, prices, and other explanatory factors are either extracted or constructed from the GLSS4. To obtain the output prices, we also used the data contained in the price survey, which was conducted alongside GLSS4. We could not derive lagged prices of outputs, which could be perfect for the use of expected prices. Nonetheless, we relied on the cross-section/cross-farm price variation to estimate effects as price data showed sufficient variation. We describe both surveys- GLSS4 and price in detail and also show how the variables used for the empirical estimations are defined and constructed.

## 3.2 The Data Sources

The Ghana Living Standard Survey (GLSS4) data was obtained from the Ghana Statistical Service, the authoritative body that collected and processed the data. The survey, which was collected over a twelve month period, is a multi-topic household survey, designed to provide comprehensive information on the living standards of Ghanaian households. The main objective of the survey was to provide information on patterns of disaggregated household consumption and expenditure. Each of the ten regions in the country was represented in the survey using a two-staged sampling technique. At the first stage, 300 enumeration areas (EA) were selected using systematic sampling with probability proportional to size method where the size measure is the 1984 number of households in the EA. At the second stage, a fixed number of 20 households were systematically chosen from each selected EA to give a total of 6,000 households. An additional 5 households were selected as reserve to replace missing households. Out of the selected 6,000 households, 5,998 were successfully interviewed representing 99.7% coverage. Overall, some 25,694 eligible household members were covered in the survey. Because the focus of this thesis is agricultural supply responses, we utilized the dataset on sections 1, 2, 4(A-E), 8(A1-G) and 12(B-C). These sections capture information on household demographics, education, employment status, agriculture, and household assets respectively.

As mentioned in the introduction, we complemented the GLSS4 dataset with other primary/secondary datasets. As part of the GLSS4 survey, a price questionnaire was designed to collect prices of most essential commodities in the local markets. In this survey, each cluster had at least two visits to record the prevailing local price of outputs and some inputs. This was done to account for seasonality.

Other data collected for the period under consideration included rainfall figure from the Ghana Meteorological Department in Accra and soil quality data from the Soil Research Institute in Kumasi. It should be noted that both surveys provide only cross-sectional data. We also used these surveys as they were the latest at the time we were carrying out the study.[7]

The GLSS4 survey categorises Ghana's ten regions into three agro-ecological zones by the use of enumeration areas: Coastal, Forest and Savannah (see Figure A3.1 in chapter appendix). It was, however, difficult to work with the original zone classifications as six of the ten regions have EAs in more than a single zone (columns 3-5 in Table A3.1 in chapter appendix). As a result we could not tell which EA, hence zone, a farm is located in. This does not only make analysis difficult in terms of the geographical demarcations of the regions, but also affects inferences on domestic agricultural policy as, for example, some of the regions classified as in the Forest zone have areas in the Savannah according to the survey. A re-categorisation of the zones was therefore necessary and suitable for our objective. We re-classified the zones based on the enumeration allocations used in the survey (see last column of appendix A3.1). The new classifications still maintains the three zones. We adopted a

[7] The 5$^{th}$ wave (GLSS5 survey 2009/10) has been completed but the data has not yet been released. This time around there was no separate price data collected. Using this data to perform this sort of analysis will mean that prices needed to be adjusted to reflect 2009/10 conditions.

relatively predominant approach in these new classifications. For example, the eastern region had 30 EAs in the Forest zone, 9 in Coastal and 2 in Savannah. By our approach, we classified the eastern region as a Forest zone due to its predominant share (73%). Our classifications led to three regions - Greater Accra, Central and Volta - forming the Coastal zone; three representing the Savannah (Upper West, Upper East, Northern) zone, and four (Western, Ashanti, Eastern, Brong-Ahafo regions) making up the Forest zone (see Table A3.1 in chapter appendix).

The Coastal zone comprises of regions mostly cited near the Gulf of Guinea - Greater Accra and Central regions - and the Volta region, which is home to the largest man-made lake in the world (by surface area). They are located in the southern parts of the country. The main economic activities of the Coastal regions are farming, fishing, small scale commerce and tourism.

Regions making up the Forest zone are predominantly located in the middle belt of the country (a location usually referred to as high Forest zone) and are characterized by favorable farming conditions. Ghana's major cash crop, cocoa, performs remarkably well in this zone.

The regions in the Savannah zone are among the poorest in Ghana according to the most recent poverty census. These three regions are located in the northern part of Ghana. In terms of total land size, the Savannah zone is the biggest (Figure A3.1 at Appendix). The zone is home to very harsh agro-climatic conditions including extreme weather (rainfall and sunshine) conditions.

Table 3.1: Comparison of farmers by GLSS4 classifications of ecological zones

| Zone | Original Classification | | | | | New Classification | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | 3 | | 4 | | 5 | 6 | |
| | HH | %[a] | Farm HH | Ecological share of all farm hh (% ) N[b] | Sample[c] | HH[d] | %[a] | Farm HH | Ecological share of all farm hh (% ) N[b] | Sample[c] |
| Coastal | 2078 | 35 | 728 | 35.0 | 19.8 | 2379 | 39.7 | 1112 | 46.7 | 30.2 |
| Forest | 2720 | 45 | 1927 | 70.8 | 52.4 | 2879 | 48.0 | 1914 | 66.5 | 52.1 |
| Savannah | 1200 | 20 | 1022 | 85.2 | 27.8 | 740 | 12.3 | 651 | 88.0 | 17.7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Totals | 5998 100 | 3677 | 100.0 | 5998 100.0 | 3677 | 100.0 |

***Source:*** *Author's calculations from GLSS4*

*Notes:*

[a] *This is the proportion of respondents (from the GLSS4 survey's sample (population in our case) that represent each zone. The matching actual numbers are shown by N in the same column 4.*

[b] *This shows the proportion of farmers, out of the respondents from each zone, that constitute the sample for our study. The matching actual numbers are shown in column 5.*

[c] *This denotes the percentage of farmers (from our total sample of 3677) that represent each zone.*

*d HH denotes "households"*

In the GLSS4 survey, the population respectively drew 35%, 45%, and 20% of respondents from the Coastal, Forest, and Savannah zones (see figure A3.1 in Appendix). By contrast, the percentages for the new zones are 39.7, 48, and 12.3 respectively in that order (columns 4 in Table 3.1). Columns 2 and 5 and 3 and 6 of Table 3.1 show the farming households' distribution of the population by number and its corresponding differences in percentages. We did not use the original survey weights in our final analysis as these are not appropriate judging from the fact that we used a sub-sample of the population (only farming households in GLSS4). Although the EA allocations may be slightly different, ecological demarcations hardly change, hence differences in columns 3 and 6 should not introduce significant bias in our estimates.

Based on these new classifications, it would be insightful to know, firstly, how our sample is different from the original case and secondly, what constitutes the respective samples which will be used for the estimations in the next two chapters. The survey shows that about 61% of the respondents were farmers (3,677 out of 5,998 from columns 1 and 2 and 4 and 5 in Table 3.1 respectively). In this study, we defined 'farmers' as 'those who are engaged in agricultural crop production in the year under review'. It thus excludes those in farming managerial and supervision positions (but includes hired labour), livestock farmers (as our main focus was on crops rather than livestock), forestry workers and fishermen, hunters and those in other agricultural related work.

The survey sampling presumably reflects relative population in each region/zone. A greater proportion of households in the Savannah zone are in farming than the Forest zone, because the former is poorer and there are fewer non-farm opportunities. The lowest proportion of farm households is in the Coastal zone, as that is the most urbanised and industrialised zone.

The Forest zone has one of the most fertile farmlands in Ghana and produces the largest share of Ghana's major cash/export crop, cocoa. The Coastal zone has the lowest share of population engaged in crop production (47%) compared to the other two zones. This zone is the most urbanised and industrialised and adjoins the sea (Gulf of Guinea) so fishing is also a major primary sector activity. The Volta region boasts of the second largest man-made lake in the world (China has the biggest). The breakdown of the sampling units (column 4) clearly reflects the population density of these zones (according to the 2000 Population Census of Ghana).

### 3.3 Selection of Crops

The GLSS4 survey collected data on over fifteen agricultural crops[8]. For this study eleven individual crops are covered (Table 3.2), although this reduces to nine[9]. Cocoa and groundnut are considered tradable whilst the other seven crops are non-tradable. In selecting the crops, we employed a single criterion: a crop must be produced in at least two of the three zones (see Table A3.2 in chapter appendix). Coincidentally, the qualified crops were confirmed by Ghana's Ministry of Food and Agriculture as the most important across the three ecological zones. The selection of these crops was not to allow for direct production comparisons among the zones but rather to enable us to employ identical inputs in our modelling process. It must be noted that farming in Ghana is predominantly on a smallholder basis.

Table 3.2: Groups of crops for each zone

| | |
|---|---|
| Food Crops: | Maize, Rice, Tomatoes, Cowpea |
| Staples: | Cassava, Yam, Millet/Sorghum/Guinea Corn |
| Export/Cash: | Cocoa and Groundnut |

*Source: Author's own classifications based on the GLSS data.*

[8] We used six of these crops to carry out our empirical chapters due to data insufficiency.

[9] These crops are cultivated at the least levels and only the Forest and Savannah zones have dominance in its cultivation. For the purpose of this study, we create a new term, *migso*, to represent the summation of these three crops.

Cassava and yam are classified as root and tubers whilst maize, rice and millet are grains. Cowpea and groundnut (or peanut) are legumes and cocoa is classified as cash or industrial crop. The cultivation of yam tend to favour both the Forest and Savannah zones while cocoa has a high yield in the Forest zone, although few parts of the regions in the Coastal zone also cultivates the cash crop. Farming conditions in the Coastal regions are not favourable to millet/guinea corn/sorghum (*migso* in the study).

## 3.4 Definition and Measurement of Variables

The empirical analysis considers all Ghana and each of the three zones individually. As such weighted averages were utilized with weights being equal to zonal size according to the sampling frame. Weights are needed in order to present combined averages. In this regard, all final results are highly likely to be representative and thus give little room for the effect of regional or individual measurement error and/or sampling biases. In all, the study employs nine outputs, three variable inputs (hired labour, seeds, fertilizer), four fixed and quasi fixed inputs (land size, family labour animal power, farm equipment) and five other variables which famers in each zone have less control of (exogenous factors). The following subsections explain how each of the variables is defined or constructed and measured.

### 3.4.1 Output Quantities

The questionnaire recorded over twenty-five quantity units of measurement for each of the nine selected products for this study. The first task was to convert all local units of measurement for the nine outputs into a common unit kilogram**.** The first difficulty was to find accurate quantity conversion rates to carry out the conversion. In doing this, we employed standard and/or estimated conversion scales[10]. Each of the nine output variables is measured as the total amount of crop harvested in the previous farming season for farm households[11]. We did not account for output quantities consumed for subsistence purposes, and so focus only on outputs sold (marketed output). Also omitted from this study are both outputs given to labour (as payments in kind for labour used on the farms) and those given to

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[10] The original data did not come with these scale factors. Where the standard conversion tables were inadequate other information from Ghana was used. Details are presented in Table A3.5 in the appendix of this chapter.

[11] Final farm households' outputs are the summation of the four levels of farming occupations - the major and three alternative farming occupations. Farming is defined as before.

landowners as sharecropping. All the mentioned cases emanated from the ‘total output harvested’ and hence we measured output as the total output harvested for the period under consideration. Lack of appropriate conversion factors for some of the local units of measurement led to the rejection of few quantities of crops.

The survey data presented us with two different output choices - total harvested crops and total output sales. We opted for the latter to fit in well with our research focus, which is more on trade and hence marked outputs is of prime interest to us. The choice was also motivated by the difference between harvested and sold outputs due to either post-harvest losses and/or subsistence reasons. It is therefore obvious that we failed to account for own-consumption sharecropping repayments and outputs retained to be used for the subsequent farming season. Tables 3.3-3.5 display summarized statistics of the final outputs for each of the three ecological zones.

### 3.4.2 Output Prices

We use prices from the price survey that was conducted alongside GLSS4 to collect prices and other demographic information in the same enumeration areas used during the GLSS4 survey. In the price survey, except for cocoa, all output prices are recorded in cedi[12] (national currency) per kilogram and the information is provided for each EA in each region of the country.

Theoretically producers respond to anticipated rather than actual prices. However, it is difficult to represent expected prices in terms of observable variables. In the literature, alternative price data is used as a proxy for expected prices. Three proxies have gained the most attention: actual prices (Mallon and Musgrave, 1983), past or lagged prices (Nerlove, 1979), and future prices (Weaver and Banerjee, 1982). Future prices are either forecasted by way of expectations through agricultural futures markets, with the former method supported by economic theory. Fisher and Munro (1983) investigate which of the four methods - extrapolative expectations, adaptive expectations, naïve expectations and arithmetic lags - best captures how farmers form price expectations. They conclude that short term

[12] At the time of writing this thesis, a new currency, Ghana Cedi (Ghc), has been issued. The new debases the old by 10,000. This means the previous 10,000 cedis would be Ghc1.

expectations data in the naïve expectation framework have the highest explanatory power suggesting that surveyed producers relied heavily on the *actual price* at the time the expectations are formed. Thus any deviations will only be random, according to the rational expectations advocates.

It is fairly easy to model price expectations with time series data. However in this study, we only have observations for one survey year so estimation is from spatial (farm household) variation rather than variation over time. Provided there is sufficient spatial variation in the data, we can in effect assume that all farmers form expectations in a similar manner (with similar information) and we model their response to realized expectations (observed prices).

In this study we adopted the actual price methodology because of the unique nature of the price data. During the price survey, prices of crops were collected on three different occasions or visits. The three different market prices mirrored the lean, harvest, and 'normal' seasons where prices are expected to be above average, below average, and just about average respectively. In most cases, the data showed variations in the three prices for each crop in each region, confirming the theoretical trend in agricultural output prices during different seasons in most developing economies. This is mainly due to inadequate storage facilities to smooth out prices during lean seasons. We were unable to find any rural and urban price indices computed by the Ministry of Agriculture. Such indices may, however, not be of prime importance as they are usually designed to obtain a single (average) price accounting for spatial variation (e.g. a Fisher index) whereas we actually use the spatial prices.

A major critique in choosing to model agricultural supply as a function of current rather than expected prices is likely, theoretically (the Cobweb model), to produce a simultaneity bias. However, at crop level analysis the bias is unlikely to occur. This is mainly due to the fact that smallholder farmers produce only a small fraction of each crop and this could only affect aggregate supply marginally. Hence a change in each producer's output will do little to affect prices.

The price survey records prevailing local market prices for each crop except cocoa. Cocoa prices were derived by dividing the total value of cocoa sold by the quantity produced for each household. This meant that the cocoa price for each household was different, accounting for quality and price variation between regions and zones. In situations where we did not have corresponding output prices for any of the crops in a particular cluster, we took the average price of the immediate before-and-after cluster prices. This outcome was much preferred to using the overall cluster or ecological average price, as the former resulted in prices similar to crop prices in the given clusters. The price recovery process avoided about 40-60% of data lost. We then use the mean prices (of the three visits) of each crop to calculate the total values.

### 3.4.3 Average Output, Price and Profit of Farmers in Ghana

In terms of non-tradable crops, farmers in Ghana tend to grow more of rice and maize (Table 3.3). The ecological production matrix is mixed.

Table 3.3: Average output, price, and restricted Profits by Ghanaian farmers: by crops

| | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cow* | *Tom* | *C'va*[1] | *Yam*[2] | *Migso* |
|---|---|---|---|---|---|---|---|---|---|
| Output (kg) | 1073 | 413 | 510 | 635 | 121 | 13 | 98 | 73 | 380 |
| Productivity (Kg/ha) | 1433 | 2240 | 404 | 144 | 45 | 4 | 54 | 32 | 160 |
| Price (¢/kg) | 1318 | 1722 | 788 | 1403 | 1668 | 7766 | 442 | 891 | 378 |
| Rev. (¢'000/kg) | 1503 | 6401 | 3195 | 8290 | 1623 | 560 | 390 | 496 | 1340 |
| Profit(¢'000/kg) | 610 | 5872 | 2338 | 7559 | 775 | 420 | 236 | 338 | 585 |
| Observation | 509 | 817 | 3153 | 487 | 665 | 454 | 1663 | 459 | 613 |

*Source: Calculations from GLSS4 data. Figures are rounded to the nearest whole numbers*

*Notes: [1] is measured as cassava sticks which are usually packaged in bundles*

*[2] is measured by suckers*

The average production of these two crops in the Forest zone is above national average (Table 2.3B). The exact opposite can be said of the regions in the Savannah zone. We however observed a mixed case in the Coastal zone. Although the cultivation of rice exceeded that of the national average, maize production ebbed behind. It is difficult to know the reasons behind these figures at this stage.

Table 3.4: Average output, output price, revenue, and profit by crops: Coastal Zone

| | ***Exportable*** | | ***Food Crops*** | | | | ***Staples*** | | |
|---|---|---|---|---|---|---|---|---|---|
| *Variable* | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cowpea* | *Tom.* | *Cassava* | *Yam* | *Migso* |
| Output: | | | | | | | | | |
| Quantity (kg) | 543 | 142 | 480 | 904 | 46 | 7 | 95 | 36 | - |
| Zonal Share (%) | 21 | 4 | 30 | 8 | 6 | 14 | 38 | 14 | - |
| Price (¢/kg) | 1330 | 2790 | 1132 | 2300 | 3340 | 9260 | 616 | 1058 | - |
| Rev. (¢'000/kg) | 545 | 4434 | 3957 | 14700 | 1539 | 431 | 462 | 329 | - |
| Profit (¢'000/kg) | -318 | 4153 | 3124 | 14400 | 649 | 23 | 315 | 175 | - |
| Observation | 211 | 92 | 1007 | 26 | 99 | 132 | 658 | 111 | - |

*Note: Figures are rounded to the nearest whole number*

In terms of productivity (kg/ha), however, farmers in the Coastal regions recorded extremely higher output per hectare in maize production compared to both the national and the other two zones (we have accounted for any outliers). Assuming price factors could not explain then one is likely to attribute this performance to non-price factors such as using best farming practices (through the visits of extension officers), favourable weather (right amount and timing of rainfall) and/or other ecological factors like soil fertility.

Table 3.5: Average output, output price, revenue, and profit by crops: Forest Zone

| | ***Exportable*** | | ***Food Crops*** | | | | ***Staples*** | | |
|---|---|---|---|---|---|---|---|---|---|
| *Variable* | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cowpea* | *Tom.* | *Cassava* | *Yam* | *Migso* |
| Output: | | | | | | | | | |
| Quantity (kg) | 1453 | 256 | 536 | 905 | 147 | 17 | 99 | 71 | 268 |
| Share (%) | 79 | 18 | 57 | 42 | 33 | 84 | 60 | 83 | 4 |
| Price (¢/kg) | 1312 | 1955 | 621 | 1608 | 2246 | 7652 | 321 | 846 | 369 |
| Rev. (¢'000/kg) | 2187 | 5026 | 2920 | 13000 | 2454 | 657 | 335 | 466 | 970 |
| Profit (¢'000/kg) | 1276 | 4438 | 2041 | 12200 | 1585 | 514 | 179 | 308 | 603 |
| Observation | 297 | 238 | 1724 | 142 | 183 | 299 | 995 | 337 | 36 |

*Note: Figures are rounded to the nearest whole number*

We could, however, not establish the same (price) reason for rice (compare output/ha and price in tables 2.3A-C). The issue of land productivity will be discussed in detail.

Table 3.6: Average output, output price, revenue, and profit by crops: Savannah Zone

| | | *Exportable* | *Food Crops* | | | *Staples* | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Variable* | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cowpea* | *Tom.* | *Cassava* | *Yam* | *Migso* |
| Output: | | | | | | | | | |
| Quantity (kg) | - | 541 | 477 | 493 | 128 | 5 | 98 | 77 | 387 |
| Share (%) | - | 78 | 13 | 51 | 61 | 2 | 2 | 3 | 96 |
| Price (¢/kg) | - | 1404 | 652 | 1238 | 960 | 671 | 666 | 584 | 378 |
| Rev. (¢'000/kg) | - | 7458 | 2498 | 5687 | 1248 | 38 | 658 | 497 | 1363 |
| Profit (¢'000/kg) | - | 6905 | 1676 | 4917 | 420 | -87 | 489 | 338 | 585 |
| Observation | - | 487 | 422 | 319 | 383 | 23 | 30 | 11 | 577 |

*Note: Figures are rounded to the nearest whole number*

### 3.4.4 Variable Inputs: Use and Prices

We measured variable input prices from input costs data provided by the GLSS4 survey. There is no reliable data on input prices in the country nor was there an independent survey providing these figures, unlike that of the output prices. This means that we made use mainly of estimates. Any measurement error recorded during the survey is likely to have a pass-through effect on our estimates. The study used three variable inputs - hired labour, seeds, and fertilizers.

Agricultural labour comprises hired labour, own labour, and family labour. Own labour usually refers to the adult head of the farm household while family labour is measured usually by the number of other adults in the household. We treated hired labour and own labour as variable inputs but family labour as a quasi-fixed input. Two challenges present themselves in deriving a price for labour. Firstly, we need to ascertain the wage paid to hired labour, which was not readily available in the data. The second challenge was to compute imputed costs (wages) for own labour. We assume that only own (and family) labour was used if the number of hired labour was zero[13] but output was recorded. We applied the UNIFEM's average estimated informal (agricultural) own-labour wage rate for the imputation.[14] The UNIFEM computations were based on the GLSS4 dataset. We did not use

[13] As distinct from households with no data on hired labour (missing data).

[14] The report 'Women, Work, and Poverty in Ghana' a Background Study for *Progress of the World's Women 2005* estimated an average self-employed (own labour) earned 1331 old Ghana cedis per hour and 1334 for hired labour (who on average worked 9.7 hours per day)

off-farm wages, as many studies have utilized, because of the huge diversity in this activity and also the average non-farm wages were found to be very different from farm mean wages. Moreover, we do not know the opportunity cost across age and gender dimensions so using non-farm wages might not reflect these demographics.

The GLSS4 provides data on the total number of hired labour for each crop as well as the total cost of hired labour but not on wage rates. We derive the wage rate by dividing the value of expenditure by the number of labour employed. On average, there was not much difference compared to the estimation by UNIFEM. For farmers with missing numbers of hired labour expenditure values as well as wage rates (but had corresponding observations for outputs and quantity of hired labour), we used the wage rates from the UNIFEM's estimates for hired agricultural labour.

Finally, for those farmers who had no data on quantity of hired labour, wage rates as well as total hired labour costs, we imputed the wage rate from other related crops. In that line and coupled with data limitations we used labour data for sweet potatoes as a proxy for both cassava and yam respectively and labour for pepper to proxy tomatoes.

We did not adjust for any payments in kind to labour (e.g. outputs given to labour) since such benefits were not clear whether it relates to the harvested outputs. We summed up all the scenarios above to obtain the data for hired labour.

Total seeds expenditure could not be measured directly as the survey only produced the quantity of seeds farmers had to plough back from the previous harvest and planted for the period under consideration. The difficult task, like that of output quantities, was to convert all the nine crops from various local units of measurements into a common unit-kilogram. We applied the same conversion rates used under the output transformation. These results were a fraction of the total seeds expenditure. To obtain the full expenditure for this input, we added an imputed value of seeds purchases for the farming period under the study's consideration.[15]

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[15] These estimates were obtained from the Crop Research Institute of Ghana and confirmed by the various crop associations by telephone interview. For most crops farmers purchase 60% of the seeds required; the exceptions are cocoa, rice, and tomatoes where the proportion of seeds purchased was 90%, 100%, and 80% respectively.

We again used pepper's seed expenditure as a proxy for tomatoes for the proportion of the 'plough back seeds' after which an estimated purchases component (for tomatoes) was added.

The quantities demanded for the fertilizer input could also not be measured directly but were calculated implicitly as the total value divided by the price of the input. Farmers in Ghana use two types of fertilizer: organic and Ammonium Sulphate and hence fertilizer used in this survey comprises the sum of the two. For those farmers who do not report use of fertilizer, the ecological mean of those who applied was used.

### 3.4.5 Fixed and Quasi-Fixed Inputs

A number of farm and farm operator related variables are defined as quasi-fixed inputs in the model. In all we employed four fixed and quasi-fixed factors. As in other studies, we included farmland size (measured as the total area of land cultivated, in hectares, for a particular crop during the period under consideration) with the assumption that the variable constraints production at least in the short run. There was another task of converting all the five local land measurements units into a standard unit (hectares). We did not distinguish between ownership and leasers of land. We partially adjusted for land quality across the three ecological zones by interacting land size with soil fertility (measured as described below). We do not account for land access (due to data constraints) although it is important in terms of land reform. The amount of land cultivated for each crop (land size) was measured directly from the survey.

Following the normal dual modelling of agricultural supply responses, we used 'eligible' household size as an indicator of access to family labour. We restricted the age category of farm family labour to include 10-75 years olds due to the large informality of the sector.[16] The age-gender difference will not affect the outcome significantly since the wage differentials showed insignificant wage differentials across gender.

[16] From the survey statistics, we limited the age scope to the 10-75 range. This range did not make much difference to the 16-65 age brackets. We did not account for differences in labour quality by different age cohorts.

The other two quasi-fixed factors are animal power and farm equipment.[17] The former is measured as the quantity of draught animals including cows owned by famers (a proxy for farm household wealth). Farm equipment comprises tractors, ploughing equipment, trailer/cart, sprayer and all other animal and tractor drawn equipment (measured by number/quantity). This data is provided in the survey, but there is no data on equipment purchases, hire, or depreciation.

### 3.4.6 Average Input Use and Cost of Farmers in Ghana

Comparisons of the three ecological zones show that, cocoa and *migso* excluded, there are no significant differences in the amount of hired labour used across crops (Tables 2.4A-C). As expected, the low amount of hired labour is usually due to the substitution of family labour numbers.

Table 3.7: Average input use and cost by crops: Coastal Zone

| *Variable* | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cowpea* | *Tom.* | *Cassava* | *Yam* | *Migso* |
|---|---|---|---|---|---|---|---|---|---|
| Hired Labour: | | | | | | | | | |
| Quantity (#) | 2 | 2 | 2 | 3 | 2 | N/A | N/A | N/A | - |
| Cost (¢'000) | 210 | 172 | 110 | 121 | 141 | N/A | N/A | N/A | - |
| Seeds: | | | | | | | | | |
| Quantity (kg) | 3 | 4 | 14 | 0.4 | 0.2 | 2 | 12 | 12 | - |
| Cost (¢'000) | 62 | 44 | 52 | 53 | 79 | 59 | 75 | 76 | - |
| Fertilizer: | | | | | | | | | |
| Quantity (kg) | 9 | 4 | 5 | 6 | 4 | 5 | 5 | 9 | - |
| Price (¢'000/kg) | 15 | 18 | 17 | 18 | 18 | 18 | 18 | 17 | - |
| Cost (¢'000) | 92 | 72 | 72 | 111 | 69 | 78 | 76 | 78 | - |
| Land size (ha) | 3 | 4 | 3.3 | 2.3 | 1.4 | 2 | 2 | 3.5 | - |
| Family Lab.(#) | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | - |
| Farm Equip (#) | 1 | 3 | 2 | 3 | 2 | 2 | 1 | 1 | - |
| Animal Power (#) | 0 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | - |
| Observation | 211 | 92 | 1007 | 26 | 99 | 132 | 658 | 111 | - |

[17] These are costs that do not change with hours worked but do change with employment or usage. Quasi-fixed costs affect demand for labour but also the nature of that demand, such as the choice between hiring new employees and increasing hours worked of existing employees.

*Note: Figures are rounded to the nearest whole numbers*

*Source: Author's calculations from GLSS4*

The relatively lower cost of hired labour in the Savannah zone is high due to less economic activity in this part of the country. The data on seeds shows a similar trend to that of hired labour. Fertilizer input is however different. In terms of usage, farmers in the northern part Ghana use the least amount of fertilizer not because of the quality of the soil but rather due to the price.

Table 3.8: Average input use and cost by crops: Forest Zone

| *Variable* | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cowpea* | *Tom.* | *Cassava* | *Yam* | *Migso* |
|---|---|---|---|---|---|---|---|---|---|
| Hired Labour: | | | | | | | | | |
| Quantity (#) | 2 | 3 | 3 | 3 | 2 | N/A | N/A | N/A | 3 |
| Cost (¢'000) | 253 | 266 | 248 | 489 | 311 | N/A | N/A | N/A | 196 |
| Seeds: | | | | | | | | | |
| Quantity (kg) | 10 | 5 | 14 | 8 | 0.6 | 7 | 89 | 27 | 4 |
| Cost (¢'000) | 77 | 46 | 52 | 54 | 78 | 59 | 74 | 76 | 70 |
| Fertilizer: | | | | | | | | | |
| Quantity (kg) | 5 | 3 | 3 | 3 | 3.5 | 3.5 | 3 | 3 | 2.9 |
| Price (¢'000/kg) | 20 | 27 | 27 | 26 | 27 | 27 | 27 | 28 | 26 |
| Cost (¢'000) | 88 | 78 | 78 | 83 | 78 | 85 | 82 | 83 | 77 |
| Land size (ha) | 3 | 3.5 | 3.8 | 4.5 | 2.8 | 3.3 | 4.0 | 4.3 | 5 |
| Family Lab.(#) | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 5 |
| Farm Equip (#) | 0 | 0 | 2 | 2 | 1 | 1 | 3 | 2 | 1 |
| Animal Power (#) | 5 | 6 | 2 | 7 | 4 | 8 | 4 | 3 | 4 |
| Observation | 297 | 238 | 1724 | 142 | 183 | 299 | 995 | 337 | 36 |

*Note: Figures are rounded to the nearest whole numbers*

*Source: Author's calculations from GLSS4*

In fact, farmlands in this zone have the lowest amount of organic matter and thus low soil fertility (Table 2.5) and it would have been expected that, all things being equal, fertilizer usage in this zone would be the highest. A quick analysis of fertilizer prices across the three zones show that on average, there is a 35% increase in the input price in the Forest zone compared to prices in the Coastal regions and a whopping 51% hike in the Savannah zone compared to the Coastal regions. These price differentials cannot all be attributed to differences in transportation cost as most studies report. The total effect of the liberalisation of the agricultural sector is yet to be seen in the fertilizer input market in Ghana.

Table 3.9: Average input use and cost by crops: Savannah Zone

| *Variable* | *Cocoa* | *G'nut* | *Maize* | *Rice* | *Cowpea* | *Tom.* | *Cassava* | *Yam* | *Migso* |
|---|---|---|---|---|---|---|---|---|---|
| Hired Labour: | | | | | | | | | |
| Quantity (#) | - | 3 | 3 | 3 | 3 | N/A | N/A | N/A | 3 |
| Cost (¢'000) | - | 249 | 302 | 250 | 289 | N/A | N/A | N/A | 147 |
| Seeds: | | | | | | | | | |
| Quantity (kg) | - | 18 | 15 | 17 | 4.3 | 3 | 89 | 28 | 7.6 |
| Cost (¢'000) | - | 44 | 52 | 60 | 77 | 54 | 96 | 73 | 69 |
| Fertilizer: | | | | | | | | | |
| Quantity (kg) | - | 2 | 2 | 2 | 2.2 | 1.9 | 2.0 | 2.4 | 2 |
| Price (¢'000/kg) | | 32 | 32 | 31 | 31 | 37 | 35 | 36 | 32 |
| Cost (¢'000) | - | 62 | 69 | 59 | 62 | 71 | 73 | 86 | 62 |
| Land size (ha) | - | 3.2 | 4.0 | 5.3 | 3.2 | 2.1 | 5.8 | 4.4 | 3.0 |
| Family Lab.(#) | - | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 5 |
| Farm Equip (#) | - | 2 | 3 | 2 | 2 | 0 | 1 | 0 | 3 |
| Animal Power (#) | - | 2 | 7 | 6 | 6 | 7 | 8 | 5 | 5 |
| Observation | - | 487 | 422 | 319 | 383 | 23 | 30 | 11 | 577 |

*Note: Figures are rounded to the nearest whole numbers*

*Source: Author's calculations from GLSS4*

### 3.4.7 Other Explanatory Factors

In all, the study makes use of five exogenous factors that affect farmers' profit but these factors are beyond the control of most farmers. The effect of weather on production decisions was measured, on average, by the amount of rainfall (in millimeters) in each region and aggregated into ecological zones. Rainfall was chosen instead of temperature (in most of the literature) due to farmers' over-reliance on the rain in Ghana. To somewhat capture rainfall timing, we took the weighted average of the minor (usually) and-major (usually) raining seasons. This was done to match the pre-season and growing periods. Rainfall data was obtained from the Ghana Statistical Service. It would have been insightful if the survey collected the amount and timing of rainfall since the right amount of rain is as important as the timing. On average, the Savannah region recorded more rainfall than the rest of the two zonal regions (see Table 2.5). What could not be verified is the right amount of rainfall needed for a ‘good’ yield. The pre and growing season rainfall figures follow a similar pattern.

To capture the role of human capital on production and input use, we included farmer’s experience on the farm (measured as number of years of farming), education (years of highest level of completed formal education) and the age of the household head farmer. We grouped education into six. The least number of ‘0’ was assigned to farmers with no formal education whilst those with tertiary level qualification got the highest number ‘6’. The age and experience variables are also included to capture any non-linearity in the profit function. Each of the last three exogenous variables was derived from the GLSS4 dataset.

Table 3.10: Exogenous Variables by ecological zones

| Variable | Coastal | Forest | Savannah |
|---|---|---|---|
| Household Education (highest completion level) | 3.0 | 3.2 | 2.7 |
| Household Head Age (years) | 30 | 44 | 49 |
| HH head Farming Experience (farming years) | 8 | 12 | 18 |
| Soil Fertility (level organic matter) | 10.54 | 10.53 | 6.67 |
| Rainfall (mm) | 10.83 | 11.19 | 20.41 |

*Source: Author’s calculations from GLSS4*

It must be known, however, that literacy measures alone will be inadequate. Supply responsiveness is likely to be affected considerably by the training and skills of farmers and/or agricultural extension officers.

The data on age and experience sheds more light as to why agricultural activities have and continue to dominate Ghana’s economic activity scale. As expected most farmers in northern Ghana have the oldest age and have been in the farming business for longer (Table 2.5). Two reasons explain this. Firstly, farmers in this part of the country have the lowest levels of education (see Table 2.5). Our data reveals that on average, the highest level of formal education completed by farming household heads, in the period under discussion, is at the junior high level. In terms of comparison, farmers in the three northern regions of Ghana have the least (primary level). However the impact of formal education on farm output is unclear. The second reason, based on GLSS data, could be attributable to the low degree of non-farm enterprises that exist in the Savannah zone. Non-farm enterprises are seen as a diversifiable economic activity. From the data, the other two zones have more non-farm enterprises.

Choosing a suitable indicator to proxy soil fertility was equally challenging as most of the indicators used in major works have been found ineffective in most tropical countries. It is believed that in the tropics, like Ghana, what matters most is not the soil alkalinity or the soil's ph but rather the amount of organic carbon in the soil (Soil Research Institute, Ghana). It is this chemical element that helps crops to produce their best yields. Soil fertility in this study was thus measured by the amount of organic carbon in the soil (k/jg) and this dataset was obtained from the same Institute. We obtained regional figures that were later aggregated to zonal levels. The data shows that the three regions in northern Ghana (Savannah zone) have the lowest level of organic matter in their soils. This means that naturally it is difficult for crops to yield their utmost unless much inorganic factors like fertilizers and/or hybrid seeds are used in these parts of the country.

Ideally a comprehensive supply response analysis will incorporate other factors such as social systems (e.g. land ownership systems), tenancy structures, and government policies but we could not capture any of these owing to data limitations.

It should be noted that the omission of agro-climatic factors in the ensuing estimations do not render our results invalid. This is because we have estimated three agro-climatic zonal models which accommodate, at least to some extent, such factors.

#### 3.4.8 Distribution of Farmlands

Crucially important for the success of any agricultural development is the amount of and/or access to farmlands. The success of the green revolution is in part attributed to the access of land and basic farm infrastructure such as irrigation. Theoretically agricultural productivity is inversely related to farm size in many developing countries. This may be due to market imperfections, such as missing rural land and labour markets. Empirical studies affirm this relationship (see Kimhi (2003) on Zambia). There is also the argument of economies of scale in farming, where positive relationships are established. This could be attributed to lumpy inputs such as machinery. It is therefore not conclusive, at least from a theoretical viewpoint, the exact relationship between farmland size and actual productivity, although other empirical studies have found an inverted U-shape non-monotonic relationship between agricultural productivity and farm size.

Hayami (2003) argues that Japan's agricultural success is in part due to the smallholder system. On the other hand Malaysia's oil plantation success comes from operating large scale farms. The system in Ghana is mixed. Table 3.11 shows the distribution of plot size used for the cultivation of the crops.

Table 3.11: Distribution of farmland (size) use by famers in Ghana: by crops

| | ***Land distribution in hectares (%)*** | | | | |
|---|---|---|---|---|---|
| ***Crop*** | <1.00 | 1.00-1.99 | 2.00-2.99 | 3.00-3.99 | >3.99 |
| Cocoa | 21 | 1 | 28 | 37 | 14 |
| G'nut | 1 | 2 | 4 | 78 | 15 |
| Maize | 3 | 1 | 3 | 76 | 16 |
| Rice | 1 | 0 | 5 | 1 | 93 |
| *Migso* | 2 | 2 | 9 | 73 | 13 |
| Cowpea | 0 | 18 | 33 | 46 | 3 |
| Cassava | 6 | 2 | 3 | 76 | 14 |
| Yam | 2 | 0 | 0 | 24 | 74 |
| Tomatoes | 4 | 0 | 33 | 64 | 2 |

*Source: Author's calculations from GLSS4. Figures represent percentage of farmers rounded in nearest whole numbers. This means horizontal totals might not exactly sum up to 100*

During the period 1998/99, the majority of Ghanaian farmers had access to at least 3 hectares of farmland for production purposes, with the exception of cocoa farmers who had a more spread out farmland allocation. It is not difficult to recognise that the theoretical inverse relationship between plot size and productivity applies to the case of Ghana when one compares Tables 3.3 and 3.11. For example about 93% of rice farmers own or have access to at least four hectares of land (compared to 14% of cocoa farmers and 19% of maize farmers) but the average yields per hectare for the latter crops far exceed rice productivity. There is also the positive relationship in the case of tomatoes and cowpea farmers.

Plot size allocations in the ecological zones are somewhat different from the national position (Tables 3.12-3.14). Unlike the case where rice and yam farmers typically have large farm plots, groundnut farmers in the Coastal zone have access to four or more hectares of farmland more than any other farmer.

Table 3.12: Distribution of farmland by crops (% of farmers): Coastal Zone

| *Crop* | *Land distribution in hectares (%)* | | | | | Totals | |
|---|---|---|---|---|---|---|---|
| | <1.00 | 1.00-1.99 | 2.00-2.99 | 3.00-3.99 | >3.99 | % | # |
| Cocoa | 21 | 0.5 | 64 | 0.5 | 14 | 100 | 211 |
| G'nut | 1 | 1 | 1 | 0 | 97 | 100 | 92 |
| Maize | 6 | 1 | 4 | 84 | 6 | 100 | 1007 |
| Rice | 4 | 4 | 85 | 4 | 4 | 101 | 26 |
| *Migso* | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Cowpea | 1 | 99 | 0 | 0 | 0 | 100 | 99 |
| Cassava | 7 | 2 | 2 | 80 | 9 | 100 | 658 |
| Yam | 2 | 0 | 0 | 98 | 0 | 100 | 111 |
| Tomatoes | 2 | 2 | 95 | 1 | 1 | 101 | 132 |

*Note: Figures are rounded to the nearest whole numbers*

*Source: Author's calculations from GLSS4*

All but cocoa and cowpea farmers in the Coastal zone use at least 2 hectares of farmland in the cultivation of their crops during the period under discussion. This is different from both the Forest and Savannah zones, where a greater proportion of farmers have access to farm plots, the minimum being 2 hectares.

Table 3.13: Distribution of farmland by crops (% of farmers): Forest Zone

| *Crop* | *Land distribution in hectares (%)* | | | | | Totals | |
|---|---|---|---|---|---|---|---|
| | <1.00 | 1.00-1.99 | 2.00-2.99 | 3.00-3.99 | >3.99 | % | # |
| Cocoa | 20 | 2 | 2 | 62 | 14 | 100 | 297 |
| G'nut | 1 | 0.0 | 1 | 95 | 2 | 100 | 238 |
| Maize | 2 | 2 | 2 | 89 | 5 | 100 | 1724 |
| Rice | 1 | 1 | 0 | 0 | 98 | 100 | 142 |
| *Migso* | 3 | 0 | 0 | 0 | 97 | 100 | 36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cowpea | 0 | 0 | 97 | 0 | 3 | 100 | 183 |
| Cassava | 6 | 3 | 3 | 75 | 14 | 101 | 995 |
| Yam | 2 | 0 | 1 | 0 | 98 | 101 | 337 |
| Tomatoes | 0 | 0 | 0 | 98 | 2 | 100 | 299 |

*Note: Figures are rounded to the nearest whole numbers*

*Source: Author's calculations from GLSS4*

Table 3.14: Distribution of farmland by crops (% of farmers): Savannah Zone

| *Crop* | *Land distribution in hectares* | | | | | Totals | |
|---|---|---|---|---|---|---|---|
| | <1.00 | 1.00-1.99 | 2.00-2.99 | 3.00-3.99 | >3.99 | % | # |
| Cocoa | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| G'nut | 1 | 3 | 6 | 84 | 6 | 100 | 487 |
| Maize | 3 | 1 | 6 | 4 | 87 | 100 | 422 |
| Rice | 0 | 0 | 0 | 1 | 99 | 100 | 319 |
| *Migso* | 2 | 2 | 10 | 78 | 8 | 100 | 577 |
| Cowpea | 1 | 5 | 10 | 80 | 5 | 101 | 383 |
| Cassava | 3 | 0 | 0 | 0 | 97 | 100 | 30 |
| Yam | 0 | 0 | 0 | 0 | 100 | 100 | 11 |
| Tomatoes | 4 | 0 | 96 | 0 | 0 | 100 | 23 |

*Note: Figures are rounded to the nearest whole numbers*

*Source: Author's calculations from GLSS4*

Land access/plot sizes available to cocoa farmers in the Coastal and Savannah zones need a quick comment. About a fifth of its farmers cultivate the crop under a hectare of land at both zones. In terms of plot size used for the crop, the export/cash crop is produced on a relatively larger scale in the Forest zone than the Coastal (see Tables 3.4 and 3.5 for confirmations).

Cereal farmers - rice and maize - in the Savannah zone relatively have more plot size than its counterparts in the other two zones but the zone's actual production is comparatively lower (compare Tables 3.12-14 with Tables 3.4-3.6), again demonstrating the negative relationship between plot size and productivity. A similar trend reflects the cultivation of staples, *migso*.

### 3.5 Farm Incomes and Poverty Distributions

In Ghana, the major source of household income is agriculture (37%), followed by non-farm self-employment (31%), wage employment (23%), net remittances (5%), rental income (2%) and other income (2%) (G.S.S., 200a). Table 3.15 shows the component of incomes sources in Ghana 1998/99. Agricultural income share for the Savannah zone remains the highest of the three zones. Rural Savannah's share alone is about 31%, far more than the income shares from rural forest zone.

Table 3.15: Distribution of household income by component, locality, ecological and quintile

Based on GLSS4 dataset (1998/99): Percentages (%)

| | Wage Employment Income | Household Agricultural Income | Non-farm self-employment Income | Rental Income | Income from Remittances | Other Income | Total |
|---|---|---|---|---|---|---|---|
| *Ecological Zone*:* | | | | | | | |
| Coastal | | | | | | | |
| Cedis ('000) | 22.24 | 144.29 | 182.49 | 4.53 | 15.48 | 2.36 | 371.40 |
| Income Share (%) | 7.3 | 49.6 | 29.3 | 3.2 | 9.6 | 1.0 | 100.0 |
| Forest | | | | | | | |
| Cedis ('000) | 23.26 | 310.21 | 152.62 | 4.79 | 15.39 | 3.71 | 509.98 |
| Income Share (%) | 4.3 | 69.3 | 18.4 | 1.6 | 5.4 | 1.0 | 100.0 |
| Savannah | | | | | | | |
| Cedis ('000) | 12.82 | 226.78 | 72.57 | 4.36 | 6.68 | 2.34 | 325.54 |
| Income Share (%) | 3.1 | 70.3 | 15.4 | 3.5 | 6.3 | 1.4 | 100.0 |
| *Locality* | | | | | | | |
| Urban | 32.3 | 10.3 | 39.7 | 1.8 | 13.0 | 2.8 | 100.0 |
| Accra | 34.7 | 7.9 | 42.4 | 2.1 | 10.8 | 2.0 | 100.0 |
| Other Urban | 30.3 | 12.3 | 37.5 | 1.6 | 14.9 | 3.5 | 100.0 |
| Rural | 13.7 | 54.0 | 23.8 | 2.2 | 4.9 | 1.4 | 100.0 |
| Rural Coastal | 18.7 | 35.1 | 35.2 | 2.9 | 7.1 | 1.0 | 100.0 |
| Rural Forest | 15.6 | 54.6 | 21.4 | 1.8 | 4.7 | 1.8 | 100.0 |
| Rural Savannah | 6.4 | 71.4 | 16.0 | 2.0 | 3.0 | 1.2 | 100.0 |
| *Quintile:* | | | | | | | |
| Lowest 20% | 6.3 | 59.7 | 20.4 | 4.1 | 7.6 | 1.9 | 100.0 |
| Second 20% | 13.4 | 53.1 | 25.3 | 2.3 | 4.6 | 1.3 | 100.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Third 20% | 14.5 | 49.4 | 26.9 | 2.2 | 5.4 | 1.5 | 100.0 |
| Fourth 20% | 23.0 | 36.9 | 29.3 | 1.7 | 7.4 | 1.7 | 100.0 |
| Highest 20% | 29.0 | 20.3 | 34.6 | 1.5 | 11.7 | 2.9 | 100.0 |

*Source: Ghana Statistical Service (2000a) and calculations from GLSS4 dataset*

*Note: * These figures are from farm households (3,677) only*

A low degree of wage employment and especially non-farm enterprises remain the lowest in this zone. Rural coastal income sources are spread across wage employment, agriculture, non-farm activities and remittances. As expected, the availability of non-farm enterprises in the urban sectors is demonstrated by their proportion of income coming from wage employment and non-farm self-employment. The distribution of farm incomes is akin to that of the poverty distributions shown by Tables 3.16 and 3.17. The two tables draw comparisons between the 1991/92 and 1998/99 GLSS surveys.

Table 3.16: Comparisons of GLSS3 and GLSS4 food poverty incidence by location, region and at the national level.

| | GLSS3 (1991/92) | | GLSS4 (1998/99) | |
|---|---|---|---|---|
| | Poverty Index | % Contribution to National Poverty | Poverty Index | % Contribution to National Poverty |
| National | 36.5 | 100 | 26.8 | 100 |
| *Location:* | | | | |
| Rural | 47.2 | 86.3 | 34.4 | 85.6 |
| Urban | 15.1 | 13.7 | 11.6 | 14.4 |
| *Coastal zone/Regions:* | | | | |
| Greater Accra | 13.4 | 4.3 | 2.4 | 1.1 |
| Central | 24.1 | 6.8 | 31.5 | 10.5 |
| Volta | 42.1 | 10.4 | 20.4 | 9.5 |
| *Forest zone/Regions:* | | | | |
| Western | 42.0 | 11.7 | 13.6 | 5.9 |
| Eastern | 34.8 | 12.3 | 30.4 | 13.2 |
| Ashanti | 25.5 | 11.1 | 16.4 | 10.3 |
| Brong Ahafo | 45.9 | 14.9 | 18.8 | 6.1 |
| *Savannah zone/Regions:* | | | | |

| | | | | |
|---|---|---|---|---|
| Northern | 54.1 | 14.0 | 57.4 | 21.9 |
| Upper West | 74.3 | 6.4 | 68.3 | 8.2 |
| Upper East | 53.5 | 8.2 | 79.6 | 13.4 |

*Source: Ghana Statistical Service (2000a)*

On the basis of the Ghana Living Standards Survey (GLSS) data and a food poverty line set at the estimated annual expenditure per person required to meet minimum nutritional requirements, the poverty incidence in Ghana fell from nearly 37% in 1991/92 to 27% in 1998/99 (Table 3.16). Given the rise in the population numbers, this means a drop from 5.8 to 5.0 million people faced with food poverty. Christiaensen et al. (2002) report consumption poverty indices for 1992 and 1998 of 51% and 39% respectively, based on the food intake required to meet a minimum caloric intake with adjustments for essential non-food consumption.

There are large rural and regional differences in poverty levels and their changes. Poverty has fallen steeply in Greater Accra and other regions but has increased in the Central, Northern and Upper East regions (Table 3.16). At the national level, the reduction in poverty was almost entirely due to economic growth. The overall redistribution effect was negligible, although it played an important role in the Accra region where reduced inequality helped reduce poverty significantly (IMF 2000).

Table 3.17: Comparisons of GLSS3 and GLSS4 poverty incidence by employment

| Economic Activity | GLSS3 (1991/92) | | GLSS4 (1998/99) | |
|---|---|---|---|---|
| | Poverty Index | % Contribution to National Poverty | Poverty Index | % Contribution to National Poverty |
| Export farmers | 49.6 | 8.5 | 19.4 | 5.1 |
| Food crop farmers | 51.8 | 61.7 | 45.0 | 64.6 |
| Non-farm self-employment | 23.3 | 17.7 | 18.1 | 22.8 |
| Public sector | 21.2 | 7.9 | 9.5 | 3.8 |
| Private formal sector | 15.1 | 1.6 | 4.5 | 0.8 |
| Private informal sector | 22.5 | 1.9 | 16.1 | 1.7 |
| Non-working | 13.0 | 0.7 | 15.1 | 1.2 |

*Source: Ghana Statistical Service (2000a)*

The Economic Recovery Programme (ERP) and the resulting economic growth led to significant improvements for households engaged in export farming and for those in formal employment, in both the public and private sectors. Households in the food crop farming sector continued to perform worst, with the incidence of food poverty falling from about 52% to 45% for this group over the 1991/92 to 1998/99 period (Table 3.17). By 1998/99, households in the food crop farming sector accounted for 65% of national poverty, up from 62% in 1991/92.

These developments reflect the fact that the ERP benefited primarily export-oriented farmers. Outside the export sector agriculture grew sluggishly and, with weaker income growth and fewer non-farm income-earning opportunities, this negatively impacted on the welfare of food crop farmers. In the northern parts of the country (Northern and Upper Regions), where most farmers are dependent on food crop farming, poverty worsened as a result of lower agricultural and off-farm earnings.

### 3.6 Conclusion

The GLSS4 dataset is comprehensive but still lacks some vital variables needed to undertake crucial agricultural supply analysis. This means that some of the variables needed to be derived. Where we could not, those variables were omitted completely. Ecological and agro-climatic factors were omitted. The data shows rather poor information on farm capital, a necessary tool for achieving higher yields in the crop subsector. Farmers in all three zones could not boast of more than two farm equipments. Irrigation would have been a better choice considering the climatic conditions of the country. However, data on this variable is limited. Another area of concern was the uneasiness to work with conversion tables for different units of measurements prompting and delaying data analysis.

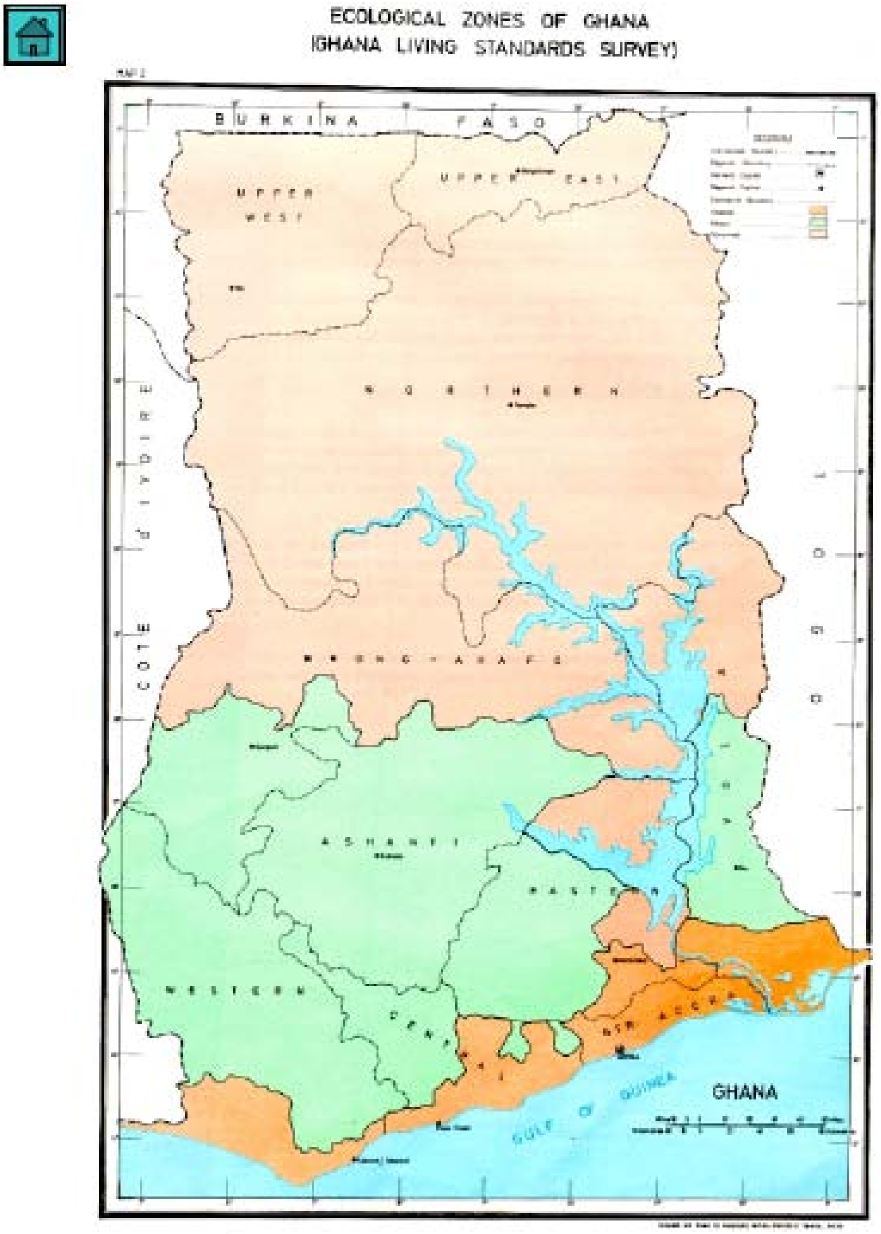
Ideally a farm-based survey data would be the best choice. Nonetheless, the dataset provided relevant information on most of the variables used in our estimation.

## Chapter 3 Appendix

**A3.1:** Allocation of Ecological Zones in GLSS4

Figure A3.1 shows how the GLSS4 survey demarcated Ghana into three ecological zones: Coastal (pink regions), Forest (green regions), and Savannah (orange regions).

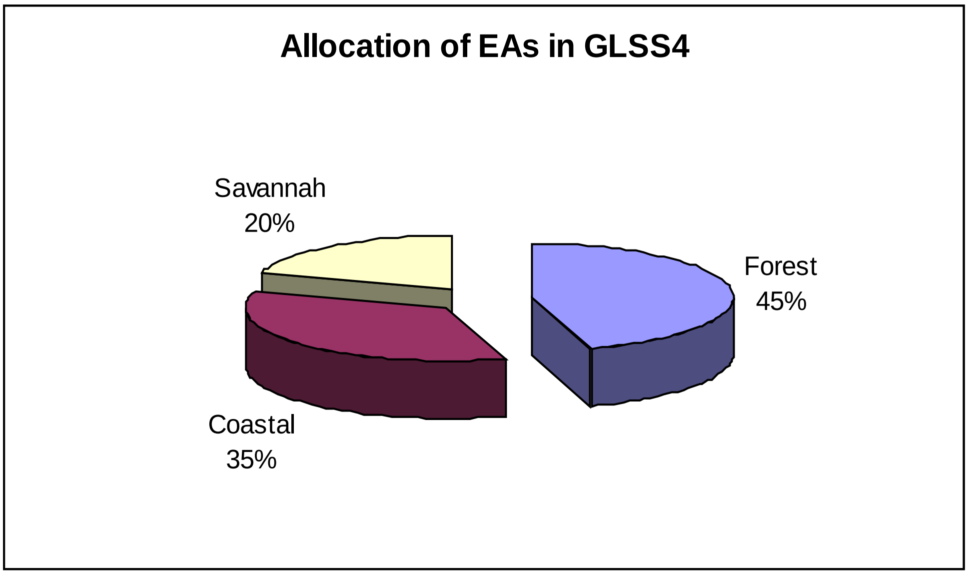
*Fig. A3.1: Map showing ecological zones according to GLSS4*




*Source: GLSS4 Secretariat of the Ghana Statistical Service*

In the survey itself, the choice of sampling units from each of the zones did not follow the size of the regions *per se* but rather according to the population density of the zones.

*Fig.A3.2: Allocation EAs in GLSS4 survey*




*Source: Ghana Statistical Service*

Figures A3.1 and A3.2 respectively show that although the Savannah zone is by far the biggest in terms of size, yet the zone had only 20% of the sampling unit in the survey.

Table A3.1: Allocation of GLSS4 enumeration areas (EAs) and our Decision

| *Region* | *Total EAs in GLSS4* | *No. of EAs in Coastal* | *No. of EAs in Forest* | *No. of EAs in Savannah* | *Our Classification* |
|---|---|---|---|---|---|
| Gt. Accra | 43 | 41 | 2 | 0 | Coastal |
| Central | 35 | 27 | 8 | 0 | Coastal |
| Western | 32 | 14 | 18 | 0 | Forest |
| Eastern | 41 | 9 | 30 | 2 | Forest |
| Volta | 32 | 13 | 9 | 10 | Coastal |
| Ashanti | 53 | 0 | 53 | 0 | Forest |
| B. Ahafo | 27 | 0 | 16 | 11 | Forest |
| Northern | 18 | 0 | 0 | 18 | Savannah |
| U. West | 6 | 0 | 0 | 6 | Savannah |
| U. East | 13 | 0 | 0 | 13 | Savannah |
| **Total** | 300 | 104 | 136 | 60 | |

Based on the above allocations and for simplicity reasons, we adopted the criteria of relative enumeration area (EA) dominance in allocating the regions into ecological zones. Thus we have three regions making up the Coastal (Gt. Accra, Central, Volta) and Savannah (Upper West, Upper East, Northern) zones respectively, and four regions (Western, Ashanti, Eastern, Brong-Ahafo) making up the Forest zone.

Re-classifications were necessary due to the nature of the inherent difficulties. The basic idea is that within the regions of each zone there are sub-regions with the agro-climatic characteristics of a different zone. Ideally we would want to be able to examine which zone the farm household characteristics in these sub-regions are most similar to. Maintaining the original classifications, we were not able to tell clearly which EA some farm units belong to.

It is important to recognise that our analysis is at the ecological rather than EA level so the re-classification of the regions would not affect the EAs allocations. For policy reasons, it could be imperative to carry out ecological-based analysis. The EAs are mostly for data collection and political reasons (in demarcating constituencies for election purposes). Hence we do not foresee a drastic bias in our approach.

Table A3.2: Final selection of crops across agro-ecological zones in Ghana

| Crop Group | Crop Selected | Coastal | Forest | Savannah |
|---|---|---|---|---|
| Cereals/Grains | Maize | √ | √ | √ |
| | Rice | √ | √ | √ |
| | Sorghum/Millet/Guinea Corn | X | √ | √ |
| Staples | Cassava | √ | √ | √ |
| | Yam | X | √ | √ |
| Legumes | Cowpea | √ | √ | √ |
| | Groundnut/Peanut | √ | √ | √ |
| Vegetables | Tomatoes | √ | √ | √ |
| Industrial/Exports | Cocoa | √ | √ | X |

*Notes:* √ denotes crop is cultivated in that zone; and X is otherwise.

# CHAPTER 4: CROP LEVEL AGRICULTURAL SUPPLY RESPONSE BY ECOLOGICAL ZONE IN GHANA

## 4.1 Introduction

The effectiveness of agricultural policy depends on the responsiveness of agriculture with economic incentives. Any reform to restructure the incentive system at the farmers' level through different agricultural development policies requires detailed knowledge of supply response behaviour. In Ghana, agriculture policies have been directed towards achieving higher outputs for food security.

The strategy to utilize the agricultural sector as the catalyst for economic growth and hopefully to reduce poverty (especially rural poverty), has been rekindled in Ghana. This strategy has received a huge boost from the donor community since it is believed that agriculture has special powers in reducing extreme poverty (WDR, 2008). The renewed development strategy has received large resources ranging from inputs subsidisation to supply of selected agro-equipment with the aim to modernising the sector in order to increase supply and enhance its competitiveness (for trade). Most of the effort has been geared towards obtaining the 'correct' market prices for outputs (supporting output prices). For example, some farmers are guaranteed ready markets for their produce either by para-governmental agencies or agricultural 'middlemen'.

The aim of Ghana's policy choice to overly concentrate on supporting output prices (at the expense of inputs) is clear - to help farmers increase outputs for sufficient domestic consumption and export. Nevertheless, agricultural outputs have only seen a minimal increment nationally in spite of the injection of huge amount of resources. Can Ghanaian farmers increase output in commensuration to the chosen policy design? What policy ingredients are needed to move outputs beyond the current margins if Ghana is to use agricultural development as a tool for achieving the targeted annual economic growth rate of 7% on average?

The success of this renewed commitment will depend, to a large extent, on how agricultural producers (mostly smallholder farmers) respond to these policies. What would be more interesting is to see how farmers respond to non-price factors as very little attempt is directed towards this area of incentives. Clearly most developing countries will be faced with the choice of choosing either price incentive policies (supporting output prices) or non-price incentive policies (subsidizing inputs). Which approach will optimize farmers' responses? A systematic supply response analysis, price and non-price, will be needed to guide policy.

Given the policy relevance of agricultural supply responses and the limited amount of evidence on its size in Ghana, especially on food and cash (export) crops, this chapter attempts to add to the literature albeit we adopt a different methodology - the duality framework. This is the second difference. This work uses modified cross-sectional data discussed extensively in the previous chapter to estimate output supply and input demand elasticities for six selected crops in three ecological zones of Ghana. This study is unique on two fronts. Firstly we use cross-sectional data, which is different from studies that employ time series analyses. The few cross-sectional studies adopt the primal production estimation methodology. Cross-sectional studies by themselves do not inform policy. However, knowledge of agricultural supply responses at such disaggregated units will provide useful policy signposts for practitioners and stakeholders.

Two set of analyses are discussed in this chapter. The first, at ecological level, is solely limited to the three ecological agricultural zones in Ghana - Coastal, Forest and Savannah. Ecological elasticities, apart from providing general response indicators to policy makers, give a guiding principle to local authorities as to what is essential in maximising regional agricultural budgets. The second task is to evaluate total (national) supply responses. This follows from the findings and recommendations by the study of Binswanger (1994), that price change only leads to crop mix shifts rather than pass-through effect in total agricultural output change. Specifically, we investigated the response of total output changes to potential changes in the prices of individual crops.

Preceding the actual estimations is a brief description of the duality framework - the main methodological framework used for the analysis in this chapter. The final econometric model is then discussed followed by the examination of the results.

## 4.2 The Duality Estimation Framework

The two fundamental approaches used in studying production decisions are the production function (primal approach) and the profit function (dual approach). Under appropriate regularity conditions, and with the assumption of profit maximization, both functions contain the same essential information on a given production technology.[18] The dual approach has several advantages over the primal approach. Firstly, prices are specified as the exogenous variables as opposed to input quantities in the primal approach. In microeconomic studies, especially at farm level, it is shown that prices are the proper exogenous variables (Wall and Fisher, 1987). A statistical advantage related to specifying prices as the independent variables is the fact that prices are usually less collinear than input quantities (Varian, 1992).

Another advantage the dual has over the primal is that estimates of output supply, input demand, and the price (and cross-price) elasticities are more easily derived. However, when the primal approach is utilized, the matrix of estimates has to be inverted to derive elasticities, whereas with the dual approach, the elasticities are simply the derivatives of the profit function. Finally, the dual approach is more flexible for modelling multiple output and input systems (what this study seeks to do) than the primal approach, which because of the axiom of non-jointness, makes it difficult to specify adequate specification of a multiple output production technology (Varian, 1992; Abrar et al. 2004a).

In the dual approach, the production technology set is not estimated directly. Instead, a profit, cost, or revenue function is estimated. This study employs a variant specification of the profit function. If we assume that farmers attempt to maximise restricted profit, defined as the return to the variable factors, then a profit maximisation problem, according to Lau (1976, 1978a) can be expressed as:

$$\text{Max}\ \Pi\,(\mathbf{p},\mathbf{w};\mathbf{z}) = Max\ \mathbf{p'y} - \mathbf{r'x} \tag{4.1}$$

$$s.t.\ F(\mathbf{y},\ \mathbf{x};\ \mathbf{z}) \leq 0,$$

where $\Pi$, $p$, $w$, respectively, represent restricted profit (defined as total revenue less variable costs), and vectors of output and input prices. The variables $y$ and $x$ represent vectors of

[18] See Lau (1978a), Nadiri (1982), Varian (1992), and McFadden (1978) for more discussion

output and input quantities respectively. *F(.)* is the production technology set of the producer. The set of control variables are defined by *z*. The restricted profit function represents the maximum profit the farmer could obtain with available prices, fixed factors, and production technology. Given that the profit function has passed the regularity tests (i.e. convexity, monotonicity, and homogeneity tests) and one applies the Hotelling's Lemma theorem (this theorem allows us to relate the supply of a good to its profit function. This is done by finding the first derivative of the profit function with respect to output prices) to the profit function, we obtain profit-maximising output supply and input demand functions, given by equations (4.2) and (4.3), respectively

$$y_m(p, w; z) = \frac{\partial \Pi(p, w; z)}{\partial P_m}, \quad \forall\ m = 1, ..., M, \tag{4.2}$$

and

$$-x_n(p, w; z) = \frac{\partial \Pi(p, w; z)}{\partial W_n}, \quad \forall\ n = 1, ..., N. \tag{4.3}$$

where *m* and *n* index the outputs and variable inputs respectively. The first equation (4.2) is the output supply function. There are usually four functional forms (translog, generalised Leontief, generalised Cobb-Douglas, and the quadratic forms) of the profit function that have been used in the literature. A choice of a particular specification, in part, depends on the nature of the dataset available. On the basis of better fit and conformity to regularity properties, Wall and Fisher (1987), show that the translog profit function stands out (see appendix - A4.1 - for a detailed account of the four different specifications). Once an appropriate functional form has been chosen, which satisfies the regularity conditions for duality between the profit and transformation functions, the parameters of equations (4.2) and (4.3) can be empirically estimated. The estimated coefficients are then used to derive the elasticities that describe the production relations of multiple-input, multiple-output farms. The derived elasticities are the output supply and input demand responses.

## 4.3 Data, Model and Estimation Process

We employ some versions of the GLSS wave 4 data described extensively in chapter 3. Unless otherwise stated, all variables are defined and measured as described in the previous chapter. Summarised descriptions of the variables used are presented in Table 4.1. In all, six outputs[19], two variable inputs (seeds and chemical fertilizers after wages for hired labour was used as a *numeraire*), three fixed and quasi-fixed variables (land size, family labour, farm animal capital) and three control variables are used in the final estimation. The data is grouped into the three ecological zones. It should be noted that in this and the next chapter we have assumed that all output is allocated to the primary enterprise. In chapter 6, we relax this assumption by proportionally allocating dominant outputs to inputs.

The appropriate functional form, empirically, is a compromise between theoretical underpinnings and econometric feasibilities. A commonly used form, and the one adopted in this study, is the transcendental logarithmic functional form by Christensen et al., (1973).[20] This is one of the most commonly used flexible functional forms for the profit function. This model is popularly used in agricultural supply analysis and appears to fit data from the sector well mainly because of its flexibility strength (Farooq, et al., 2001) and the fact that it adheres strictly to regularity properties (Wall and Fisher, 1987). The downside of this functional form, however, is that it cannot produce non-constant elasticities and hence cannot capture any non-linear relationships between output supply and input demand equations.[21]

The translog form has been found to be more sensitive to farm-level data than the quadratic specification. Indeed our goodness-of-fit check confirmed the suitability of the translog specification, based on the data used for this chapter (see Table A4.1 in appendix). An added merit of the Translog form, as opposed to the quadratic form, is that the choice of a *numeraire* in the former specification does not drastically affect the final estimates (Kumbhakar, 1996).

The Translog profit function used for this study is specified econometrically as:

[19] We initially used nine outputs but due to less variation, we dropped three crops - tomatoes, cassava and yam.

[20] The quadratic functional form has also been found to be useful and indeed fit our data well too. For robustness we use this functional form in the estimations in chapter 5.

[21] This anomaly is rectified when using the quadratic functional form, which is adopted in the next chapter. Thus the use of translog in this chapter and quadratic in the next is a barometer of robustness.

$$
\left.\begin{aligned}
&ln\pi^*(p,w,z;\beta) = \beta_0 + \sum_i \beta_i \, ln(P_i^*) + \sum_v \beta_v \, lnW_v^* + \sum_m \beta_m \, lnZ_m + \\
&\sum_i \sum_v \beta_{iv} \, ln(P_i^*) \, lnW_v^* + \sum_i \sum_m \beta_{im} \, ln(P_i^*) \, lnZ_m + \sum_v \sum_m \beta_{vm} \, lnW_v^* \, lnZ_m \\
&+ \frac{1}{2}\left[\left(\sum_i \sum_j \beta_{ij} \, ln(P_i^*) ln\left(P_j^*\right) + \sum_v \sum_r \beta_{vr} \, lnW_v^* lnW_r^* + \sum_m \sum_k \beta_{mk} \, lnZ_m lnZ_k\right)\right] + \varepsilon
\end{aligned}\right\} \quad (4.4)
$$

where

| | |
|---|---|
| $\pi^*$ | = restricted variable profit, normalized by the price of labour |
| $P_i^*, P_j^*$ | = price of outputs, respectively, normalized by the price of labour |
| $W_v^*, W_r^*$ | = price inputs, respectively, normalized by the price of labour |
| Z | = quantity of fixed and quasi-fixed inputs (land size, family labour, animal capital) and other farmer social-demographic and human capital factors (farmer age, education and farming experience). |

The *βs* are parameters to be estimated and *ε* is an error term with the usual properties.

It would be ideally beneficial to include ecological variables such as rainfall and soil fertility but inadequate data have limited their inclusion. As noted earlier in the thesis, this would not have a greater impact (unbiasedness of the estimates) as our estimations are carried out on an ecological basis. The trade-off would be to compromise the efficiency of the estimates.

The corresponding derived equations (output supply and input demand) are correspondingly expressed by equation (4.5) with the application of the Hotelling's Lemma property to equation (4.4).

$$
\left.\begin{aligned}
&S_y(\boldsymbol{p},\boldsymbol{w},\boldsymbol{z};\boldsymbol{\beta}) = \frac{P_i X_i}{\pi_i} = \frac{\partial ln\pi(.)}{\partial lnP_i} = \beta_i + \sum_j \beta_{ij} \ln\left(P_j^*\right) + \sum_v \beta_{iv} \ln(W_v^*) + \\
&\qquad \sum_m \beta_{im} \ln(Z_m) + e_y \\
&-S_v(\boldsymbol{p},\boldsymbol{w},\boldsymbol{z};\boldsymbol{\beta}) = \frac{P_v X_v}{\pi_i} = \frac{\partial ln\pi(.)}{\partial lnW_v} = -[\beta_v + \sum_v \beta_{vr} \ln(W_r^*) + \sum_i \beta_{iv} \ln(P_i^*) + \\
&\qquad \sum_m \beta_{vm} \ln(Z_m) + e_v \\
&i = \overline{1,6} \; v = \overline{1,2}, \; and \; m = \overline{1,6}
\end{aligned}\right\} \quad (4.5)
$$

where $S_i$ and $S_v$ represent, respectively, vector of outputs and variable inputs. To estimate the profit and the associated output and input function, linear homogeneity (in prices) is automatically imposed because of the normalized specification used and hence homogeneity cannot be tested. Responses under the translog framework would be semi-elasticities. In what follows, Table 4.1 describes the variables used in both equations (4.4) and (4.5).

Table 4.1: Summary of variables used in regression

| Variable Category | Variable Name | Description/Measurement |
|---|---|---|
| Profit | Restricted farmer profit ($\pi^*$) | Total revenue less variable costs in cedis, normalized by the price of labour |
| Prices of Outputs | Output price ( $P_i^*, P_j^*$ ) | Average market price of harvest crops, normalized by the price of labour |
| Prices of Inputs | Input Price ( $W_v^*, W_r^*$ ) | Price of variable inputs in cedis, normalized by the price of labour |
| Fixed/quasi fixed (Z) | Land Size | Total area cultivated in hectares |
| | Family Labour | Total number of labour available to a farming household between the ages 15 and 65 inclusive |
| | Animal Capital | Total number of farm animals available to a farming household |
| Control Variables | Age | Farmer age in years |
| | Experience | Total farmer experience in years |
| | Education | Farmer formal education in years |

The homogeneity is imposed by normalizing all prices of outputs and inputs as well as profits by the price of labour (the *numeraire*). The wage rate was chosen because it was the only variable that produced a closer normal distribution of our data. Due to inadequate data, three of the nine outputs (cassava, yam and tomatoes) were dropped from the analysis. Besides, total seeds estimation for cassava and yam could not have been without errors in measurement. On the beneficial side, dropping them from the estimation improved the model fit. For the monotonicity property to hold in the translog model, the estimated output shares must be positive. The convexity property is assumed to hold in a translog specification (Wall and Fisher, 1987) and hence not tested.

We did, however, test for the symmetry restriction where $\beta_{iv} = \beta_{vi,\ \forall_{i,}} v = \overline{1,3}$. The final estimation is therefore a system of six output equations and two input (seeds and fertilizer) demand equations. We did not estimate the demand function for the labour variable input because the price of (hired) labour was used as the *numeraire*. We iteratively estimated equations (*4.4*) and (*4.5*) simultaneously using the Seemingly Unrelated Regression (*SUR*) technique. The (Marshallian) demand and supply price and price-cross elasticities are respectively computed from equations (*4.5*).

## 4.6 Discussion of Findings

It is important we model three different profit functions for each of the three ecological zones (Coastal, Forest, and Savannah) because of the multiple input-output matrices used. We could not include agro-climatic factors such as rainfall and soil fertility due to invariance in the data. We did, however, include farmer socio-demographic and human capital factors, to account for any heterogeneity.

### 4.6.1 Output Supply and Input Demand Functions

We estimated the system of equations made up of six output supply and two input demand functions. Table 4.2 summarises the output supply and input demand estimates. These are not the elasticities but estimated coefficients from equation (4.4). The chapter appendix (Tables A4.2 to A4.4) carries the full detailed estimates. Overall we found, in conformity with expectations, the right signs. Many of the estimates are significant although some estimates are low.

Farmers are likely to increase (reduce) supply (demand) for higher output (input) prices with input reaction relatively higher. The positive response to the price of outputs and strong negative response to the prices of fertilizers and seeds provide some evidence confirming Ghanaian producers were responding to some market signals after years of market pricing reforms (profit maximisers), a component of the Structural Adjustment Programme (SAP). It also gives an indication that sectoral price policy reforms before the GLSS4, such as the ASRP (1987-90) and the early part of the MTADP (1991-2000), were quite effective.

Table 4.2: Summarised Output Supply and Input Demand parameters: price effects only[A,B]

| Own Price of Output /Input | Coastal | Forest | Savannah |
|---|---|---|---|
| *Outputs* | | | |
| Cocoa | 0.064** | 0.608*** | - |
| Groundnut | 0.061* | 0.928*** | 0.597* |
| Maize | 1.084*** | 1.014* | 0.309* |
| Rice | 1.050* | 1.184*** | 0.194** |
| *Migso* | - | 0.247** | 1.026*** |
| Cowpea | 0.444* | 0.191* | 0.420* |
| *Inputs* | | | |
| Fertilizer | -1.433** | -1.125** | -0.825** |
| Seeds | -1.600*** | -0.602*** | -0.541** |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively.*

[A]*:Complete table can be found in appendix (Tables A4.2 – A4.4)*

[B]*:Figures have been stated in percentages*

Farmers in the Savannah zone recorded the least reaction to changes in the prices of both inputs with coastal farmers picking up the largest. We hypothesise that the low input response could be as a result of the subsidy given to farmers in this part of the country. Maize and rice farmers responded very well to own price crops than any of the other crops. As expected, *migso* farmers in the Savannah zone are likely to respond heavily to price changes of the staple crop. Aside from prices, it is also important to notice how farmers responded to non-price factors - size of farmland, family labour and human capital (household education and experience). Tables A4.2 through to A4.4 (in chapter appendix) present the entire output supply and input demand estimates for each of the three zones. The following subsection discusses the degree of responsiveness by farmers across the three ecological zones.

#### 4.6.2 Estimation of Elasticities

*Outputs Supply Elasticities*

Table 4.3 shows the ecological own-price elasticities for the three zones. All the elasticities are significant and positive as expected. Apart from cocoa, the results show that farmers in the Coastal zone are more likely to respond relatively heavily to price changes than their counterparts in the other zones. These and all elasticities are low, which is to be expected as we only have cross-section variation for one year. Farmers are unable to look at prices over time.

Markets in and around the Coastal zone are relatively well organized compared to the rest of the cities in the other two zones. Reardon and Timmer (2006) argued out the importance of market proximity to supply responses. Proximity to a ready market and satisfactory infrastructure, they argued, serve as production 'incentives' for farmers to respond to the least price changes. There is the likelihood that the cities in the Coastal zone could benefit from ready market for agricultural produce, although this assertion needs further investigation.

Table 4.3: Output Own-Price Elasticities for three ecological zones

| Crop | Coastal | Forest | Savannah |
|---|---|---|---|
| Cocoa | $0.04^{*}$ | $0.08^{***}$ | - |
| Groundnut | $0.12^{***}$ | $0.06^{*}$ | $0.09^{***}$ |
| Maize | $0.10^{***}$ | $0.05^{***}$ | $0.04^{**}$ |
| Rice | $0.15^{**}$ | $0.07^{***}$ | $0.02^{**}$ |
| *Migso* | - | $0.06^{**}$ | $0.14^{**}$ |
| Cowpea | $0.13^{**}$ | $0.09^{**}$ | $0.06^{*}$ |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively*

Moreover, farmers in and around the Coastal zone also benefit from the country's ports and harbours, thus reducing transaction costs for exportable farmers. Another reason could be attributed to greater competition from food imports.

Cocoa is different. Farmers of this cash crop recorded the highest response rate in the Forest zone mainly because the cultivation of cocoa is heavily concentrated in the regions making up the Forest zone. Beyond the 'incentive' argument, there are other non-price factors that motivate cocoa farmers to increase the yield such as family labour, land size, animal capital and the education of farmers.

The response rate to changes in the price of exportables (cocoa and groundnut) is mixed. The results show that coastal farmers are likely to respond more to changes in the price of groundnut than cocoa. The reverse is the case for farmers in the Forest zone, where a 10%

increase in the prices of cocoa and groundnut are likely to lead to about 0.8% and 0.6% increase in the cultivation of cocoa and groundnut respectively. In a related manner, coastal farmers are likely to respond more to food crops - maize, rice, cowpea - than exportables. This, in part, could be attributed to the relatively short harvest periods of the latter set of crops.

Table 4.4: Output Cross-Price Elasticities

| | Coastal | Forest | Savannah |
|---|---|---|---|
| *Substitutes* | | | |
| Groundnut-Cowpea | $-0.22^{***}$ | $-0.08^{**}$ | $-0.15^{***}$ |
| - Cocoa | $-0.01^{*}$ | - | - |
| Maize-Rice | $-0.17^{**}$ | $-0.31^{***}$ | $-0.04^{**}$ |
| -*Migso* | - | - | $-0.10^{***}$ |
| Rice - *Migso* | | | $-0.09^{***}$ |
| *Complements* | | | |
| Groundnut-Cocoa | - | $0.19^{***}$ | - |
| -Maize | $0.11^{**}$ | $0.14^{***}$ | $0.32^{***}$ |
| -Rice | $0.20^{***}$ | $0.18^{**}$ | $0.09^{*}$ |
| -*Migso* | - | - | $0.16^{***}$ |
| Maize-Cowpea | $0.09^{**}$ | $0.08^{***}$ | $0.14^{**}$ |
| Maize- *Migso* | - | $0.09^{**}$ | - |
| Rice-Cowpea | $0.18^{***}$ | $0.41^{**}$ | $0.07^{**}$ |
| *Migso*-Cowpea | - | - | $0.12^{***}$ |

*Note: $^{*}$, $^{**}$, $^{***}$ denote level of significance at 10%, 5% and 1% respectively*

Table 4.4 shows the various cross-price supply responses. Overall the cross-price elasticities show five pairs of substitutes and eight pairs of complements distributed across the three ecological zones. Farmers who grow both export crops are likely to have a mixed response to changes in the price of one of the two crops. For instance farmers in the Coastal zone are likely to increase the cultivation of groundnut by almost 0.01%, on average, should the price of cocoa go up by 1%. However, farmers in the Forest zone are likely to reduce the cultivation of groundnut by nearly 0.19% for the same change in the price of cocoa. It should be noted, however, that the 0.01% increase in groundnut cultivation recorded by coastal farmers is only true at 90% confidence level and was not within expectation. Crop substitution is most likely when the crops do compete for inputs, requiring land or labour at the same time.

It is also imperative to note farmers' responses to export-food price changes. Farmers who simultaneously cultivate groundnut (export crop) and cowpea (food crop) are likely to treat the two crops as substitutes whilst growers of both groundnut with either maize or rice are likely to treat the pair as complements across the three zones. Another revelation was the reaction of *migso*-maize farmers: on one hand those crops are treated as substitutes (by Savannah zone farmers) and on the other as complements (by Forest zone farmers), suggesting that promoting crops production warrants different approaches to different regions of the country. It could also suggest differences in soil quality (for example Savannah may only support one crop per year, whereas Forest may sustain two or more).

The response relationship between food crops and the staple crop (*migso*) is also as expected. Although the staple crop is seen as the major direct substitute to rice or maize in the Savannah zone, our results show that farmers who cultivate *migso* and any food crop are likely to respond heavily to the staple's complements (0.16 and 0.12) rather than its substitutes (0.10 and 0.09). This trend is not surprising as it reflects the structure of smallholder agriculture in Ghana. Many farmers in Ghana prefer to hedge themselves against large increases in food prices during lean or bad seasons and thereby are likely to grow more than one crop (usually two), thus are likely to treat both crops as complements rather than substitutes. This is usually called mixed cropping. Crops are either planted at the same time or rotated depending on the farming seasons.[22]

Apart from serving as a buffer stock in times of food shortages (and its ripple effects on food prices), such practice is seen as an income smoothing technique for farmers in developing countries especially in cases where non-farm activities are limited (Chirwa, 2007). The system of smallholder agriculture could explain the relative large coefficients in the complementarity nature of the crops in Table 4.4. 'Production timing' could be yet another reason behind the complementarity. If planting and harvesting times differ and/or agronomic benefits of inter-cropping are present, one expects the appearance of such complementarity.

[22] This technique could raise some econometric concerns. One has to find a way to handle this complexity - modelling divisible outputs against non-divisible inputs. For example, allocating a given farmland size to one (usually the largest share) output could lead to some bias in the parameters. We address this problem in chapter 6, where we check the sensitivity of the parameters.

The final category of output supply elasticities is presented in Table 4.5. The results show the rate at which farmers respond, in terms of output supply, to changes in the prices of either seeds or chemical fertilizers, but not both simultaneously. Theoretically, given input price ratios, a fall in the price of one of the inputs will culminate in negative effects in both (input) substitution and (output) production. As expected, all the estimates are negative and statistically significant.

Higher prices for essential variable inputs (seeds and fertilizers) are likely to make profit maximisers react appropriately - negative. On average, farmers in the Coastal zone will respond relatively more to any change in the price of seeds than that of fertilizers for all the selected crops, except for maize and cocoa, but the latter is statistically not significant. This explanation should be treated with caution as there is no data showing the intensity of the inputs discussed by way of regions and by crops.

Table 4.5: Output supply responses *w.r.t.* variable inputs prices

| | Coastal | | Forest | | Savannah | |
|---|---|---|---|---|---|---|
| Crop | Seeds | Fertilizer | Seeds | Fertilizer | Seeds | Fertilizer |
| Cocoa | -0.15*** | -0.07 | -0.06** | -0.16* | - | - |
| Groundnut | - 0.16** | -0.08*** | -0.08** | -0.12** | -0.19*** | -0.39** |
| Maize | -0.13*** | -0.17*** | -0.11*** | -0.22*** | -0.06** | -0.20*** |
| Rice | -0.18 *** | -0.13** | -0.13*** | -0.18** | -0.12*** | -0.27*** |
| *Migso* | - | - | -0.08** | -0.15*** | -0.05 *** | -0.23** |
| Cowpea | -0.11 ** | -0.07** | -0.07*** | -0.11*** | -0.09*** | -0.03*** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance respectively.*

On the contrary, fertilizer price changes seem to attract a relatively greater response from farmers in both the Forest and Savannah zones. For instance, whilst maize and rice farmers in the Coastal zone are likely to reduce output supply by 0.17% and 0.13% respectively for any given 1% rise in fertilizer prices, their fellow counterparts in the Forest and Savannah zones are likely to ebb their supply by a larger cut - 0.22% and 0.18% (Forest) and 0.20% and 0.27% (Savannah), respectively. Two factors could be responsible for this. Firstly, it is possible fertilizers are scarce in the Forest and Savannah zones thereby triggering hikes in its prices promoting farmers to use less of the input and therefore less output. The second reason, deriving from the first, could allow some famers to turn to other substitutes. A direct substitute could be animal manure.

*Input Demand Elasticities*

Our results show that the elasticity of substitution between animal capital and fertilizer is almost 0.25 and statistically significant, suggesting a possible substitution between those two inputs (Table 4.6). A similar conclusion holds for cocoa when we consider crop-level input and cross-price elasticities (not reported), except that the figure was statistically insignificant. Assuming our data sources are accurate on cocoa fertilizer usage then it is likely that the recent improvements in cocoa seedlings (hybrid and relatively high yield) may account for this, in addition to some sort of animal manure.

Table 4.6: Input Demand Elasticities (Own- and Cross-Price): Combined Sample[23]

| | Seed | Fertilizer | Land Size | Animal capital |
|---|---|---|---|---|
| Seed | -0.31*** | | | |
| Fertilizer | -0.11*** | -0.18*** | | |
| Land Size | -0.13** | -0.28*** | -0.06** | |
| Animal Capital | -0.22** | 0.24*** | -0.15*** | -0.09** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance.*

On the contrary, seeds (and seedling plants) appear to be very crucial to farmers in the Coastal zone in particular so much so that farmers are likely to respond the greatest, on average, than farmers in the other two zones to changes in the price of the underlying input. Staple growers in the Savannah zone are likely to respond more to changes in fertilizers than to seeds. This is not very surprising as fertilizer use in this part of the country is low, prompting the governments' initiative to subsidize the price of the input. However, the emergence of 'middlemen' has distorted the market for fertilizers, resulting in the wide variation in prices, which is helpful as our estimates are based on the cross-section variations rather than time.

[23] With symmetry imposed

From the major importers or manufacturers, the fertilizers usually reach the final end-users (farmers) through intermediary channels consisting of registered wholesalers/retailers, located in most of the regional capitals. These registered wholesalers/retailers distribute fertilizers through a network of rural shops dealing in agricultural inputs and located in the districts. Alternatively, farmers may buy fertilizers directly from the wholesalers or the rural retail shops, whichever they find convenient. There are about 700 (as of 2004) rural retailers of fertilizers spread throughout the country, with the highest concentration in the maize belt in the Brong Ahafo region (part of the Forest in our study).

The supply channel is likely to be short if the Agricultural Development Bank, the bank responsible for officially providing finance to the sector, becomes the only intermediary between importers/manufacturers on the one hand and farmers on the other. The lengthier the distribution chain, the more distorted the price of fertilizer becomes, in most cases rising through extra costs such as loading and unloading charges, transportation, storage costs, insurance, interest on loans and the erratic exchange rates in Ghana. The retail prices of 15-15-15 and Urea (the most common types of fertilizers used in Ghana) rose by 828% and 923% between 1990 and 1998 respectively. Between 1999 and 2002, the retail prices shot up by 208% and 191% respectively for the two types of fertilizers (FAO, 2005).

There are also regional/zonal price disparities. Fertilizer prices, on average, increased by almost 50% between the Coastal and Forest zones between 1998 and 1999. In the same period, fertilizer prices in the Savannah zone increased by about 90% compared to Coastal prices. The main reason for such price rises is due to the fact that the fertilizer market is completely privatised. In the 1970s and 1980s subsidies on fertilizers were among the major incentives given to farmers by the government of Ghana. From 1987 onwards, subsidies were removed gradually. By 1989 all subsidies had been withdrawn. After this period, fertilizer prices started its sustained increasing trend. Any meaningful fertilizer policy would therefore have to put measures in place in getting prices ‘right’ and/or drastically narrow the growing huge regional/zonal price disparities.

Information in Table 4.6 suggests that there are five combinations of complementarities among the inputs used for this study. Each for these five input complementarities - seed with fertilizer, land size, animal capital, fertilizer with land size and land size and animal capital, are not unexpected. Fertilizers and animal capital are seen as substitutes. In this case, a more expensive fertilizer would lead to farmers substituting manure for fertilizer, and animal capital provides readily access. As this result is based on cross-sectional data (and animal capital is seen as a stock variable), its implication is that farmers with more (farm) animals can use and reduce fertilizer purchases if prices are higher.

Of all the own-price input demand elasticities, farmers will reduce the purchases of seeds (although not categorized into crops) by almost 0.31% should the price of seeds go up by 1%. This compares with a purchase reduction of 0.18%, 0.06%, and 0.09% for fertilizers, land size and animal capital for a similar percentage change in these inputs respectively. The relative importance of seeds and fertilizers are by no means crucial in the development of Ghana's agricultural sector. By this, their accessibility and affordability must be among policy targets if the sector is to be 'modernised'. One such policy was the launching of the Ghana Agro-Dealer Development (GADD) project to increase the use of modern agricultural inputs such as seeds, fertilizers and crop protection products with a view to raising the productivity and incomes of smallholder farmers (MOFA, 2003).

*Non-Price Elasticities*

In his paper, Thiele (2002) strongly argues the importance of incorporating non-price factors into agricultural supply responses in Sub-Saharan countries, where the agrarian sector is the major growth contributor. In assessing agricultural supply responses in Africa, Thiele, 2002 and FAO, 2011 argue that much of the impediments to supply responses are not about getting prices 'right' but rather the implicit non-price factors which are mostly ignored by many studies. He recommended inter alia that *"emphasis should then be on the removal of non-price constraints which limit agricultural production"*. Chhibber (1989) concluded his study of supply responses in developing countries by saying that price is certainly not the most limiting factor for agricultural output but non-price factors. He argues that once the non-price restrictions are eliminated, the price sensitivity of the supply increases sharply.

Finding the balance, Schiff and Valdes (1992) caution that a 'good' agricultural supply response should incorporate both price and non-price factors. In our study, four non-price factors - land size, animal capital, family labour and education of the farm household head –

were included.

Table 4.7: Output Non-Price Elasticities: Coastal

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | ***Migso*** | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | 0.19** | 0.08*** | 0.30** | 0.16*** | - | 0.09*** |
| Animal Capital | 0.04* | 0.06*** | 0.09*** | 0.07*** | - | 0.05** |
| Family Labour | 0.12** | 0.10*** | -0.08** | -0.13 | - | 0.09* |
| HH Education | 0.08*** | 0.05*** | 0.08*** | 0.11*** | - | 0.06*** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance.*

The summary of farmers' responses to non-price factors across the three ecological zones is presented in Tables 4.7-4.9. Farmers' non-price elasticities range from a low of minus 0.15% (Savannah zone maize farmers) to a high of 0.35% (Forest zone rice farmers).

Land size is seen to be a very crucial non-price input to the production of rice, maize, cocoa and groundnut in all three ecological zones.

Table 4.8: Output Non-Price Elasticities: Forest

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | ***Migso*** | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | 0.19*** | 0.20*** | 0.11** | 0.35*** | 0.02** | 0.09*** |
| Animal Capital | 0.04* | 0.13*** | 0.06*** | 0.05** | 0.08*** | 0.16* |
| Family Labour | 0.13** | 0.10** | -0.05* | -0.10* | 0.19** | 0.09* |
| HH Education | 0.10*** | 0.19*** | 0.06*** | 0.14*** | 0.04*** | 0.12*** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance.*

In fact, farmers are predicted to increase their cultivation of rice and maize, the two most consumed grains in Ghana, by 0.35% and 0.30% in the Forest and Coastal zones respectively with any 1% hectare increase in farmland size. Export crops, cocoa and groundnut, are expected to increase by almost 0.20% each in output supply, given the same incremental change in the percentage of the size of farmland (1%). Apart from animal capital, farmers in the Savannah zone consider the size of farmland as the most important factor, especially groundnut, maize and rice farmers.

Table 4.9: Output Non-Price Elasticities: Savannah

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | - | 0.18*** | 0.07*** | 0.06*** | 0.01*** | 0.08** |
| Animal Capital | - | 0.24*** | 0.12** | 0.10*** | 0.12*** | 0.14*** |
| Family Labour | - | 0.09*** | -0.15** | 0.08*** | 0.13** | 0.11** |
| HH Education | - | 0.07*** | 0.10*** | 0.04*** | 0.09** | 0.03*** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance.*

Farmers who cultivate staples in the latter zone, however, do not consider land size as the most important non-price factor. The overall positive responses to changes in the size of farmland (Table 4.11) suggest the need for a strategic reform to the size of farmland, an issue which has been a major impediment to successful agricultural progress in Ghana.

Animal capital remains the dominant non-price factor for farmers in the Savannah zone so much so that groundnut farmers are predicted to increase supply by nearly 0.25% should the number of farm animals increase by 1%, other factors controlled for. We believe animal capital serves as both farm 'equipment' (ploughing and tilling) and a rich source of organic manure, more so when fertilizer prices in the zone are relatively expensive.

Manure from these farm animals may be regarded as a direct substitute for chemical fertilizers. A detailed study on Kenya farmers has shown that animal manure can serve as a direct substitute for chemical dairy farmers who could not afford chemical fertilizers (Otsuka and Yamano, 2005). The authors believe a large production of these manures could spark a 'white revolution' (similar to green revolution in East Asia) in Kenya in particular and Sub-Saharan Africa.

Table 4.10: Crop Rankings and Non-Price Factors

| Non Price Variable | Crop Rankings (Best three) | Matching Ecological Zone |
|---|---|---|
| Land Size | Rice, Maize, Groundnut | Forest, Coastal, Forest |
| Animal Capital | Groundnut, Cowpea, Maize | Savannah, Forest, Savannah, |
| Family Labour | *Migso*, Maize, Cocoa | Forest, Savannah, Forest |
| HH Education | Groundnut, Rice, Cowpea | Forest, Forest, Forest |

*Rankings based on Tables 4.7, 4.8, and 4.9*

Whilst human capital (farmers' education) was found to be a positive booster to agricultural supply across all the zones in Ghana (see Table 4.11), family labour recorded mixed results. The two major different outcomes of its marginal (significant positive and negative) effects communicate an important message. Studies on Africa that completely omit family labour are likely to lead to biases in the supply response elasticities. Due to massive unemployment in the region, family labour is seen as crucial to the survival of many farms. Maize farmers in each of the zones are likely to respond inversely to the supply of family labour. In contrast, rice farmers will respond to family labour differently across the three ecological zones.

Table 4.11: Non-Price Factor Rankings and Crops

| Crop | Non-Price Factor Rankings |
|---|---|
| Cocoa | Land Size, Family Labour, HH Education |
| Groundnut | Animal Capital, Land Size, HH Education |
| Maize | Land Size, Animal Capital, HH Education |
| Rice | Land Size, HH Education, Animal Capital |
| *Migso* | Family Labour, Animal Capital, HH Education |
| Cowpea | Animal Capital, Land Size, HH Education |

*Rankings based on Tables 4.7, 4.8, and 4.9*

Tables 4.10 and 4.11 present two different (although crude) policy approaches to addressing non-price elasticities. They should be treated as policy substitutes in the light of budget constraints. The policy target for Table 4.10 is to address, for each non-price factor, the three most significant crops that farmers are likely to increase its supply the most at its corresponding zone. For instance, any farmland reform (for agricultural purposes) should begin with rice, maize and groundnut farmers in the Forest, Coastal and Savannah zones respectively on a pilot study before rolling it out to other ecological zones. In similar vein, a policy to educate farmers will be of much social benefit to the country if it begins with famers who cultivate groundnut, rice and cowpea, all in the Forest zone. Holding other factors unchanged, such a policy direction is likely to lead to a 0.19%, 0.14% and 0.12% increase in total output supply of the respective crops. For example one more year of formal education of the farmer will increase maize production in the Savannah zone by 0.10%, with other estimated factors fixed. This shows how non-price factors are important to the dynamics of supply responses in developing countries.

An alternative policy target would be to focus on crop development *viz a viz* non-price factors as illustrated by Table 4.11. Apart from the staple crop, farmland size is a crucial non-price factor that farmers are likely to respond to positively. According to this policy path, in encouraging the cultivation of cocoa, policy should be directed to addressing access to farmland, management of family capital and educating household farmers of the techniques to be adopted before and during cultivation, as well as harvest and post-harvest measures. These priorities are likely to change if the policy target is directed to the development of another crop, say rice or maize, where much emphasis should be placed on access to farmland size and animal capital as well as educating farmers. These policy priorities, if replicated ecologically, could provide a sound guide towards the development of major crops in each zone, thereby avoiding a 'one-for-all' agricultural policy usually fashioned for many developing countries, Ghana included. This could go a long way to ensure food security in each of the zones (in the case of Ghana), thus reducing the food import bill.

## 4.7 Conclusion and Policy Implications

We sought to estimate supply responses to six crops - cash or export crops (cocoa and groundnut), food crops (maize, rice and cowpea) and staple (millet and sorghum referred to as *migso*). We used the dual (profit) framework as compared to the usual primal methodologies. On methodological and empirical grounds, we opted for ecological estimation (although estimated as a system of equations) as supposed to its alternative of using (ecological) dummy variables to account for differences in key parameters. The latter is usually not sufficient when differences are subtle.

Several conclusions emerge from the findings. Firstly, our results confirm the common assertion that agricultural supply response has the ability to respond to both price and non-price incentives and Ghana's case was no different. In terms of price responsiveness, farmers in the Coastal zone demonstrated the highest response for each of the six crops except for cocoa and *migso*, which showed strong responses in the Forest and Savannah zone respectively, mainly due to the high degree of concentration of the crop cultivation.

Secondly, our results run counter to the common pessimism regarding the Savannah agriculture's ability to respond to better incentives, particularly in the case of price incentives. There were mixed results across the zones regarding the nature of responses to price incentives. Farmers in the Coastal zone responded relatively well to non-export crops. By contrast, Forest zone farmers showed a higher response rate towards the two cash crops.

Thirdly, our results confirmed the significance of essential inputs - seeds and fertilizers - to the success of any agricultural progress. As such, farmers would react strongly to increases in the prices of these inputs. What might also jeopardize farmers' ability to respond positively to output supply will be a large price disparity in these inputs between the three ecological zones. This will encourage arbitrage to the benefit of 'middlemen' but to the detriment of both farmers and the economy. As expected also, our results established the complementarity of fertilizer with seeds and farmland size. Fertilizer and animal capital came out as input substitutes and that magnitude, 0.24, was relatively large and statistically significant at 1% level.

Our observations from non-price elasticites would challenge supply responses that concentrate solely on price responses. In most cases, non-price factors (size of farmland, family labour, animal capital and education of household head) recorded relatively higher elasticities than price factors in all ecological zones. For instance nearly 3 out of 10 maize farmers in the Coastal zone will respond to increases in the size of farmland, compared to 10% reaction to potential maize price increases.

These results have important policy implications. As the results show, agricultural policies aimed at boosting production either for food security or exports can only succeed if they address both price and non-price factors. Although we used only four non-price factors due to data limitations, we believe other non-price factors such as soil fertility, rainfall, farmland access, financial constraints and other agro-climatic factors ought to be considered. In doing this, we recommend spatial planning and formulation and implementation of these policies as our results have shown. The one-fit-all policy should be minimized, if not abolished altogether. Sectoral agricultural policies should be pursued. Our recommendation will provide uniqueness in the policies for each zone. Tables 4.10 and 4.11 provide policy options.

Another area of policy concern would be to consider opening up new frontiers in our export markets by considering other non-cash crops such as maize, rice and cowpea as our results on own price and cross price elasticities show. Farmers in each of the zones responded well to these non-traditional crops with changes in both price and non-price incentives. Any policy strategy to boost the production of these crops is likely to be pro-poor growth driven as the majority of Ghana’s poverty numbers are in the food growing agricultural sector.

## Chapter 4 Appendix

Table A4.1: Goodness-of-fit Criteria

| Functional Form | Adjusted $R^2$ | $C_p$ Criterion[1] | AIC[2] | Schwarz's[3] |
|---|---|---|---|---|
| Quadratic | 0.53 | 0.06 | 14.5 | 13.8 |
| Translog | 0.55 | 0.03 | 10.1 | 9.7 |
| Generalised | 0.46 | 0.08 | 9.8 | 10.7 |
| Cobb-Douglas | 0.44 | 0.11 | 12.2 | 9.0 |

*1: In choosing a model based on this criterion, the model with low Cp value is preferred to a higher Cp value. The reader should refer to Gujarati and Porter, basic Econometrics 4th ed. (PP 494-495) for detailed exposition on the Colin. L. Mallow's (Cp) goodness-of-fit criterion.*
*2, 3: the lower the value, the better the model*

Based on the adjusted $R^2$ and *Cp* criteria, the translog function appears superior (i.e. fits the data better than any of the remaining functional forms). The difference between the translog and quadratic is not much, suggesting the possibility that the latter functional could also be used for this dataset. We use the translog in chapter 4 and the quadratic in chapter 5 for the purposes of sensitivity checks. Both the Akaike and Schwarz criteria give conflicting signals.

Table A4.2: Output Supply and Input Demand Function Estimates: Coastal Zone

| Variable | Cocoa | Groundnut | Maize | Rice | Cowpea | Fertilizer | Seed |
|---|---|---|---|---|---|---|---|
| Price of Cocoa | 0.064 | 0.517 | 1.323 | 0.892 | 0.099 | 1.285 | 1.112 |
| | (2.17)** | (1.69) * | (1.71) * | (1.03) | (2.34) * | (0.94) | (2.04) ** |
| Price of Groundnut | 0.517 | 0.061 | -0.443 | 0.644 | 0.049 | 1.152 | 0.930 |
| | (1.69) * | (1.94)* | (2.88) *** | (1.20) | (2.05) ** | (4.63) *** | (2.64) ** |
| Price of Maize | 1.323 | -0.443 | 1.084 | 0.705 | -1.181 | 1.201 | 1.026 |
| | (1.71) * | (2.88) *** | (3.06) *** | (5.04) *** | (3.05) *** | (3.41) *** | (3.14) *** |
| Price of Rice | 0.892 | 0.644 | 0.705 | 1.050 | 0.177 | 1.082 | 1.063 |
| | (1.03) | (1.20) | (5.04) *** | (1.81) * | (0.85) | (2.54) *** | (1.78) * |
| Price of Cowpea | 0.099 | 1.049 | -1.181 | 2.177 | 0.444 | 2.425 | 1.009 |
| | (2.34) * | (2.05) ** | (3.05) *** | (0.85) | (0.86) * | (2.85) *** | (2.94) *** |
| Price of Fertilizer | -1.285 | -1.152 | -1.201 | -1.082 | -2.425 | -1.433 | 1.008 |
| | (0.94) | (4.63) *** | (3.41) *** | (2.54) *** | (2.85) *** | (1.88)** | (3.04) *** |
| Price of Seed | -1.112 | -0.930 | -1.026 | -1.063 | -1.009 | 1.008 | -1.600 |
| | (2.04) ** | (2.14) ** | (3.14) *** | (1.78) * | (2.94) *** | (3.04) *** | (2.58) *** |
| Land Size | 1.118 | 1.895 | 0.052 | 0.233 | -0.989 | 0.112 | 1.081 |
| | (3.89) *** | (2.07) ** | (2.12) ** | (2.00) ** | (1.01) | (4.73) *** | (3.13) *** |
| Animal Capital | - | 1.091 | 0.360 | 0.245 | 0.033 | 1.021 | 0.560 |
| | | (0.82) | (2.97) *** | (2.14) ** | (2.88) *** | (2.19) ** | (2.11) ** |
| Education of HH | 0.322 | 0.070 | 0.400 | 2.112 | 1.063 | 0.807 | 1.001 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1.22) | (3.01)*** | (2.09)** | (1.80)* | (0.84) | (3.84)*** | (2.96)*** |
| Experience of HH | 0.403 | 0.552 | 1.206 | 1.205 | -0.544 | 0.161 | 0.995 |
| | (2.02)** | (1.73)* | (1.98)* | (1.77)** | (0.36) | (3.67)*** | (1.85) |
| Constant | -1.004 | 2.081 | -0.550 | -0.133 | -1.213 | -1.019 | -0.174 |
| | (2.54)** | (1.18) | (1.86)* | (1.27) | (2.99)*** | (1.23) | (0.58) |

*Notes: Figures in parentheses denote absolute value of z-statistics. *, **, *** denote 10%, 5%, and 1% significance*

Table A4.3: Output Supply and Input Demand Function Estimates: Forest Zone

| Variable | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea | Fertilizer | Seed |
|---|---|---|---|---|---|---|---|---|
| Price of Cocoa | 0.608 | -0.273 | 0.017 | 0.222 | 1.001 | 0.075 | 1.409 | 0.796 |
| | (2.96)*** | (0.85) | (2.91)*** | (1.90)* | (4.03)*** | (0.71) | (0.88) | (3.92)*** |
| Price of Groundnut | -0.273 | 0.928 | -0.032 | -1.021 | -0.006 | 1.102 | 2.003 | 1.355 |
| | (0.85) | (2.90)*** | (2.89)*** | (1.18) | (1.87)* | (3.41)*** | (2.87)*** | (3.06)*** |
| Price of Maize | 0.017 | -0.032 | 1.014 | 1.019 | 1.212 | -0.054 | 1.110 | 1.905 |
| | (2.91)*** | (2.89)*** | (1.87)* | (2.99)*** | (2.23)** | (3.01)*** | (2.90)*** | (2.99)*** |
| Price of Rice | 0.222 | -1.021 | 1.019 | 1.184 | 0.170 | -0.841 | 1.663 | 0.206 |
| | (1.90)* | (1.18) | (2.99)*** | (2.96)*** | (1.79)* | (2.98)*** | (2.91)*** | (3.17)*** |
| Price of *Migso* | 1.001 | -0.006 | 1.212 | 0.170 | 0.247 | -0.023 | 0.065 | 2.029 |
| | (4.03)*** | (1.87)* | (2.23)** | (1.79)* | (2.39)** | (2.32)** | (2.92)*** | (2.87)*** |
| Price of Cowpea | 0.075 | 1.102 | -0.054 | -0.841 | -0.023 | 1.191 | 2.177 | 1.001 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (0.71) | (3.41) *** | (3.01) *** | (2.98) *** | (2.32) ** | (1.83) * | (2.35) ** | (2.22) ** |
| Price of Fertilizer | -1.409 | -2.003 | -1.110 | -1.663 | -0.065 | -2.177 | -1.125 | 1.601 |
| | (0.88) | (2.87) *** | (2.90) *** | (2.91) *** | (2.92) *** | (2.35) ** | (2.02)** | (2.44) ** |
| Price of Seed | -0.796 | -1.355 | -1.905 | -0.206 | -2.029 | -1.001 | 1.627 | -0.602 |
| | (3.92) *** | (3.06) *** | (2.99) *** | (3.17) *** | (2.87) *** | (2.22) ** | (2.91) *** | (3.58) *** |
| Land Size | 1.445 | -1.096 | 0.918 | 1.396 | 0.334 | 0.453 | 1.380 | -0.794 |
| | (1.87) * | (0.37) | (3.44) *** | (6.228) *** | (2.53) ** | (0.48) | (1.73) * | (1.13) |
| Animal Capital | - | 0.913 | 0.872 | 1.553 | 0.112 | 1.611 | 0.288 | 0.667 |
| | | (2.28) ** | (1.86) * | (1.24) | (3.90) *** | (2.38) ** | (3.79) *** | (2.61) *** |
| Education of HH | -0.649 | 1.126 | 0.899 | 0.209 | 0.584 | 0.363 | 2.334 | 0.733 |
| | (1.22) | (2.11) ** | (1.79) * | (2.70) *** | (1.77) * | (0.84) | (2.41) ** | (3.44) *** |
| Experience of HH | 1.781 | 0.884 | 2.155 | 0.114 | -3.228 | -0.003 | 0.818 | -4.220 |
| | (3.59) *** | (1.73) * | (0.68) | (1.85) ** | (1.27) | (0.36) | (1.67) * | (1.05) |
| Constant | -4.393 | 1.336 | -1.201 | -1.086 | 1.030 | -0.755 | -1.553 | -0.398 |
| | (2.41) ** | (1.81) * | (2.76) *** | (0.94) | (2.61) *** | (2.61) *** | (0.65) | (2.29) ** |

*Notes: Figures in parentheses denote absolute value of z-statistics.* *, **, *** *denote 10%, 5%, and 1% significance*

Table A4.4: Output Supply and Input Demand Function Estimates: Savannah Zone

| Variable | Groundnut | Maize | Rice | *Migso* | Cowpea | Fertilizer | Seed |
|---|---|---|---|---|---|---|---|
| Price of Groundnut | 0.597 | -0.043 | -0.451 | -0.595 | 1.004 | 2.028 | 1.001 |
| | (1.86)* | (2.96) *** | (1.87) * | (2.19) ** | (2.72) *** | (2.89) *** | (3.10) ** |
| Price of Maize | -0.043 | 0.309 | 1.002 | 2.582 | -0.046 | 1.711 | 1.320 |
| | (2.96) *** | (1.71) * | (3.00) *** | (3.30) *** | (3.96) *** | (3.91) *** | (2.99) *** |
| Price of Rice | -0.451 | 1.002 | 0.194 | 0.058 | -0.604 | 1.061 | 0.138 |
| | (1.87) * | (3.00) *** | (2.46) * * | (1.83) ** | (1.87) ** | (3.22) *** | (2.27) ** |
| Price of *Migso* | -0.595 | 2.582 | 0.058 | 1.026 | -2.078 | -0.067 | -1.049 |
| | (2.19) ** | (3.30) *** | (1.83) ** | (1.23) *** | (2.18) ** | (2.40) ** | (2.42) ** |
| Price of Cowpea | 1.004 | -0.046 | -0.604 | -2.078 | 0.420 | -1.082 | -0.349 |
| | (2.72) *** | (3.96) *** | (1.87) ** | (2.18) ** | (1.79) * | (3.19) *** | (2.89) *** |
| Price of Fertilizer | -2.028 | -1.711 | -1.061 | -0.067 | -1.082 | -0.825 | 1.033 |
| | (2.89) *** | (3.91) *** | (3.22) *** | (2.40) ** | (3.19) *** | (1.84)* | (2.85) *** |
| Price of Seed | -1.001 | -1.320 | -0.138 | -1.049 | -0.349 | 1.026 | -0.541 |
| | (3.10) ** | (2.99) *** | (2.27) ** | (2.42) ** | (2.89) *** | (2.96) *** | (2.38)** |
| Land Size | -1.502 | 0.665 | 1.051 | 0.852 | 0.080 | 0.380 | -0.794 |
| | (1.07) | (2.44) ** | (4.04) *** | (2.56) ** | (1.78) * | (2.93) *** | (1.13) |
| Animal Capital | 0.061 | 1.439 | 1.048 | 0.728 | 1.266 | 1.073 | 0.844 |
| | (3.58) *** | (2.96) *** | (0.68) | (1.81) * | (2.61) ** | (4.08) *** | (2.81) *** |
| Education of HH | 0.126 | 0.727 | 0.054 | 0.105 | 0.083 | 1.014 | 0.116 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | (3.02) *** | (1.07) | (2.90) *** | (1.86) * | (0.84) | (2.50) ** | (1.76)* |
| Experience of HH | 0.300 | 0.085 | 0.099 | -0.384 | -0.241 | 0.181 | -0.006 |
| | (1.69) * | (1.77) * | (0.81) | (3.27) *** | (2.36) ** | (1.87) * | (0.09) |
| Constant | 0.017 | -1.048 | -1.012 | 1.111 | -0.083 | -1.446 | -0.330 |
| | (0.96) | (2.89) *** | (1.44)* | (2.90) *** | (1.71) * | (1.04) | (3.29) *** |

*Notes: Figures in parentheses denote absolute value of z-statistics.* *, **, *** *denote 10%, 5%, and 1% significance*

A4.1: Exposition of agricultural response supply functional forms

Equations (4A.1)-(4A.3) show the general mathematical specifications of the three most used functional forms. The normalised quadratic specification is generally specified as:

$$\frac{\Pi}{P} = \alpha_0 + \sum_{i=1}^{n-1} \alpha_i \left(\frac{P_i}{P_n}\right) + \sum_{i=n+1}^{p} \alpha_i Z_i + \tfrac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} \alpha_{ij} \left(\frac{P_i}{P_n}\right)\left(\frac{P_j}{P_n}\right) + \tfrac{1}{2} \sum_{i=n+1}^{p} \sum_{j=n+1}^{p} \alpha_{ij} Z_i Z_j + \sum_{i=1}^{n-1} \sum_{j=n+1}^{p} \alpha_{ij} \left(\frac{P_i}{P_n}\right) Z_j \quad \text{(4A.1)}$$

The generalised Leontief profit function can be expressed as:

$$\Pi = \beta_0 + \sum_{i=n+1}^{p} \beta_i Z_i + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \left(P_i P_j\right)^{1/2} + \tfrac{1}{2} \sum_{i=n+1}^{p} \sum_{j=n+1}^{p} \beta_{ij} Z_i Z_j + \sum_{i=1}^{n} \sum_{j=n+1}^{p} \beta_{ij} P_i Z_j \quad \text{(4A.2)}$$

The Translog profit function is expressed generally as:

$$\ln \Pi = \delta_0 + \sum_{i=1}^{n} \delta_i \ln P_i + \sum_{i=n+1}^{p} \delta_i \ln Z_i + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{p} \delta_{ij} \ln P_i \ln P_j + \tfrac{1}{2} \sum_{i=n+1}^{p} \sum_{j=n+1}^{p} \delta_{ij} \ln Z_i \ln Z_j + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{j=n+1}^{p} \delta_{ij} \ln P_i \ln Z_j \quad \text{(4A.3)}$$

The output supply and input demand equations are then derived from the three profit functions respectively.

$$\frac{\partial(\Pi/P_n)}{\partial(P_i/P_n)} = Y_i = \alpha_i + \sum_{j=1}^{n-1} \alpha_{ij} \left(P_i/P_n\right) + \sum_{j=n+1}^{p} \alpha_{ij} Z_j, \quad \forall \quad i = 1,\ldots,n-1 \quad \text{(4A.4)}$$

$$\frac{\partial \Pi}{\partial P_i} = Y_i = \sum_{j=1}^{n} \beta_{ij} \left(P_j/P_i\right)^{1/2} + \sum_{j=n+1}^{p} \beta_{ij} Z_j, \quad \forall \quad i = 1,\ldots,n \quad \text{(4A.5)}$$

$$\frac{\partial \ln \Pi}{\partial \ln P_i} = S_i = \delta_i + \sum_{j=1}^{n} \delta_{ij} \ln P_j + \sum_{j=n+1}^{p} \delta_{ij} \ln Z_j, \quad \text{(4A.6)}$$

To simplify the mathematical expressions above, both output and (variable) input quantities are included in the vector *Y*. Thus, positive values are outputs and negative values are variable inputs. Also both input and output prices are included in the vector *P*. Moreover, fixed inputs and other exogenous factors are captured by the vector *Z*. In all cases, n denotes the number of items in vectors *Y* and *P*.

As explained in chapter 4 of this study, on the basis of production theory, the estimated profit function must satisfy the properties of homogeneity, symmetry, monotonicity and convexity. All but equations (A.3) and (A.3.1) satisfy homogeneity in prices. Homogeneity can, however, be imposed on the translog functional form by using relative prices (McFadden, 1978). For symmetry property to hold, the following should apply:

$$\alpha_{ij} = \alpha_{ji} \,;\, \beta_{ij} = \beta_{ji} \,;\, \delta_{ij} = \delta_{ji} \qquad \forall \quad i, j = 1,...,n \qquad \text{(4A.7)}$$

Wall and Fisher (1987) had explained that the monotonicity and convexity properties for each model need to be verified at post-estimation. The general rule, however, is that the monotonicity condition for output supply and input demand must be positive for the normalised quadratic and generalised Leontief functional forms. The translog specification takes a negative value. To satisfy the convexity property, the typical Hessian of price derivative must be positive semi-definite for all three forms.

# CHAPTER 5: CROP LEVEL SUPPLY RESPONSE AND TECHNICAL INEFFICIENCY IN GHANA

## 5.1 Introduction

Up until recently, much of the empirical studies on agricultural production have either been centred on estimating the price response of output supply and input demand by assuming efficiency or focusing on the estimation of production inefficiencies and thereby ignoring price responses. Output supply and input demand elasticities from either strand of studies have been shown to be biased unless inefficiency estimates are incorporated (Kumbhakar, 2001 and Arnade and Trueblood, 2002). Kumbhakar (1996) was the first to deal with both issues. He jointly estimated both the profit function parameters and efficiency scores in a single equation. The core merit of this technique is that technical inefficiency estimates could be tested statistically. However, this approach is computationally intensive and it is very difficult to detangle allocative inefficiency from technical inefficiency. Arnade and Trueblood (2002) henceforth referred to as AT, have developed a more tractable approach to incorporate inefficiencies into the profit function for duality analysis. The approach requires fewer assumptions, and follows a two-step approach. In the first stage, one needs to obtain inefficiency scores using a programming or stochastic technique. Econometric methods are then employed to model the impact of these scores on output supply and input demand with the inefficiency scores specified as explanatory variables. AT employed this technique to model agricultural responses in Russia. Using two years (1994 and 1995) of cross-sectional data, the study found that (technical and allocative) inefficiencies limit the supply response to prices. Utilizing the same technique but with a farm-level panel data on Ethiopia, Abrar et al. (2004a) found that model specification based on this technique reliable and yields much more robust estimates.

Having shown the strength of the duality approach for modelling output supply and input demand responses in the previous chapter, this chapter advances by applying a modified version of AT's method to incorporate technical inefficiency into the profit functions estimated in the previous chapter. The objective here is to investigate the impact of technical inefficiency on the response of small-holder (peasant) farmers in Ghana. Three things distinguish our work from AT's. Firstly, we account for only technical inefficiency in this study. Technical inefficiency is one of the major problems facing the Ghanaian farmer, arising from infrastructure constraints and lack of agricultural innovation leading to sub-optimal farming practices (Hattink et al., 1998). Secondly, we take into account non-price factors and their relation to technical inefficiency. Finally we employ the Stochastic Frontier Approach (SFA) to estimate technical inefficiency rather than the Data Envelopment Approach (used AT and Abrar et al., 2006). The SFA is a *parametric approach* that hypothesizes a functional form and uses the data to econometrically estimate the parameters of that function using the entire set of the decision making units (DMUs). The strength of this approach lies in its ability to separate random noise from efficiency.

The remainder of the chapter is organised into four sections. Section 5.2 sets out the theoretical framework for identifying technical inefficiency of this study. The econometric model, data and the estimation procedure is outlined in section 5.3. Section 5.4 discusses the econometric results and Section 5.5 concludes by discussing the implications for the performance of Ghanaian farmers.

## 5.2 Theoretical Framework

### 5.2.1 Technical Efficiency: Conceptual Meaning and Measurement

Generally speaking, technical efficiency (TE) can be defined from two fronts: either to minimise input use in production of a given output vector or to maximise output from a given input vector. The concept of TE itself is derived from an engineering approach to (manufacturing) production: the core idea is that technology determines the maximum attainable output given the physical quantities of inputs.

The basic concept underpinning the measurement of technical efficiency commences with the description of production technology, which by itself could be represented using isoquants, production functions, cost functions or profit functions. Each of these four models will lead to different tools for measuring technical efficiency. The level of technical efficiency of a particular farm is characterised by the relationship between observed production and some ideal or potential production. The measurement of farm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier (usually known in the literature as gap). If a farm's actual production point lies on the frontier it is perfectly efficient. If it lies below the frontier then it is technically inefficient, with the ratio of the actual to potential production defining the level of efficiency of the individual farm. We illustrate this in figure 5.1.

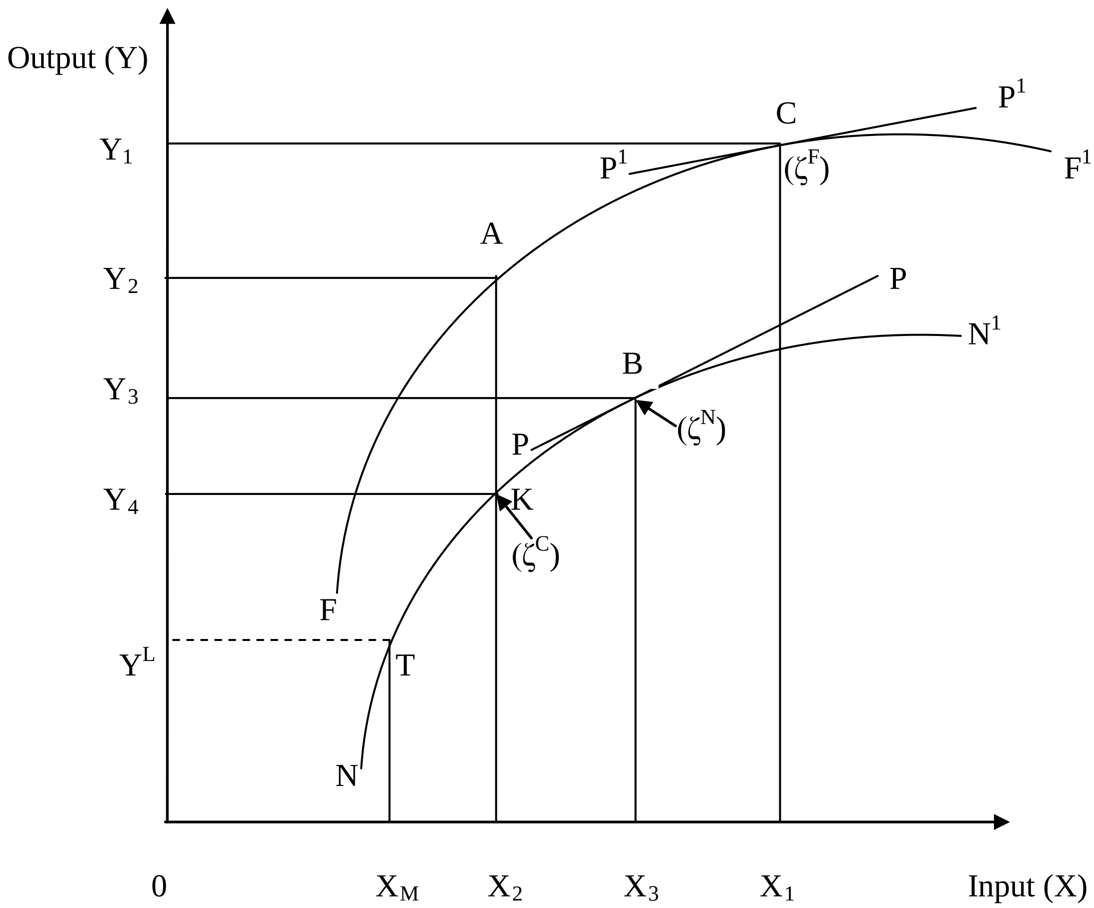



Figure 5.1: Conceptual framework of farm-specific technical, allocative and economic efficiencies

*Note: $NN^1$ is perceived or actual frontier; $FF^1$ is potential frontier; PP is price line associated with production technology $NN^1$, $P^1P^1$ is the price line associated with production technology set $FF^1$. ($\zeta^F$), ($\zeta^C$) and ($\zeta^N$) denote net profits associated with concerned inputs and technology sets.*

According to the foundations of the neoclassical production economics, a typical farmer will operate below the potential frontier, (for example on $NN^1$). At inputs $X_2$, it will operate at point *K*, produces $Y_4$ output and thus earns ($\zeta^C$) amount of profits. On this perceived frontier, point *K* is allocatively inefficient. To maximise its profits ($\zeta^N$), the typical farmer would have to operate at point *B* (the tangent of $NN^1$ and *PP*), use $X_3$ amount of inputs and produces $Y_3$ output. At point *K*, nonetheless, potential economic efficiency would not be achieved, as by definition, potential economic efficiency can only be attained with potential technical efficiency (Kumbhaker and Lovell, 2001).

From the neoclassical viewpoint, (production) efficiency needs to be measured in relation to the potential production frontier, $FF^1$. By this conclusion, if a typical farm operates at point $K$ on its actual production frontier, then its economic inefficiency could be measured either in terms of its profits as ($\zeta^C$ / ($\zeta^F$) or output ($Y_4$/ $Y_1$). At any given point in time economic inefficiency is divided into two - technical and allocative inefficiencies. Thus at point $K$ for instance the total loss in economic inefficiency ($Y_4$-$Y_1$) is divided into loss due to technical inefficiency ($Y_2 - Y_4$) and allocative ($Y_1 - Y_2$). Although point $B$ is optimal for the typical farm to produce, that point is still below the potential optimal (point $C$) on the potential frontier. It is only at that point, $C$, that we can say the farm is achieving both economic and technical efficiencies, where the use of input $X_1$ yields optimum profit ($\zeta^F$) and output ($Y_1$), respectively.

It is important to note that point $T$ in figure 5.1 is associated with a relatively lower output ($Y^L$) when $X_M$ input is utilised. In an attempt to improve output, a typical farmer would attempt to increase input to $X_2$. If we assume technical efficiency (i.e. restricting the farmer to frontier $NN^1$), then output will increase but only to point $K$ (output level $Y_4$). On the other hand, if we consider improvements in technical efficiency of this typical farm (an upward shift of the frontier curve to $FF^1$), then output is likely to increase from the pre-technical efficiency point $K$ to point $A$, with its corresponding output $Y_2$. This suggests that increasing the supply of inputs (as advocated by many of the donor agents) will by itself not lead to the desired output level ($Y_2$). Improvements in technical efficiency could, however, guarantee the desired output. [24]

Farrell (1957) provided the seminal definition of economic efficiency distinguishing between allocative (cost-minimising) and technical efficiency, stimulating the development of methods for estimating the technical efficiency of farms. The common feature of these estimation techniques is that information is extracted from extreme observations for sample farms to determine the best practice production frontier (Lewin and Lovell 1990). From this,

[24] It must be noted that the overall increase in output with increases in input reaches optimum with both allocative and technical efficiencies. This study, however, focuses on only the latter.

measures of technical inefficiency for individual farms below the frontier can be derived. The approaches for estimating technical efficiency can be categorised into parametric and non-parametric methods (Seiford and Thrall 1990).

The estimation of a stochastic production frontier incorporates a measure of random error; the output of a farm is a function of a set of inputs, inefficiency and random error. An often quoted disadvantage of this technique is that it imposes an explicit functional form and distribution assumption on the data. In contrast, the linear programming technique of data envelopment analysis (DEA) does not impose any assumptions about functional form; hence it is less prone to mis-specification. As DEA is a non-parametric approach it does not take into account random error and does not require assumptions about the underlying distribution of the error term. However, as DEA cannot take account of the statistical 'noise', the efficiency estimates may be biased if the production process is characterised by stochastic elements (see Kumbhakar and Lovell 2000). We adopt the stochastic estimation approach in this study mainly because stochastic elements are found to be important. Besides, as we are interested in the inefficiency scores, it is imperative that a chosen method decomposes these inefficiencies from the usual 'noise'.

The most commonly used tool of analysis for measuring technical efficiency is the primal production function. In the neoclassical theory of production, the primal production function defines the maximum possible output of a farm for combinations of inputs and technology, i.e. it is the frontier production function, because, the neoclassical theory assumes that firms would be using the best practice techniques of the chosen technology.

The production frontier of the *ith* farm, producing a single output with multiple inputs following the best practice techniques can be defined as

$$Y_i^* = f(X_i)\,|\,T, \qquad i = \overline{1-N}, \tag{5.1}$$

where $Y_i^*$ and $X_i$ are the frontier maximum output and inputs of a typical *ith* farm. *T* is the given technological set used by all farms in the given sample. If a typical farm is not producing its maximum output due to say supply constraints induced by non-price and other socio-economic organisational factors, then that farm's (actual) production function could be written as

$$\mathrm{Y_i = f(X_i)exp(u_i)} \qquad \mathrm{i = \overline{1-N}.} \tag{5.2}$$

where $u_i$ (farm-specific) denotes the effects of various non-price factors that limit the firm from achieving its maximum possible level of output $Y_i^*$. It measures the *ith* farm technical efficiency. The actual value of $u_i$ depends on the extent to which the farm is affected by the constraints. In effect, the farm's technical efficiency could be measured as

$$exp(u_i) = \left[\frac{Y_i^*}{Y_i}\right]^{-1}, \tag{5.3}$$

Equation (5.3) is the fundamental model generally used for measuring technical efficiency. We can observe actual output ($Y_i$) but not maximum output ( $Y_i^*$). Three separate methods exist in the literature (deterministic, stochastic or Bayesian) but we adopt the stochastic technique in our measurement due to its inherent advantages.

### 5.2.2 A Stochastic Frontier Production Model: Econometric Approach

Following Aigner, et al. (1977), Meeusen and van den Broeck (1977) and Battese and Coelli (1995) a stochastic frontier production model is specified as

$$\ln Y_i \ = \beta_0 \ + \ \textstyle\sum_n \beta_{ni} lnX_{ni} + e^{\ln{(V_i - U_i)}}, \tag{5.4}$$

Where $Y_i$ and $X_i$ are a set of outputs and inputs respectively from a sample farm, $v_i$ is the usual two-sided random error and $u_i$ is the non-negative (one-sided) technical inefficiency component of the error term $(v_i - u_i) = \varepsilon_i$, the usual error term. The noise component of the error term is assumed to be *iid* and symmetric, distributed independently of $u_i$. Premised on the *iid* assumption, the use of OLS to estimate the above equation will yield consistent estimates of the $\beta_n$, but not of $\beta_0$, since $\mathrm{E}(\varepsilon_i) = -E(u_i) \ \le 0$ (Kumbhakar and Lovell 2001). Producer-specific technical inefficiencies are not captured if the method of estimation is OLS. Coelli (1995) proposed tests to detect the presence of technical inefficiencies based on analysis of the error structure obtained from OLS estimation. Both methods are criticized on the grounds of the asymptotic assumption which most data samples fail to meet.[25] The estimation of technical (in) efficiency on equation (5.4) depends on the assumed distribution of the one-sided error term $u_i$.

Four different assumptions have been made but the half-normal distribution of the one-sided error term has received much attention in the literature. The other three entail the assumption of $u_i$ being either distributed exponentially, truncated-normal, or gamma-normal.[26] Greene (1993) estimated technical efficiency coefficients based on these distributional assumptions and found that the differences in estimates are statistically insignificant albeit estimates from the exponentially distributed model yielded relatively large coefficients. Based on its wide usage in production economics, we assume a half-normal distribution of the one-sided error component.

Assuming a half-normal distribution of *u* (i.e. $u_i \sim iidN^+(0.\sigma_u^2)$ and normal distribution of *v* (i.e. $v_i \sim iidN(0.\sigma_v^2)$, we can write the density function of $u \geq 0$ as

$$f(u) = \frac{2}{\sqrt{2\pi\sigma_u}} \cdot exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} \quad (5.5)$$

In which case the log likelihood function will be expressed as

$$lnL = Constant - \frac{1}{2} ln\sigma_u^2 - \frac{1}{2\sigma_u^2} \sum_i u_u^2 \quad (5.6)$$

---

[25] Their method gives a signpost: if we assume there is a negative skewness in the OLS residuals, then we can have evidence of technical inefficiency in the data and we could proceed to estimate a stochastic production frontier.

[26] See Kumbhakar and Lovell (2000) and Shand and Kalirajan (1999) for rigorous treatment of these assumptions. What is of less debate is the use of the Maximum Likelihood Estimation technique rather than the OLS. Greene (1993) and Harris (1992) have also applied the Method of Moment approach to estimated technical efficiency.

The density function of $v$ will be the standard density function. Given the assumption of independence between $u$ and $v$, the joint density function of the two error components will be the product of the two individual density functions. When the de-composition of the error term is accounted for, the joint density function of $u$ and $\varepsilon$ will be expressed by:

$$f(u,\varepsilon) = \frac{2}{2\pi\sigma_u\sigma_v} \cdot exp\left\{-\frac{u^2}{2\sigma_u^2} - \frac{(\varepsilon+u)^2}{2\sigma_v^2}\right\} \tag{5.7}$$

If equation (5.7) is integrated with respect to u, we obtain the marginal density function from which the log likelihood function could also be obtained for a sample. From the log function, one could obtain the maximum likelihood estimates when the parameters are maximised (Kumbhakar and Lovell, 2000). Technical efficiency estimates for each producer is obtained from point estimates of $u_i$ by

$$TE_i = exp\{-\hat{u}_i\} \tag{5.8}$$

where $\hat{u}_i$ is either $E(u_i|\varepsilon_i)\ or\ M(u_i|\varepsilon_i)$. Battese and Coelli (1995) have developed the *FRONTIER* software for estimating technical efficiency in different ranges.

It is interesting to note that the half-normal distribution of the one-sided error term is both plausible and tractable and have been employed more frequently in empirical work than any of the other three distributional assumptions (Kumbhakar and Lovell, 2000).

### 5.2.3 Supply Response and Technical Inefficiency

Kumbhakar and Lovell (KL) (2000) were the first to provide a theoretical basis for incorporating technical inefficiency into the profit function. Their approach provides a single joint estimation of the profit function. This approach is very intensive computationally and the estimation could not disentangle technical from allocative inefficiency. Arnade and Trueblood (AT) (2002) introduced a less restrictive two stage approach to combat the limitations of KL's technique.

AT explored the relationship between input distance and cost functions on the one hand and then established the relationship between distance functions and technical inefficiency on the other. They later incorporated technical inefficiency into the profit function to assess the impact of (technical) inefficiency on output supply or input demand. Below is a summary of their method:

Assume a production technology homogeneous of degree *k* in inputs and outputs and which is characterised by the input distance function $D_I(\boldsymbol{y},\boldsymbol{x})$, where y and x denote vectors of *m* outputs and *n* inputs respectively. If inefficiency is omitted, the duality between $D_I(\boldsymbol{y},\boldsymbol{x})$ and the cost function can be specified by equation (5.6), where $\boldsymbol{w}$ is a vector of input prices and *C(.)* represents the cost function.

$$C(\boldsymbol{y},\boldsymbol{w}) = \underbrace{min}_{x} \boldsymbol{w}'\boldsymbol{x}, \qquad s.t.\ \ \boldsymbol{D}_I(\boldsymbol{y},\boldsymbol{w}) = 1, \tag{5.9}$$

Fare et al. (1994) demonstrate that technical inefficiency $\alpha$ is equal to the reciprocal of the input distance function. Thus for a given producer facing technical inefficiency, its distance function could be represented as $1/\alpha = D_I(\boldsymbol{y},\boldsymbol{x})$ or $\alpha D_I(\boldsymbol{y},\boldsymbol{x})$=1. This means that, if technical inefficiency is indeed present, the behaviour of the farm will be influenced by this inefficiency (negatively through the profit function). If inefficiency is present and the technology is homogeneous of degree *k*, then the input distance function is homogeneous of degree *-1/k* (Fare and Primont, 1995). This relationship is expressed by

$$\gamma^{-1/k} D_I(y,x) = D_I(\gamma y,x)\ , \tag{5.10}$$

where $\gamma$ is a positive parameter.

The cost minimisation problem is then derived as follows:

$$\left.\begin{aligned} \underbrace{min}_{x} \boldsymbol{w}'\boldsymbol{x}, \qquad s.t.\ \ \boldsymbol{D}_I(\boldsymbol{y},\boldsymbol{x}) = \boldsymbol{1/\alpha} \xrightarrow{\boldsymbol{yields}} \boldsymbol{\alpha D}_I(\boldsymbol{y},\boldsymbol{x}) = \boldsymbol{1} \\ = \ \boldsymbol{D}_I\left(\boldsymbol{\alpha^{-k}y},\boldsymbol{x}\right) = \boldsymbol{1} \\ = \boldsymbol{C}\left(\boldsymbol{\alpha^{-k}y},\boldsymbol{w}\right) = \boldsymbol{\alpha^{-1}C}(\boldsymbol{y},\boldsymbol{w}) \end{aligned}\right\} \tag{5.11}$$

The last line is the cost function that is also homogeneous of degree *1/k* in outputs. From the latter model, the profit maximisation economic problem can then be stated as follows:

$$max_{\boldsymbol{y}}\, \boldsymbol{\pi} = max_{\boldsymbol{y}}\, \boldsymbol{p}'\boldsymbol{y} - \boldsymbol{\alpha}^{-1}\boldsymbol{C}(\boldsymbol{y},\boldsymbol{w}), \tag{5.12}$$

where *p* represent a corresponding vector of output prices.

The first order condition with respect to each output will culminate in the equation of marginal cost to the product of prices and technical inefficiency in the presence of technical inefficiency as expressed by

$$\frac{\partial C}{\partial y_i} = \alpha P_i\,, \quad i = \overline{1,N} \tag{5.13}$$

In equation (5.14), the resultant maximised profit equation where $y*$ is the optimal output levels and $\pi*$ represent maximum profits. As expected both maximised profits and outputs as well as cost are affected by the inefficiency element α.

$$\pi^*(\boldsymbol{\alpha p},\boldsymbol{w}) = \boldsymbol{p}'\boldsymbol{y}^*(\boldsymbol{\alpha p},\boldsymbol{w}) - \boldsymbol{\alpha}^{-1}\boldsymbol{C}(\boldsymbol{y}^*(\boldsymbol{\alpha p},\boldsymbol{w}),\boldsymbol{w}), \tag{5.14}$$

Applying Hotelling's Lemma to (5.14) yields the profit maximising output supply and input demand outcomes where $y_i^*$ and $x_j^*$, respectively denote output of good *i* and the total amount of input *j* used.[27]

$$\left.\begin{aligned} \frac{\partial \pi^*(\boldsymbol{\alpha p},\boldsymbol{w})}{\partial p_i} &= y_i^*(\boldsymbol{\alpha p},\boldsymbol{w}), \quad \overline{\iota,N} \;\; and \\ -\frac{\partial \pi^*(\boldsymbol{\alpha p},\boldsymbol{w})}{\partial w_j} &= \frac{x_j^*(\boldsymbol{\alpha p},\boldsymbol{w})}{\boldsymbol{\alpha}}, \quad \overline{\iota,M} \end{aligned}\right\} \tag{5.15}$$

[27] Applying the Envelope Theorem to (4.12) yields $\frac{\partial \pi^*(\boldsymbol{\alpha p},\boldsymbol{w})}{\alpha} = \frac{C(y_i^*(\boldsymbol{\alpha p},\boldsymbol{w}),\boldsymbol{w})}{\boldsymbol{\alpha}^2}$, which can be jointly estimated with (4.12) although multicollinearity will be an issue. If one considers allocative inefficiency, total maximised profits will be further affected. Kumbhaker (1996), Kumbhakar and Lovell (2000, pp 192-214) and Arnade and Trueblood (2002) consider both types of inefficiency. We only consider technical inefficiency due to the inherent problems of dealing with both in a duality context. This means that allocative efficiency is implicitly assumed.

As stated earlier, this method follows a two-step procedure. In the first stage, technical inefficiency scores need to be calculated. Econometric methods are then employed to model the impact of these scores on output supply and input demand functions with the inefficiency scores specified as explanatory variables. There are two limitations of this technique. The 'right' method of calculating technical inefficiency scores are not given but a survey of the literature favours the stochastic method (Kumbhakar, 2001). Secondly, unlike the method of Kumbhakar (1996, 2001), this method does not provide an avenue to statistically test the significance of the inefficiencies.

### 5.3 Data, Model and Estimation Procedure

We use data from the fourth wave of the Ghana Living Standard Survey (GLSS4) as discussed in chapter 2 and the variables used in this chapter are subsequently set out in chapter 4. This chapter models elasticities for farmers in selected two out of three ecological zones for each crop.[28] The econometric estimation involves three stages. Firstly, technical inefficiency scores, $\alpha$, are estimated for each crop using the stochastic production specification

$$ln\, Y_e = \theta_0 + \sum_v^3 \theta_v \, lnX_v + \sum_f^2 \theta_f \, lnX_f + e^{ln\,(V_i - U_i)}, \qquad (5.16)$$

where $Y_e$ is ecological zone output for each of the selected crops (relevant zones vary by crop), $X_v$ is the vector of variable input (hired labour, seeds and fertilizer) and $X_f$ represents the fixed and quasi-fixed inputs (land size and animal power). As (5.16) is stochastic, the error term is decomposed into the usual *iid* component *(v)* and an idiosyncratic component *(u)*. Using the parameterization from Battese and Corra (1977), replace $\sigma_v^2$ with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\sigma_u^2$ with $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$, where the parameter, $\gamma$, must lie between 0 and 1.

Mean technical inefficiency scores from the estimation of (5.16) are then fed directly into the duality profit function (5.17). Our data fitted well with a quadratic functional form of the form,

[28] Cocoa and maize are covered for zones 1 and 2; groundnut and rice for 2 and 3; cowpea for 1 and 3 and *migso* for zone 3. Zones 1, 2 and 3 denote Coastal, Forest and Savannah respectively.

$$\Pi^*(\alpha p, w, z; \beta) = \beta_0 + \sum_i \beta_i (\alpha P_i^*) + \sum_v \beta_v W_v^* + \sum_m \beta_m Z_m + \frac{1}{2}\Big(\sum_i \sum_j \beta_{ij} (\alpha P_i^*)(\alpha P_j^*) +$$

vrβvrWv ∗)(Wr∗+mkβmkZmZk+ivβivαPi∗ Wv∗+imβimαPi∗ Zm+vmβvmWv∗Zm + εi,

(5.17)

where $\alpha$ is the technical inefficiency parameter with all the other variables as defined previously. The $\pi^*, P_i^*, and\ W_v^*$ are normalised (by the price of labour) profit, price of output and price of the other variable inputs (seeds and fertilizer) respectively. The quasi-fixed inputs are land size, family labour and animal capital. The model also considers two exogenous factors - farmers' education and experience (defined by the number of farming years). As stated earlier α=1 when there is no technical inefficiency (comparable model).[29]

The third stage involves the application of Hotelling's Lemma to the duality function to obtain the associated output supply and input demand equations:

$$\left.\begin{aligned} Y_i(\boldsymbol{\alpha p}, \boldsymbol{w}, \boldsymbol{z}; \boldsymbol{\beta}) &= \frac{\partial \pi(.)}{\partial P_i} = \alpha\beta_i + \sum_j \beta_{ij} (\alpha^2 P_j^*) + \sum_v \beta_{iv} (\alpha W_v^*) + \\ &\qquad \sum_m \beta_{im}\, \alpha Zm + \vartheta_i \\ -S_v(\boldsymbol{\alpha p}, \boldsymbol{w}, \boldsymbol{z}; \boldsymbol{\beta}) &= \frac{\partial \pi(.)}{\partial W_v} = \alpha\beta_v + \sum_v \beta_{vr} (\alpha W_r^*) + \sum_i \beta_{vi} (\alpha^2 P_j^*) + \\ &\qquad \sum_m \beta_{vm}\, \alpha Z_m + \vartheta_v \\ &\qquad i = \overline{1,6}\ and\ v = \overline{1,3} \end{aligned}\right\} \quad (5.18)$$

where $Y_i$ and $S_v$ represent, respectively, vector of outputs and variable inputs with $\vartheta$ being the error term which is *iid*. To test the efficacy of this technique, we estimate two sets of output supply and input demand models: model without technical inefficiency and model 2 incorporating technical inefficiency (model 2 reduces to model 1 if $\alpha$ = 1). We employ an iterative Seemingly Unrelated Regression technique to estimate the system of equations (5.18).

[29] The comparable model is similar to equation (4.14) but without the inefficiency term. In the same vein, the output supply and input demand equations follow suit.

## 5.4 Estimation and Discussion of Results

### 5.4.1 Stochastic Function Investigation and Technical Inefficiency Estimates

Firstly, we investigate the appropriateness of a stochastic production function by testing the significance of the parameter, $\gamma$ in (5.16). If the null hypothesis of $\gamma = 0$ is not rejected, we conclude that $\sigma_u^2$ is zero and hence the one-sided error component should be removed from the model, leading to a case where OLS could be employed. There are two ways to calculate these efficiency scores: either by value analysis or unit analysis. We opted for the second technique mainly because tests on the data reject the null hypotheses of $\gamma = 0$ (i.e a stochastic model is preferred) for both the combined and ecological zones samples.

Combined and ecological technical inefficiency scores are estimated using STATA (version 10.1) and by FRONTIER (version 4.1) as a robustness check. The scores are presented in Table 5.1.[30]

Table 5.1: Technical Inefficiency Scores: Pooled, Coastal, Forest and Savannah Zones

| Crop | Pooled | Coastal | Forest | Savannah |
|---|---|---|---|---|
| Cocoa | 0.56[0.59] | 0.52 | 0.57 | - |
| Null (u=0) | *3.22*$^{*}$ | *2.11*$^{*}$ | *8.78*$^{***}$ | - |
| Groundnut | 0.64[0.69] | 0.87 | 0.78 | 0.56 |
| Null (u=0) | 70.17$^{***}$ | 4.83$^{***}$ | 20.71$^{***}$ | 22.0$^{***}$ |
| Maize | 0.59[0.62] | 0.67 | 0.60 | 0.54 |
| Null (u=0) | 44.42$^{***}$ | 5.37$^{***}$ | 33.77$^{***}$ | 20.59$^{***}$ |
| Rice | 0.56[0.56] | 0.28 | 0.47 | 0.54 |
| Null (u=0) | 4.69$^{***}$ | 1.09 | 2.15$^{**}$ | 5.51$^{***}$ |
| *Migso* | 0.40[0.48] | - | 0.57 | 0.39 |
| Null (u=0) | 10.51$^{***}$ | - | 15.85$^{***}$ | 1.65$^{*}$ |
| Cowpea | 0.63[0.63] | 0.57 | 0.35 | 0.27 |
| Null (u=0) | 12.24$^{***}$ | 2.58$^{*}$ | 3.70$^{**}$ | 5.06$^{**}$ |
| Cassava | 0.39[0.44] | 0.18 | 0.45 | 0.50 |
| Null (u=0) | 0.001 | 2.89$^{**}$ | 0.003 | 0.001 |

[30] STATA estimates tend to be lower than the FRONTIER software if one corrects for heteroskedasticity (in our case). However, if idiosyncratic variances are constant, both estimates converge. We report only technical efficiency from the combined outputs in this study.

| | | | | |
|---|---|---|---|---|
| Yam | 0.35[0.46] | 0.005 | 0.005 | 0.003 |
| Null (u=0) | 0.002 | 0.001 | 0.006 | 0.002 |
| Tomatoes | 0.41[0.51] | 0.007 | 0.009 | 0.004 |
| Null (u=0) | 0.001 | 0.001 | 0.002 | 0.001 |

*Notes: *, **, *** denote 10%, 5%, and 1% statistically significance. Frontier estimates of technical inefficiencies in square brackets. Null (u=0) is a test of possibility of stochastic presence in the data) using the statistic* $\gamma$*. Source: Calculations from STATA and Frontier based on GLSS data.*

As shown in Table 5.1, the null hypotheses of one-sided error terms (Null (u=0)) are rejected supporting the use of a stochastic production function for farmers in Ghana. In addition, *lamda*, the ratio of the one-sided error *(u)* to the idiosyncratic error, *(v)*, exceeded one in value and are statistically significant at 1% and 5%, respectively, which implies a good fit of the model.

Estimates from the stochastic production function show that peasant farmers in Ghana are not using best farming practices. Mean technical inefficiency for the combined sample ranges from near 35% (yam) to as high as 64% (groundnut). Overall mean inefficiency stood at 57% for the first six crops used in the subsequent analysis. For the remaining three crops, TI estimates are less accurate as data is limited.[31] Cocoa inefficiency stood at 56%, which compares to a 55.8% cocoa inefficiency found by Dzene (2010) for the period 2005/06 based on random effects model.

Table 5.2: Technical Inefficiency (TI) Scores by Crop (% of farms)

| TI (%) | Cocoa | G'nut | Maize | Rice | *Migso* | Cowpea | Cassava | Yam | Tomatoes |
|---|---|---|---|---|---|---|---|---|---|
| <0.5 | 39 | 29 | 34 | 40 | 85 | 27 | 90 | 98 | 100 |
| 0.5-0.7 | 43 | 31 | 37 | 37 | 12 | 35 | 9 | 1 | 0 |
| 0.8-0.9 | 17 | 28 | 24 | 21 | 3 | 27 | 1 | 1 | 0 |
| >0.9 | 1 | 12 | 5 | 2 | 0 | 11 | 0 | 0 | 0 |
| *Observation* | *509* | *802* | *2757* | *457* | *615* | *631* | *1259* | *349* | *349* |

*Notes: All figures are percentages except the last row (N observations).*
*Source: Calculations from STATA*

[31] We thus decided to drop these three crops from our analysis at this stage. Data from the three ecological zones is scant and largely has missing sections. The variation in *Migso* data justifies its inclusion in our analysis, but only for zone 3 regions.

Out of the six crops, farmers from the Savannah zone were technically efficient (with the exception of rice where farmers in the Coastal zone appear least inefficient) relative to the other zones. This is perhaps surprising especially when all the three regions making up the zone - Northern, Upper East and Upper West - are the three poorest regions in Ghana at the time of GLSS4 data collection. Our inefficiency estimates are closer to the findings of Abdulai and Huffman (2000) and Seidu (2000) but lower than Seidu (2008). Seidu (2008) adopted a translog production function on farm specific data on rice production in the Northern part of Ghana only, so has less coverage and a different functional form. Moreover, we used the dual approach employed by other studies. All the results confirm that smallholder farmers in Ghana are technically inefficient and operate under their respective production frontiers.

The largest proportion of cocoa, groundnut, maize and cowpea farmers within the period under consideration recorded 50-70% technical inefficiency although few were beyond 90% inefficiency. Table 5.2 shows that farmers of staple crops - (millet/sorghum/guinea corn (*migso*), cassava, and yam - appear to be relatively efficient (less than 50% technical inefficiency for the majority of farms).

Table A5.2 (chapter appendix) explores the determinants of technical efficiency. A number of farm characteristics appear important, notably farm size, household size, farmers' level of formal education, age, experience and interactions of education level with inputs (fertilizer, seed and farm size). These factors explain about half of the variation of inefficiency signalling the relevance of both price and non-price factors (such as erratic rainfall, soil fertility, production credit, social networks) in agricultural supply response in Ghana.[32] The significance of land size, family labour, farmers' education and experience justified their inclusion in estimating supply responses. Their inclusion, with technical inefficiency estimates, improved the significance of the own-price effects of the crops in model 2.

The cross-price effects were however mixed although many of the pairings saw improvements in the statistical significance. Using the Random Tobit methodology, Dzene (2010) found, among other factors, that demographic factors - age, gender, relation to

[32] See Siedu (2008) for a discussion of determinants of technical inefficiency for rice farmers in Northern Ghana.

household head and Education - had a positive impact on the technical efficiency of cocoa farmers in Ghana for the 2005/05 periods but household size had a negative impact on technical efficiency. An interactive term between education and maintenance used as a proxy for quality of farm maintenance had a positive and significant impact on technical efficiency.

### 5.4.2. Model Comparisons, Output Supply and Input Demand Estimates

As described above, a system of output supply and input demand functions are derived with elasticities computed for two separate models: model 1 omits technical inefficiency and model 2 incorporates technical inefficiency into the profit function. The sign of the technical inefficiency parameter is as expected, negative and highly significant in model 2, both at the ecological and pooled samples (Tables A5.5 and Table A5.6 in appendix).

Next we use Davidson and Mackinnon's *J*-test and Fisher and McAleer *JA*- tests to determine which of the two non-nested models (models 1 and 2) should be preferred.[33] The difference between the *J*- and *JA*- tests lies in the augmenting variable, which incorporates information from the alternative hypothesis. Doran (1993) argues that an added advantage of the *JA*- test lies in the exactness of the test when the hypotheses are linear and the disturbances are normal.

Although the *J*- test estimates produce inconclusive results sometimes, it is always advisable to calculate both tests (Pearson and Deaton, 1978; Doran, 1993). The two tests are implemented by re-estimating the profit functions and testing the relative performance of the fitted values from each model in a composite model. The t-statistic of the fitted variable is examined. Four likely outcomes are possible from either of the tests, in the 'worst' of which both models are rejected. If both are accepted, traditional criteria such as $R^2$ are employed to select the superior model.

The results from the tests are presented in Table 5.3. In most cases the *J*- test either provided inconclusive or rejection outcomes for cocoa, groundnut, maize and cowpea. The *JA*- test, on the other hand, supports model 2 (*TI*) for these crops. The *JA*- test provided inconclusive results for both rice (both models accepted) and *migso* (reject both models) but the

[33] See appendix A5.1 for exposition of these two approaches

application of $R^2$ favours model 2 for both crops. In general, there is support for model 2, i.e. incorporating technical inefficiency. As noted by Doran (1993), inconclusive results in the application of *J-* test are not uncommon. Arnade and Trueblood (2002) found similar arrays of results for Ethiopia and Russia respectively.

The authenticity of duality models is premised on regularity restrictions of the models including homogeneity, symmetry, monotonicity and convexity. Homogeneity is implied (both models) as all prices were divided by the price of labour.[34] The test for symmetry was mixed; joint symmetry of both models was not accepted even at 10%. However, we could not reject symmetry conditions for all crops (except for *migso*) in model 2 or in model 1 except for *migso,* cowpea and rice.

Table 5.3: *J-* and *JA-* Tests for the 'Standard' and Technical Inefficiency Models

| Crop | Adj. $R^2$ | $H_0$: Model i is better (i=1,2) | *J-* Test | *JA-* Test |
|---|---|---|---|---|
| Cocoa | *0.50* | Model 1 | $24.726^{**}$ | $53.02^{***}$ |
| | *0.54* | Model 2 | $-50.861^{*}$ | -36.53 |
| Groundnut | *0.48* | Model 1 | $1..882^{**}$ | $-1.610^{*}$ |
| | *0.48* | Model 2 | $0.970^{***}$ | -1.734 |
| Maize | *0.22* | Model 1 | 0.998 | $1.496^{**}$ |
| | *0.23* | Model 2 | 1.001 | 1.050 |
| Rice | *0.53* | Model 1 | $0.658^{**}$ | 0.759 |
| | *0.55* | Model 2 | 0.860 | 1.661 |
| *Migso* | *0.55* | Model 1 | $0.925^{*}$ | $0.316^{*}$ |
| | *0.59* | Model 2 | 0.704 | $0.093^{*}$ |
| Cowpea | *0.41* | Model 1 | $0.825^{***}$ | $0.935^{**}$ |
| | *0.42* | Model 2 | $0.639^{**}$ | 0.258 |

*Note: Model 1 is without technical efficiency and Model 2 is with. A significant J- or JA- coefficient implies the rejection of the null hypotheses and acceptance of the alternative (model).*
*Note: $^{*}$, $^{**}$, and $^{***}$ denote significance at 10%, 5%, and 1%, respectively.*

[34] The marginal homogeneity tests from STATA were predominantly confirmed although marginally.

Duality studies in this area are plagued by inconclusive results and often impose symmetry and convexity conditions (Shumway, 1995). Weak symmetry conditions could arise from inadequate data or measurement error so we impose (theoretical) symmetry and convexity conditions. As hinted by Abrar (2001a), an alternative way to test for convexity is to observe the own-price elasticities. An expected positive sign is an indication of the non-rejection of convexity. In our estimates, all but two crops - *migso* and rice - did not have a positive sign in model 1. For model 2 all crops have positive own-price elasticity.

The axiom of monotonicity requires that the fitted values of the output supply (and input demand) functions are positive (negative) after estimation. An examination of pooled sample estimates (see Tables A5.4 and A5.6 in chapter appendix), at data mean points, satisfy monotonicity requirements (although not strict)[35] for both models. Input demand estimates in both tables are noted by the effects of fertilizer and seed prices on each of the six crops.

We estimate the profit functions for both models for five crops (cocoa, groundnut, maize, cowpea and rice) and for *migso* in the Savannah zone. Iterated Seemingly Unrelated Regression is used to estimate parameters from a system of eight equations (six output supply and two input demand - seed and fertilizer) derived from the two separate profit functions (models 1 and 2 respectively). The output supply and input demand results are presented in Tables A5.3-A5.6 (with symmetry imposed). Most coefficients have the expected sign and significance. The own price estimates (under pooled sample), from Table 5.3, that were insignificant or narrowly significant in model 1 either became significant or more significant when technical inefficiency is accounted for. Similar stories could be told with the ecological samples. Inclusion of inefficiency in model 2 increased the number of significant variables such as seed price on the rice cultivation (pooled samples). Confirming the outcome by the *J*- and *JA*- tests, the R-squares of model 2 are generally higher than for model 1.

### 5.4.3. Estimates of Elasticities

Elasticities are estimated at data averages and compared between the two models. We estimate both output and input elasticites for only pooled samples for both models for easy

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[35] A strict test would be to perform either the Kolmogorov-type test or construct a Cholesky factorization. See Lau (1974) for detailed exposition on the subject matter.

comparison and analysis. The estimation formulas are outlined in Appendix A5.2 of this chapter. Following are discussions of selected (relevant) output and input sensitivities.

*Own-Price Elasticities*

The responsiveness of Ghanaian peasant farmers to price incentives is shown in Table 5.4. The elasticities are very low but positive and significant (except for rice). The highest elasticity is 0.11 for cocoa and *migso* whereas it is as low as 0.02 for cowpea and 0.04 for maize. One reason for these low elasticity values may be due to limited spatial price variation for the estimates.

Table 5.4: Output Own-Price Elasticities of Models With and Without Technical Inefficiency

| Crop | Model 1 | Model 2 |
|---|---|---|
| Cocoa | 0.19 | 0.11* |
| Groundnut | 0.08** | 0.10** |
| Maize | -0.23** | 0.08** |
| Rice | 0.06** | 0.07*** |
| *Migso* | -0.48 | 0.03** |
| Cowpea | 0.08** | 0.02** |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively*

Model 2 estimates suggest that production of food (maize, rice, and cowpea), exportables (cocoa and groundnut) and staples (*migso*) crops in Ghana is inelastic although cocoa and groundnut farmers are more responsive to price incentive than the rest of the crops.[36] This could be that both crops are tradable internationally. Our estimates are close to the findings by Hattink et al. (1998), who used a similar estimation technique but with farm-level data from 1987-88.[37] They found own-price elasticities of 0.13 and 0.12 for cocoa and maize, respectively. The estimates by Hattink et al. (1998) and ours are, however, smaller than elasticities found in the macro-level time series analyses that either use the Nerlovian supply

[36] The focus of analysis from this point is based on model 2 estimates as model 1 estimates are largely insignificant.

[37] Their dataset was completely different from ours. However both datasets were collected within the same period.

response model or cointegration analysis (Frimpong-Ansah (henceforth FA), 1992; Abdulai and Rieder (henceforth AR), 1995 and Ocran and Biekpe (henceforth OB), 2008).

Elasticities from the latter studies are usually partitioned into short- and long-run. FA and AR found short-run elasticities for cocoa to be 0.18 and 0.29 with long term elasticities ranging from 0.43 to 0.72. OB conducted a multiproduct supply response for Ghana categorising outputs into food and export crops. The latter is tradable whilst the former is quasi-tradable in the domestic market. They reported aggregated (combined) short term elasticity of 0.27 again affirming the general inelastic production of Ghana farmers. They however found elasticities of 0.30 and 0.25 for exportables (cocoa and coffee) and food (maize, rice, sorghum and millet) crops suggesting that exportable farmers are more price sensitive to food farmers. The trend was, however, the opposite in the long-run, where food farmers responded more positively (0.76) than farmers of export crops.

Table 5.5 gives the zonal elasticities of the various crops. Farmers in the Coastal zone respond more to price changes for groundnut and maize than farmers in the other two ecological zones. One reason to explain such a difference may be due to the low cultivation capacity of the coastal farmers coupled with poor out of season marketing channels that exist in Ghana. Cocoa farmers in the Coastal zone will increase their production by 0.09% in the event of the crop’s market price increasing by 1%. This response is almost doubled by farmers in the Forest zone, where the cultivation of cocoa is the highest. Rice farmers in the Savannah zone are likely to respond more to any price change for the crop than other crop farmers in the other zone.

Farmers in the Savannah zone account for about 70% of total rice cultivation holders in Ghana (Seidu, 2008). In addition, rice is seen as direct substitute for *migso*, the main staple in the three regions making up this zone (Northern, Upper East and Upper West). The relatively large own-price elasticity of *migso* (Table 5.4) and the cross-price (Table 5.5) could explain why farmers in this zone are likely to be relatively more responsive to price change in rice.

Table 5.5: Own-Price (output) Elasticities for Model 2: Ecological Analysis

| Crop | Coastal | Forest | Savannah |
|---|---|---|---|
| Cocoa | 0.09* | 0.17*** | - |
| Groundnut | 0.28** | 0.16** | 0.08** |
| Maize | 0.31*** | 0.04*** | 0.05* |
| Rice | 0.09*** | 0.06** | 0.11* |
| *Migso* | - | 0.04*** | 0.20*** |
| Cowpea | 0.07* | 0.07** | 0.04* |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively*

Rice and *migso* are substitutes. Another reason accounting for the low elasticity of rice farmers in the Coastal zone may be due to the ever increasing variety of rice on the market from the international market. Any price change in domestic price for rice is likely to see consumers switch to other foreign brands, thereby leaving farmers with little adjustment choices. We are not sure to what extent the substitution degree is between domestic and foreign rice consumption.

Agricultural supply response estimates are sensitive to the dataset and method of estimation used. Generally studies based on duality estimations tend to produce relatively lower elasticities than estimates by macroeconomic time series analysis (Schiff and Montenegro, 1995). Many reasons account for these differences of which data type and structure, modelling challenges and neglect of other control variables such as structural factors have been discussed extensively in the literature (see Bond, 1983; Chhibber, 1989; Schiff and Montenegro, 1995; Hattink et al, 1998).

*Cross-Price Elasticities (cpe)*

Generally all *cpe* signs were as expected and the majority of the pairs were significant at not less than 0.05% (Table 5.5). We only present estimates from model 2 as model 1 is mostly insignificant. Our estimates show the pattern of crop relationships. The three sets of substitute crops are as expected with maize and *migso* recording the highest degree of substitution although not perfect. When the price of rice increases by 1%, producers of rice are likely to shift to maize production by almost 0.16%. The shift effect for *migso*, a staple crop, is likely to be larger (0.34%). Farmers on average are also likely to switch about 0.11% of their cultivation of groundnut to cowpea should the price of the latter crop fall by 1%. From these results, one can draw an inference that the elasticity between export (groundnut) and food (cowpea) crops has the lowest substitution (response) rate to price changes. Farmers of food (maize) and staple (*migso*) crops has the highest elasticity rate (0.34%) placing much emphasis on domestic food security. The substitution effect for food crops (0.16) is smaller than that found by OC (0.25) mainly because of the different methodologies as explained above.

We also found seven sets of complementary crops - groundnut with cocoa, maize, rice and *migso*, maize-cowpea, rice-cowpea, and *migso*-cowpea. Farmers who simultaneously cultivate groundnut and *migso* responded the most with a cross-price elasticity of 0.31.

Table 5.6: Output Cross-Price Elasticities: Combined Sample

| Substitutes | | Complements | |
|---|---|---|---|
| Groundnut-Cowpea | -0.11*** | Groundnut-Cocoa | 0.06* |
| Maize-Rice | -0.16** | -Maize | 0.15*** |
| -*Migso* | -0.34*** | -Rice | 0.10** |
| | | -*Migso* | 0.31** |
| | | Maize-Cowpea | 0.14** |
| | | Rice-Cowpea | 0.26*** |
| | | *Migso*-Cowpea | 0.27* |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively*

The supply elasticity of cocoa production with respect to the groundnut price is 0.06 and marginally significant suggesting a small complementary effect between the crops. Although not as expected yet the complementarity between the latter pair of crops is not surprising. The ideal case is to see a substitution effect that demonstrates rationality of profit maximising behaviour. However, with limited resources to farmers, crop substitution is likely to lag behind price change, although this cannot be tested with cross-sectional analysis. Thus, all we observe are correlations in production.

One can also attribute this to the unmatched seasonality of the crops involved as cocoa is a perennial crop whilst groundnut is cultivated twice a year. One would therefore have to defer any substitution decisions to at least after the harvest period of the main cash crop, cocoa. This complexity was encountered by Hattink et al. (1998) who found a (complementarity) value of 0.05 between cocoa and maize (which was treated as food crop). This relationship was against their substitution hypothesis between export crop (cocoa) and domestic food crop (maize). The lack of robustness in the Ghanaian model of farming, coupled with inadequate appropriate technology, will make relocation between these crops and any unmatched seasonal crops somewhat strenuous. Any substitution may not show an instantaneous effect.

*Cross-Price Elasticity w.r.t. Variable Inputs*

As expected almost all the crops exhibited negative elasticity signs and several show a clear sensitivity to price with the exception of fertilizer's effect on cocoa (Table 5.6). A negative elasticity demonstrates farmers' inverse reaction to price increases in input prices. Only estimates from model 2 are reported by Tables 5.6 and 5.7.

Table 5.7: Output Cross-Price elasticity *w.r.t.* variable Inputs: Combined Sample

| Crop | Seeds | Fertilizer |
|---|---|---|
| Cocoa | -0.04** | 0.12 |
| Groundnut | -0.18*** | -0.18*** |
| Maize | -0.09*** | -0.06** |
| Rice | -0.38 *** | -0.25*** |
| *Migso* | -0.26 ** | -0.16* |
| Cowpea | -0.30 ** | -0.08 *** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance respectively.*

The insignificance of cocoa fertilizer is somewhat startling. We use data on organic and inorganic fertilizer in the estimation. The result from the ecological analysis (in chapter 4) did not alter from the present outcome (Table 5.7) although the expected sign was registered. Any insignificance could mean either of two reasons. Firstly, the data on fertilizer could be inadequate or its measurement inaccurate as in some cases we have to extract from a series of data on fertilizer expenditures. Secondly assuming the data is *'fair'* and representative, we posit that other forms of fertilizer could have been used such as 'own' (human) manure, especially that animal capital was insignificant. It should be noted also that the cocoa-fertilizer relationship in chapter 4 was (only marginally) significant in the Forest zone but insignificant in Coastal regions.

The rest of the crops revealed the expected negative signs for fertilizer price effect on cultivation. On average, rice farmers are likely to cut back cultivation by a quarter should fertilizer price increase by a unit. Maize farmers are the least likely to react to changes in the price of the input. On average Ghanaian food crop farmers (maize, cowpea), with rice exception, have a lower reaction to fertilizer price changes than farmers of export crops (cocoa and groundnut) and staples (*migso*). This pattern was repeated throughout the three ecological zones, except for the Forest zone, where maize and rice farmers recorded the opposite.

Farmers in the Savannah zone recorded the highest reaction to the changes in fertilizer prices in the country, in some cases tripling the effect from coastal farmers. This is not very surprising as much price variation of the input occurs in the zone due to few marketing structures (mostly middlemen) dealing in the input.

Table 5.8: Output Cross-Price elasticity w.r.t. variable Inputs: Ecological Analysis

| | Coastal | | Forest | | Savannah | |
|---|---|---|---|---|---|---|
| Crop | Seeds | Fertilizer | Seeds | Fertilizer | Seeds | Fertilizer |
| Cocoa | -0.06** | 0.08 | -0.28*** | -0.14 | - | - |
| Groundnut | -0.09** | -0.10** | -0.22** | -0.10* | -0.17* | -0.37** |
| Maize | -0.04*** | -0.06** | -0.09** | -0.24*** | -0.08** | -0.13*** |
| Rice | -0.18 *** | -0.06*** | -0.20** | -0.14** | -0.20*** | -0.21** |
| *Migso* | - | - | -0.05*** | -0.11** | -0.31 ** | -0.18* |
| Cowpea | -0.30 ** | -0.05 *** | -0.18*** | -0.08*** | -0.19*** | -0.14** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance respectively.*

The three regions in the Savannah zone (Upper East, Upper West and Northern) see little economic activity compared with the two other zones. Any policy direction to affect the use of the input must consider, in part, these unique peculiarities of the regions. Seeds are undoubtedly one of the most important ingredients of agricultural productivity success and have been a major factor behind the success of the green revolution in Asia. Farmers in

Ghana do not only respond to the price of seeds (cocoa farmers included) but also the degree of sensitivity outweighs that of fertilizer effect in almost all expected cases. The difference ranges from 0.03 (maize) to 0.22 (cowpea). Also revealing was the fact that the expected significant elasticities generally increased in size with the inclusion of technical inefficiency. Rice farmers are likely to respond more to the prices of both inputs than any of the crops analysed.

In terms of ecological effects, maize farmers were the least likely to respond to changes in the price of seeds in all three zones. This could be as a result of high ploughing back culture, popularly practiced by most farmers in Ghana. In this system, a proportion of the previous harvest (usually the high yield) is preserved for use in the next planting season. This system is popular among maize (corn) farmers in Ghana. Cocoa farmers in Ghana, on average, respond to changes in seed prices although the elasticity is very small (0.04 and 0.06 in Tables 5.6 and 5.7 respectively). However, the figure rose to 0.28 and significantly, in the Forest zone, where the cultivation of cocoa is highly concentrated because of favourable agro-climatic (rainfall especially) conditions (Vigneri, 2008). Improvement in cocoa seedlings (the development of hybrid seeds) is very essential for the future prospect of the major cash crop.

*Input Demand Elasticities*

Inputs own- and cross- price elasticities are recorded in Table 5.9 for model 2. All signs are as expected and significant of at least 5%. Farmers are likely to respond to changes in fertilizer prices (0.23) more than changes in the price of seeds (0.16), land size (0.05) and animal capital (0.01), suggesting a strong emphasis on the need to get prices ‘right’ for fertilizers and seeds. As such, any large increases in the price of the inputs could lead to a severe reduction in the cultivation of the crops. The small elasticity value for land size is explainable as most peasant farmers in Ghana either cultivate their own farmlands or other family land. Only few landless farmers will lease farmlands.

Table 5.9: Input Demand Elasticities (Own- and Cross-Price): Combined Sample

| | Seed | Fertilizer | Land Size | Animal capital |
|---|---|---|---|---|
| Seed | -0.16*** | | | |
| Fertilizer | -0.13** | -0.23*** | | |
| Land Size | -0.09*** | -0.21*** | -0.05** | |
| Animal Capital | -0.20*** | 0.07** | -0.14** | -0.01** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance.*

In terms of relationship between the inputs, there is a clear degree of complementarities between five pairs of inputs: seeds-fertilizer, seeds-land size, seeds-animal capital, fertilizer-land size and land size-animal capital. Their relationship is plausible and expected. The significant but low degree of substitutability (0.07) between fertilizer and animal capital is not very surprising as most farmers are left with little funds to spend on fertilizers after spending much on animal capital. Many farmers prefer to get their farms ready for the planting season than the application of fertilizer on the farm. One reason could be attributed to the over-reliance on timely rainfall. The ever increasing price variation of fertilizer between the three ecological zones (in spite of the government's subsidy on the input) could force owners/hirers of farm animals to substitute fertilizer with animal manure, which in itself is a high source of crop nutrient and costless.

*Non-Price Responsiveness*

Table 5.10 reveals the importance of non-price factors in the promotion of agricultural development in Ghana. All the four non-price inputs are imperative to the successful cultivation of groundnut, maize *migso* and cowpea crops. Land size is significant in all cases when we account for technical inefficiency. Rice farmers positively respond the most to land size (0.27). Land size, in our analysis, seems not to be a major issue to *migso* farmers partly because the crop in question is a staple and it is cultivated by a few clustered sections of the Ghanaian population, mainly in the Savannah zone.[38]

[38] The elasticity was 0.03 (estimate based on model 1 - not presented as the focus is more on model 2) but insignificant when technical efficiency was assumed. Similarly model 1 estimate, with the assumption of technical efficiency, saw rice and cowpea farmers unresponsive to land size.

Table 5.10: Non-Price Elasticities: Combined (Model 2)

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | ***Migso*** | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | 0.19** | 0.25** | 0.12** | 0.27*** | 0.01* | 0.18** |
| Animal Capital | 0.08 | 0.18** | 0.21*** | 0.24*** | 0.08** | 0.07** |
| Family Labour | 0.06* | 0.26** | 0.15*** | -0.09 | 0.25*** | -0.12** |
| HH Education | 0.07* | 0.14*** | 0.10*** | 0.09** | 0.15** | 0.17** |

*Notes: *, **, *** denote 10%, 5%, and 1% significance.*

Output sensitivity to animal capital is positive and significant for all crops except for cocoa, the only cash (non-food) crop in this analysis. Bear in mind that animal capital serves a dual purpose - wealth effect and fertilizer effect (either as a substitute or complement). The improvement in cocoa seedlings over time (drought-resistance seeds) could partly explain the insignificance of its output's response to animal capital as more cocoa farmers are supplied with these seedlings as part of the government's cocoa improvement plan. We also believe that cocoa farmers are likely to respond to farm or agricultural equipment rather than animal capital due to the fact that the crop in question is a perennial (10-15 years life span). Vigneri (2007), in a special report of an Overseas Development Institute (ODI) study on cocoa production in Ghana, found that farmers of the crop respond to agricultural equipment. Rice farmers once again responded the highest to animal capital.

Export (cocoa and groundnut) and staple (*migso*) farmers are likely to respond positively to household labour with the latter group of farmers registering relatively smaller elasticities. Farmers' responses are however mixed among food crops. Whilst maize farmers are likely to increase output with household labour, cowpea and rice farmers show the opposite effect, but the figure for cowpea is not significant. Our negative findings of family labour effect differ from the norm where mostly positive and significant estimates are found. Our findings are, however, not surprising. Many of the positive effect studies in this area usually combine all three categories of labour ('own' labour by the farmer, hired labour and household labour which we call family in this study).

These aggregations are likely to produce a positive response as the opportunity cost of that 'labour' is used in the estimation. This has a major measurement problem. Firstly, not all household labour is employable on the family farm. Secondly, it is possible households with surplus labour are likely to attract lower wages and in some cases are not ‘priceable’. In that case, hired labour could have a different effect from household labour. In this study, we segregated labour into hired (tradable) and household (own plus family, which are not tradable).

The literature on the impact of farmer education on agricultural productivity is huge. A greater percentage of growing literature found significant productivity-enhancing effects of farmer education (Arene and Manyoung, 2007). This study found similar conclusions. There is a positive response for output with farmer education for all crops, the least effect being 0.07 registered by cocoa farmers. For example, an extra year of farmer education is likely to lead to a 0.17% increase in cowpea output assuming other factors are unchanged. The imperative of farmers’ education in our findings is inferable. Farmers’ (schooling) knowledge is essential in the adoption of new farming systems and technology such as hybrid seeds, as well as the application of pesticides and other essential high yielding ingredients. Formal education (which we used) needs to be complemented by appropriate periodic extension farmer visits. Such combinations are likely to boost productivity.

Table 5.11: Rankings of Non-price factors by crop

| Crop | Ranking of Non-Price Factors | | |
|---|---|---|---|
| Cocoa | Land Size | Family Labour | HH Education |
| Groundnut | Family Labour | Land Size | Animal capital |
| Maize | Animal capital | Family Labour | Land Size |
| Rice | Land Size | Animal capital | HH Education |
| *Migso* | Family Labour | HH Education | Animal capital |
| Cowpea | Land Size | HH Education | Family Labour |

*Rankings based on the results from Table 5.10*

It is appropriate, before closing this section, to point out the ranking of the elasticities (in terms of magnitudes) by crops with respect to non-price factors. The relevance of these rankings gives a crude guide for policy targeting amidst limited budget (almost always the case) in promoting the crop’s productivity. Rice farmers respond more to land size, animal capital and farmer education than any of the crops. What does this mean? Cultivators of rice will respond positively to increases in land size and affordable fertilizer (and higher revenues emanating from ready and huge market size). Furthermore, consistent and appropriate farmer education such as periodic extension officers' visits will boost rice cultivation in Ghana. Of course other non-price agro-climatic factors such as rainfall and soil fertility are crucial in achieving high yield.

Cocoa farmers tend to respond strongly to land size (mainly because of scale economies), household labour and farmer education. This could be true for farmers using the new hybrid cocoa seedlings, which relatively needs more education than the old cocoa trees. The new plant takes relatively less time to bear fruit and is less prone to diseases.

The three most important non-price factors to growers of groundnut are household size, land size and animal capital - in that order. Whilst the first two are expected, the last factor confirms a popular call by agricultural stakeholders over the years. The high price of fertilizers calls for alternative methods in increasing the yield of this and other fertilizer-dependent crops. In the absence of the optimal solutions (irrigation and subsidizing the price of the input, which by itself is unsustainable in most developing economies), the second best solution, although a long term policy measure, is to develop drought-resistant crops. Financing will be challenging due to its initial huge sunk cost but such investment will have colossal potential gains thereby justifying its investments.

## 5.5 Conclusions

In this study, we sought to estimate supply responses in an innovative way. This we did by incorporating technical inefficiencies into the dual profit function to estimate the relationship between inefficiencies and a system of output supply and input demand responses. Arnade and Trueblood (2002) first introduced this approach. Efficiency scores in this study were estimated parametrically to capture any crop-specific deviations as well as inter-crop linkages.

We used the Stochastic Frontier Approach to estimate technical inefficiencies for six crops cultivated by peasant Ghanaian farmers - cocoa, groundnut, maize, rice, cowpea and *migso* (millet and sorghum). Our findings confirm technical inefficiencies were widespread. The lowest inefficiency was 27% for cowpea farmers in the Forest zone whilst groundnut growers in the Coastal zone recorded the highest technical inefficiency (87%). The overall average technical inefficiency for Ghanaian farmers within the period under review was 56%. This compares with earlier studies such as Seidu (2008), who found a mean technical inefficiency score of 51% for rice farmers in the Northern region of Ghana. Using the same technique, but on a cross-country analysis, Nkamleu et al. (2010) found an overall average technical inefficiency score of 56% for Ghana. Judging from the fact that agriculture is the backbone of the Ghanaian economy, a higher inefficiency score calls for much policy attention. None of the many sectoral policies pursued have been targeted on the improvement of technical efficiency so far. However, achieving self-sufficiency in food supply and/or enhancing (agricultural) exports to competitive levels would not be feasible without tackling the huge technical inefficiency levels in the country.

We then estimated two sets of output supply and input demand functions to investigate the efficacy of incorporating technical inefficiency into the modelling of supply elasticities. We found, among other things, that Ghanaian farmers responded to both price and non-price factors. When technical efficiency is assumed, farmers did not respond so well to non-price factors and the supply elasticities were either insignificant and/or large, suggesting a possible overestimate of parameters. Accounting for technical inefficiency in the dual profit functions led to consistent estimates although in some cases estimates were smaller but significant. The technically incorporated model (model 2) was favoured ahead of an assumed technically inefficient model (model 1) with the former satisfying the regular properties including convexity and monotonicity.

Mixed (signs and significance) outcomes were recorded for own-price elasticites when technical efficiency was presupposed (model 1). Consistent (positive) results were obtained with model 2. Farmers of cowpea and cocoa crops recorded the lowest and highest own-price elasticities of 0.02% and 0.11% respectively. These are relatively low response rates but they were all consistent, positive and significant. The responses to own-price changes for export crop farmers (cocoa and groundnut) outweigh that of food (maize, rice, and cowpea) and staple (*migso*) growers. In terms of ecological own-price supply response, maize and groundnut farmers were the ones with the largest rate in the Coastal zone. The cross-price supply elasticites also produced expected and consistent results to a greater extent.

Our preferred model also reveals strongly that prices of fertilizer and seeds are the most essential ingredients in the productivity of agricultural output. Considering the scant use of fertilizer in agricultural production in Ghana, it is only necessary for policy targeting. One clear target is to narrow the huge price variation pattern of fertilizer. Getting the 'right' prices for these important inputs is crucial to the success of any agricultural policy design for Ghana. Cocoa farmers, however, appear not to respond to changes in fertilizer prices but seeds. The continuous development of hybrid cocoa seedlings could be one major explaining factor. Farmers responded to changes in the price of seeds at each stage than any other inputs. The degree of response to a 1% increase in seed prices ranges from a low of 0.04% (cocoa farmers) to a high of 0.38% for rice farmers. Cocoa farmers in the Forest zone, where the crop is heavily concentrated, recorded an elasticity of 0.29 with respect to the price of cocoa seedlings.

It is interesting to note the linkage between own price and the output-input elasticities. There appears to be evidence that farmers of all the crops but rice, responded to some market signals after the government began subsidising fertilizers and seeds (and in some cases developing some form of hybrid seeds). The response was an increase in output (positive own price elasticities). Price policies appeared to be effective over the period under consideration. These results, however, should be interpreted cautiously as we are only dealing with cross sectional analysis. A panel or pseudo-panel analysis is needed to confirm these findings.

We also found support for non-price factors. We used four of them - farmers' education, land size, family labour and animal capital. Most of them were significant and in some cases their parameters exceeded most of the price factors. The significance of animal capital (wealth effect) could suggest the importance of famers' asset base to the overall development of the agricultural sector. Animal capital could also capture animal manure (fertilizer) which had proved to be essential in India's agricultural system popularly called the 'white revolution' (Otsuka and Yamano, 2005). The data on animal capital suggests, however, that few farmers own or use this category of 'fertilizer' either owing to inaccessibility or inaccurate data. Farmers' education and land size have a positive effect on output supply response. The effect of family labour on output response was mixed. Household (family) labour had a positive effect on groundnut growers but a negative impact on food crop (rice and cowpea) cultivators.

Much of the agricultural policies in Ghana have been directed towards ‘getting prices right’ like most Sub-Saharan countries that went through the Structural Adjustment phase of economic recovery. Less attention was and continues to be focused on non-price factors. This study has shown that both price and non-price factors are essential in the promotion of the agrarian sector. The focus of the current agricultural policy is aimed at modernising the sector. It would be more impact driven if policy makers equally consider non-price factors such as the education of farmers or the availability of extension officers. The application of technology to agriculture, in part, is dependent on farmers’ user capabilities. Clearly there is a need for the current unproductive land tenure system to be revamped to bring about meaningful productivity of the sector, which doubles as the poverty-led sector.

The large fertilizer price variation also needs policy attention if farmers are to be encouraged to apply the input. The insignificance of fertilizer on cocoa production could be further investigated. Confirmation of a similar outcome will demonstrate the importance of the development of soil and drought-resistant seedlings. The second best option though is to ensure alternative chemical fertilizers. The significance of farmers’ experience can be a yardstick for forming farming cooperatives at strategic farming communities. This could be a cost-effective channel for the dissemination of essential agricultural policies.

**Chapter 5 Appendix**

A5.1: Testing Non-nested or competing Models

Consider two non-nested regression models

$$H_0: y = X\beta + u_0, \;\; u_0 \sim N(0, I_n\sigma_0^2) \qquad (5\text{A}.1)$$

$$H_1: y = Z\gamma + u_1, \;\; u_1 \sim N(0, I_n\sigma_1^2) \qquad (5\text{A}.2)$$

where $y$ is the vector of *n* observations on the dependent variable, *X* and *Z* are a matrix of *N* observations on $k$ and $g$ linearly independent exogenous regressors, $\beta$ and $\gamma$ are vectors of *k* and $g$ unknown parameters and $u_0$ $and$ $u_1$ are $n$-vectors of random errors.

To test against the two alternative non-nested models and possibly select the 'best' model 2 tests have gained much attention in the literature. These are *J*- test proposed by Davidson and Mackinnon (1981) and the *JA*- test by Fisher and McAleer (1981). Both approaches begin by constructing a linear combination of equations (5A.1) and (5A.2) with weights ($1$-$\rho$) and $\rho$, respectively, leading to the combined regression model

$$y = (1-\rho)X\beta + \rho Z_\gamma + u \qquad (5\text{A}.3)$$

where $u = (1-\rho)u_0 + \rho u_1$ and $\rho$ is the scalar test parameter. It is however clear that none of the parameters- $\rho$, $\gamma$, $\beta$- are identifiable in (5A.3). One practical way is to replace $\gamma$ in (5A.3) with a consistent estimate of it. An alternative is to impose identification restrictions. Either way, it becomes feasible to test the null hypothesis against the alternative. In effect, Davidson and Mackinnon (1981) replaced $\gamma$ in (5A.3) with its OLS estimate under $H_1$ (i.e. $\hat{\gamma} = (Z'Z)^{-1}Z'y$) to obtain

$$y = (1-\rho)X\beta + \rho Z_{\hat{\gamma}} + u \qquad (5\text{A}.4)$$

The test statistic for the null hypothesis that (5A.1) is preferred to (5A.2) is the *t* statistic of $\hat{\gamma}$ in the OLS regression (5A.4). The *t*-ratio is called the *J*- test and it is asymptotically distributed as *N*(0,1) under $H_0$. The null hypothesis is rejected if the coefficient $\gamma$ is statistically significant as indicated by its $t$ ratio. Likewise the second model could be re-estimated and the predicted value included as an additional explanatory variable in the first model, under the similar null hypothesis.

The *J*- test will then indicate that one of the two models is robust. If neither hypothesis is rejected, then the data is not helpful in ranking the models. If both models are rejected, then we conclude that neither of the models are adequate, calling for a search of a more robust specification. If one rejection is received then the test is definitive in indicating that one of the models dominates (subsumes) the other and not vice versa.

The test by Davidson and Mackinnon (1981) has been criticised as unstable (especially with small samples), yielding ‘too high significance values in the range of 15-25% and thereby rejecting the null hypothesis more frequently’ (Godfrey and Pesaran, 1983; Gouri´erou and Monfort, 1994). As an alternative, Fisher and McAleer (1981) put forward the *JA*- test, which is used in our study. Their approach replaces $\hat{\gamma}$ with $\hat{\gamma}_0$, a more consistent estimate of the probability limit of $\hat{\gamma}$ under the null hypothesis. Thus (5A.4) is modified into

$$y = (1 - \rho)X\beta + \rho Z_{\widehat{\gamma_0}} + u \qquad (5A.5)$$

Where $\hat{\gamma}_0 = (Z'Z)^{-1}Z'P_x y)$ and $P_x$ is the orthogonal projection of $\partial[X]$. The $t$-ratio of $\rho$ in (5A.5) is called the *JA* statistic, also distributed asymptotically as $N(0,1)$ under the null hypothesis. The substitution of $\widehat{\gamma_0}$ for $\hat{\gamma}$ has been shown to be an attractive method, yielding an exact test of $H_0$ (Godfrey and Pesaran, 1983). Besides since the critical values of the $t$-distribution increase in absolute value as the degrees of freedom decreases in small samples, the *JA*- test favours the model which is more generous with regards to the number of parameters.

A5.2: Derivation of Elasticities

The output supply and input demand elasticities are estimated premised on the data mean points in this chapter. We only present the derivation used for chapter 4.

*Output Elasticities of Supply*

Own price elasticity of demand ($\gamma_{ii}$) $= \frac{\partial Y_i}{\partial P_i} * \frac{P_i}{Y_i} = \beta_{ii} * \frac{\alpha^2 P_i}{Y_i}$

Cross price elasticity of demand ($\gamma_{ij}$) $= \frac{\partial Y_i}{\partial P_j} * \frac{P_j}{Y_i} = \beta_{ij} * \frac{\alpha^2 P_j}{Y_i}$

Price elasticity of demand w.r.t. vth variable input ($\gamma_{iv}$) $= \frac{\partial Y_i}{\partial W_v} * \frac{W_v}{Y_i} = \beta_{iv} * \frac{\alpha W_v}{Y_i}$

Price elasticity of demand w.r.t. mth quasi-fixed input ($\gamma_{im}$) $= \frac{\partial Y_i}{\partial Z_m} * \frac{Z_m}{Y_i} = \beta_{im} * \frac{\alpha Z_m}{Y_i}$

*Input Elasticities of Demand*

Own price elasticity of demand for variable input $(\zeta_{vv}) = -\frac{\partial S_v}{\partial W_v} * \frac{W_v}{S_v} = -\beta_{vv} * \frac{\alpha W_v}{S_v}$

Cross price elasticity of demand for variable input (*v*) with respect to *r* $(\zeta_{vr})$ is given as

$$(\zeta_{vr}) = -\frac{\partial S_v}{\partial W_r} * \frac{W_r}{S_v} = -\beta_{vr} * \frac{\alpha W_r}{S_v}$$

Input elasticity of demand w.r.t. ith output price $(\zeta_{vi}) = -\frac{\partial S_v}{\partial P_i} * \frac{P_i}{S_v} = -\beta_{vi} * \frac{\alpha^2 P_i}{S_v}$

Input elasticity of demand w.r.t. mth quasi-fixed input $(\zeta_{vm}) = -\frac{\partial S_v}{\partial Z_m} * \frac{Z_m}{S_v} = -\beta_{vm} * \frac{\alpha Z_m}{S_v}$

We used an average inefficiency mean value of 0.56. We report selected (relevant) elasticities for this work.

Table A5.1: Output Cross-Price Elasticities for Model 2: Combined Sample

| Paired Crops | Elasticities |
|---|---|
| Cocoa-Groundnut | 0.06* |
| Cocoa-Maize | -0.13 |
| Cocoa-Rice | 0.05 |
| Cocoa-*Migso* | 0.02 |
| Cocoa-Cowpea | 0.01 |
| Groundnut-Maize | 0.15*** |
| Groundnut-Rice | 0.10** |
| Groundnut-*Migso* | 0.31** |
| Groundnut-Cowpea | -0.11*** |
| Maize-Rice | -0.16** |

| | |
|---|---|
| Maize-*Migso* | -0.34*** |
| Maize-Cowpea | 0.14** |
| Rice-*Migso* | -0.17 |
| Rice-Cowpea | 0.26*** |
| *Migso*-Cowpea | 0.27* |

*Note:* *, **, *** *denote level of significance at 10%, 5% and 1% respectively*

Table A5.2: Determinants of Technical Efficiency in Ghana: Pooled Sample

| Crop | Land Size | Household Size | HHH Education Level | HH Head Age[39] | HH Head Experience | Education & Fertilizer | Fertilizer & Seed | Education & Seed | Education, Seed, & Fertilizer |
|---|---|---|---|---|---|---|---|---|---|
| Cocoa | + | +*** | - | -*** | +** | +** | +** | + | - |
| Groundnut | +*** | +*** | +*** | -*** | + | -** | + | - | +* |
| Maize | +*** | +*** | +* | -*** | +** | - | +*** | -* | +** |
| Rice | +*** | +*** | + | - | + | - | - | +** | +* |
| Millet/ Sorghum/G. Corn | +** | +*** | +*** | -*** | +** | -* | - | - | +** |
| Cowpea | +** | +*** | +** | -*** | + | + | -* | + | +*** |

*Source: Estimations from STATA.*

*Note: *, **, *** denote 10%, 5%, and 1% significance*

*Note: '+' denote a positive impact; "-"is negative impact*

[39] Age square variable was 1% significant statistically and had the appropriate negative sign for all the crops but for Rice which, although it had the right sign, was not significant.

Table A5.3: Output Supply Function Estimates: Ecological Analysis Model 1 (Model without Technical Inefficiency)

| Variable | Cocoa | | Groundnut | | Maize | | Rice | | *Migso* | Cowpea | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coastal | Forest | Forest | S'vanah | Coastal | Forest | Forest | S'vanah | S'vanah | Coastal | S'vanah |
| Price of Cocoa | -18.415 | 7.851 | 8.013 | 15.002 | 8.188 | 6.252 | -13.207 | - | - | 7.643 | -10.533 |
| | (2.38)*** | (2.69)* ** | (2.45)* * | (1.66)* | (2.18)** | (4.02)* ** | (0.88) | | | (1.68)* | (0.88) |
| Price of G'nut | 2.007 | 8.013 | 13.480 | 24.510 | 33.670 | 35.710 | 41.772 | -8.889 | 9.570 | 0.912 | 39.153 |
| | (5.11)*** | (2.45)* * | (2.13)** | (1.17) | (5.91)*** | (3.67)*** | (0.71) | (1.04) | (2.87)*** | (2.29)** | (6.97)*** |
| Price of Maize | 8.188 | 6.252 | 33.670 | 14.055 | 5.752 | 18.035 | 4.826 | -2.002 | 21.733 | -12.008 | -8.203 |
| | (2.18)** | (4.02)* ** | (5.91)*** | (2.98)*** | (1.66)* | (2.31)** | (2.54)*** | (1.20) | (4.06)*** | (5.52)*** | (1.88)* |
| Price of Rice | - | -13.207 | 41.772 | -8.889 | 9.291 | 4.826 | -5.214 | -11.330 | 15.622 | -24.106 | -1.542 |
| | | (0.88) | (0.71) | (1.04) | (2.78)*** | (2.54)*** | (1.41) | (0.86) | (2.37)** | (3.01) | (1.26) |
| Price of *Migso* | - | -8.264 | 21.772 | 9.570 | 15.093 | -6.420 | 22.529 | 15.622 | 24.025 | -4.438 | -7.636 |
| | | (1.88)* | (0.91) | (2.87)*** | (0.54) | (1.81)* | (0.48) | (2.37)** | (2.94)*** | (2.31)** | (1.75)* |
| Price of Cowpea | 7.643 | 8.551 | 15.487 | 39.153 | -12.008 | -41.019 | 13.210 | -1.542 | -9.454 | 28.011 | 6.367 |
| | (1.68)* | (2.69)* ** | (3.22)*** | (6.97)*** | (5.52)*** | (3.45)*** | (2.86)*** | (1.26) | (4.78)*** | (1.91)* | (2.61)** |
| Price of Fertilizer | -20.145 | -18.225 | -21.733 | -19.606 | -26.006 | -14.027 | -21.789 | -18.012 | 17.826 | 5.813 | -12.245 |
| | (1.08) | (1.68)* | (2.41)** | (2.89)*** | (3.02)*** | (2.36)** | (1.87)* | (2.54)** | (0.74) | (1.27) | (2.86)** |
| Price of Seeds | -17.332 | -24.005 | -12.251 | -18.150 | -14.782 | 11.347 | -15.247 | -10.119 | -23.603 | -30.610 | -18.884 |
| | (2.38)** | (4.89)* ** | (2.28)** | (1.68)* | (2.22)** | (2.15) | (3.47)*** | (1.78)* | (1.81)* | (6.14)*** | (2.93)*** |
| Land Size | 17.1042 | -6.112 | 9.109 | -10.056 | 6.501 | 12.471 | 3.413 | 5.116 | 16.201 | 12.210 | 17.020 |
| | (2.97)*** | (0.39) | (2.43)** | (1.10) | (1.82)* | (2.45)** | (3.72)*** | (2.26)** | (0.28) | (1.88)* | (1.22) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Animal Capital | - | - | -7.473 | 26.200 | 5.266 | 17.600 | 3.380 | 11.103 | 34.624 | 0.617 | 6.774 |
| | | | (1.14) | (4.11)*** | (2.44)** | (6.09) ** | (1.77) * | (2.26) ** | (3.36) *** | (1.79) * | (3.19) *** |
| Education of HH | 2.181 | -6.251 | 10.909 | 17.328 | 13.117 | 4.229 | -1.552 | 14.072 | -8.183 | 28.443 | 3.409 |
| | (2.53)** * | (1.24) | (1.70) * | (1.59)* | (2.78) *** | (3.42) *** | (1.34) | (4.19) *** | (1.01) | (7.02) *** | (0.96) |
| Experience of HH | 11.411 | 9.316 | 42.017 | 19.061 | 31.161 | 10.080 | 6.003 | 4.613 | 12.040 | 4.994 | 10.032 |
| | (4.25)*** | (6.03)* ** | (2.71)** * | (3.46)*** | (2.39) ** | (2.40) ** | (2.78) *** | (1.64) * | (2.91) *** | (1.87)* | (4.27) *** |
| Constant | -7.114 | -8.251 | 21.772 | 14.560 | -9.553 | -27.009 | -5.214 | -11.330 | -6.644 | 13.010 | -18.235 |
| | (3.38)*** | (1.89)* | (0.91) | (2.87)*** | (4.72) *** | (2.11) ** | (1.87) * | (0.86) | (3.78) *** | (0.41) | (1.78) * |

*Notes: Figures in parentheses denote absolute value of z-statistics.* *, **, *** *denote 10%, 5%, and 1% significance*

Table A5.4: Output Supply and Input Demand Function Estimates: Pooled Analysis: Model 1 (Model without Technical Inefficiency)

| Variable | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea | Fertilizer | Seeds |
|---|---|---|---|---|---|---|---|---|
| Price of Cocoa | 1.157 | 7.004 | 1.782 | 15.009 | 4.418 | 8.703 | 13.817 | 12.290 |
| | (1.68)* | (2.95)*** | (2.21)** | (0.61) | (2.13)** | (2.71)*** | (1.01) | (1.92)* |
| Price of Groundnut | 7.004 | 7.992 | -2.868 | -8.214 | -1.079 | 18.581 | 24.144 | 11.001 |
| | (2.95)*** | (1.91)* | (2.80)*** | (0.53) | (1.19) | (2.55)*** | (2.63)*** | (2.40)** |
| Price of Maize | 1.782 | -2.868 | 9.336 | 14.240 | 23.882 | -6.006 | 12.207 | 17.780 |
| | (2.21)** | (2.80)*** | (1.11) | (3.23)*** | (2.43)** | (5.83)*** | (3.91)*** | (2.79)*** |
| Price of Rice | 15.009 | -8.214 | 14.240 | 23.379 | 6.020 | -11.304 | 12.663 | -8.334 |
| | (0.61) | (0.53) | (3.23)*** | (2.46)* * | (1.81)** | (1.97)** | (4.59)*** | (1.17) |
| Price of Migso | 4.418 | -1.079 | 23.882 | 6.020 | -12.909 | -28.402 | 5.431 | 19.505 |
| | (2.13)** | (1.19) | (2.43)** | (1.81)** | (0.71) | (4.28)*** | (2.58)** | (1.82)* |
| Price of Cowpea | 8.703 | 18.580 | -6.006 | -11.304 | -28.402 | 10.766 | 20.100 | -8.814 |
| | (2.71)*** | (2.55)*** | (5.83)*** | (1.97)** | (4.28)*** | (1.83)* | (2.45)** | (2.47)** |
| Price of Fertilizer | -13.817 | -24.144 | -12.207 | -12.663 | -5.431 | -20.100 | -7.825 | 10.622 |
| | (1.01) | (2.63)*** | (3.91)*** | (4.59)*** | (2.58)** | (2.45)** | (2.14)** | (2.96)*** |
| Price of Seeds | -12.290 | -11.001 | -17.780 | 8.334 | -19.505 | -8.814 | 10.622 | -3.541 |
| | (1.92)* | (2.40)** | (2.79)*** | (1.17) | (1.82)* | (2.47)** | (2.96)*** | (3.58)*** |
| Land Size | 16.445 | 6.096 | 9.834 | 19.396 | 7.334 | 4.453 | 10.380 | 12.794 |
| | (1.87)* | (2.17)** | (3.44)*** | (6.228)*** | (2.53)** | (0.48) | (3.73)*** | (4.13)*** |
| Animal Capital | - | 0.913 | 3.872 | 12.553 | 6.112 | 14.611 | 26.288 | 9.667 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | (2.28) ** | (1.86) * | (2.04) ** | (3.90) *** | (2.38) ** | (3.79) *** | (2.61) *** |
| Education of HH | 5.649 | 3.126 | 0.899 | 3.209 | 0.584 | 6.363 | 12.334 | 15.733 |
| | (1.22) | (2.11) ** | (1.79) * | (2.70) *** | (1.77) * | (0.84) | (2.41) ** | (3.44) *** |
| Experience of HH | 11.781 | 0.884 | 2.155 | 8.114 | 3.228 | 7.003 | 0.818 | 2.220 |
| | (3.59) *** | (1.73) * | (0.68) | (1.85) ** | (1.27) | (2.96) *** | (1.67) * | (2.05) ** |
| Constant | -16.393 | 8.336 | -11.201 | -10.086 | 10.030 | -7.755 | -13.553 | -6.398 |
| | (2.41) ** | (1.81) * | (2.76) *** | (0.94) | (2.61) *** | (2.61) *** | (0.65) | (2.29) ** |

*Notes: Figures in parentheses denote absolute value of z-statistics. *, **, *** denote 10%, 5%, and 1% significance*

Table A5.5: Output Supply Function Estimates: Ecological Analysis: Model 2 (Technical Inefficiency Model)

| | Cocoa | | Groundnut | | Maize | | Rice | | *Migso* | Cowpea | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Coastal | Forest | Forest | S'vanah | Coastal | Forest | Forest | S'vanah | S'vanah | Coastal | S'vanah |
| Price of Cocoa | 4.035 | 9.851 | 13.023 | 0.145 | -14.560 | 16.647 | 0.422 | - | - | 0.892 | -5.227 |
| | (1.98) * | (2.42) ** | (4.41)*** | (2.33)** | (1.10) | (2.07)** | (1.88) * | | | (1.08) | (0.76) |
| Price of G'nut | 4.049 | 13.023 | 9.310 | -12.099 | 33.670 | -13.700 | -24.473 | 7.016 | -4.108 | -8.469 | -13.024 |
| | (2.32)** | (4.41)* ** | (2.41)** | (2.17) ** | (5.91) *** | (2.80) *** | (1.71) * | (1.84) * | (3.01)*** | (2.42)** | (2.37)** |
| Price of Maize | -14.560 | 16.647 | -13.700 | 10.717 | 5.378 | -9.911 | 2.724 | 3.604 | 21.733 | -10.316 | -27.503 |
| | (1.10) | (2.07)** | (2.80) *** | (1.85)* | (1.86)* | (2.44) ** | (2.81) *** | (2.20) ** | (4.06) *** | (3.18) *** | (2.88) *** |
| Price of Rice | - | 0.422 | -24.473 | 7.016 | 10.007 | 2.224 | 17.755 | -8.241 | 6.037 | -18.663 | 42.073 |
| | | (1.88) * | (1.71) * | (1.84) * | (4.04)** * | (2.71) *** | (2.85) *** | (1.02) | (2.44) ** | (2.38) ** | (2.40) ** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Price of *Migso* | - | 10.001 | 0.424 | -4.108 | 0.136 | 3.445 | 8.866 | 6.037 | 38.159 | -14.077 | -19.043 |
| | | (2.38) ** | (0.77) | (3.01)*** | (0.54) | (2.76) *** | (1.73) * | (2.44) ** | (2.96) *** | (2.77)*** | (2.86) *** |
| Price of Cowpea | 0.892 | 9.505 | 0.073 | -13.024 | -10.316 | -34.011 | -24.844 | 42.073 | -19.043 | 0.058 | 36.397 |
| | (1.08) | (0.69) | (0.62) | (2.37)** | (3.18) *** | (4.03) *** | (2.76) *** | (2.40) ** | (2.86) *** | (0.86) | (5.80) *** |
| Price of Fertilizer | -8.107 | 7.225 | -34.422 | -8.775 | -13.300 | -22.553 | -48.218 | -8.060 | -25.228 | -11.988 | -51.022 |
| | (0.74) | (1.18) | (2.39) ** | (1.89)* | (2.81) *** | (3.05) *** | (3.25) *** | (2.34) ** | (1.85) * | (2.27) ** | (2.36) ** |
| Price of Seeds | -10.233 | -8.466 | -22.046 | -64.105 | -20.333 | -29.416 | -32.002 | -13.365 | -29.552 | -7.820 | -18.884 |
| | (5.22) *** | (2.99)* ** | (3.39) *** | (2.88) *** | (2.17) ** | (4.63) *** | (3.47) *** | (0.88) | (2.89) *** | (3.27) *** | (2.88) *** |
| Land Size | 11.910 | -14.000 | 6.612 | 17.188 | 5.450 | 7.066 | 27.540 | 5.120 | 8.508 | 2.347 | 5.443 |
| | (1.93)* | (1.77) * | (1.93)* | (2.41) ** | (2.82)*** | (1.85) * | (4.71) *** | (1.16) | (2.18) ** | (1.88) * | (1.02) |
| Animal Capital | - | - | 14.699 | 43.474 | 0.927 | 10.221 | 4.762 | 15.466 | 30.255 | 0.087 | 26.650 |
| | | | (2.74) *** | (6.08)*** | (0.44) | (2.99) *** | (2.91) *** | (1.84)* | (4.07) *** | (1.09) | (4.25) *** |
| Education of HH | 2.008 | 0.887 | 3.677 | 2.380 | 3.114 | 6.031 | 19.200 | 7.751 | 12.272 | 13.044 | 11.775 |
| | (2.77)** * | (2.44)** | (1.88) * | (1.87)* | (2.43)** | (2.29) ** | (3.43) *** | (2.42) ** | (2.11) ** | (3.32) *** | (2.45) ** |
| Experience of HH | 9.709 | 3.404 | 34.501 | 12.222 | 14.455 | 8.860 | 10.519 | 5.033 | 19.118 | 0.851 | 11.158 |
| | (2.27)** | (1.83)* | (2.91)*** | (1.96)* | (2.79) *** | (3.27) *** | (2.77)*** | (2.20) ** | (2.79) *** | (2.32)** | (3.05) *** |
| T. I. (α) | -54.068 | -39.556 | -48.001 | -37.144 | -44.907 | -18.352 | -33.251 | -59.784 | -76.599 | -59.411 | -44.079 |
| | (2.75)*** | (2.94)*** | (3.91) *** | (1.87)* | (2.84) *** | (6.28)*** | (2.88) *** | (6.55) *** | (2.44) ** | (2.32) ** | (2.29) ** |

*Notes: Figures in parentheses denote absolute value of z-statistics.* *, **, *** *denote 10%, 5%, and 1% significance*

Table A5.6: Output Supply and Input Demand Function Estimates (Technical Inefficiency Model): Pooled Analysis

| Variable | Cocoa | Groundnut | Maize | Rice | ***Migso*** | Cowpea | Fertilizer | Seeds |
|---|---|---|---|---|---|---|---|---|
| Price of Cocoa | 3.008 | 6.355 | 10.903 | -8.202 | 6.330 | -10.009 | 15.734 | 8.225 |
| | (2.18)* * | (2.45) ** | (1.21) | (0.91) | (2.33) ** | (0.84) | (1.03) | (2.42) ** |
| Price of Groundnut | 6.355 | 5.510 | -7.349 | 0.885 | 6.644 | -0.795 | 34.159 | 13.144 |
| | (2.45) ** | (4.01) *** | (4.19) *** | (1.73) * | (0.88) | (2.29)* * | (3.27) *** | (1.90) * |
| Price of Maize | 10.903 | -7.349 | -8.011 | 3.302 | 3.843 | -15.575 | 22.310 | 7.144 |
| | (1.21) | (4.19) *** | (2.29) ** | (3.01) *** | (1.83) * | (2.94) *** | (2.86) *** | (2.99) *** |
| Price of Rice | -8.202 | 0.885 | 3.302 | 14.313 | 5.141 | -9.202 | 20.001 | 11.772 |
| | (0.91) | (1.73) * | (3.01) *** | (3.74) *** | (1.83) * | (2.97) *** | (3.17) *** | (1.76) * |
| Price of *Migso* | 6.330 | 6.644 | 3.843 | 5.141 | 8.101 | -29.980 | -10.006 | 19.505 |
| | (2.33) ** | (1.88) * | (1.83) * | (1.83) * | (2.71) *** | (2.44) ** | (0.88) | (1.82) * |
| Price of Cowpea | -10.009 | -0.795 | -15.575 | -9.202 | -29.980 | 17.622 | 38.841 | -8.814 |
| | (0.84) | (2.29)* * | (2.94) *** | (2.97) *** | (2.44) ** | (2.92) *** | (5.05) ** | (2.47) ** |
| Price of Fertilizer | -15.734 | -34.159 | -22.310 | -20.001 | 10.006 | -38.841 | 12.002 | 14.118 |
| | (1.03) | (3.27) *** | (2.86) *** | (3.17) *** | (0.88) | (5.05) ** | (2.14) ** | (1.98) * |
| Price of Seeds | -8.225 | -43.144 | -57.144 | -41.772 | -12.288 | -20.449 | 11.955 | -7.070 |
| | (2.42) ** | (1.90) * | (2.99) *** | (1.76) * | (2.82) *** | (2.40) ** | (1.96) * | (2.88) *** |
| Land Size | 9.109 | 11.037 | 17.885 | 8.807 | 1.460 | 6.568 | 8.326 | 4.088 |
| | (2.37) ** | (1.77) ** | (2.44) ** | (3.33) *** | (2.83) *** | (2.29) ** | (2.73) *** | (2.73) *** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Animal Capital | - | 1.876 | 5.083 | 2.206 | 8.018 | 3.301 | 0.954 | 6.155 |
| | | (2.41) ** | (2.36) ** | (2.34) ** | (2.90) *** | (1.78) * | (2.39) ** | (4.14) *** |
| Education of HH | 2.055 | 1.306 | 3.553 | 4.041 | -2.363 | -2.801 | 22.148 | 10.008 |
| | (2.22) ** | (2.31) ** | (0.86) * | (5.07) *** | (1.07) | (1.18) | (6.25) * ** | (2.44) ** |
| Experience of HH | 9.008 | 0.884 | 0.408 | -12.317 | 6.071 | 5.471 | 2.911 | 0.233 |
| | (1.59) * | (3.477) *** | (2.28) ** | (2.35) ** | (2.08) ** | (2.36) ** | (2.87) *** | (1.73) * |
| T. I. (α) | -71.562 | -88.113 | -78.077 | -56.080 | -89.554 | -77.006 | -55.343 | -26.223 |
| | (2.93) *** | (4.22) *** | (2.34) ** | (3.38) *** | (4.77) *** | (2.48)** | (2.93) *** | (1.88)* |

*Notes: Figures in parentheses denote absolute value of z-statistics.* *, **, *** *denote 10%, 5%, and 1% significance*

# CHAPTER 6: OUTPUT SUPPLY RESPONSES IN GHANA: A ROBUSTNESS ANALYSIS

## 6.1 Introduction

This chapter provides a sensitivity analysis of the empirical estimates in chapters 4 and 5 that were based on the assumption that each farm produced only one output so all inputs were 'allocated' to the principal output. In Ghana, however, it is a very common practice for farmers to produce more than one crop on the same piece of farmland during a farming season (mixed cropping), or at times some end up practising mixed farming (combining both crop and animal farming) on the same piece of land. The first kind of practice - mixed cropping - is relevant to this study. In fact more than 7 out of 10 famers in Ghana grow more than one crop (Table 6.1). The reasons for these practices are not ambiguous. Mixed cropping provides the room for farmers to smooth out family income throughout the year. Perhaps the major reason is that there are different farming seasons for the crops used in this study, hence mixed cropping or crop rotation becomes the best farming practice.

The survey data did not, however, detail how inputs such as farm inputs such as land and fertilizer were allocated to outputs for multiple crops. With no information on input allocations across multiple outputs, we can only assume that all inputs are assigned to the predominant output. This assumption - that farms only produced one output (the principal output) and allocated all inputs to that - underlined the discussions in chapters 4 and 5. In cases where one output dominates (say 70% of output or more) (see Tables 6.2 and 6.3), this should give reasonably unbiased estimates. However, many farmers produce multiple outputs (at least 7 out of 10 farm households cultivated more than one crop in the period under review - see Table 6.1) and the principal product may account for less than 70% of the total harvest. In such cases the previous estimates may be biased as we may have overstated the volume of inputs allocated to produce the principal crop which may have led to underestimated production efficiency.

Allowing for inputs to be allocated across multiple outputs compared to assuming only one output, there may not be a marked difference in estimated output elasticities but there may be differences in estimated technical efficiency (TE) and input elasticities (but perhaps not if the principal crop is predominant). This means that estimates based on the translog modelling (without TE) should not alter remarkably compared to previous chapters. However, estimates from the quadratic estimation (model with TE) should see significant changes compared to previous chapters.

To assess if these biases may be significant we consider an alternative assumption by assuming inputs are allocated to outputs according to the share of outputs in total farm production. For single product farms, where one output is predominant, the estimates should not differ remarkably. However, in the case of multiple product farms the previous estimates are likely to be biased.

The next section reviews the distribution of crop cultivation in our data and a discussion on output shares. We also discuss the descriptive statistics. Section 6.3 presents the estimates when we allocate inputs in proportion to output shares in total production. As our concern is with identifying cases where this assumption affects the estimates, we focus on comparing the results with corresponding estimates from the previous chapters, taking technical efficiency, translog and quadratic estimates in turn. For discussion purposes, a difference of +/- 5% of the previous estimate is considered significant. Section 6.4 presents the chapter conclusions.

## 6.2 Distribution of Multiple Output Production in the Data

As the data shows, more than half of farm households (71%) in Ghana cultivate two or more crops (Table 6.1). Multiple-crop farming practice is not uncommon in the country as it serves as an income buffer for predominantly farm households. Moreover the practice enhances (farm) land efficiency for hire/contract-land farmers who seek to maximise farmlands within the stipulated farming season. As it would be seen, some of the crop pairings help to maintain the potency of the land, which by itself enhances efficiency in some sort.

Growing two or more crops takes the form of either mixed cropping (growing multiple crops at the same time) or crop rotation (following crop sequences). In both cases, there is usually one perennial crop which is inter-cropped with other short-harvested crops. Among food/staple farmers, however, all crops cultivated usually have a similar harvest life.

Table 6.1: Distribution of crops grown by farmers in Ghana

| *Quantity of Crops grown* | *Number of HH Farms* | *% of HH Farms* | *Cumulative Frequency* |
|---|---|---|---|
| 1 | 1,053 | 29.07 | 29.07 |
| 2 | 931 | 25.73 | 54.80 |
| 3 | 861 | 23.79 | 78.59 |
| 4 | 565 | 15.61 | 94.20 |
| 5 | 177 | 4.89 | 99.09 |
| 6 | 32 | 0.91 | 100.00 |

*Source: computed from GLSS4and based on the six crops for this study*

Of the farmers surveyed almost a third cultivated single crops, with maize being the dominant crop, during the farming season under the period of discussion (Table 6.1). Farmers in the Savannah zone recorded the highest in terms of single crop cultivation with more than half of its farmers concentrating on the growing of staple crops (Table 6.4), with more than half of its farm size allocated to the growing of this staple crop - millet, sorghum and guinea corn (*migso*). Maize is the dominant crop for single-crop cultivators in both the Coastal and Forest zone, with the proportion of farms allocated to its cultivation in the Coastal zone was as twice as that of the Forest zone.

Table 6.2: Proportion of farms, number of crops cultivated, average farm size, dominant crop and common crop combinations: Coastal Zone

| Quantity of Crops Grown | % of HH Farms | Average Plot Size (hec) | Dominant Crop | Dominant Crop Mainly Combined With |
|---|---|---|---|---|
| 1 | 40.12 | 0.6 | Maize | - |
| 2 | 31.16 | 1.7 | Rice | Cowpea |
| 3 | 24.81 | 2.1 | Maize | Cocoa |
| 4 | 2.80 | 2.5 | Maize | Groundnut |
| 5 | 1.06 | 2.8 | Maize | Groundnut |
| 6 | 0.05 | 2.8 | Maize | Cowpea |

*Source: computed from GLSS4and based on the six crops for this study*

The relatively large proportions of farms allocated to staple and food crops may be explained by the worsening conditions of food crop farmers' contribution to the national poverty benchmark, where that category of farmers recorded a 5 percentage point increment in their contribution to the national poverty levels between the two survey periods (GLSS3-1991/2 and GLSS4-1998/99).

The proportion of farms cultivating more than one crop (70%) is large enough to support our assertion of carrying out sensitivity analysis to verify the respective elasticities. Even so the data shows a certain pattern of plot size and the number of crops cultivated.

Table 6.3: Proportion of farms, number of crops cultivated, average farm size, dominant crop and common crop combinations: Forest Zone

| Quantity of Crops Grown | % of HH Farms | Average Plot Size (hec) | Dominant Crop | Dominant Crop Mainly Combined With |
|---|---|---|---|---|
| 1 | 20.03 | 1.1 | Maize | - |
| 2 | 26.66 | 2.2 | Groundnut | Cowpea |
| 3 | 34.32 | 2.9 | Cocoa | Maize |
| 4 | 12.05 | 3.4 | Cocoa | Groundnut |
| 5 | 4.80 | 3.5 | Cocoa | Cowpea |
| 6 | 2.14 | 4.2 | Cocoa | Cassava |

*Source: computed from GLSS4and based on the six crops for this study*

We also noted some form of relationship between plot size and number of crops grown by farmers. Farms that cultivated at least four crops during a particular farming season had access to at least 3 hectares of farmland, supporting a possible claim that farmers who have access to bigger parcels of farmland are likely to grow multiple crops. Farmers in the Savannah zone have the most access to farmlands at each number of crops grown. This is not very surprising as regions in the zone - Northern, Upper East and Upper West - have the largest parcels of land (though not all are arable lands). These regions also had the least proportion of non-farm activities (Table 3.16), suggesting that agriculture becomes the mainstay of the zone.

Table 6.4: Proportion of farms, number of crops cultivated, average farm size, dominant crop and common crop combinations: Savannah Zone

| Quantity of Crops Grown | % of HH Farms | Average Plot Size (hec) | Dominant Crop | Dominant Crop Mainly Combined With |
|---|---|---|---|---|
| 1 | 53.15 | 1.2 | *Migso* | - |
| 2 | 25.02 | 2.0 | Groundnut | *Migso* |
| 3 | 15.33 | 2.6 | Groundnut | Cowpea |
| 4 | 4.05 | 2.9 | *Migso* | Groundnut |
| 5 | 2.15 | 3.0 | *Migso* | Yam |
| 6 | 0.31 | 3.2 | Yam | Cowpea |

*Source: computed from GLSS4 and based on the six crops for this study*

Regarding crop cultivation, the majority of single-crop farmers (77%) were into food crops (maize, cowpea, rice) farming, with farmers in the Coastal and Forest zones dominating. Staples - millet, sorghum and guinea corn (*migso*) - are the most single crop cultivated by farmers in the three poorest regions - Northern, Upper East, Upper West - of Ghana (Savannah zone).

In terms of crop combinations, it is common practice to have a perennial crop intercropped with a legume or other short-harvest crops such as groundnut, maize and cassava. Food crops (maize and rice) are the dominant crops among Coastal farmers as against a mixture of staples (*migso* and yam) and export crops by Savannah farmers on the one hand and food and export crops by farmers in the Forest zone on the other. The distribution of the crops also met the expected agro-climatic conditions of the three ecological zones described earlier in chapter 3.

A further important observation is worth noting about the distribution of crops cultivated by farmers across the three zones as shown by Table 6.5. Of the total amount of export crops produced, more than half (52%) of farmers in the Coastal zone produce between 30-70% of total zonal cocoa output with only a quarter producing over 70%. In contrast, 8 out of ten farmers produce over 70% of the total cocoa production from the Forest zone. Regarding groundnut, the other export crop, a greater percentage of Savannah farmers produce the highest zonal proportion (more than 70%) than any of the other two zones. Groundnut cultivation is the dominant crop of the Savannah zone.

Table 6.5: Percentage distribution of crops grown by farmers across ecological zones

| Crop | Coastal | | | Forest | | | Savannah | | |
|---|---|---|---|---|---|---|---|---|---|
| | <30% | 30-70% | >70% | <30% | 30-70% | >70% | <30% | 30-70% | >70% |
| Export: Cocoa | 23 | 52 | 25 | 17 | 10 | 83 | - | - | - |
| Groundnut | 58 | 23 | 19 | 14 | 50 | 36 | 11 | 28 | 61 |
| Food: Maize | 14 | 23 | 63 | 27 | 25 | 48 | 27 | 31 | 42 |
| Rice | 5 | 11 | 84 | 12 | 72 | 16 | 78 | 22 | 0 |
| Cowpea | 78 | 18 | 4 | 23 | 68 | 9 | 34 | 14 | 52 |
| Staple: *Migso* | - | - | - | 86 | 12 | 2 | 4 | 76 | 20 |

*Note: figures are in percentage and are rounded to the nearest whole number.*

*Source: calculations from GLSS4*

The proportion of zonal food cultivation is relatively more even than that of staples and export crops. Coastal food farmers produce a greater proportion (at least 70%) of maize and rice than farmers in the same category from the other zones. The production of cowpea is highest among Savannah farmers where more than half of its farmers are involved in its production. Staple (*migso* in this study) production in the Forest zone is very minimal if one compares it with cultivation in the Savannah zone, mainly due to the high demand in the latter zone, apart from the climatic conditions that favour regions in the zone.

Given the distributions in Table 6.5 and without rigorous econometric estimations, we can crudely predict the effects of output supply elasticity estimates in chapters 4 and 5. The rule of thumb is that if the cultivation of any particular crop is adjudged to be the dominant crop in a zone, then their corresponding elasticity estimates in chapters 4 and 5 may still be accurate. Otherwise, they may change and be incorrect. Based on this crude criterion, elasticity estimates for cocoa, groundnut and cowpea for the Coastal zone would change. By the same standard, elasticity estimates for export (groundnut), food (rice, cowpea) and staple (*migso*) crops for the Forest zone would change. In the Savannah zone, we would expect a change in elasticity estimates for rice and staples. By estimation, however, any change in estimates is adjudged to be important and hence biased only when such difference in estimates is outside the -/+ 5 percentage point range. Otherwise, such changes are random that could emanate from data imperfections.

It should again be noted, however, that although a small proportion of farms - 3% in Coastal, 6% in Savannah and 17% in Forest - cultivated at least four crops during the farming year under review, they are still relevant in our analysis due to their output-input allocation mix. If a plot is used for two or more crops, it implies inputs would not be divisible across multiple crops, allowing for the proper allocation of output-input mix. Input indivisibility against output divisibility calls for one to work out the proportion of inputs likely to be assigned to a particular output. This is dealt with in Table 6.6, where shares analysis is introduced.

Table 6.6: Crop output shares by ecological zones

| Output | Coastal (%) | Forest (%) | Savannah (%) |
|---|---|---|---|
| Cocoa | 12 | 35 | - |
| Groundnut | 7 | 8 | 13 |
| Maize | 37 | 28 | 11 |
| Rice | 22 | 11 | 12 |
| *Migso* | - | 3 | 40 |
| Cowpea | 4 | 6 | 9 |
| Other crops | 18 | 9 | 15 |

*Source: Author's calculation based on GLSS4 data on sampled data; Figures rounded to whole numbers.*

Cocoa production is over a third of the output in the Forest zone but this accounts for almost 79% of cocoa produced by Ghana. Although groundnut is 13% of Savannah's output, it represents 68% of groundnut production in Ghana. The Coastal zone's share of groundnut is about 12% of national output. In terms of food crops, Forest maize output shares account for more than half (57%) of national (maize) output whereas Coastal and Savannah maize shares are equivalent to 30% and 13% respectively of national output. Cowpea output shares are the lowest in each of the three zones. The shares of 9% (Savannah) and 6% (Forest) represent 61% and 33% of national cowpea output for the period under review. The proportion (22%) of rice produced by farmers in the Coastal zone translates into 76% of total (local) rice production in Ghana. Out of all the crops cultivated by the Savannah zone for the period under review, staples (*migso*) accounted for 40% of total zonal. That proportion, however, corresponds to more than three-quarters (76.3%) of national output for *migso*. The above picture shows how ecological output shares may not always reflect the contribution of the zone to national output. We can conclude, based on the above descriptions, that some of our earlier estimates (from chapters 4 and 5) might just be biased. We would discuss any bias or otherwise from what follows in section 6.3.

A brief description of our ‘new’ data (based on crop shares) is appropriate before proceeding to discuss estimated results. Prices shown in Table 6.7 are (mean) market prices, similar to what was defined (in chapter 3) and used in our empirics in chapters 4 and 5. As expected, average prices for all crops, including maize and rice (predominantly produced crops at the zone), in the Coastal zone are comparatively higher than that from the other two zones. One of several reasons explaining this causality between outputs supply and their prices may be the demand factor, which is completely missing from our analysis.

Table 6.7: Descriptive Statistics for core variables

| | Costal | | Forest | | Savannah | |
|---|---|---|---|---|---|---|
| *Outputs* | Mean* | S.D | Mean* | S.D | Mean* | S.D |
| Cocoa Price (¢/kg) | 1330 | 0.96 | 1312 | 1.81 | - | - |
| Groundnut Price (¢/kg) | 2790 | 5.12 | 1955 | 3.06 | 1404 | 10.05 |
| Maize Price (¢/kg) | 1132 | 19.08 | 1021 | 7.03 | 865 | 6.02 |
| Rice Price (¢/kg) | 2030 | 5.22 | 1708 | 2.97 | 1638 | 7.70 |
| *Migso* Price (¢/kg) | - | - | 369 | 12.54 | 378 | 1.91 |
| Cowpea Price (¢/kg) | 2340 | 3.10 | 2246 | 4.43 | 1960 | 0.89 |
| | | | | | | |
| *Inputs* | | | | | | |
| Price of Seeds(¢/kg) | 17,010 | 13.96 | 17,989 | 9.03 | 18,844 | 16.22 |
| Price of Fertilizer(¢/kg) | 15,037 | 24.09 | 17,004 | 31.11 | 19,101 | 29.18 |
| Cultivation Area(ha) | 0.85 | 1.52 | 1.34 | 11.41 | 2.02 | 8.04 |
| Family Labour (#) | 1.03 | 0.88 | 2.39 | 0.76 | 3.63 | 1.87 |
| HHH Education (years) | 10.06 | 4.31 | 8.08 | 3.67 | 6.69 | 1.66 |
| Animal Power | 0.08 | 0.07 | 1.09 | 0.73 | 3.22 | 2.38 |
| Profit (¢'000/kg) | 396 | 38.87 | 616 | 42.33 | 141 | 19.17 |

* *Output and input prices are rounded to nearest whole numbers. S.D denotes standard deviation*

If the rise in output supply (of maize and rice) still falls short of rising demand for these crops, one should expect prices to rise. Although rice is one of the dominant crops produced in the Coastal zone, its zonal share (22%) accounts for a little over half (53%) of the total rice produced in Ghana. A second possible justification for this seeming paradox may be explained by price arbitrage. Assuming no differences in ecological yield quality and no transportation cost, a typical marketing farmer/agent is likely to cash in an extra 10% and 31% in price between Forest-Coastal and Savannah-Coastal zones respectively. The low standard deviations among cocoa prices matches expectation as the Cocoa Marketing Board (CMB), a para-governmental body, is the sole buyer of the major cash crop in the country, hence price variation could come from differences in the quality of cocoa beans.

Prices of seeds and fertilizer are unit prices derived from the survey data. Following a similar trend, farmers in the Forest zone pay about 11% more for a kilogram of seeds compared to farmers in the Coastal zone. In the same way farmers from the Coastal regions pay about 13% and 27% less for a kilogram of chemical fertilizer compared to their counterparts in the Forest and Savannah zones respectively. These price variations are usually caused by 'middlemen' including wholesalers, retailers, and cooperatives among others (F.A.O., 2005).

On average, Savannah farm households employ more family labour and animal power on their farms than any farm household in both the Forest and Coastal zones. These revelations conform to the poverty and income status of the zone (see Table 3.16), where rural Savannah is adjudged the poorest in Ghana (for the same year under review). Large average family populations (4 per family) and the low degree of non-farm opportunities in the zone (see Table 3.15) make employment in the farms one of the few lucrative employments available in the zone. The proportion of agricultural share of total household incomes is about 70.3% among Savannah households (considerably more among rural Savannah households), comparing with 49.9% in Coastal and 69% in Forest zones respectively (Table 3.15). Households in the Savannah zone also have the least income shares from wage employment (3%) and non-farm self-employment (15%) compared with households in the Coastal (7%, 29%) and Forest (4%, 18%) zones respectively (Table 3.15). On average, a farm household in the Coastal zone comparatively earns less profit than a typical farmer from the Forest zone. The difference could come from the sale of cocoa (an export crop) that is largely grown in the Forest zone. Farm households from the Savannah zone earn the least profit.

Farmers from the Coastal zone, on average, have had relatively more years of formal education but it is farmers from the Forest zone who enjoy the most profit from farming. We believe a greater proportion of the zonal profit would come from cocoa farmers in the zone due to the crop's guaranteed ready market (by the CMB) and the high international price for the cash crop.

## 6.3 Estimation and Results

As in previous chapters (4 and 5), GLSS4 is used to construct output and input shares for the estimations of elasticities using both the translog (equations akin to 4.4 and 4.5 in chapter 4) and the quadratic (equations analogous to 5.17 and 5.18 in chapter 4) functional forms. The translog estimation does not include technical inefficiency but the quadratic functional form does. All variables used are as defined in Table 4.1 except that we use output and input shares in our estimation in this chapter. We do not expect large changes to our estimates from the previous chapters mainly because the underlying assumptions in chapters 4 and 5 - allocating all inputs to principal outputs - produce similar descriptive statistics to the assumption used here - allocating a proportionate amount of inputs (what we call 'shares' in this study) to outputs.

### 6.3.1 Estimation of Technical Efficiency Scores

We utilised the stochastic production frontier technique used in chapter 5 (equation 5.16) to estimate technical inefficiency scores at both at the national (pooled) and ecological levels. This is to provide a direct comparison with inefficiency scores in chapters 4 and 5. The results are presented in Table 6.8. Among other comparisons, we did not find wide disparities in inefficiency scores, compared to those found in chapter 5. The average nationwide production inefficiency score was found to be 53%, 3 percentage points 'better' than earlier estimates. Matching this difference by our expected bias range (-/+ 0.05), the difference is not biased.

A quick glance at the pooled estimates revealed a general downward trend in production inefficiencies. Only the cultivation of rice recorded a 'significant' change in technical inefficiency score (producing a difference of more than the 5 percentage points) nationally.

Table 6.8: Technical Inefficiency Scores: Pooled (national) and ecological zones

| Crop | Pooled | Coastal | Forest | Savannah |
|---|---|---|---|---|
| Cocoa | 0.54 (0.56) | 0.53 (0.52) | 0.60 (0.57) | - |
| Groundnut | 0.61 (0.64) | 0.84 (0.87) | 0.79 (0.78) | 0.50 (0.56) |
| Maize | 0.60 (0.59) | 0.67 (0.67) | 0.65 (0.60) | 0.55 (0.54) |
| Rice | 0.48 (0.56) | 0.32 (0.28) | 0.44 (0.47) | 0.52 (0.54) |
| *Migso* | 0.42 (0.40) | - | 0.56 (0.57) | 0.38 (0.39) |
| Cowpea | 0.59 (0.63) | 0.59 (0.57) | 0.30 (0.35) | 0.31 (0.27) |

*Notes: Figures in parentheses are estimates from chapter 5.*

In terms of ecological differences, the results from both the Coastal and Forest zones showed mixed movements in production inefficiencies compared to their previous respective estimates. The technical inefficiency score increased for cocoa, rice and cowpea farmers in the Coastal zone whilst farmers who cultivated groundnut recorded a lower inefficiency score. Although maize was the dominant crop for the Coastal zone (see Tables 6.2 and 6.5), its technical inefficiency score saw no modification.

Technical inefficiency estimates for cocoa, rice and cowpea all increased with share estimations but none registered a 'significant' change. Rice, the dominant crop among farmers who grow two crops in the Coastal zone, registered the biggest change (14% increment comparatively) in technical inefficiency. The change is, however, within our expectation (-/+ 0.05).

In the Forest zone, farmers who cultivate rice, *migso* and cowpea saw their technical inefficiency downsized at various margins as opposed to increments in production inefficiencies of cocoa, maize and groundnut farmers. Two out of the three crops in the Forest zone - maize and cowpea - registered almost 'significant' changes in their production inefficiency estimates. These changes suggest, once again, that there is an element of multiple outputs, which in fact is the case according to the data (Table 6.5). Although maize yield is very high in the zone, about 63% of farms in the zone produce about 30-60% of cowpea. Again cowpea production is highly cultivated by farmers in the zone who grow two and five crops within a given year.

Farmers in the poorest zone – Savannah - had their technical inefficiency estimates staples, groundnut and rice scaled down but only the cutback in groundnut was 'significant'. The results introduce some sort of ambiguity. Judging from the results from the Forest zone, we would have expected technical inefficiency estimate for staples in the Savannah zone to change 'significantly' instead as 30-60% of its quantum is produced by some 76% of farms, as against 61% of farms producing over 70% of groundnut crop in this zone. These suggest that inefficiency scores are not only sensitive to data transformations but equally responsive to data composition. The only justification for high alteration in technical inefficiency for groundnut in this zone is that the cash crop is usually combined with staples (*migso*) during a farming season (multiple crop, see Table 6.4). Production inefficiency scores for some food crops - maize and rice - saw relative increments in their inefficiencies although none of them was 'significant'.

In summary, technical efficiencies for some export crops (groundnut) among farmers in the Savannah zone are affected when we adopt shares analysis, although scores among food (maize and cowpea) from the Forest zone could alter. Among the same food crops category, technical inefficiency estimates produced in chapter 5 would see no change for farmers of maize crops in the Coastal regions.

### 6.3.2 Estimation of Elasticities

In a similar fashion, we estimated the output supply and input demand elasticities using the output and input shares. In what follows we only present, on a comparative basis, all categories of the elasticities except the cross-price. For effective comparisons, we estimated both the translog function (model without technical inefficiency) and the quadratic function (model incorporating technical inefficiency). Thus the final econometric equations are akin to equations (4.5) and (5.18) respectively used in chapters 4 and 5, except that we used output-input shares dataset in this chapter. This exercise was to allow us to assess whether our results in chapters 4 and 5 are robust. This in effect investigates to what extent output supply elasticities change when different datasets are used for estimations.

***Outputs Own-Price Supply Elasticities***

Output from Tables 6.9 and 6.10 present the estimates (from shares analysis) and compares them with earlier estimates. We found a rather mixed (and in some cases unclear) potential reaction to changes in output supply in the event of likely changes in output and input prices.

Table 6.9: Ecological Output Own-Price Elasticities: Translog Model

| Crop | Coastal | Forest | Savannah |
|---|---|---|---|
| Cocoa | $0.04^{**}$ ($0.04^{*}$) | $0.10^{**}$ ($0.08^{***}$) | - |
| Groundnut | $0.13^{***}$ ($0.12^{***}$) | $0.05^{*}$ ($0.06^{*}$) | $0.10^{**}$ ($0.09^{***}$) |
| Maize | $0.11^{***}$ ($0.10^{***}$) | $0.04^{***}$ ($0.05^{***}$) | $0.02^{*}$ ($0.04^{**}$) |
| Rice | $0.12^{***}$ ($0.15^{**}$) | $0.08^{***}$ ($0.07^{***}$) | $0.02^{**}$ ($0.02^{**}$) |
| *Migso* | - | $0.06^{*}$($0.06^{**}$) | $0.15^{*}$ ($0.14^{**}$) |
| Cowpea | $0.10^{*}$ ($0.13^{**}$) | $0.10^{**}$ ($0.09^{**}$) | $0.06^{**}$ ($0.06^{*}$) |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively.*

*Figures in parentheses are from earlier estimations (from chapter 4).*

Results from the translog model suggest that farmers in the Coastal zone are likely to register mixed reactions to potential price changes of groundnut, maize, rice and cowpea respectively. Compared to estimates from chapter 4, farmers of the last two crops (rice and cowpea) show a lesser price reaction than the first two farmers. However, there was no ‘significant’ change in the output supply elasticities in this zone that exceeded our expectation (-/+ 5%). Output supply elasticities for cocoa farmers in the Coastal zone remain unchanged and hence insensitive to data transformations (at least share analysis) involving multiple outputs. In some cases too (e.g. cowpea in the Coastal zone), statistical significance was weak (i.e. lost grounds from estimations based on our new dataset). Statistical significances for rice and cocoa, however improved.

The story for the Coastal zone is somehow different when we accounted for technical inefficiency. Farmers’ potential price change reaction is lower for all crops except rice, with the change in reaction ranging from a low of 2 percentage points difference (cocoa and cowpea farmers) to a high of 6 percentage points (groundnut) - the only ‘significant’ change we observed. Maize farmers’ output supply elasticity estimate also reduced by 0.03 points comparatively, but the change is within expectation margins. Maize and groundnut are seen as complements (chapter 4 results) and are the common pairings for farms that cultivate 4 or 5 crops within a farming season. The fall in elasticity is explained by the dynamics of supply. Any output price/input change should have led to a rise in elasticity for groundnut but if maize is the dominant crop, coupled with time horizon in changing scale of farming production, we expect the elasticity of groundnut to be lower.

The 'insignificant' changes in the output supply elasticity estimates for maize and rice farmers in the Coastal zone confirm our prior expectations as these food crops are the dominant crops produced in the zone so allocating all inputs to the estimation of output elasticities (as carried out in chapters 4 and 5) should not alter the elasticities 'significantly'. The 'significance' among groundnut farmers (Table 6.10) in the Coastal zone also confirms our *apriori* expectation that not factoring any substitutability among the crops implies biased (output cross price) elasticity estimates in our earlier chapters (4 and 5).

Outcomes from both profit functions did not provide 'significant' changes in output supply elasticities for farmers in the Savannah zone for all crops. The biggest changes were a positive 0.02% (maize under translog) and a reduction of 0.03 percentage points (staples-*migso* under quadratic model), comparatively. Other food crops - rice and cowpea - did not see any change in their elasticities with technical inefficiency assumed but saw some changes when inefficiency is accounted for, although any variance in elasticity was 'insignificant'. The low differences in the elasticities are not very surprising as own-price price sensitivity does not capture possible crop interactions (substitutes and complements).

Table 6.10: Ecological Output Supply Own-Price Elasticities: Quadratic Model

| Crop | Coastal | Forest | Savannah |
|---|---|---|---|
| Cocoa | $0.07^{**}$ $(0.09^{*})$ | $0.21^{***}$ $(0.17^{***})$ | - |
| Groundnut | $0.22^{**}$ $(0.28^{**})$ | $0.14^{***}$ $(0.16^{**})$ | $0.06^{***}$ $(0.08^{**})$ |
| Maize | $0.28^{***}$ $(0.31^{***})$ | $0.04^{***}$ $(0.04^{***})$ | $0.03^{***}$ $(0.05^{*})$ |
| Rice | $0.09^{***}$ $(0.09^{***})$ | $0.08^{**}$ $(0.06^{**})$ | $0.09^{**}$ $(0.11^{*})$ |
| *Migso* | - | $0.04^{***}$ $(0.04^{***})$ | $0.17^{***}$ $(0.20^{***})$ |
| Cowpea | $0.05^{**}$ $(0.07^{*})$ | $0.05^{**}$ $(0.07^{**})$ | $0.03^{*}$ $(0.04^{*})$ |

*Note: *, **, *** denote level of significance at 10%, 5% and 1% respectively.*

*Figures in parentheses are from earlier estimations (chapter 5).*

Similar to the outcomes from the Coastal and Savannah zones, output supply elasticities in the Forest zone did not produce any 'significant' results (Table 6.9), suggesting that our own-price output supply elasticity estimates are insensitive to data transformation (at least at shares level).

We found that when we assume technical efficiency (translog model), shares estimations would not provide 'significant' changes in output supply elasticity estimates among farmers of all crops at the ecological level. Nevertheless, accounting for production inefficiency would lead to 'significant' changes in some output supply responsiveness, leading us to conclude that groundnut own-price supply output elasticity estimates (from chapter 5) changes may be overestimated. Furthermore, since groundnut is not the dominant crop produced in the Coastal zone, we infer that cross-price elasticities in chapter 5, especially the pairings of groundnut with cowpea, cocoa, maize, rice and *migso*, may all be underestimated due to the neglect of allowing for multiple outputs (i.e. not capturing substitution possibilities). These implicit under-estimated elasticities might be channelled through changes in potential outputs and input prices. Take as an example a farm that produces maize and groundnut, but we only allow for maize. In this case higher maize (predominant output) prices would be associated with observed higher production, whereas higher ('other'/ combined output) groundnut prices would be correlated with observed lower maize production. In the same example the effect of a higher input price is spread across the two products so the observed reduction in maize output is less than would be predicted if it was the only product.

The above analysis is summarised as follows. Own-price elasticities for all crops at each of the three ecological zones are not sensitive to our data transformation (share analysis) when we assume technical efficiency. However, if production inefficiency is accounted for, farmers of some export crops - groundnut (from Coastal zone) - would alter 'significantly' their output supply own-price elasticities. This leads us to conclude that in Ghana output supply own-price elasticity estimates are sensitive to (data) aggregation, method of estimation and in some cases data transformation (share analysis in our study). We also noted, though trivial, that statistical significance overall improves with our new dataset, but mainly within the quadratic profit framework, confirming our conclusions in chapter 5 that the quadratic framework is superior to the translog at least as far as our dataset is concerned.

***Output Supply Responses with Respect to Inputs Prices***

Tables 6.11 and 6.12 present output supply elasticities with respect to potential changes to prices of variable inputs - seeds and chemical fertilizers. In all, the translog model recorded 28 different changes (12 downward and 16 positive movements) as compared to 24 changes from the quadratic profit function (12 even for both directions) (See Table A6.1 at chapter appendix).

If technical inefficiency is assumed, farmers in the Savannah zone change their output supply responsiveness least in the event of future changes in input prices. However, in the quadratic profit function, the least likely to react would be farmers from the Coastal zone. We also observed more 'significant' changes in elasticities in the quadratic model than that of the translog function possibly due to the estimation procedure. Elasticities from the shares approach were predominantly downsized comparatively, again due to data transformations. The degrees of significance were predominantly weaker under the output shares approach, with some crops recording statistically insignificant estimates. The expected signs were also maintained as with previous estimates.

Table 6.11: Ecological Output supply responses *w.r.t.* variable inputs prices: Translog Model

| | Coastal | | Forest | | Savannah | |
|---|---|---|---|---|---|---|
| Crop | Seeds | Fertilizer | Seeds | Fertilizer | Seeds | Fertilizer |
| Cocoa | $-0.11^{**}$(-) | $-0.03^{*}$(-) | $-0.04^{**}$(-) | $-0.13^{**}$(-) | - | - |
| Groundnut | $- 0.18^{**}$(+) | $-0.09^{**}$(+) | $-0.08^{**}$(0) | $-0.10^{**}$(-) | $-0.20^{**}$(+) | $-0.30^{**}$(-) |
| Maize | $-0.09^{**}$(-) | $-0.19^{*}$(+) | $-0.08^{**}$(-) | $-0.19^{*}$(-) | $-0.06^{***}$(0) | $-0.16^{**}$(-) |
| Rice | $-0.15^{*}$(-) | $-0.10^{**}$(-) | $-0.10^{**}$(-) | $-0.15^{**}$(-) | $-0.10^{**}$(-) | $-0.28^{**}$(+) |
| *Migso* | - | - | $-0.06^{**}$(-) | $-0.11^{**}$(-) | $-0.05^{**}$(0) | $-0.20^{**}$(-) |
| Cowpea | $-0.08^{**}$(-) | $-0.04^{***}$(-) | $-0.07^{*}$(0) | $-0.09^{***}$(-) | $-0.07^{**}$(-) | $-0.07^{**}$(+) |

*Notes:* $^{*}$, $^{**}$, $^{***}$ *denote 10%, 5%, and 1% significance respectively.*

*Note: This table is from the model without technically efficiency. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate.*

Any potential change in the price of seeds and fertilizer would not produce ‘significant’ alterations in the output supply elasticities among farmers in both the Coastal and Forest zones when production inefficiency is ignored (Table 6.11). However, if we account for technical inefficiency, export (cocoa) and food (cowpea) crops in the Forest and Coastal zones would lead to ‘significant’ changes in their output supply elasticities with respect to probable changes in the price of chemical fertilizers and seeds respectively. An added enhancement for cocoa’s elasticity is that the estimate, compared previously, becomes statistically significant at 5% level but also maintained its expected (inverse) sign.

Two other ‘credible’ and statistically significant changes in the output supply elasticity estimates from the Savannah zone emanated from farmers who cultivate staples (*migso*) and export (groundnut) crops. Changes produced from the quadratic functional form are of most interest to us. Groundnut and staple farmers would not respond any differently to potential changes in the prices of seeds and fertilizers respectively than they already did in chapter 5 even when we transform the dataset, making them insensitive to those input price changes.

Table 6.12: Ecological Output supply elasticities *w.r.t.* variable inputs: Quadratic Model

| | Coastal | | Forest | | Savannah | |
|---|---|---|---|---|---|---|
| Crop | Seeds | Fertilizer | Seeds | Fertilizer | Seeds | Fertilizer |
| Cocoa | $-0.05^{***}$(-) | -0.02(-) | $-0.25^{**}$(-) | $-0.09^{**}$(-) | - | - |
| Groundnut | $-0.12^{**}$(+) | $-0.10^{**}$(0) | $-0.22^{**}$(0) | $-0.13^{*}$(+) | $-0.18^{**}$(+) | $-0.28^{*}$(-) |
| Maize | $-0.04^{**}$(0) | $-0.05^{**}$(-) | $-0.11^{***}$(+) | $-0.21^{**}$(-) | $-0.11^{**}$(+) | $-0.13^{**}$(0) |
| Rice | $-0.13^{**}$(-) | $-0.09^{**}$(+) | $-0.17^{**}$(-) | $-0.10^{***}$(-) | $-0.18^{*}$(-) | $-0.18^{**}$(-) |
| *Migso* | - | - | $-0.05^{**}$(0) | $-0.11^{***}$(0) | $-0.24^{**}$(-) | $-0.20^{***}$(+) |
| Cowpea | $-0.24^{**}$ (-) | $-0.05^{**}$(0) | $-0.14^{**}$(-) | $-0.10^{**}$(-) | $-0.19^{***}$(0) | $-0.13^{**}$(-) |

*Notes: $^{*}$, $^{**}$, $^{***}$ denote 10%, 5%, and 1% significance respectively.*

*Note: This table is from the model with technically efficiency. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate.*

In line with the above changes, it is fair to say that some of our cross-price elasticity estimates from earlier chapters were estimated with some bias. One reason is due to the neglect of adjusting for output effects arising from changes in the prices of seeds and fertilizers (i.e. not capturing substitution possibilities). The outcomes from Tables 6.11 and

6.12 would have effects on both the elasticity estimates presented in Tables 4.5 (chapter 4) and 5.6 (chapter 5) either directly or indirectly.

The total effect would also depend on whether the crop in question is the dominant crop and/or the relationship between the dominant crop and the main pairing crop as stated in Tables 6.2-6.4. The three crops that registered 'significant' changes in their output elasticity estimates are cocoa (from the Forest zone), groundnut (from the Savannah zone and both export crops) and cowpea (food crop from the Coastal zone). Cowpea is not a dominant crop among farmers in the Coastal zone (less than 30% of its output grown by about 78% of farms - Tables 6.2 and 6.5) and therefore any elasticity estimates arrived at in chapters 4 and 5 would in fact be without any considerations of cowpea farmers. However with such a magnitude, one cannot completely ignore its substitutability effect on output supply elasticities. With that in mind, the output supply elasticity estimates for the pairings of groundnut-cowpea (farmers who grow two crops) and cocoa-cowpea (farmers who grow five crops) in the Coastal zone would have been estimated with bias in chapters 4 and 5.

There would, however, not be any significant effect on the pairings of any crop with cocoa in the Forest zone. This should not be difficult to comprehend. The export crop is the dominant crop among farmers who grow at least three different crops in the zone (Table 6.3). In fact over 70% of cocoa production is produced by some 83% of farms in the zone, making it the highest concentration zone. Any changes arising from changes in input prices would not see significant changes in supply output of the cash crop.

The crops in question here are groundnut and *migso*, a staple. Groundnut is a dominant crop among farmers in the zone who grow two or three different crops in a farming season. In contrast, the staple crop is the principal crop for farmers who grow four or five different crops. Across those two crops, groundnut and *migso* are the closest main crops for farmers who simultaneously cultivate four and two different crops, respectively in the zone. By our predictions, there should not be major effects on output supply elasticities for the dominant crops of a change in input prices; in this case among farmers who cultivate between two and five different crops in the zone. The distribution in Table 6.5, however, confirms only that of groundnut (as over 61% of farms grow at least 70% of total groundnut output in the zone).

The case of *migso* is different. With 76% of farmers producing between 30-70%, we should expect an effect on output supply elasticity. This is the ambiguity.

There is, however, no doubt about the effects on output supply elasticities of input with respect to input prices estimates for the pairings of groundnut-*migso* (for farmers who grow two or four different crops) in the zone. Although these crops are not the main crops cultivated in the zone but the proportions of farms allocated to the production of at least 60% of zonal total output (48% for groundnut and 80% for staples) are too large to be ignored.

It is not clear what medium through which the above would affect output supply elasticities of input with respect to input prices reported in Tables 4.5 and 5.6 in chapters 4 and 5 respectively. We speculate there may be both direct and indirect effects. Directly, all output supply elasticities of input with respect to input prices estimates from Tables 4.5 and 5.6 related to the three crops - cocoa, groundnut and cowpea - would have been underestimated due to any inherent crop substitutability that were missed especially those relating to the quadratic functional form. The indirect effect would be likely to run through output cross-price elasticity estimates. With cowpea 'ignored' any change in the price of cowpea seeds, for example, could affect not only its own output production (own-price effect) but also the production of other crops sharing the same farmland.

An illustration would help to clarify this. Assume a two-crop typical farmer say cowpea and maize. If 52% of the farmland is used for the cultivation of cowpea prior to any adjustments in input prices, then given an unchanging agro-climatic conditions, a rise in only the price of cowpea seeds would spill over to an increase in the quantity supply of its land-competing crop – maize - although the (maize) supply responsiveness was not prompted by the output price change but rather crops substitutions.

Inferring from this single analogy, all output cross-price elasticity estimates reported in chapters 4 and 5, but only related to the affected crops in this chapter (cocoa, groundnut and cowpea) are equally under- or over-estimated depending on whether they are substitutes or otherwise. The net effect would obviously depend on the relative directional strength.

***Non-Price Elasticities***

Results from the non-price elasticities, once again, confirmed their importance to the development of the agricultural sector in Ghana. These non-price fixed (land size) and quasi fixed factors (the rest) are non-divisible across the crops. The same farmland, for example, is used for the cultivation of all the crops assuming a typical farmer grows more than a single crop. Any changes in the magnitude and/or price of these factors are highly likely to affect all crops in a proportion. For example, an increase in the price of leasing a given size of farmland would see an incremental effect on the price of all the crops grown on this parcel of land for the given farm season. Given the direct (through output prices) and circumlocutory (through output supply) effects of changes in non-price factors, it is understandable that our non-price elasticities estimated in chapters 4 and 5 are estimated with bias, even if the magnitude is small. What follows next is an analysis of any possible changes in elasticities, bearing in mind that major modification should be in the region of 5 percentage points over previous estimates.

Our modified non-price elasticities are presented in Tables 6.14 - 6.17. In all, 14 elasticities remained unchanged (under the Translog estimation). Only six elasticities (spread across the ecological zones) saw ‘significant’ changes. Food crops (maize and rice) saw the most significant changes.

Table 6.14: Output Non-Price Elasticities: Translog Model (Coastal)

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | $0.18^{**}$(-) | $0.05^{*}$(-) | $0.19^{**}$(-) | $0.12^{**}$(-) | - | $0.09^{**}$(0) |
| Animal Capital | $0.06^{**}$(+) | $0.04^{**}$(-) | $0.09^{*}$(0) | $0.08^{**}$(+) | - | $0.05^{**}$(0) |
| Family Labour | $0.07^{**}$(-) | $0.10^{***}$(0) | $-0.04^{*}$(-) | $0.05^{**}$(s) | - | $0.08^{**}$(-) |
| HH Education | $0.08^{**}$(0) | $0.04^{**}$(-) | $0.08^{**}$(0) | $0.06^{**}$(-) | - | $0.03^{**}$(-) |

*Notes: $^{*}$, $^{**}$, $^{***}$ denote 10%, 5%, and 1% significance. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate. (s) denote a change in significance.*

It was also observed that in areas where family labour was insignificant in our previous estimations, they both become statistically significant and maintained their previous expected signs or the new significance comes with the opposite sign. We exercise much caution in claiming the accuracy or otherwise of the possible changes in these signs as less evidence exists in the literature. Our guess is that such differences in signs would have emerged as a result of heterogeneity factors across the three ecological zones. Whatever direction the sign takes, we have shown that family labour is very important in supply response analysis, at least within the developing economies contest. Neglecting them could lead to inaccurate output supply elasticities.

The results from the translog model suggest that output supply (of each of the six crops) would not significantly alter in the event of changes in education levels of farmers, making this category insensitive to this method of data transformation. Meanwhile, land size, animal capital and family labour all recorded 'significant' changes in all three zones. The biggest change came from farmland, recording over 14 percentage points difference (rice output in the Forest zone).

Table 6.15: Output Non-Price Elasticities: Translog Model (Forest)

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | $0.14^{**}$(-) | $0.16^{**}$(-) | $0.11^{**}$(0) | $0.21^{**}$(-) | $0.06^{***}$(+) | $0.13^{**}$(+) |
| Animal Capital | $0.06^{**}$(+) | $0.10^{**}$(-) | $0.08^{**}$(+) | $0.08^{*}$(+) | $0.09^{***}$(+) | $0.11^{**}$(-) |
| Family Labour | $0.14^{**}$(+) | $0.10^{**}$(0) | $-0.07^{*}$(+) | $0.06^{*}$(+) | $0.21^{***}$(+) | $0.10^{**}$(+) |
| HH Education | $0.11^{*}$(+) | $0.15^{***}$(-) | $0.08^{**}$(+) | $0.15^{**}$(+) | $0.07^{***}$(+) | $0.12^{**}$(0) |

*Notes: *, **, *** denote 10%, 5%, and 1% significance. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate. (s) means a change in significance.*

A potential change in the size of (farm) land size available to farmers in the Coastal zone is expected to lead to less than previous estimates for all crops except for cowpea farmers, who are likely to maintain their previous response rate. There were, however, mixed changes to the land size elasticity estimates in both the Forest and Savannah zones. If we account for technical inefficiency (Table 6.17), we see that only food (rice) and export (groundnut) crops recorded significant changes to land size elasticities.

Likewise, only food (rice and maize) farmers in both the Coastal and Forest zones would see 'significant' changes to plot size changes (if efficiency is assumed). Given these modifications and the crops cultivation distributions in Tables 6.2-6.5), we can conclude that the effects on non-price elasticities in our earlier chapters would be different.

Table 6.16: Output Non-Price Elasticities: Translog Model (Savannah)

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | - | $0.15^{**}$(-) | $0.09^{***}$(+) | $0.08^{**}$(+) | $0.06^{*}$(+) | $0.06^{**}$(-) |
| Animal Capital | - | $0.18^{**}$(-) | $0.16^{**}$(+) | $0.13^{**}$(+) | $0.09^{*}$(-) | $0.11^{**}$(-) |
| Family Labour | - | $0.09^{**}$(0) | $0.07^{*}$(s) | $0.08^{**}$(0) | $-0.03^{***}$(s) | $0.12^{**}$(+) |
| HH Education | - | $0.07^{**}$(0) | $0.10^{**}$(0) | $0.04^{***}$(0) | $0.06^{*}$(-) | $0.05^{*}$(+) |

*Notes: *, **, *** denote 10%, 5%, and 1% significance. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate. (s) means a change in significance.*

Maize and rice are more dominant crops in the Coastal zone than the Forest zone, suggesting that non-price (farmland) elasticity estimates among food crop farmers in chapters 4 and 5 are underestimated for both zones although the underestimation for the Forest zone would be greater due to a failure to capture rice as a supporting crop. Land size elasticity for export crops and staples would either not be affected in each of the three zones (translog model) or marginally underestimated (through groundnut farmers) with technical inefficiency admitted.

Animal capital elasticity estimates from the Savannah zone would see the most modification from our new estimations. The changes would mostly affect farmers of export crops (mainly groundnut) from this zone. For farmers in the zone that groundnut is their most dominant crop (i.e. who grow at most three crops), there would not be much change in the animal capital elasticity estimates. The same effect cannot be said of farmers who grow at least four crops in the zone. In that case our earlier animal capital estimates would have been underestimated. The net effect for the zone would be minimal though as groundnut remains by far the most dominant crop from the zone (Table 6.5).

A further 'significant' change in cocoa's animal capital elasticity is also predicted (Table 6.17), although not assigned particularly to any of the ecological zones. We believe that this change, if credible, is likely to affect estimates from either the Coastal or Forest zones or both. However, because cocoa is predominantly produced in the Forest zone, any changes in the animal capital elasticities for this zone would be relatively lower than that of the Coastal zone, where much attention is focused on the cultivation of food crops - maize and rice (Table 6.5).

Table 6.17: Non-Price Elasticities: Quadratic Model (Combined Sample)

| Non-Price Inputs | Cocoa | Groundnut | Maize | Rice | *Migso* | Cowpea |
|---|---|---|---|---|---|---|
| Land Size | $0.16^{***}$(-) | $0.18^{**}$(-) | $0.08^{*}$(-) | $0.20^{**}$(-) | $0.06^{**}$(+) | $0.14^{**}$(-) |
| Animal Capital | $0.02^{**}$(s) | $0.12^{**}$(-) | $0.17^{**}$(-) | $0.19^{***}$(-) | $0.10^{**}$(+) | $0.07^{**}$(0) |
| Family Labour | $0.07^{**}$(+) | $0.19^{**}$(-) | $0.12^{**}$(-) | $-0.04^{*}$(s) | $0.26^{**}$(+) | $0.10^{**}$(-) |
| HH Education | $0.07^{*}$(0) | $0.11^{**}$(-) | $0.13^{*}$(+) | $0.09^{**}$(0) | $0.12^{**}$(-) | $0.14^{**}$(-) |

*Notes: *, **, *** denote 10%, 5%, and 1% significance. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate. (s) means a change in significance.*

Failure to control for technical inefficiency in the profit model would lead to 'significant' variations in the family labour elasticity estimates for the Coastal (rice) and Savannah (staples). In fact, it is estimated that an additional family labour would lead to an increase in rice output by 5 percentage points over the previous estimate and this is comparatively statistically significant (Table 6.14). However, if we account for production inefficiency, estimates suggest that family labour elasticity for groundnut farmers would see 'significant' changes (Table 6.17). These separate modifications confirm that non-price elasticities in this case, and indeed agricultural supply responsiveness, are not only sensitive to data calibration but also to the method of analysis.

## 6.4 Conclusions

We have used output and input shares to re-estimate output supply elasticities previously estimated in chapters 4 and 5. The main aim was to carry out a sensitivity analysis with respect to a transformed dataset and method. Not many 'significant' changes were found. A 'significant' change here is defined as a 5 percentage point alteration comparatively.

We found that estimates in the previous empirical chapters are likely to change although most of the changes were 'insignificant'. The model with technical inefficiency scores also produced more of the 'significant' outcomes, confirming the relative superiority of the quadratic functional form. We also found that overall statistical significance, based on shares estimations, predominantly improved. The average technical inefficiency score among Ghanaian farmers also fell by 3 percentage points compared to non-shares estimations in chapter 5.

Regarding output own-price elasticities, we found that farmers' output supply responses were relatively lower than previous estimates across both methodologies, albeit the differences were marginal. The only 'significant' own-price output supply elasticity change came in the way of export (groundnut) farmers in the Coastal zone and only when we controlled for production inefficiency. Farmers of food (cowpea) and staple (*migso*) crops on the one hand and export (cocoa and groundnut) crop farmers on the other are susceptible to potential changes in the prices of seeds and chemical fertilizers respectively. Farmers are likely to react more to potential seed price changes when production inefficiency is accounted for than when we assume efficiency. Our new estimates also confirmed the importance of non-price inputs, with the size of farmland edging out the other three - animal capital, family labour and human capital (measured by the formal education of the household head).

Before concluding this chapter, we make a comparison of crop rankings against non-price inputs as presented by Tables 6.14-6.17 (as compared with Tables 4.7-4.9 and 5.10 in chapters 4 and 5 respectively). We find minimal changes across the two estimation techniques (see Tables A6.1 and A6.2 at chapter appendix). There were overall 'gains' for both the Coastal and Savannah estimates but not for the Forest zone in the translog model. Farmers' education also did not see any changes in the rankings. The most significant change came in the way of groundnut and cocoa rankings (translog model), where the latter gained some grounds for policy direction. Food and export crop farmers still consider the size of farmland more crucial. This means that, among other factors, any policy aimed at reducing poverty rates among food crops farmers in the country (the poorest economic category in the poverty profile) should address ways of minimising the accessibility of farmlands, an endemic problem that continues to hamper development in Ghana.

Increasing production of food crops and sustaining food security in the country must also see policies that would improve farmers' education on crops (from growing to post-harvest management) as well as making farm equipment accessible. The provision of farm equipment (denoted by animal capital) must be thought through. One has to consider the scale of farms operation in the country. A partnership balance of government action (through farm cooperatives in smallholder farms) and the private sector investment (in large farms) could be a starting point. Another angle to the animal capital factor is the indirect supply of fertilizer. With the price of chemical fertilizers driving down, animal manure production should be seriously invested in. Ultimately drought-resistant hybrid food crop seeds need to be developed.

After a careful robustness analysis, we can conclude that the changes in the elasticities by incorporating multi-cropping are small. Thus, elasticity estimates in chapters 4 and 5 are reasonably robust. Moreover, we can make a key statistical conclusion based on analysis in this chapter that is also akin to observations made by Schiff and Montenegro (1997). That is agricultural (output) supply responses in Ghana are sensitive to the data type (non-shares and shares in our case), estimation method and the level of aggregation (pooled or ecological levels). From a policy viewpoint, we suggest any comprehensive agricultural policy in Ghana, and other developing agricultural-led economies, must be preceded by a detailed research based on each of these supply response sensitivity angles - type of data to be used, supply response estimation technique and level of disaggregation.

## Chapter 6 Appendix

Table A6.1: Distribution of output supply response changes *w.r.t* possible input price changes

| *Translog* | Coastal | | | Forest | | | Savannah | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | + | - | 0 | + | - | 0 | + | - | 0 | + | - | 0 |
| Seeds | 1 | 4 | 0 | 0 | 4 | 2 | 1 | 2 | 2 | 2 | 10 | 4 |
| Fertilizer | 2 | 3 | 0 | 0 | 6 | 0 | 2 | 3 | 0 | 4 | 12 | 0 |
| *Quadratic* | Coastal | | | Forest | | | Savannah | | | Totals | | |
| | + | - | 0 | + | - | 0 | + | - | 0 | + | - | 0 |
| Seeds | 1 | 3 | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 4 | 8 | 4 |
| Fertilizer | 1 | 2 | 2 | 1 | 4 | 1 | 1 | 3 | 1 | 3 | 9 | 4 |

*Sources: summary from Tables 6.5 and 6.6 comparisons. (-) means current estimate is lower than previous estimate. (+) means current estimate is lower than previous estimate.*

Table A6.2: Comparisons of Crop Rankings and Non-Price Inputs: Translog Model

| Non Price Variable | Crop Rankings (Best Three) | Matching Ecological Zone |
|---|---|---|
| *Non-shares estimation rankings* | | |
| Land Size | Rice, Maize, Groundnut | Forest, Coastal, Forest |
| Animal Capital | Groundnut, Cowpea, Maize | Savannah, Forest, Savannah, |
| Family Labour | *Migso*, Maize, Cocoa | Forest, Savannah, Forest |
| HH Education | Groundnut, Rice, Cowpea | Forest, Forest, Forest |
| *Shares estimation rankings* | | |
| Land Size | Rice, Maize, **Cocoa** | Forest, Coastal, **Coastal** |
| Animal Capital | Groundnut, **Maize, Ric**e | Savannah, **Savannah**, Savannah |
| Family Labour | *Migso*, **Cocoa, Cowpea** | Forest, **Forest, Savannah** |
| HH Education | Groundnut, Rice, Cowpea | Forest, Forest, Forest |

*Rankings based on Tables 4.7, 4.8, and 4.9(chapter 4) and Tables 6.8-6.10 in this chapter. Note: Crops and ecological zones in bold represent changed crop/zone.*

Table A6.3: Comparisons of Crop Rankings and Non-Price Inputs: Quadratic Model

| Non Price Variable | Crop Rankings (First Highest Three) |
|---|---|
| *Non-shares estimation rankings* | |
| Land Size | Rice, Groundnut, Cocoa |
| Animal Capital | Rice, Maize, Groundnut |
| Family Labour | Groundnut, *Migso*, Maize |
| HH Education | Cowpea, *Migso*, Groundnut |
| *Shares estimation rankings* | |
| Land Size | Rice, Groundnut, Cocoa |
| Animal Capital | Rice, Maize, Groundnut |
| Family Labour | ***Migso*, Groundnut**, Maize |
| HH Education | Cowpea, **Maize,** Groundnut |

*Rankings based on Tables 5.10 (chapter 5) and Tables 6.11 in this chapter. Note: Crops in bold represent changed crop/structure.*

# CHAPTER 7: GENERAL CONCLUSIONS, POLICY IMPLICATIONS, AND FUTURE RESEARCH

## 7.1 General Conclusions and Policy Implications

Ghana is often described as one of West Africa's development success stories: the country's growth and poverty reduction rates are among the very best in the region. Ghana's stable, peaceful political climate supports a policy environment conducive to economic and social progress and poverty reduction. Since 1991, the country's poverty rate has dropped by almost half. Despite these many successes, however, Ghana's rural population still faces some challenges.

Both the report from Economic Commission of Africa (ECA, 2010) and the World Development Report (WDR, 2008) argue that agricultural growth is the engine of economic growth for developing countries. Urey (2004) also contends that agricultural growth is a fundamental pre-requisite for widespread poverty reduction in poor economies. Ghana seems to have taken this development path - economic growth spearheaded by the growth in the agricultural sector. The sector has seen more interventions over the years with the hope of increasing the sector's output and enhancing its competitiveness.

The emphasis on agriculture is justified. A greater proportion of poor people in Ghana live in the rural areas (39.2% according to the 2010 World Bank estimated figures, compared to only 10% of the urban population living below the poverty line) and agriculture is the major economic activity in this part of the economy, employing more than half of the rural labour force. In fact it is an essential part of the livelihoods of many poor people in Ghana. Sustaining agricultural growth therefore has the potential not only to stimulate national economic growth but also reduce severe poverty, usually caused by malnutrition. Agricultural development in Ghana also has the potential to increase the earning base of farmers through exports.

Despite the strong arguments in favour of pro-poor agricultural-led economic growth in Ghana, output has not seen a major increase. Food imports continue to rise. Clearly productivity in the sector must be struggling in spite of many sectoral interventions.

The literature discusses some of the sources that impede the growth of agricultural productivity in developing countries, of which Ghana is no exception. Urey (2004) and Brooks et al (2009) discuss three key factors - categorised into local, global and policy conditions. Local conditions are mainly supply-sided problems, not limited only to soil fertility constraints, inadequate fertilizer usage, information constraints, dried out government investment coupled with low level private sector involvement due to greater risks and lower returns to investment associated with the sector. Another crucial local constraint to agricultural growth has to do with the high post-harvest deterioration. These local challenges are further aggravated by low levels of human capital and inadequate infrastructure.

Global impeding factors are mainly demand-sided. They include the improvement in technologies and indeed the demand for technological products, dynamics of population trends and composition of global markets. These combined factors culminate in the downward trend in real prices for primary agricultural commodities.

Policy factors have to do with policy failures to the detriment to agricultural development in developing countries. Policy factors are blamed on market failure and state failure. The large reduction of state funded agricultural research and investment is the major source of falling trends in agricultural productivity. This is further exacerbated by the shrink in private sector involvement arising from market failure. This argument is usually referred to as the ‘new institutional argument’. There is also the liberalisation agenda argument, which stems from market failure.

We also reviewed the literature discussing the factors responsible for improving productivity in the agricultural sector. These factors - called supply response factors - are broadly categorised into price and non-price sources. Price factors have to do with how agricultural productivity responds to prices of both outputs and inputs. Non-price factors include all other factors, apart from price, that make producers of agricultural commodities respond positively to increase output.

A related supply-sided (local) constraint to agricultural productivity is the operation at sub-optimal efficiency levels by farmers. This is technical inefficiency in production economics under the neoclassical school of thought. A farmer who is technically inefficient would not be operating at the highest possible production frontier (what we referred to as potential frontier) and thereby reaping suboptimal outputs. Not even the supply of extra inputs would move the typical farmer to a higher production frontier. Any upward adjustment can only occur if the technically inefficient gap (difference between farmers' actual and potential production frontiers) is minimised or completely bridged. We found out, through the review of Ghana's agricultural policies, that no attention is given to this important policy ingredient, which we believe has been one of the fundamental government failures in Ghana needing policy redress.

In fact Urey (2004) and Rodrik (2000) argue against any economic policy in developing countries without first acknowledging the structural obstacles, to which technical inefficiency is key. In a policy direction for agricultural transformation, Urey (2004) recommends three phases, of which the first - establishing the basics - concerns restructuring of productivity factors. Most agricultural supply response studies assume technical efficiency for a number of reasons. We incorporated it in our analysis. We address its impact on agricultural supply response in Ghana at the most disaggregated unit - ecological levels. The effect of that was noticeable to neglect.

As noted earlier, we aimed to carry out an agricultural supply response analysis not at the aggregate level, as most of the previous studies have done, but at a much disaggregated level to aid spatial agricultural development especially within the crop subsector. This subsector has been the engine behind the speed growth rate of the agricultural sector in Ghana. We carried out our analysis at the ecological level, where all the ten regions of the country were categorised into three zones - Coastal, Forest and Savannah. To provide an alternative to time series modelling (capable of addressing supply responses to changes in (relative) output/input prices over time), we used a cross-sectional dataset - GLSS4 - in our analysis. GLSS4 dataset is the closest we can get to using farm-level dataset, which has been adjudged as the best in carrying out agricultural supply response analysis (Schiff and Valdės, 1992). Knowledge of supply responses at such disaggregation levels will prevent the 'one-size-fit-all' agricultural policies that are usually formulated mainly due to budget constraints.

In a related case and to offset some of the limitations of previous (global and country-specific) supply response studies, we have carried out output supply response analysis, first, at the farm (or household) level, which is better placed to be able to capture non-price factors at a disaggregated crop or regional level, but is constrained by the inability to incorporate changes in prices; in the absence of farm panel data, supply response is based on the cross-section or spatial variation in prices. The lack of farm-level data, however, has constrained microeconomic agricultural supply response studies in Sub-Saharan Africa.

An added limitation of many of the studies on Ghana is the implicit assumption of production (technical) efficiency under profit maximisation of the typical farmer. However, given the prevalence of inefficient institutions, imperfect markets and relatively few producers adopting best farming practices in Ghana, technical inefficiency is likely to be widespread, causing a gap between actual and potential production. Thus omitting production inefficiency factors under conditions such as those that exist in Ghana would render any supply response less accurate.

There are two major ways of computing technical efficiency scores - the Data Envelope Analysis (DEA), a parametric technique, and the Stochastic Frontier Analysis (SFA), a non-parametric technique. The second method is superior, especially if one is to use the one-sided error terms (i.e. technical inefficiencies) for further estimation, which we did. We incorporated the scores in the supply response models in chapter 5. This approach was first introduced by Arnade and Trueblood (2004).

It was in light of the limitations discussed, coupled with insufficient country case studies on Ghana that this study was conducted. The vigorous pursuit of agricultural-led economic growth for Ghana has also motivated this study especially at a disaggregated level involving a selection of six critical crops believed to enhance the achievement of securing a food sufficiency and boost export competitiveness. The six crops were grouped into export (groundnut and cocoa), food (cowpea, rice and maize) and staples, coined *migso* (millet, sorghum and guinea corn).

In the empirical analysis, we used the six crops, three variable inputs (seeds and chemical fertilizer but wages was used as a *numeraire*) and four controlled factors (farmland size, animal capital, family labour and formal education level of heads of farm households). We employed both the translog and the quadratic functional forms in our estimation analyses. In the translog model, termed model 1 in chapters 4 and 5, we assumed technical inefficiency. The quadratic model, usually referred to as model 2, incorporates production inefficiency estimates computed by the stochastic frontier technique. We employed a modified version of the methodology of Arnade and Trueblood (2002) where we incorporated technical inefficiencies (model 2). Few studies explicitly incorporate production inefficiency scores into the estimation of supply responses. Abrar et al. (2004a)'s study on Ethiopia is an exception. All the non-price factors were captured at both ecological and national levels.

Finally we conducted a sensitivity analysis in chapter 6 where our focus was to confirm (or otherwise) output supply elasticity estimates from chapters 4 and 5. The method used though was based on share analysis. The transformed (shares) dataset was to account for adjustments in the output-input allocations. The robustness analysis also compared and assessed the importance of allowing directly for technical inefficiency. Our prime objective from this exercise was to investigate whether response estimates are sensitive to the functional form also, apart from checking the sensitivity to data type and aggregation.

Our study unearthed a number of conclusions. Firstly, our empirical results supported claims that farmers in Ghana respond to market signals by responding to price incentives (Table 7.1). Further revealed was the fact that farmers in the Savannah zone also responded to price signals. It has been the belief that that part of the country is less responsive to policies and had not seen much developmental reforms from past governments. However, as shown from our results, food, export and staple farmers in that part of the country are all likely to respond to both price and non-price incentives. Moreover, many of the supply responses for both output own-price and cross-price were all as expected - low. This reflects the poor economic state of the zone, and with many staple crops, one expects models based on profit maximisation to perform theoretically well.

The above conclusions should be discussed with reference to the functional form used as our results from the two methodologies differ on the grounds of crop and ecological zone.[40] Table 7.1 summarises the results from the two methodologies used. Incorporating technical inefficiency led to relatively higher output supply elasticites for export crops (cocoa and groundnut) in both Coastal and Forest zones but not the Savannah, although the difference in supply response is marginal.

Table 7.1: Output supply and input demand own-price elasticities: Translog vs. Quadratic

| | Translog | | | Quadratic [z] | | |
|---|---|---|---|---|---|---|
| *Output Supply* | Coastal | Forest | Savannah | Coastal | Forest | Savannah |
| Cocoa | 0.04* | 0.08** | - | 0.09* | 0.17*** | - |
| Groundnut | 0.12*** | 0.06* | 0.09*** | 0.28** | 0.16*** | 0.08** |
| Maize | 0.10*** | 0.05*** | 0.04** | 0.31*** | 0.04** | 0.05* |
| Rice | 0.15** | 0.07*** | 0.02** | 0.09*** | 0.06** | 0.11** |
| *Migso* | - | 0.06** | 0.14** | - | 0.04*** | 0.20*** |
| Cowpea | 0.13** | 0.09** | 0.06* | 0.07* | 0.07** | 0.04** |
| | | | | | | |
| *Input Demand* | Translog: Combined Sample | | | Quadratic: Combined Sample | | |
| Seed | | -0.31*** | | | -0.16*** | |
| Fertilizer | | -0.18*** | | | -0.23*** | |

[z] *These estimates are from model 2 in chapter 5*

However, food crops (maize, rice and cowpea) and staples (*migso*) crops elasticities are mixed from the two methodologies. When inefficiency is accounted for, response magnitudes for grains (maize and rice) in the Savannah zone are relatively higher than in cases where technical inefficiency was omitted. The opposite was the case for the two crops in the Forest zone, where lower elasticities were recorded with the second methodology. Elasticities for Coastal zone grain farmers were mixed. Maize farmers are likely to record relatively higher supply responses than rice farmers when production inefficiency is accounted for. The factoring in of technical inefficiency also led to relatively higher supply elasticities for

[40] It must be noted that the two methodologies might not be directly comparable on one main count. Appropriately we should compare one set of similar methodology (translog or quadratic functional forms) with one accounting for technical inefficiency.

cowpea famers in each of the three ecological zones. A similar (mixed) outcome was also found for staple farmers (*migso*) in the Forest and Savannah zones.

The effects discussed above are indeed a good signal for both the government and the private sector. To the private sector, such responses to prices give a good implication that investments in this sub-sector (agricultural inputs) could be profitable. This of course is a cautious statement as investments in developing countries may go beyond responses to market prices. Institutional and government influences play a critical role too. The price responses are also an indication of policy success chalked by the government for implementing market (price) policies in the sector in the 1980s and early years of 1990 including squashing any input subsidy schemes and abolishing price controls. These policies have indeed yielded positive outcomes based on our findings.

Farmers in Ghana are not only likely to respond to output supply when the price of output alters. They are also very likely to respond to demand in the event of changes in input (seeds and fertilizers) prices.

We found that farmers are more likely to respond to seeds price changes than changes in fertilizer prices in each of the three zones when technical inefficiency is not accounted for. We did not, however, measure the degree of response to the interaction of seeds and fertilizer prices, which we believe could be much higher. Accounting for production inefficiency also yields similar conclusions - where responses to seed price changes will outweigh that of fertilizer price changes. In comparison, results from the two different methodologies, as summarised by Table 7.1, yielded an inconclusive outcome across input type. When technical efficiency is assumed, farmers are likely to respond more to potential seeds price changes than they would do when the price of fertilizer changes. On the other hand, when technical efficiency is accounted for, the response rate for potential price changes for fertilizer dominates, although differences in the response rate in fertilizer is smaller when production efficiency is assumed.

Seed demand elasticity for the combined sample was also found to be relatively higher in the model without technical inefficiency but fertilizer elasticity exceeded seed demand elasticity under the quadratic model that accounted for technical inefficiency. This inconclusive outcome suggests different methodological implications. Seed demand elasticity is lower with technical inefficiency but fertilizer demand elasticity is lower without inefficiency. We, however, make these conclusions cautiously, as further research is needed on these comparisons. One way of course is to use a single methodology (translog or quadratic) and evaluate elasticities with and without production inefficiency.

A note of caution at this stage about fertilizer usage and its ecological price variation is worthy. It is important to reverse the increasing ecological price differences of fertilizers to encourage and increase its usage. It is not clear of the source of these price differences but the price wedge between the Coastal and Savannah zones is more than transportation differences between the zones. A review by the Food and Agricultural Organisation on the economics of fertilizer usage in Ghana suggests that the lower usage of the input has both economic and political dimensions (F.A.O., 2009).

It also emerged from our results that farmers in Ghana are very likely to respond to non-price agricultural factors. Our analysis revealed that all four non-price/quasi-fixed factors - land size, animal capital, family labour and education of household head - matter in the development of an effective agricultural policy regardless of whether technical inefficiency is accounted for or not. Tables 4.10, 4.11, and 5.10 support this evidence. Farmland size appears to dominate the other three factors. For example, with inefficiency assumed, land size elasticity exceeded household head education both in the Coastal and Forest zones for all crops expect for cowpea and *migso* in the Forest zone.

There was no clear cut effect with regards to the Savannah zone (see Tables 4.7-4.9). The inclusion of technical inefficiency (Table 5.10) produced a similar result to the one described above, where land size dominated household education for all crops except for *migso*.[41] On average, non-price elasticities from the quadratic model (where technical inefficiency is accounted for) are relatively higher for land size than when production efficiency is assumed. Land size matters less to staple crop farmers across the two (Forest and Savannah) zones. Maize, rice, cocoa and groundnut farmers are likely to be affected more than cowpea and

[41] Table 5.10 results are for combined sample, a contrast from the ecological versions produced in Tables 4.7-4.9

staple crop farmers with unfavourable changes to its allocations. The account for inefficiency reveals that land size elasticity ranges from 0.12% to 0.27% (pooled sample).

The above synopsis of farmland size has key policy implications. Firstly, it goes to add to the call to 'free' farmlands earmarked for agriculture, which had hitherto been customarily owned. Farmland reform is long overdue in the country and our findings suggest that if Ghana needs to 'modernise' the growth catalyst sector, the issue of farmland accessibility is crucially addressed. A suitable method is, however, needed to carry out these reforms to eschew production setback. We recommend an appropriate agricultural land reform where more emphasis is placed on output increment rather than asset ownership. Reforms must be gradual, unique (regional basis), informative and efficient.

Another important non-price agricultural factor is human capital (formal education of household head farmers). We found that on average, an extra year of farmer education is likely to increase output by approximately 0.19% of groundnut in the Forest zone, 0.11% of rice in the Coastal zone, and 0.10% of maize in the Savannah zone. With technical inefficiency, an extra year of formal education, however, is likely to up groundnut production by approximately 0.14% (0.05% lower) and rice production by 0.09%. With inefficiency assumed, education elasticity was highest within the Forest zone for groundnut, rice and cowpea farmers, all in the Forest zone. Accounting for inefficiency produces higher elasticities in all three categories of crops - export (groundnut), staple (*migso*) and food (cowpea) in that order. Cocoa education elasticity was only higher in the ecological zone (0.19%) but only 0.07% in a combined data with production inefficiency accounted for.

Although the education elasticities are relatively higher than expected, the results point to a vital policy direction: relevant agricultural education is a crucial ingredient for agricultural development. It also calls for government-led investment in agricultural education either through farming cooperatives, extension officers' visits or period relevant education upgrade to farmers. Initial farmers' education should be followed by periodic visits and checks. Any development of sophisticated agricultural equipment/technology with the aim of modernising agriculture will only become beneficial with appropriate farm education. With the low literacy rates of most farmers, it is imperative the best information dissemination medium should be explored. The much successful 'farmers day celebration', which was established to award the best farmers in the country based on productivity criterion could have the award indicator ‘configured’ to include, among other things, the application of new technology or period attendance of relevant education.

Both animal capital and family labour were shown to be significant non-price factors in the development of agriculture in Ghana. Animal capital elasticity was particularly essential to farmers in the Savannah zone for all crops except cocoa. This is not surprising as fertilizer prices are comparatively expensive in this part of the country due to ‘middlemen’ factors such as transportation. In that case it is very much expected that animal capital could have a dual usage - for ploughing and as a substitute for chemical fertilizer, which may come rather less expensive. Within the Savannah zone, groundnut farmers are likely to react to potential changes in the quantity of farm animals available for farming with rice farmers likely to respond the least. In the Forest zone, groundnut and cocoa farmers, on average, show potential signs of the most and least reactors with changes in animal capital. Farmers in the Coastal zone would respond less to potential changes in the availability of farm animals. When technical inefficiency is accounted for, animal capital continues to be a major factor, ranging from the lowest of 7% (cowpea farmers) to 24% for rice farmers.

Family labour is rarely incorporated in agricultural supply response analysis in developing economies partly due to its capture. However, it remains an important factor to the progress of the sector mainly due to the different family setup systems in developing countries, Ghana not being an exception. In this setting, family labour is either seen as a direct substitute to hired labour or as a complement (especially if they have different skills). Our results could not find concrete and positive supply responses with extra family labour used on the farm, when production efficiency is assumed. In many cases, family labour estimates were statistically significant. Staple crop (*migso*) farmers in the Forest zone will gain the most from any increase in family labour (0.19% increase in produce) whilst maize farmers in the Savannah zone will potentially lose the most (0.15% reduction). However, all the negative effects disappeared with the control of technical inefficiency (see Table 5.10). After accounting for inefficiency, we found that groundnut and *migso* farmers are the most potential reactors to possible changes in the number of family labour availability. Cocoa and rice farmers are expected to respond the least.

The significance of animal capital provides some direction for policy makers. In ecological places where chemical fertilizers are rarely used but farm animal usage is prominent, measures should be put in place to develop alternative ‘fertilizer’ (animal manure). When well-managed, it could be exported to other areas where the use of farm animals is scarce. This can reduce the large and rising disparity in fertilizer prices. Of course this is a long-term investment policy measure. The short to intermediate policy direction is for the government to reduce the growing price variability between the south (Coastal zone) and north (Savannah zone) parts of the country. One way is to reduce the influence of unlicensed middlemen.

As stated earlier, a robustness analysis (in chapter 6) was carried out where the focus was to use output and input shares to re-estimate output supply elasticities. Pooled and ecological elasticities did change but many of the changes are ‘insignificant’ (less than a 5 percentage point difference from previous estimates). We also found that statistical significance overall did improve with the effect of fertilizer price changes on cocoa output in the Forest zone standing out.

The sensitivity analysis also confirmed the relative superiority of the quadratic functional form - model with technical inefficiency scores - suggesting the relative importance of accounting for production inefficiency in supply response analysis especially those affecting developing countries. Many of the ‘significant’ changes in the output supply elasticities occurred within the quadratic modelling framework. The average technical inefficiency score among Ghanaian farmers also fell by 3 percentage points compared to non-shares estimations in chapter 5.

With regard to output own-price elasticities, outcome from the sensitivity analysis revealed among other things that farmers’ output supply response estimates were relatively lower than previous estimates across both methodologies, albeit the differences were marginal. The only ‘significant’ own-price output supply elasticity change came by way of export (groundnut) farmers in the Coastal zone and only when we controlled for production inefficiency. Farmers of food (cowpea) and staple (*migso*) crops on the one hand and export (cocoa and groundnut) crop farmers on the other are susceptible to changes in the prices of seeds and chemical fertilizers respectively. Farmers are likely to react more to seed price changes when production inefficiency is accounted for than when we assume efficiency. Our new estimates also confirmed the importance of non-price inputs, with the size of farmland edging out the other three - animal capital, family labour and human capital (measured by the formal education of the household head).

Based on our estimates from the sensitivity analysis, we are able to conclude that agricultural (output) supply responses in Ghana are sensitive to the data type (non-shares and shares in our case) estimation method, and the level of aggregation (pooled or ecological levels). From a policy viewpoint, we suggest any comprehensive agricultural policy in Ghana must be preceded by detailed research based on each of these supply response sensitivity angles.

Overall, our study makes two vital recommendations for future (supply response) methodologies and policy orientation for developing countries aiming at 'modernising' agriculture and adopting an agricultural-led growth strategy. The latter contribution needs expansion. Developing the agricultural sector in most agricultural-growth led economies goes beyond pursuing market reforms in getting prices 'right'. Other (non-price) policy elements should be addressed. The results from this study have shown that, among other factors, technical inefficiency and non-price factors should be considered as an integral part of any policy aimed at developing the primary sector.

On methodological grounds, the study reveals that agricultural supply response estimates are different when technical inefficiency, which most developing economies face, are accounted for. Additionally, we found that supply response estimates are sensitive to functional forms (although the quadratic functional form leads to theoretically expected elasticities but could also produce inconsistent estimates) and data aggregation. This suggests that the omission of (technical) efficiency could render agricultural supply response estimates inaccurate. This relates to our discussions on trade flow model - the (conventional) gravity model.

Based on its limitations, especially assuming efficiency, we believe such analysis might predict bilateral or multilateral trade flows to the detriment of developing countries.[42]

[42] It should be noted that if two developing countries are involved in bilateral trade flows, the effect of omitting technical inefficiency would not be much as production inefficiency pattern could be similar. A similar conclusion can be said of two middle-income or developed countries. The main issue arises with different

Consequently, we have proposed an alternative model - the stochastic frontier gravity model. This new gravity model is more comprehensive in that it accounts for efficiency. If our empirical evidence from the production efficient model is any conclusion to go by, then it is possible that the 'standard' gravity model is not an ideal trade flow model for developing countries, let alone to be used to model multilateral trade flows and hence to be used to compute multilateral trade liberalisation gains. The Stochastic Frontier Gravity Model (SFGM) is, in this regard, a more appropriate framework.

### 7.2 Limitations of the Thesis

A number of limitations were encountered in the course of writing this thesis. However, these challenges should be interpreted in light of the time and dataset available to us during the thesis period. The first constraint was with the dataset used for the empirical chapters. Working with primary dataset from developing economies like Ghana will always be met with several limitations. The first problem with the GLSS4 is measurement issues with the production sector. There were no agreed standard convertible units of measurement for some of the recorded output. The records accompanying the dataset did not include any acceptable conversion units. We have to rely on information from one of the officials in the Statistical Service of Ghana and the ministry of agriculture for help. Thus it is possible that some of our final converted yields might be hit by errors, although we applied the best available conversion rates. Also, there was a difficulty in identifying which 'price' to use for outputs as the dataset presented three different prices taken across the year of the enumeration. We had to take average prices of the three. This means that our estimates could change with the type of prices used.

A related dataset constraint has to do with the type of dataset. GLSS4 is a cross sectional dataset with no panel dimension. In principle one could construct a pseudo panel of representative households, but as these should be based on time invariant criteria (such as region, age and gender of head of household) you would lose too much of the farm-level spatial variation.

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development levels of countries. This therefore becomes essential in multilateral trade flows and has implications on (multilateral) trade liberalisation.

A third dataset limitation was the difficulty in measuring some non-price factors and inability to allow for agro-climatic factors notably rainfall and soil quality. Family labour and animal capital were the two main non-price inputs we could not measure effectively. Ideally we could have imputed their market values but we were not able to do that owing to data constraints. We also could not control for rainfall and soil quality as these variables were absent from the survey. One explanation for the absence is that the survey (GLSS4 and other rounds) was not designed to collect only agricultural information but comprehensively designed to measure the general living standards of Ghanaians. An ideal case was to administer a farm-tailored survey but time and financial constraints did not permit that.

There is no doubt these two agro-climatic non-price inputs would have impacts on our estimates. Rainfall for instance is crucial to the development of the agricultural sector especially for food crops cultivators. The quantum of rain is as important as the timing of the rain. We attempted to use rainfall obtained from the meteorological service of Ghana but were unsuccessful due to no ecological variations. Soil quality was also omitted from our discussion due to the same obstacle faced with rainfall.

Although the above supply response constraints are crucial, they do not render our estimates entirely irrelevant. We believe that when these omissions are corrected and the right variables are accounted for, there might be infinitesimal rather than structural alterations in supply response estimates. As evidence to substantiate our claim, it could be seen that the magnitudes of our supply responses are not very different from previous studies. Our methodological approach might also account for any significant disparities in the output supply and/or input demand elasticities.

Finally we had to completely ignore own-consumption of food crops due to data inadequacies. Surely this would have some effects on our estimates. The best way to analyse this is through ‘perverse or marketed’ responses. We speculate that the larger the amount for sustenance (own-consumption) and the higher the market price (of the proportion consumed), the bigger the ‘perceived’ supply response.

## 7.3 Extensions and Future Research

Regarding our supply response estimates, we believe we have tried to model to the best of the dataset available to this study but we also recognise that future research could argument the findings of our studies. There are three major contributions future studies could add to our study. Firstly, we only considered accounting for technical inefficiencies within the duality profit function modelling framework. We suggest a complete treatment of both technical and allocative efficiencies. Arnade and Trueblood (2002) give a theoretical direction of how this could be done.

Secondly, we believe that although the omission of the agro-climatic factors might not alter our estimates significantly, any future crop-level agricultural study carried out at ecological disaggregation should incorporate these factors as they are very likely to improve the overall efficiency of the model. Other important variables that should be considered include farm education either delivered by extension officers or by farm cooperatives. Access to ready markets, storage and credit facilities are all very crucial development indicators if farmers are to respond favourably to agricultural policies.

Another area of extension lies in the use of a more robust modelling technique. Here we suggest a pseudo panel analysis due to the lack of longitudinal dataset. We suggest the use of GLSS4 and GLSS5 (which was not officially released at the writing of this thesis). Alternatively one could independently estimate similar functions in the thesis but based on GLSS5 and include the lag dependent variable (in this case the one calculated based on GLSS4) as a regressor to help capture price expectations. This has theoretical foundations.

As noted throughout this thesis, our focus was to investigate how ecological agricultural producers would respond to price and non-price policy interventions by either the state or private sector. We also examined how farmers' supply responses would change with technical efficiency accounted for.

There is a possible linkage to the discussion of technical (in)efficiency. The World Development Report (WDR, 2008) explained one way agriculture growth can lead to poverty reduction in developing countries. It argues two ways. The first was through sustainable food supply, which our study has adequately dealt with. The second channel is through enhancing the competiveness of the agriculture exports. One way to achieve that is to improve production efficiency. Technical and production efficiencies are interchangeably used. The argument is that until farmers identify, measure and take steps to improve their production inefficiencies, increments in agricultural inputs would not produce the desired increase in output.

If the above conjecture holds tight, then we can estimate a modified version of the ‘standard’ gravity model that incorporate these production (in)efficiency scores. ‘Standard’ here is defined as gravity models that assume technical efficiency. This would probably be called the ‘Stochastic Gravity Model’ (SGM), which is a proposed alternative to the conventional gravity model.

Alternatively, one could estimate a ‘minor’ form of stochastic gravity (with a composite error structure) and then estimate the one-sided error term as a function of both the supply and demand sided inefficiencies (although one has to assume ‘full’ normality of the country specific one-sided inefficiency term).[43] Both approaches would involve a two-step estimation technique. A third and one-step estimation technique would be to jointly estimate both trade flow and (in)efficiency factors, similar to what Coelli (1996) explains in his stochastic production function, which has become the basis of the development of the *FRONTIER* (version 4.1) software.

[43] This is true when one assumes the one-sided error term follows a half normal distribution. If other distributions are assumed, such as gamma or truncated, it becomes even more complicated.

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