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THE STRUCTURE OF SOUTH AFRICAN MILK PRODUCTION TECHNOLOGY: A PARAMETRIC APPROACH TO SUPPLY ANALYSIS.

by

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ABSTRACT

THE STRUCTURE OF SOUTH AFRICAN MILK PRODUCTION TECHNOLOGY: A PARAMETRIC APPROACH TO SUPPLY ANALYSIS.

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A parametric approach was used in this study to analyse milk production and supply systems based on farm level production cost data from a cross-section of dairy farms in South Africa for the 1997/1998 production year. Both single equation and system estimation techniques were applied to Normalised Quadratic, Normalised Translog and standard Translog specifications of the profit and derived output supply and input demand functions. Estimated functions were evaluated for adherence to structural properties. Results showed that convexity of the profit function in all prices holds in South African milk production. Uncompensated and compensated price elasticities of supply and demand were calculated. The results indicated that milk production and livestock trading activities are complements in the production activities of the observed multi-input, multi-output dairy farms. Both activities were intensive in the use of purchased and self-produced feed inputs, with a higher intensity in purchased feed use. The variable inputs are gross complements in the long-run and net substitutes in the short term. The long-term expansion effects overshadow short-term substitution between inputs.

The data provided details on input use, output and input prices and herd structures. However, the sample was too small, for a cross-sectional sample, to allow for a high degree disaggregation in inputs. Consequently, aggregate price and quantity indices had to be constructed for some variables.

The results from this study suggest that dairy producers in South Africa are rational profit maximisers who use resources efficiently to the point where the marginal returns are zero. They allocate bought and self-produced feed components as substitutes in the short-run but treat both inputs as complements in the long-run. The intensity of purchased feed use is higher than that of self-produced feed use. This has implications for the animal feed sector in terms of confirming dairy farmers' preferences for scientifically formulated feed components. It also suggests increased pressure on the international competition for already limited natural animal protein sources (fish meal, bone meal, etc.).

Milk supply shows an inclination to contract over time. This study's results suggest that increased milk prices will not stimulate expansion of the industry. Very useful information can be obtained if similar analysis is conducted for different production regions (given the high geographic diversity) and different groups of producers (based on technology preferences or size of operations) to establish what effects input and output price changes might have on short and long term production dynamics.

Supply analysis, as it was performed here, provides testable hypotheses about producer behaviour, and a basis from which supply and demand elasticities for dairy products can be computed for policy simulation and analysis, thus enabling the dairy sector to be proactive in its response to international and local economic stimuli.

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To my family (especially my parents) and Gustav for their support and faith in me and to friends (especially Nicola and Adèle), for their empathy, I am deeply indebted and very grateful.

I serve a great, big, wonderful God who has shown His faithfulness to me – to Him be all the praise!

Psalm 121 verses 1, 2, 7 and 8:

"I lift my eyes to the hills – where does my help come from?
My help comes from the Lord, the maker of heaven and earth.
The Lord will keep you from all harm –
He will watch over your life;
The Lord will watch over your coming and going
both now and evermore".

---

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CHAPTER 1: INTRODUCTION

1.1 MOTIVATION AND OBJECTIVES OF THE STUDY

Livestock husbandry and the production of food and by-products from animal origin, is an important part of the highly diverse agricultural sector of the South African economy. The country has the potential to be self-sufficient in milk production, but it currently exports and imports fluid milk and processed dairy products. If the dairy sector strives to attain a larger world market share, it has to be competitive. A proper understanding of the structure of the underlying dairy production technology is the key to improving the sector's competitiveness. Thus, analysis of the supply of fluid milk (the focus of this study) will provide useful information to managers and policy makers for predicting how the dairy sector would respond to shifts in world and local market prices of production inputs and fluid milk. Appropriate and timeous adjustment mechanisms can hence be designed to improve the dairy sector's local and international competitiveness.

Analysis of milk supply response continues to be an important part of the international agricultural economics literature. However, the same cannot be said for South Africa. During the 1960's, published work focused on consumer demand and price trends for dairy products and efficiency comparisons between different technological options in the 1960's [Maree, 1962; Du Plessis and Nel, 1963; National Marketing Council, 1964; Viljoen, 1967; and Graham and Groenewald, 1968 and 1969]. The focus of the 1970's was on dairy forage valuation [Comrie and Behrmann, 1977]. Published research in the 1980's focussed on the impact of government intervention in the sector, optimum feed planning models, efficient resource allocation, and analysis of the economic impact of the fresh milk scheme [Backeberg, 1982; Durham and Nieuwoudt, 1982; McKenzie and Nieuwoudt, 1985a and 1985b; and Gordijn and Ortmann, 1988]. The 1990's research pertained to purchasing power of emerging consumers, the impact of uncertain labour legislation changes prior to democratisation, adoption of modern computer technology on dairy farms and the political economy of the dairy sector before market liberalisation in 1995 [Campbell, Jobo and Phakisi, 1990; Antrobus and Donkin, 1991; Wright and Nieuwoudt, 1993; and Hildebrand and Ortmann, 1994]. Contemporary estimation of supply and demand elasticities, structure and efficiency of production and input substitutability in dairy farming is lacking. Such analysis for the industry as a whole and for different production groups within the industry is imperative for a better understanding of the impacts of changes in the business environment and for developing effective policy measures.

1.1.1 OBJECTIVES OF THE STUDY

The main objective of this study is to analyse the underlying structure of milk production technology in South Africa.

Under this main objective the following three specific objectives were pursued, namely:

a) Use available cross-sectional farm survey data to analyse the supply response to policy changes;
b) Evaluate whether the dual approach to supply response analysis, as applied to cross-sectional production cost data, is appropriate for analysis and testing of the properties of South African milk production technology, in order to model meaningful milk supply response behaviour; and
c) Based on the results, show that production cost surveys provide a valuable basis from which to improve upon the type of information collected.

Duality theory is applied to available cross-sectional farm survey data. An econometric approach is followed in which the Iterative Seemingly Unrelated Regression method is used to estimate the restricted profit system parameters that describe the underlying production technology.

This is a positive, rather than a normative approach, which should ideally form the basis for further, more expanded studies.

A brief background to the South African dairy sector and its contribution to the South African economy follows in section 1.2.

1.2 OVERVIEW OF THE SOUTH AFRICAN DAIRY SECTOR

An industry's absolute size, as well as the size and dispersion of the enterprises of which it is comprised, is influenced by environmental factors (substantial variation in climate and topography); quality of infrastructure; social and economic trends (availability of labour, wage rates, population density and resulting service provision, and interest rates) and government policy (labour legislation, import- and export regulations, health policies).

The milk industry in South Africa is characterised by a wide range of farm sizes (measured in terms of production of milk per annum) and substantial geographic diversity [Dairy Development Initiative, 1999]. Some farms invest in expensive capital equipment with emphasis on mechanisation, whilst other farms are more labour intensive and rely on manual operations. At the lower end of the size scale, one finds a decrease in farm size and in sophistication of the production systems. Typically, a frequency distribution of average daily production shows a distribution that is highly skew to the lower tail indicating a very large number of low output farms in South Africa.

1.2.1 ORGANISATIONAL STRUCTURES IN THE INDUSTRY

Recently, the industry saw the disappearance of production support measures as administered by the former Milk Marketing Board. After abolition of the marketing board (1995), the industry reorganised itself through the formation of various substitute bodies that address the needs of specific groups of milk producers and processors. The milk buyers and producer-distributors are organised into two organisations. Larger companies, representing approximately 78% of all milk processed, are represented by the South African Milk Organisation (SAMO). Smaller processors are organised under the National Milk Distributors Association (NMDA). SAMO and NMDA, together with the Milk Producer Organisation (MPO), consumer groups and organised labour form the overarching South African Milk Federation (SAMFED). Numerous small processors are not directly affiliated to any of the mentioned organisations [Dairy Development Initiative, 1999].

A few characteristics of the industry are outlined. This is necessary for an understanding of the size and contribution of the sector to the national economy, and the consequent importance of analyses pertaining to this specific industry.

1.2.2 *RELATIVE SIZE AND DISPERSION IN THE SECTOR*

Approximately 6 200 to 6 500 commercial[5] enterprises produce milk in South Africa. These figures vary with the state of the economy. Data on the number of emerging[6] farms is incomplete. The white commercial farmers are mostly located in the traditional farming areas, whilst the bulk of small-scale and commercial dairy farmers are located in and around towns as well as in traditional farming areas [Dairy Development Initiative, 1999].

Table 1 (below) shows the relative contribution of the nine administrative provinces to the total national milk production. The coastal regions (KwaZulu-Natal, Western- and Eastern Cape) are clearly the major contributors, as their collective production constitutes 53% of the country's milk output. Based on climate and natural resources, these coastal regions are more suitable for low-cost milk production systems on natural and irrigated pastures.

The non-coastal production areas are climatically less favourable for milk production. The harsh dry winters in these regions necessitate more intensive feedlot production systems for dairy farming. Despite this, market concentration in the interior combined with the long road distances from the coastal regions, create enough incentives for the cost intensive systems in the interior to play an

[5] In South Africa, the definitions of commercial and small-scale farms are the subject of a contentious and controversial debate. For the purpose of this study, "commercial" refers to those farms that have been actively producing and selling milk to processors, dairies or directly to the consumer. Small-scale farms are regarded as those that produce milk for home consumption, and occasionally sell small quantities to consumers, but who make use of limited technology inputs.

[6] Emerging farms are those that were previously excluded from the mainstream of the economy but who are now gaining access to input and product markets through agricultural policy and market reforms.

important role in South Africa's dairy industry. These non-coastal regions supply 47% of the national output.

Table 1: Number of milk producers per province (1997) and milk production per province (1994) in South Africa[7].

	Producers		Production	
Province	Number	%	Milk output (Million litres)	%
Western Cape	1437	23	354	23
Eastern Cape	622	10	215	14
Northern Cape	100	2	15	1
KwaZulu-Natal	479	8	246	16
Free State	1505	24	277	18
North West	1144	18	185	12
Gauteng	236	4	62	4
Mpumalanga	634	10	169	11
Northern Province	63	1	15	1
Total	6220	100	1 538	100

1.2.3 COLLECTION COST AND PRODUCTION DENSITY

The economic effect of widely dispersed, low volume of milk production per producer is reflected in the collection cost of milk. In the interior of the country, the cost of collecting milk is high where the milk production per square kilometre is low. The stark reality of South Africa's low litres/ km² /day in comparison with other countries stands out in Table 2. In the coastal areas, the milk density (volume of production per area) is higher. Dairy, together with maize, beef and mutton production, form the main agricultural enterprises in the interior regions.

The low density of milk production per square kilometre in South Africa should be viewed against the general trends in international dairy farming: numbers of herds decrease; herd sizes increase; production yield per cow increases; and the fat and protein contents of milk improve. All these tendencies are conducive to low collection and transaction cost per unit milk collected. Table 2

[7] All tables in this chapter are modified versions of those found in the Dairy Development Initiative [1999].

compares the daily production per square kilometre for the leading international dairy countries with that of South Africa in total, and the more optimal production zones in the country [Dairy Development Initiative, 1999].

Table 2: International comparison of milk production per km² per day

Country	Litres / km^2 / day
France	125
Germany	308
Netherlands	892
UK	257
New Zealand	94
South Africa: Total area	5
: Production areas	25
: Coastal area 1	103
: Coastal area 2	96

1.2.4 DOMESTIC PRODUCTION

In 1996 South Africa produced 2.22 million tons of milk (equivalent to 2 150.49 million litres) by approximately 6 220 commercial farmers. With a gross value of production (1997/1998) of R2 620 million, fresh milk and dairy products represents the fourth largest agricultural sector in South Africa (7,4% of gross value of all agricultural products). If the value of slaughtered dairy cattle is included, the producer of primary dairy products' share of the gross value of all agricultural products is an additional R 388 million.

The basic nature of the dairy industry is varying production and consumption patterns. There is some predictability in, for example, weekly and seasonal consumption patterns. Predicting the variability in production of raw milk is more difficult [Dairy Development Initiative, 1999]. A significant proportion of South Africa' s milk is produced partially or wholly from natural or artificial pastures with resulting seasonality in supply. Farmers generally view these systems as the least costly production options. However, the inherent variability in climatic conditions across years destabilises farmers' milk supplies, milk prices and cash flows. In addition, unstable inter- and intra-seasonal milk flows have a cost increasing effect on the dairy processing industry. The market is drastically destabilised due to periodic surpluses and shortages, making it difficult to balance production and demand. This is aggravated by low priced subsidised imports [Dairy Development Initiative, 1999].

1.2.5 LINKAGES WITH OTHER SECTORS OF THE ECONOMY

Of great importance is that the industry has highly positive and advantageous gross domestic product (GDP)-, labour- and household income multipliers. The total GDP multiplier of the primary and secondary dairy industry is 9,66 with a total effect of R28 195 million. This multiplier gives an indication of the additional GDP created throughout the economy, due to an increase in demand for raw milk [Dairy Development Initiative, 1999]. The first round and indirect employment multipliers have the same meaning than that of the GDP multipliers. The total employment multiplier for the primary dairy industry (41.7) is less than that of the rest of agriculture (42.9) - indicating extensive use of capital equipment on dairy farms. The primary dairy industry is very friendly towards the balance of payments. Its direct import propensity is low (0.04) - that is to supply in R 1.00 increase in final demand the sector imports to the value of less than five cents. For this industry, the total import multiplier (0.14) is marginally lower than that of the rest of agriculture (0.16) [Dairy Development Initiative, 1999]. The household income multipliers are indicative of the change in household income with a R 1.00 change in final demand. The primary dairy industry multiplier (0.54) is slightly higher than that of the rest of agriculture (0.47). If the total direct and indirect effects on household income are calculated, the primary dairy industry has a substantially higher figure (8.64 compared with 3.91) than for the rest of agriculture.

The direct purchase of inputs is a first or direct indicator of the size and importance of a sector's backward linkages in the economy. Inputs such as fertiliser, seed, irrigation, etc are not listed separately, but are included in items such as cost of producing roughage. The most important variable inputs at 1998 prices are presented in Table 3 and the value of fixed investments in Table 4.

Table 3: Value of inputs purchased by dairy farmers in 1998.

Type of Input	Rand (Millions)	%
Self produced feed cost	540	25
Purchased feed cost	807	37
Milk supplements and minerals	118	5
Total Feed Cost	1 465	67
Veterinary and medicine cost	62	3
Artificial insemination	36	2
Wash and sterilisation	33	2
Other variable cost	82	4
Labour: Farm workers	263	12
Labour: Hired management	24	1
Fixed Cost	229	10
Total Cost	2 194	100

Table 4: Estimated values of fixed investments on dairy farms, at 1998 prices.

Item	Rand (Millions)	%
Fixed improvements	1 052	14
Equipment	730	10
Machinery and implements	749	10
Land	2 205	30
Livestock	2 469	34
Other	155	2
Total	7 360	100

It is clear that purchased- and self-produced feed cost constitute the largest share of farm expenditure on variable inputs. The most substantial capital investments are in livestock, followed by land.

The nature of milk (as a commodity), characteristics of milk production and the geographical dispersion of dairy farms are critical to organisation of the dairy sector. Milk for drinking purposes is a highly perishable product and thus requires continuous inspection. The dairy farm goes through a three (3) to four (4) year cycle as heifers are bred between 15 and 21 months after birth (to be 24 to 30 months old when freshened) [Dairy Subsector of American Agriculture, 1978]. From a national viewpoint, few primary products are substitutes for raw milk. Yet, many non-food goods are economic substitutes for milk and dairy products (such as cool drinks, fruit juice, coffee, tea, etc.). Milk supply response is known to be price inelastic in the short run (due to large fixed investments on dairy farms and due to the long production cycle of cows) and only slightly more elastic in the longer run.

There exists an obvious relationship between the size of dairy farms and the scale of milk production that it can achieve [CAS Report 4, July 1978]. However, two sources of variation exist for this general idea. Firstly, many farmers operate other enterprises besides dairying – from which the dairy enterprise might benefit, although it probably places an expansion limitation on the dairy enterprise; and secondly, nearly all farms utilise some level of bought feed, thereby effectively increasing the size of their dairy enterprise [Burton, 1984].

1.3 AVAILABLE DATA

A sub sample of the South African Milk Organisation' s (SAMO) annual milk production cost survey (1996/1997) was initially made available to the University of Pretoria for analytical purposes. The survey included data on 394 farms that delivered milk to on of the major South African milk processors. The survey results indicated that the primary sector is composed of three broad groups. Firstly, small producers, delivering less than 250 litres per producer per day, account for 9% of total deliveries to dairies. They represent 17,76% of the total number of milk producers. Secondly, producers delivering less than 1 000 litres per day constitute 71,32% of all dairy producers. They deliver 33,06% of the total milk production. Thirdly, only 1% of milk producers deliver more than 5000 litres per producer per day, and they produce 11% of the milk.

In addition to the cross-sectional problems inherent in the data, limited detail was given on either prices or quantities of inputs. Subsequently, more detailed data was obtained from the Milk Producer Organisation (MPO). This set was substantially smaller (49 observations), but contained a more detailed record of input use and corresponding prices. This set was comprised of cross-sectional observations on milk producing farms, for the 1997/1998-production year. The MPO dataset was chosen for the analysis as it contained more detail to support better analysis of supply response and substitution possibilities in milk production on a more disaggregated level.

1.4 OUTLINE OF THE STUDY

The study is organised into five chapters with a reference section and appendices. The second chapter contains a literature survey on supply response analysis, particularly pertaining to milk production. Chapter 3 describes the theory, hypotheses, methods of analysis and tests applied in the analysis. Chapter 4: represents the results and Chapter 5: concludes the discussion with a summary of the chapters and recommendations for further studies. The list of references contain those references specifically cited in the document as well as those that were read to broaden the author's understanding of specific topics.

A summary of the data is provided in Appendix A, and brief explanations of different system estimation techniques are given in Appendix B.

CHAPTER 2: LITERATURE STUDY

2.1 SUPPLY ANALYSIS DEFINED

Supply analysis is a term used to refer to a larger set of techniques that evaluate production responses to output-, input prices and other measurable policy and environmental changes. The theory of the firm is the basis from which analysis is conducted [Colman, 1983].

2.2 THE PURPOSE OF SUPPLY ANALYSIS

Analysis of the supply behaviour of firms, aims to improve the understanding of how producers combine inputs in the production process. Agricultural producers are both users of resources and suppliers of agricultural products. The production technology underlying this process can be described through production elasticities, input substitution possibilities, returns to scale and the bias in technology [Thijssen, 1992]. Description of production technology is necessary [Nerlove and Bachman, 1960] and the determinants of agricultural production functions are important as far as they influence the supply of agricultural products and affect the use of inputs (under varying technological conditions) [Thijssen, 1992].

Sadoulet and De Janvry [1995] discuss the application of different techniques, supply analysis amongst others, for quantitative policy analysis as one of the means by which to bridge the gap between the real world and the realm of theory. Many of the complex indirect effects of policies can be captured and better understood through empirical modelling and statistical testing, in order to give clarification on the role of behavioural assumptions and causal relationships that are implicit in the models.

Once a better understanding of supply decision-making exists, analysts can predict how farmers would respond to external factors and policy changes. They can forecast supply- and demand trends, and control and influence supply to induce desired changes in employment patterns, resource allocation, and environmental management [Hassan, 1998].

2.3 APPROACHES TO SUPPLY ANALYSIS

Approaches to supply analysis can be classified into two main groups: normative (programming) and positive (econometric) approaches [Shumway and Chang, 1977; Colman, 1983; Sadoulet and De Janvry, 1995]. Substantial advances occurred in demand analysis, especially in terms of the use and acceptability of complete systems of demand equations [Pope, 1982; Deaton and Muellbauer, 1980]. The continued efforts of analyst to develop comparable complete system approaches for supply[8] response has been less successful because of the higher degree of complexity inherent in supply response [Colman, 1983]. For this reason, various considerably differing approaches (and opinions on their appropriateness) exist for supply response analysis.

2.3.1 NORMATIVE APPROACHES

Normative approaches typically combine historical and artificial (generated) data and impose behavioural assumptions in programming models that attempt to determine optimal choices, i.e. "what ought to be" [Shumway and Chang, 1977; Hassan, 1998].

Linear and Non-linear Programming (LP and NLP) and the method of Data Envelopment Analysis (DEA) enjoy wide support as the most frequently used normative techniques [Colman, 1983; Jaforullah and Whiteman, 1999]. Colman [1983] ascribes the popularity of programming methods to their adherence to the theoretical steps for deriving profit maximising levels of output and inputs.

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[8] Colman [1983] elaborates on the semantic error of referring to supply response instead of output or production response. In this study, the term "supply response" is used, despite the apparent semantic discrepancy.

Sets of production functions for all the outputs, as well as sets of resource use restrictions are specified. Together with the objective function, (e.g. profit maximisation, with or without risk aversion) these sets are used in programming models that optimise output and input levels to obtain maximum profits or minimum cost, subject to exogenous prices and technologies [Colman, 1983; Shumway and Chang, 1977]. Supply response is derived from parametric programming that solves for different levels of optimal quantities at specified price levels [Sadoulet and De Janvry, 1995]. Iterations are performed for each farm or representative farm in the set over the range of specified prices, to arrive at a set of (partial) price-input-output relations.

Normative supply approaches have a very important advantage over positive methods. At farm level, the normative (programming) approaches are able to take account of all product and input prices, all relevant technological, institutional and physical restrictions [Colman, 1983]. In positive (econometric) studies, incorporation of all these aspects is mostly inhibited because of limited sample sizes. The normative approach suffers from various problems, the most important of which is aggregation bias that can be minimised, yet, not eliminated [Shumway and Chang, 1977; Day, 1963].

A few examples of non-parametric approaches are found in Cowling and Baker [1963], Sheehy and McAlexander [1965], Shumway and Chang [1977], Thompson and Buckwell [1979], Tauer [1998] and Jaforullah and Whiteman [1999], amongst numerous others.

2.3.2 Positive Approaches

Positive or econometric approaches are broadly classified into two sub-groups: the primal approach and the dual approach [Colman, 1983; Sadoulet and De Janvry, 1995].

The primal approach involves estimation of the structural production function or frontier from cross-sectional or time-series data. This function is given a largely arbitrary form upon which profit maximising marginal conditions are imposed to derive the supply and demand equations. [Sadoulet and De Janvry, 1995]. A few problems are associated with this method [Colman, 1983]. Simultaneity bias occurs between inputs and outputs unless experimental data is used. This problem arises from the joint and simultaneous determination of levels of inputs and resulting levels of outputs [Lau and Yotopoulos, 1972; Colman, 1983]. In addition, partial adjustments and adaptive expectations are not taken into account, resulting in over-estimation of short run elasticities and the supply elasticities are very sensitive to the chosen functional form [Wipf and Bawden, 1969; Burgess, 1975; Anderson, *et al.*, 1996]. Vide Section 2.4.

The dual or reduced form approach involves estimation of a profit function from either cross-sectional data (that shows inter-farm variation in effective prices) or from long run time series that show variation in fixed factors, or from a combination of the two data types [Sadoulet and De Janvry, 1995]. Supply and factor demand are derived analytically. Alternatively, complete systems of supply response can be estimated from the underlying profit function. In this case, cross-equation restrictions are imposed on parameters so that the system derives rigorously from a profit or cost function [Ray, 1982; Colman, 1983; Higgins, 1986; Thijssen, 1992; Sadoulet and De Janvry, 1995].

The alternative to primal or dual methods is ad hoc specification of supply response (including partial adjustment and expectations formation). This pertains mainly to Nerlovian supply response models that use time series data for one commodity and prices of a few relevant commodities. It has minimal theoretical requirements but consequently also yields unreliable results [Colman, 1983; Sadoulet and De Janvry, 1995]. A final set of methods employ estimation of complete structural models of supply and demand equilibrium (where both prices and quantities are treated as endogenous) for the economy as a whole or for relevant sub-sectors, from which the supply response is derived by simulation (e.g. multimarket or CGE models) [Sadoulet and De Janvry, 1995].

2.3.2.1 THE PRIMAL APPROACH

The first step of the primal approach involves estimation of a production (single output) or transformation (multi-output) function [Debertin, 1986; Chambers, 1988; Färe and Primont, 1995]. In real-world situations (as opposed to experimental conditions), specified models are lesser representations of the true situation, because it is impossible to collect (or include) data on all relevant variables in the production process. This is termed the "hybridity" problem by Heady and Dillon [1961]. Hybridity of estimated functions does not render them useless; but likely represent the path that firms follow during the course of their firms' development process. This is backed by the argument that the theoretical models are subject to many maintained hypotheses and assumptions that may not hold under real world conditions – making the hybrid functions more realistic in the long-run. Therefore, fitted hybrid functions (that sufficiently approximate the true functional forms) are of use as they depict firms' growth paths over time.

The second step in the primal approach (when the purpose is to test for optimality) involves choosing a behavioural model for the economic agents. From this model, production is optimised subject to some objective function (e.g. profit maximisation or cost minimisation) from which optimality conditions are derived [Colman, 1983; Chambers, 1988].

Mansfield [1968] stated that economic growth could largely be ascribed to technological advances (a view typical of the late 1960's). Production functions were said to represent the maximum levels of output producible by combinations of inputs, under given technological conditions. Changes in technology induced shifts in the production function. Therefore, technological change could be measured by the change in output associated with the shifts in the production frontier, given input levels. Mansfield [1968] discussed the problem with this approach to measuring technological change. Observed differences caused by shifts were called residuals, but these residuals captured unexplained effects in the production process, without specifying the cause (source) of variation. To attribute all changes to technological change is erroneous. Much of the responses in agricultural supply are due to policy measures or changes in the business environment that influence output or input prices – relegating these influences to the residual above technical change would be a complete misrepresentation of reality.

As an example of a production function approach to milk supply, Heady and Dillon [1961] devoted a chapter to milk production functions in which they experimented with a variety of functional forms. They maintained that milk production per cow is a function of concentrate intake, forage intake, body size, inherent breed qualities, labour inputs and other unspecified (usually unobserved or immeasurable inputs). The primary objectives of their experimental study was the calculation of, firstly, grain-forage substitution rates, secondly, rates of feed-to-milk conversion under varying rations and levels of production and, thirdly, to evaluate the economic potential of forage-grain substitution.

Heady and Dillon [1961] explained that the input-input and input-output surfaces that depict dairy cows' milk production have special features that should be considered when a functional form is specified. For example, the cows stomach capacity imposes an upper limit on the quantity of feed that can be taken in a given time period. Similarly, physiological requirements determine minimum feed levels required for survival of the animal and these minimum levels in turn depend on the feed ration. Heady and Dillon [1961] found that at high levels of milk production, the slope of the production surface declines for any ration that is converted into milk – thus diminishing returns hold for all feed inputs.

With regard to quasi-fixed (i.e. fixed in the short term) variables in the production function, Heady and Dillon [1961] suggested the use of capital services (rent, depreciation, etc.) as opposed to the value of capital investment, when studies are based on short run data. They argue that only the flow of services (in stead of the stock that creates the flow over the life span of the capital asset) is relevant to the production in an observed period. Yet, using depreciation as part of the service flow includes the bias of a firm towards depreciation – at best the possible errors or bias should be kept in mind. On the same issue, using cash flows that vary in direct proportion to the level of production (e.g. fixed handling rates or commissions) will produce near unity output elasticities and high marginal propensities, but would mean nothing otherwise.

Measurement and quality definitions of labour pose problems in most cases of functional form estimation. Heady and Dillon [1961] point to the discrepancy between actually utilised versus available labour in the specification of a production function. In addition, valuing labour quality always contains some element of bias [Thijssen, 1992]. Heady and Dillon also discussed similar issues pertaining to land and management [1961, pp. 223 – 226].

2.3.2.2 The Dual Approach

After the popularity of the production function approach in the 1960' s, the 1970' s [Blackorby, *et al.*, 1978; Fuss and McFadden, 1978] saw increased application and development of the duality approach. The simultaneous advances in econometric techniques and electronic data processing capabilities strengthened the increased application of duality theory [Colman, 1983; Chambers, 1988].

Duality between production-, cost- and profit functions implies that there exists a correspondence between the cost- and profit functions and their underlying production function. The correspondence is such that one or both of the former can be used to derive the properties of the latter. This is mainly the case with limited information on the relevant primal variables and possible estimation problems associated with the production function approach [Blackorby, *et al.*, 1978; Fuss and McFadden, 1978; Chambers, 1988; Sadoulet and De Janvry, 1995].

Producer response is determined by two elements: the technological relation between combinations of inputs and the resulting level of output, and producers' behaviour in choosing inputs (given market prices and fixed factor availability). Integration of these two elements leads to (a) definition of the profit maximising or cost minimising functions and (b) to a direct method by which optimal decisions on output supply and factor demand can be determined [Colman, 1983; Sadoulet and De Janvry, 1995].

Rulan Pope [1982] evaluated the practical use of duality theory and argued that it is indeed useful for many practical problems, but it is not always essential. Pope [1982] quotes Diewert [1974] who described the heart of duality theory as the Minkowski theorem: "... every closed convex set can be characterised by its supporting half spaces". Pope [1982] described the essence of the dual approach as the indifference of results to the use of a production function or of Shepard' s Lemma [Beattie and Taylor, 1993] on a cost function in order to arrive at explicit cost minimising demands. Pope [1982] offers some suggestions for the observed prevalence of duality in applied work. Firstly, under the primal approach, input demand and output supply cannot be derived for certain functional forms, but via Hotelling' s theorems [Beattie and Taylor, 1993], the reduced form equations of input demand and output supply are derived directly. Secondly, in some cases (e.g. Leontief technology) the cost function can bridge problems of continuous differentiability imposed on the production or profit function. Thirdly, since inputs are often used in specific proportions or combinations, input demands are probably more collinear than prices, therefore favouring dual approaches to avoid multicollinearity.

The dual approach is based on the specification of a cost or profit function from which the input demand and output supply are derived. The following sub-sections describe the cost and profit function approaches.

2.3.2.2.1 The Cost Function

The cost function represents the firm' s economic behaviour as a cost minimisation problem, subject to a given level of output, under exogenously determined levels of input prices [Chambers, 1988].

Cost elasticity (ε_c) establishes a link between scale elasticity (ε)[9] (from the primal approach) and cost functions. Cost elasticity is the inverse of scale elasticity and it represents the ratio of relative cost increase due to a relative increase in output. It constitutes the ratio of marginal to average cost, and the curve of the former intersects the latter's curve at the point of minimum average cost [Bairam, 1994]. In the case of a traditional U-shaped average cost curve (AC-curve), marginal cost is higher than average cost at points beyond minimum average cost. If the production function is homogenous of degree k (i.e. if $\varepsilon = k$, where λ is constant), a U-shaped AC-curve cannot be derived [Bairam, 1994].

An example of the dual cost function approach is found in Binswanger' s [1974] work. He applied a cost function approach to measure elasticities of factor demand and substitution in the USA agricultural sector, based on cross-sectional data. He justified his choice of a dual approach – specifically the use of a cost function – by discussing six advantages.

Firstly, cost functions are homogenous of degree one in all prices, regardless of the homogeneity properties of the production function. It is therefore unnecessary to impose homogeneity on the underlying production technology. Secondly, Binswanger [1974] argues that the estimation equations treat prices (in stead of quantities) as independent variables. However, entrepreneurs choose input levels (quantities) according to price levels (exogenous at the farm level) and therefore quantities should be endogenous to the models. The third advantage pertains to the increased estimation bias that results from inverting the matrix of production coefficients to calculate elasticities of demand and substitution. A cost function approach does not require any matrix inversions. Fourthly, when dealing with neutral or non-neutral efficiency differences in observational units, or neutral or non-neutral economies of scale, the translog cost function offers a convenient way of handling problems of biased estimates of production parameters [Christensen, Jorgenson and Lau,

[9] Under homogeneity assumptions, $\varepsilon = \lambda^k$, where the exponent, k, gives the degree of homogeneity and λ is a constant.

1970]. Fifthly, linearity of all the estimation equations is obtained through the logarithmic transformation, for both the translog cost and production functions. Finally, Binswanger [1974] argues that multicollinearity is lacking in input prices (used in the cost function approach) while it is high between input quantities (used in the production function approach).

Sadoulet and De Janvry [1995] and Chambers [1988] state that the cost function has the same ability as the profit function to fully characterise economic agents' behaviour, whether it be cost minimisation or profit maximisation.

2.3.2.2.2 The Profit Function

The profit function represents a firm' s profit as a function of input and output prices (exogenously determined) and quasi-fixed variables. The firm' s decision problem is that of choosing levels of output supply and input demand that will maximise the firm' s profit. Choosing between a primal or dual approach (i.e. production function versus a cost- or profit function) implies different representations of the underlying technology when the chosen functional form is not self-dual (e.g. as in the case of translog production and cost- or profit functions). Consequently, Thijssen [1992] (an example of a profit function approach to Dutch Milk Supply analysis) employed both the primal and dual approach (using the translog production and profit functions) and he concluded that the calculated elasticities of production and substitution did not differ significantly between the two approaches. Thijssen [1992] refers to the findings of Apelbaum [1978] and Burgess [1975] that stated significantly differing substitution possibilities between inputs, as obtained from translog specifications of the production and cost functions. However, these authors assumed full static equilibrium and they used only aggregated data [Thijssen, 1992].

In Thijssen' s study [1992] he used data on decision making units in order to evaluate the influence on dairy product supply resulting from price (input and output) changes, technological change, the quantity of available land, demand for variable and capital inputs, and the supply of farm labour in the

Dutch agricultural sector. The data set incorporated time series and cross-sectional data [Thijssen, 1992] and was analysed as an unbalanced panel.

In a microeconomic approach to input demand and output supply in Irish agriculture, Higgins [1986] applied a profit function approach to data from a cross-section of Irish farms (milk production constituted one of the main activities). The resulting parameters were used to estimate a set of own- and cross-price uncompensated and compensated supply and demand elasticities. His results did not conform to all the expected theoretical requirements, yet he was able to test some of the properties (contrary to other studies were the properties are assumed) and to find acceptable descriptions of inter-relationships between inputs and outputs.

Bouchet, *et al.* [1989] investigated possible short- and long-run sources of growth in French agriculture. They point to the use of both profit and production functions to evaluate the impact of public agriculture expenditure on research on agricultural output (milk features as on of the outputs). Those studies which used the profit function approach, assumed short-run optimisation and exogenously fixed levels of other inputs. Bouchet, *et al.* [1989], however, modifies this method to treat some inputs as quasi-fixed, rather than fixed, thereby creating a way to evaluate long-run profit that comprises variable and quasi-fixed input optimisation.

2.4 FUNCTIONAL FORMS

The choice of a functional form is usually guided by knowledge of the biological nature of production, the economic and environmental (natural or business) factors that influence the production process under study. Generally, a trade-off exists between best-fit considerations and theoretical plausibility of the functional form. Some form of judgement on the part of the analyst is required for most samples, and few of those samples are free of design, measurement or specification errors. Choosing a probability level at which regression coefficients will be accepted as significantly different from zero depends on the phenomena under study. For example, rejecting the coefficient of a quadratic term in a second order polynomial might imply acceptance of a linear relationship. However, this could be implausible under some maintained physical and economic hypotheses [Whitley, 1994].

Quoting Anderson *et al.* [1996], "... the choice of functional form is not a trivial matter". Anderson, *et al.* [1996] point out three functional forms that seem to dominate in empirical production economics literature. Those forms are the translog, the normalised quadratic and the generalised Leontief functions. They concede that economic theory is not sufficient to determine the suitable functional form, although it does aid in identifying relevant variables and homogeneity restrictions. Anderson *et al.* [1996] ascribes the importance of correct specification of a functional form to the impact it has on predicted responses of modelled policy interventions.

According to Bairam [1994], most production functions in empirical research are assumed linearly homogenous, without implementing formal statistical tests on the true structure. Yet, the assumption of linear homogeneity (implying constant returns to scale) is not appropriate for some aspects of production theory. Bairam [1994], Fuss [1978] and Christensen [1973] emphasised the importance of flexible functional structures that require a minimum of maintained hypotheses.

One of the most famous production structures is the Cobb-Douglas function [Cobb and Douglas, 1928], which forms the basis of many subsequent functional forms. The other is the Leontief production function [Leontief, 1947]. Diewert [1971] expanded the Leontief function into a generalised form, while Arrow, Chenery, Minhas and Solow [1961] proposed adaptations [Zellner, Kmenta and Dreze, 1966] of the Cobb-Douglas production function into the Constant Elasticity of Substitution (CES) function [Kmenta, 1967], to incorporate constant elasticity of substitution between inputs, as opposed to the Cobb-Douglas' s restrictive unitary elasticity. Christensen *et al.* [1971, 1973] introduced the transcendental logarithmic ("translog" for short) production function – a non-homogenous function with varying scale elasticity. Under specific parameter restrictions, this function can also represent linear homogeneity (constant returns to scale, CRS).

Heady and Dillon [1961] mention the expansion of the Cobb-Douglas (in it's log-linear transformation) into the translog as one appropriate functional form for milk production modelling. However, when corner solutions are possible [Weaver and Lass, 1989] or when dealing with missing values, functional forms in logarithmic format (such as the Cobb-Douglas and translog) run into computational problems. Heady and Dillon [1961] suggest transformation of these variables (in which corner solutions prevail) by adding a small constant to all observations on the variable, or by replacing zeros with a small positive constant. They warn that care should be taken with this procedure: with high prevalence of zero-values, the consequent adjustments might be unsatisfactory and could induce non-negligible errors.

The translog form has been used more frequently than the generalised Leontief or the normalised quadratic [Anderson *et al.*, 1996]. All three of these flexible forms are linear in their parameters – facilitating estimation with standard statistical procedures. All three are separability inflexible, implying that they are not second-order Taylor series when separability is maintained in a partition of the variables. However, compared to expansion in powers, the translog (as an expansion in logarithms) has a larger region of convergence when large dispersion occurs in the data [Anderson *et al.*, 1996]. Conversely, the translog form is less suitable for technologies that seem to exhibit low elasticities of input substitution [Anderson *et al.*, 1996]. Anderson *et al.* [1996] conclude that the preferred functional form is both data and method specific, thus making testing of alternative forms imperative to the selection process. Flexible functional forms allow for objective testing of structural properties before imposing the properties on the technology, as is done with restrictive functional forms (e.g. linear functions) [Andersen, *et al.*, 1996; Hassan, 1998].

2.5 APPROACHES TO SPECIFICATION AND ESTIMATION OF SUPPLY MODELS

Parametric representation of milk supply response usually takes the form of production functions, or systems of supply equations. From these models, elasticities of supply and input substitution, as well as economies or diseconomies of scale and size are calculated. The concept of econometric representation raises the issues of appropriate specification of functional forms (Section 2.4) and problems inherent to the type of data.

Computational difficulties are associated with different types of data [Heady and Dillon, 1961]. When cross-sectional data is used and inputs are not homogenous over observations, aggregation problems occur [Day, 1963]. Standardisation attempts also poses problems, since the standardisation inherently involves judgements on quality differences.

Using cost and profit functions has made it much easier to obtain reliable estimates than in the case of production functions. Additionally, well-behaved cost and profit functions are supported by an underlying neoclassical production function [Quiggin and Bui-Lan, 1984]. However, the main arguments in these functions are prices, which would not likely vary greatly across firms at one point in time, if the maintained hypothesis of perfect competition were upheld.

If price variations can be ascribed to differences in location, estimations can be performed to capture the inter-regional variations. Conversely, if farms are widely dispersed, the assumption of homogenous technology is violated. Other spurious variation may result from valuation errors (opportunity cost of non-traded inputs), recording errors (prices include transaction cost) and quality differences captured by prices [Quiggin and Bui-Lan, 1984].

Cross-sectional data can be useful on a broad level for analysing policy questions at regional or national levels, but it may not be suitable for inferences about individual firm performances [Heady and Dillon, 1961; Pasour, 1981]. Cross-sectional sets should thus allow for ample variation across firms.

In a study aimed at estimating an aggregate production function for the USA agricultural sector, Griliches [1963] made use of cross-sectional data with several important comments on the use thereof. In his study, Griliches faced a lack of appropriate quantity data for many of the hypothesised variables and hence opted to use values (e.g. feed cost instead of the tonnes fed or price of feed). He justifies this choice through the assumption that cross-sectional price variations are not "...too large..." - as in the case of many commodity prices. However, this assumption is unrealistic in the case of labour and land inputs: price differences are substantial and they reflect quality and geographical variation. Griliches [1963] nevertheless maintain that inclusion of values (as opposed to quantities) represents a much smaller bias than ignoring cross-sectional differences in the cases of land and labour.

On estimation methods, Griliches [1963] defends his use of ordinary least squares (OLS) – applied to the logarithms of the variables, with output as dependent variable based on the inappropriateness of a factor share approach. The latter would assume equilibrium and constant returns to scale (CRS) – which essentially implies prior knowledge of the structure to be investigated.

Due to data limitations and the context of the research problem, Griliches [1963] settled for the use of OLS although it was not optimal. He also raised the problem of simultaneity that results from the possibility that no technique could yield sensible estimates of the input-output relationships. The latter argument stems from the deduction that all firms facing the same production technology and prices, should be at the same point. However, nothing would then have to be estimated. Hence, the issue of specifying the reasons for variation in real world data from the theoretical point arises [Griliches, 1963]. The potentially significant differences between regional input-output combinations ensure estimation possibilities. However, this casts doubt on the representativeness of a single production technology specification for all regions.

Weaver and Lass [1989] presented an estimation strategy that takes account of corner solutions in duality models, based on cross sectional observations of dairy production decisions. Their results suggest that substantial estimation bias occur when corner solutions are not recognised. Even under the assumption that all farms face similar technology options, variation in prices and fixed factor-flows cause differences in the choices that farmers make. For some firms it might be possible to exclude the use of certain factors in the short run – these corner solutions are typically observed in cross-sectional samples of farm budgets [Weaver and Lass, 1989].

Weaver and Lass [1989] emphasised the importance of the short run elasticity of output supply and input demand in the design of effective dairy policies. They apply the corner-solution adapted estimation process to a cross section of Pennsylvania dairy farms. From this they derive a complete set of short run elasticities that are consistent with short run profit maximisation, multiple-input multiple-output technology and fixed input flow hypotheses [Weaver and Lass, 1989].

Jaforullah and Whiteman [1999] followed a non-parametric approach to evaluate the scale efficiencies in New Zealand's dairy industry. Data Envelopment Analysis (DEA) was employed for the sample, under the assumption of multi-product (milk fat, milk solids and milk protein) output supply. Jaforullah and Whiteman [1999] observed the level of detail and the applicability of DEA to individual farmers, tied to the advantages of benchmarking to establish so called "best practice" examples. However, they recognise the advantage of parametric stochastic production frontier methodology that allows for statistical hypothesis testing, for which DEA does not allow. In addition, Jaforullah and Whiteman [1999] concede that the results of DEA do not contradict those obtained by Jaforullah and Devlin [1996] through a parametric approach.

Tauer [1998] used the Malmquist index to decompose the productivity of New York dairy farms into technical improvement and efficiency gains. The index is computed in the DEA framework and is based on the distance function – which is free from the assumptions of profit maximisation or cost minimisation.

For Alabama dairy farms, Smith and Taylor [1998] compared results from Estimated Generalised Least Squares (EGLS) and Finite Mixture Estimation (FME) as it applies to the derivation of size economies and production cost frontiers. They argued that FME provides estimation of a stochastic cost frontier with known statistical properties, which was unattainable with available stochastic frontier estimation packages [Smith and Taylor, 1998].

Dawson and Hubbard [1987] studied the effect of management on the size economies in England and Whales' dairy sector. They econometrically estimated long run average cost curves under different levels of management. Their results pointed to U-shaped average cost curves that display higher economies than diseconomies of size [Dawson and Hubbard, 1987]. Additionally, their results suggested that better managers can produce levels of output at lower average cost (i.e. higher optimum levels of output holds for these farms). Dawson and Hubbard [1987] used cross-sectional farm budget data with incomplete price information. They applied the translog functional form due to its flexibility and minimum of maintained hypotheses. Both heteroskedasticity and multicollinearity occurred in the data. Therefore, ordinary least squares-estimation (OLS) was rejected in favour of the two-stage Aitken estimator procedure, which yielded better fits [Dawson and Hubbard, 1987].

A priori, analysts often have little information, if any, on farmers' inclination towards experimenting or innovations, differences in resource endowments and actual primary enterprise goals. Knowledge of this could very well necessitate specification of different regressions, or inclusion of additional explanatory variables.

2.6 INTERPRETING MEASURES OF EFFICIENCY

Pasour [1981] made a few sobering comments on the measurement and interpretation of efficiency and economies of farm size. He argued that farm management data is inappropriate as basis for specification of inefficient producer behaviour and economies of farm size under real world conditions of uncertainty, imperfect knowledge and costly information.

Efficiency is measured by comparing a predefined norm with observed behaviour. The norm, in agriculture, is often specified as the "perfect market". Therefore, the efficiency norm looses its appropriateness in the face of uncertainty and costly information. Pasour [1981] ascribed the immense difficulty with measuring efficiency to the neglect of the entrepreneur's role in economic theory. Since efficiency involves inevitable valuations, those valuations should reflect the cost and returns as perceived by the decision-maker – not the analyst. The traditional assumptions of perfect knowledge and perfect certainty, under constrained maximisation, render inefficiency a contradiction in terms, according to Pasour [1981].

Pasour [1981] further argued that economies of size studies should not conclude that output levels of farms are inefficient or sub-optimal because changes in farm size distribution over time does not imply that a farm's current size is inefficient. Pasour [1981] suggested that farm survey data can neither yield meaningful results concerning efficiency of decision makers, nor of the effect of increased farm size on the unit production cost (economies of scale).

2.7 EXAMPLES OF MILK SUPPLY RESPONSE STUDIES

According to Tauer [1998], previous dairy studies point to great diversity in production methods and efficiency – inherent to the dairy industry. In addition to the studies by Thijssen [1992], Bouchet, *et al.* [1989] and Higgins [1986] where milk featured as an output, the following selection of studies dealt directly with parametric estimation of supply response in the dairy sectors of various countries.

Studies of milk supply response have focused on changes in the national herd and output. Buckwell [1984] argued that the structure of the herds play an important explanatory role in the understanding of secular output increases in the face of decreasing real milk prices. Buckwell dealt with the England and Whales dairy sector for the period 1962 to 1984. In his model, changes in herd numbers, average herd size and yield were explained. Buckwell [1984] tries to demonstrate that alternative specification of milk supply over time overshadow the role of the real milk price. Previous work applied production function approaches, linear programming based studies and mostly national aggregate econometric approaches. All these models decomposed milk production into two components: cow numbers and yield.

Buckwell [1984] refers to Kislev and Peterson [1982], who explained the growth in farm size, given fixed labour inputs, based on developments in relative factor prices. This approach avoids the controversial issues of technical change and economies of scale.
Buckwell [1984] modified and applied Kislev and Peterson's model. The modified main assumptions are that dairy farms are owner- or hired manager operated units, which constitutes the fixed farm input. Secondly, the ratio of mechanical services to cows is constant, irrespective of the herd size, biological service inputs or milk output. Thus, herd size is determined by the output of mechanical services. The production process combines the two sub-processes (mechanical service formation through labour and capital application; and the biological sub-process in which feed and fertiliser is combined with cows) to yield milk. The mechanical sub-process is seen as a cow-augmenting action. Labour cost is opportunity cost of fixed farm labour, and capital cost is the effective user cost of capital [Buckwell, 1984].

Buckwell' s [1984] adaptation of Kislev and Peterson' s [1982] model is mainly the aggregate focus as opposed to the latter's firm level focus. According to Buckwell [1984], returns in dairy and alternative enterprises as well as per capita earnings in dairy and non-agricultural sectors determine herd size. Cow numbers are a function of the cost of capital and the labour in the dairy sector. Cow numbers, milk price and the feed price, determines yield. Together, yield, cow numbers and average herd size explain the total supply response of milk [Buckwell, 1984].

Buckwell [1984] concluded that economic attractions outside dairying cause the main thrust for dairy producers to leave the sector. Changes in herd size result from changes in factor prices. Observed improvements in yield are partly due to technical change associated with larger herds, but yield also responds to feed and output prices. According to Buckwell [1984], the principal determinant of output growth is not the milk price, but the growth in average herd size, which is in turn sensitive to the price of capital relative to labour cost.

Burton [1984] argued that the livestock sector is subject to substantial interdependence, thus requiring simultaneous determination of endogenous variables. Herd size, numbers and rate of culling, replacement heifer prices and milk prices are said to be endogenous and interdependent [Burton, 1984]. In Burton' s model, heifer demand depends on culling levels and herd size expansion, both of which are dependent on the heifer price. This calls for the first simultaneous determination. Secondly, the herd size and the milk price should be determined jointly.

In lieu of these studies and the surveyed theory on supply response analysis, methodology is proposed through which the given data will be analysed.

CHAPTER 3: METHODOLOGY

3.1 DEFINITION OF "MILK PRODUCTION"

A milk-producing unit is defined as a whole farm or an activity of a diversified farming enterprise, in which milk products are produced. Milk production involves the dynamics of the dairy herd, which requires replacement, culling, nourishment and improvement. In addition to milk, trade in livestock forms an important part of the production process, albeit a secondary activity. The animal products are fluid milk and butterfat. The processing of milk and butterfat into other consumables (butter, milk powder, low fat or full cream milk, etc.) is not regarded as dairy production, but classifies as dairy processing. Furthermore, for the purpose of this study, only milk from bovine origin is taken into account. This is a result of the availability of information on dairy cattle as well as the overall dominance of bovine milk in the total dairy market, as opposed to milk from goats and sheep [Dairy Development Initiative, 1999].

3.2 CHOOSING BETWEEN A PRIMAL OR DUAL PARAMETRIC APPROACH

Chambers [1988] begins his description of applied production analysis with an overview of the production function (estimating the structure of production in the primal approach). However, he argued that restrictive assumptions are generally imposed on the production function and he pointed to the fact that analysts' main interest does not pertain to the production function as such, but to reliable representation and prediction of economic behaviour. He goes on to say that a restricted production function implies restrictions on the dual function.

This is where the dual approach attempts to isolate those circumstances under which purely economic phenomena can be used to reconstruct the underlying technology, given that technological restrictions are disclosed in the economic behaviour of agents. Duality implies that well-behaved cost- and profit functions are equivalent to well-behaved production functions.

Similarly, the existence of well-behaved cost- and profit functions implies the existence of well-behaved input requirement sets. A similar relationship exists between the cost and profit function: specification of a profit function implies the existence of a cost function [Lopez, 1984; Chambers, 1988]. Higgins [1986] states that the basic behavioural assumptions required when modelling production possibilities with a profit function approach are that farmers are profit maximisers and that markets are competitive. Both are realistic assumptions in the South African context.

Cost and revenue data is usually more readily available than data on physical input quantities. Therefore, parameters of the production functions can be estimated indirectly through application of duality (via a cost or profit function approach) [Leontief, 1969; Shephard, 1970; Diewert, 1971; Lau and Yotopoulos, 1972; Binswanger, 1974; Varian, 1978; Colman, 1983; Debertin, 1986].
Availability of data on primal variables is often a problem, as is the case with the present study. Only farm level budget information (cost, profit, prices) was available for this study (as opposed to regional or national aggregated data [Higgins, 1986]). Accordingly, data available for this study could only support the use of a dual approach to supply analysis.

3.2.1 PROFIT MAXIMISATION OR COST MINIMISATION

Dairy production in South Africa is not subject to quotas or any other form of centrally determined output level specification. Therefore, farmers are assumed to be maximising profits, subject to technological and environmental constraints. It could be argued that farmers minimise cost for an "expected" level of output. Since the data does not contain a time dimension, the "expected" output cannot be calculated for each farm. The underlying assumption is that the results from the two approaches will not differ significantly. The focus is, therefore, on the profit function approach.

3.3 THE THEORETICAL MODEL

Under the profit function approach, the production function is specified as $h(q, x, z) = 0$, implying that $q = f(x,z)$ where h is the technology function with q as the vector of output quantities and x and z the vectors of variable and fixed factors, respectively. Denoting output (milk) price by p and the price of inputs by the vector w, the restricted profit function (in which only variable costs are deducted from gross revenues) is written as $\pi_r = p'q - w'x$ (with p' and w' the respective transposed vectors of p and w). A producer thus chooses levels of inputs and output that will maximise restricted profit (π_r), subject to the technological constraints. Algebraically, the profit maximisation problem can be specified as:

Equation 1:

$$\begin{aligned} &\underset{x,q}{Max} \quad \pi = (p'q - w'x), \\ &s.t. \quad h(q, x, z) = 0 \end{aligned}$$

The solution of the latter optimisation problem is a set of input demand and output supply equations:

Equation 2:

$$\begin{aligned} &x = x(p, w, z), \rightarrow \text{Input demand} \quad \text{and} \\ &q = q(p, w, z) \rightarrow \text{Output supply.} \\ &\text{Therefore:} \\ &\pi = p'q(p, w, z) - w'x(p, w, z) \end{aligned}$$

Ideally, the profit function should satisfy the regularity conditions that would make it a "well-behaved" profit function. These properties are: Non-negativity; continuity; twice differentiability; monotonicity - increasing (decreasing) in output (input) prices; non-decreasing in fixed inputs; convexity in prices; concavity in fixed inputs; and homogeneity of degree zero in all prices and homogeneity of degree one in all fixed factors (if the production functions exhibits constant returns to scale, CRS) [Chambers, 1991; Higgins, 1986]. When these properties are satisfied, or imposed, the profit function will be the dual function of the transformation function. Then the parameters of the profit function contain adequate information from which to infer the properties of the underlying technology (e.g. elasticities of substitution, homogeneity, etc) [Higgins, 1986].

When dealing with a single output, the normalised variable profit function is estimated. It represents the ratio of profit to the output price, as a function of relative prices of variable inputs (and outputs) and of quasi-fixed factors. In the case of a multi-output normalised profit function, the numéraire is the output price of the n^{th} commodity. Normalisation has the purpose of removing any money illusion – in other words, firms respond to relative price changes. Normalisation also reduces the demand on degrees of freedom, by effectively reducing the number of equations and parameters to estimate. Algebraically:

Equation 3: $$\pi^* = \pi^*(p^*, w^*, z), \quad with \quad w_i^* = \frac{w_i}{p_n} \quad and \quad p_i^* = \frac{p_i}{p_n}$$

where w_i denotes the price of input-i (x_i) and where p_n is the price of the single output, or the price of the n^{th} commodity in the case of multi-output. From the profit function a system of output supply and input demand equations are derived by using Hotelling' s Lemma and the first order conditions (F.O.C) for profit maximisation:

Equation 4: $$\frac{\partial \pi^*}{\partial p_i^*} = q_i, \quad and \quad \frac{\partial \pi^*}{\partial w_i^*} = -x_i$$

The symmetry in outputs and inputs is further exploited by treating inputs as negative outputs, thus simplifying notation:

Equation 5: $$q = \begin{bmatrix} q \\ -x \end{bmatrix}, \quad p = \begin{bmatrix} p^* \\ w^* \end{bmatrix} \Rightarrow q_i = \frac{\partial \pi^*(p,z)}{\partial p_i}$$

The derived supply and demand functions satisfy the symmetry (of the second order derivatives of the profit function) property, implying that:

Equation 6: $$\frac{\partial q_i}{\partial p_j} = \frac{\partial q_j}{\partial p_i}$$

Or, stated in terms of elasticities:

Equation 7: $$\frac{\partial q_i}{\partial p_j} \times \frac{p_j}{q_i} = \frac{\partial q_j}{\partial p_i} \times \frac{p_i}{q_j}$$

Similarly in natural logarithm form:

Equation 8: $$\frac{\partial \ln q_i}{\partial \ln p_j} = \frac{\partial \ln q_j}{\partial \ln p_i} \quad \therefore E_{q_i}^{p_j} = E_{q_j}^{p_i}$$

The cross price elasticities are inversely proportional to the corresponding profit shares:

Equation 9:

$$\frac{E(q_i / p_j)}{E(q_j / p_i)} = \frac{s_j}{s_i}, \quad where \quad s_i = \frac{p_i q_i}{\pi}$$

In addition to these partial elasticities, the total effect of price changes comprises of a substitution and expansion effect [Higgins, 1986]. Substitution in the input case implies a movement along the isoquant, and a compromise between outputs on the transformation frontier. Expansion implies a movement from one isoquant to another, as output expands along the expansion path to the new transformation frontier [Higgins, 1986]. The corresponding types of elasticities are the Marshallian (uncompensated, long-run) and Hicksian (compensated, short-run) elasticities of substitution. Based on these elasticities, outputs and inputs can be classified into categories of gross or net substitutes or complements in the production process [Higgins, 1986; Deaton and Muellbauer, 1980].

3.4 ECONOMETRIC SPECIFICATION

3.4.1 CHOICE OF FUNCTIONAL FORM

In this study, the translog function [Christensen, *et al.*, 1973] is hypothesised as an appropriate approximation of the true profit function, as well as a good representation of the underlying production function, due to its flexibility and (consequent) wide use. This study also adopts the normalised quadratic (NQ) profit functions for comparative analysis. Both forms are estimated and the results compared to establish which form is most appropriate, given the data. The normalised quadratic form has the advantage of linearity in the parameters and simple expressions for the elasticities (evaluated at any level of prices and quantities) [Bouchet, *et al.*, 1989].

3.4.1.1 THE NORMALISED QUADRATIC PROFIT FUNCTION

In the multi-output case, profit and prices are normalised by the price of the n^{th} commodity. Algebraically it is stated as follows:

Equation 10: $$\pi^* = \frac{\pi}{p_n} = \alpha_0 + \sum_i \alpha_i p_i + \frac{1}{2}\sum_{ij} \beta_{ij} p_i p_j + \sum_{im} \beta_{im} p_i z_m \quad \begin{bmatrix} i, j = 1, \cdots, n-1 \\ \beta_{ij} = \beta_{ji} \end{bmatrix}$$

where $p = \begin{bmatrix} p^* \\ w^* \end{bmatrix}$ is the vector of normalised output and input prices. This type of profit function is homogenous in prices, but not in the fixed factors (z). The derived system of output supply and input demand equations is:

$$q_i = \alpha_i + \sum_j \beta_{ij} p_j + \sum_m \beta_{im} z_m \quad and$$

Equation 11: $$q_n = \pi^* - \sum_i p_i q_i = \alpha_0 - \frac{1}{2}\sum_{ij} \beta_{ij} p_i p_j$$

for commodity n, whose price was the numéraire

Normalisation allows for evaluation of supply and input responses to relative price changes. In addition, it imposes homogeneity in prices, thereby reducing pressure on degrees of freedom during estimation. Moreover, normalisation allows one equation to be dropped from the system, thus further alleviating the degrees of freedom problem. Price elasticities are computable at any value of prices and quantities, such that:

Equation 12: $$E_{ij} = \frac{\beta_{ij} p_j}{q_i}, \quad i, j \neq n, \quad E_{nj} = \frac{1}{s_n}\sum_i s_i E_{ij}, \quad and \quad E_{nn} = -\sum_i E_{ni}.$$

This function has the distinct advantages of linearity in the parameters and simple equations for the elasticities [Bouchet *et al.*, 1989; Thijssen, 1992; Sadoulet and De Janvry, 1995].

3.4.1.2 THE TRANSLOG PROFIT FUNCTION

The translog specification is a second-degree flexible function in prices and fixed inputs, with variable elasticities of substitution and is considered as a second order approximation of any functional form. Algebraically, the translog is specified as follows [Christensen, *et al.*, 1973; Capalbo *et al.*, 1988]:

Equation 13:

$$\ln \pi = \alpha_0 + \sum_i \alpha_i \ln p_i + \sum_m \beta_m \ln z_m + \frac{1}{2}\sum_{ij} \beta_{ij} \ln p_i \ln p_j + \frac{1}{2}\sum_{mn} \gamma_{mn} \ln z_m \ln z_n + \sum_{im} \gamma_{im} \ln p_i \ln z_m$$

Certain restrictions are required when the properties of homogeneity with respect to prices and fixed factors are imposed. The necessary restrictions are symmetry, additivity and homogeneity, respectively:

$$\beta_{ij}=\beta_{ji};\quad \gamma_{mn}=\gamma_{nm};\quad \sum_i \alpha_i=0;\quad \sum_m \beta_m=1;\quad \sum_i \beta_{ij}=\sum_m \gamma_{mn}=\sum_i \gamma_{im}=\sum_m \gamma_{im}=0.$$

The system of derived factor demand and output supply is:

Equation 14: $$q_i = \frac{\pi}{p_i}\left[\alpha_i + \sum_j \beta_{ij} \ln p_j + \sum_m \gamma_{im} \ln z_m\right]$$

Elasticities are calculated as:

Equation 15: $$E_{ij} = s_j + \frac{\beta_{ij}}{s_i}; \quad and \quad E_{ii} = -1 + s_i + \frac{\beta_{ii}}{s_i}$$

The translog function has an additional beneficial property. Differentiation of the profit function with respect to input or output price (Hotelling' s Lemma) yields the profit-share equation for that specific input or output [Christensen, *et al.*, 1973]. Higgins [1986] clearly shows that:

Equation 16: $$\frac{\partial \ln \pi}{\partial \ln p_i} = \frac{\partial \pi}{\partial p_i} \times \frac{p_i}{\pi} = S_i = \alpha_i + \sum_j \beta_{ij} \ln p_j + \sum_m \gamma_{im} \ln z_m \quad i = 1,\ldots,n$$

The profit shares are the basis from which to compute price elasticities of inputs and outputs (Equation 15) [Christensen, *et al.*, 1973; Thijssen, 1992; Debertin, 1986; Sadoulet and De Janvry, 1995; Binswanger, 1974]. For the translog model, Higgins [1986] defines the Marshallian and Hicksian elasticities of substitution as follows:

Equation 17:

$$Marshallian: \quad \eta_{ii} = \frac{\beta_{ii}}{S_i} + S_i - 1$$

$$\eta_{ij} = \frac{\beta_{ij}}{S_i} + S_j \quad i, j = 1,\ldots,n$$

where η_{ii} and η_{ij} represent the own-price elasticity of supply (and demand), and the cross-price elasticity of supply, respectively. The system of compensated elasticities is represented in matrix form as follows (following the notation used by Higgins, [1986]) and this applies to the Normalised Quadratic specification' s compensated elasticities as well:

Equation 18:

$$Hicksian: \quad \{\eta_{lk}^{S}\} = \{\eta_{lk}\} - \{\eta_{lt}\} \times \{\eta_{th}\}^{-1} \times \{\eta_{tl}\}$$
$$\{\eta_{th}^{S}\} = \{\eta_{th}\} - \{\eta_{tl}\} \times \{\eta_{lk}\}^{-1} \times \{\eta_{lt}\}$$

The matrices and symbols are defined as:

- $\{\eta_{lk}^{S}\}$: Hicksian input demand elasticities with respect to input prices.
- $\{\eta_{lk}\}$: Marshallian input demand elasticities with respect to input prices.
- $\{\eta_{lt}\}$: Marshallian input demand elasticities with respect to output prices.
- $\{\eta_{th}\}$: Marshallian output supply elasticities with respect to output prices.
- $\{\eta_{tl}\}$: Marshallian output supply elasticities with respect to input prices.
- $\{\eta_{th}^{S}\}$: Hicksian output supply elasticities with respect to output prices.

3.5 METHODS OF ECONOMETRIC ESTIMATION

3.5.1 SINGLE EQUATION, SYSTEM- OR FULL INFORMATION ESTIMATION PROCEDURES

Supply response from a profit function approach can be estimated through two procedures. Firstly, by estimating the profit function itself from data on farm profits, exogenous explanatory variables, prices and fixed factors. Secondly, since observations on inputs and outputs are readily available, direct estimation of the output supply and input demand equations can be done without imposing assumptions of cost minimising or profit maximising behaviour.

When following the second approach, all equations (assuming a profit-share approach) are jointly estimated except for the profit function itself. The reasoning behind this lies in the linear dependency of the profit function on the coefficients of the share equations (identification requirement). In the translog case, the dependent variables are the profit shares, which add to one. Therefore, one share equation is dropped from the system to avoid singularity of the variance-covariance matrix. The parameters of the dropped equation are derived from the estimated parameters. An additional advantage of the system approach is the avoidance of multicollinearity problems. In the profit function, square and cross product terms introduce multicollinearity, but these terms are not present in the share- or input demand and output supply equations of the system.

In terms of obtaining full information, joint estimation of the profit function and the derived functions would yield estimates that are more efficient. This places severe restrictions on the degrees of freedom and is thus not ideal in this study where the sample size is limited to forty-eight observations.

For the system of input demand and output supply functions to be compatible with profit maximisation, monotonicity and convexity of the underlying profit function, as well as homogeneity and symmetry must hold. These constraints could be imposed on the parameters during estimation of the system, or the unrestricted system could be estimated and then the theoretical constraints could be formally tested, both locally and globally [Capalbo *et al.*, 1988]. The latter effectively provides a test for profit maximising behaviour [Lopez, 1980]. On the other hand, imposing of the theoretical restrictions reduce the number of parameters to be estimated, thus alleviating the pressure on the degrees of freedom problem due to joint system estimation of these flexible forms.

3.5.2 SINGLE EQUATION AND SYSTEM ESTIMATION TECHNIQUES

The econometric estimation of a system of equations can be done with various techniques[10] [Johnston, 1984; Zellner, 1987; Pindyck and Rubinfield, 1991; Johnston and DiNardo, 1997; Greene, 1997]. For this study, Seemingly Unrelated Regression (SUR) and Ordinary Least Squares (OLS)

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[10] Seemingly Unrelated Regressions (SUR); Full Information Maximum Likelihood (FIML); Generalised Method of Moments (GMM); Two-stage Least Squares (2SLS); Three-stage Least Squares (3SLS), Weighted Least Squares (WLS), Ordinary Least Squares (OLS), etc. See Annexure B.

estimation techniques are considered and compared to determine the appropriate estimation technique, given the data set.

While the systems approach allows for cross-equation restrictions and takes account of cross-equation error correlation, it does come at a cost. Misspecification of an equation within the system may contaminate estimates of the other parameters. When employing single equation estimation, only the parameters of the misspecified equation are affected. Therefore, both the system and single equation approach were followed and the differences are reported in the results chapter.

SUR estimation (also known as the multivariate regression or Zellner' s method) [Zellner, 1962] accounts for both heteroskedasticity and contemporaneous cross-equation error correlation. This technique is appropriate when all the right hand side variables are assumed exogenous, and when some common factors, which are not explicitly modelled, influence the disturbances across equations [Zellner, 1962; Johnston and DiNardo, 1997]. Using the Iterative-SUR makes the system indifferent to the choice of the dropped share equation. In addition, the cross-equation symmetry restrictions and possible contemporaneous correlation between the errors of the various share equations, justifies the choice of this method [Higgins, 1986; Pindyck and Rubinfeldt, 1991; Kotsoyannis, 1981; Johnston and DiNardo, 1997].

OLS system estimation minimises the sum of squared residuals for each equation, whilst considering cross-equation restrictions [EViews User Manual, 1999]. When no restrictions are imposed, the method is identical to single equation OLS. This method also provides an intuitive test for the correct specification of the different equations in the system approach. If the system estimation yields unsatisfactory results, the single equation OLS results may indicate which equation(s) causes the problems.

Each specified equation for both methods contains an additive error term that captures the unexplained difference between the profit maximising levels of input and output versus the realised levels [Higgins, 1986]. The error term will inexorably capture the effect of all variables that are not explicitly specified as well as some quality differences in inputs and outputs. No quality distinctions are reported and could thus not be incorporated. In addition, the cross-sectional nature of the data leads to the use of White's Heteroskedasticity Consistent Variance Co-variance Estimator [White, 1980] to account for possible heteroskedasticity of unknown form.

3.6 A NOTE ON PRICE VARIABILITY IN CROSS-SECTIONAL STUDIES

For estimation of a profit function or a system, sufficient price variation is necessary. While this is seldom a problem in time series data, the nature of price variation in cross-sectional studies draws attention [Higgins, 1986; Quiggin and Bui-Lan, 1984]. Difference in market prices can be the result of transaction cost such as transport or marketing cost due to differences in farms' proximity to markets. Monopoly power of processors, input suppliers or co-operatives and discounts for bulk sales or purchases may also cause variation in effective prices paid and received. The use of a profit function approach is not invalidated by these causes of price variation. However, if price variation can be ascribed to quality differences in inputs and outputs, the source of variation should be modelled, thereby removing the required variability in prices.

When dealing with aggregated inputs and outputs the price differences could be a result of the difference in the composition of the aggregates, causing the price index to be correlated with the error term (resulting in biased estimates). Similarly, difference in managerial efficiency (in interpreting market signals, timing production actions, etc.), which is not accounted for explicitly or correctly, will bias the parameter estimates [Higgins, 1986].

The assumption is made that the observed price variability is due to proximity to markets and to bulk discounts, as well as preferential contracts with processors. Furthermore, the proportion of price variability that is due to managerial differences is assumed to be captured by the management proxy.

3.7 HYPOTHESISED RELEVANT VARIABLES

3.7.1 SELECTION OF VARIABLES FOR THE EMPIRICAL ANALYSIS

The data set used for this study contains detailed production cost for fifty dairy farmers. On average, total feed cost constitutes sixty percent (60%) of the total annual cost outlay. A breakdown of self-produced (grazing and administered feed) and purchased feed types, quantities and cost is given in the data. However, data is lacking for different variables on different farms, in other words, the gaps in the data are not consistent within or between farms. The composition of labour remuneration (in terms of cash, rations, farm produce and other benefits) is detailed, but the number of hours allocated to milk production and livestock, respectively, is not recorded. Capital constitutes investment in livestock, as one group, and investment in land, fixed improvements and equipment, as the second group. The herd structure is also reported.

The lack of a time dimension precluded evaluation of technological change. In addition, the small sample size (48 farms with positive profits) places serious limitations on the size of the supply system to be estimated. Therefore, the initial choice of explanatory variables fell on two variable inputs (self-produced feed, and purchased feed) and on three quasi-fixed variables (a proxy for management, livestock capital and labour input). This choice was supported by the records of unit prices for the variable inputs for the majority of the farms. The distinction between self-produced and purchased feed is drawn, based on the assumption that the ability to produce feed lowers the input cost and thus increases profit. Similarly, the ability to purchase feed effectively expands the farm size in the short term [Burton, 1984]. Furthermore, most of the input substitution in dairy production occurs between these two input groups. It is assumed that management determines the efficient allocation of resources. A proxy for managerial ability is used, namely, restricted profit per unit of fixed cost. This measure gives an indication of a farmer' s ability to generate short-run profit sufficiently to cover medium and long-term costs.

Restricted profit was calculated as gross product value (quantity of milk multiplied by the milk price plus the value of animal trade income) minus the variable inputs (self-produced and purchased feed). The shares of the variable inputs are calculated as the total value of the input (price times quantity) divided by the restricted profit. Only those farms with positive restricted profit are considered (hence only 48 farmers out of the available fifty observations). The aggregated price of traded animals is used as the numéraire for profit normalisation.

3.7.2 *Transformation of Variables*

When estimating the translog profit system the independent variables are expressed in their natural logarithmic form. This poses problems when some observational units report zero values for a specific input. Given the already small sample size, it was decided not to exclude these observations from the system. As a solution, the relevant input is scaled by a constant, making all observations on that input larger than zero.

The income from animal trade (as the second output activity) comprises of the sales of calves, heifers, dry cows, bulls and oxen at different free market prices. Similarly, purchased feed constitutes a mix of bought feed components and self-produced feed comprises of diverse crop mixtures. Due to the small sample size, the dynamics of each of these three processes could not be modelled. The alternative is to construct three price indices for an aggregated unit of a traded animal, an aggregate unit of purchased feed and an aggregate unit of self-produced feed per farm [Higgins, 1986]. Following the methodology of Higgins [1986] and Caves *et al.* [1982], a cross-section type Divisia index is constructed for each of the three cases. The form of the index is:

Equation 19:

$$\ln P_j^k = \frac{1}{2}\sum_i^g (r_{ij}^k + \bar{r}_{ij})(\ln P_{ij}^k - \overline{\ln p_{ij}})$$

The variables in Equation 19 are defined as:

- $\ln P_j^k$: the price index for the aggregate-j (e.g. purchased feed) on the farm-k.

- r_{ij}^{k} : the share of good-i (i.e. licks in the purchased feed aggregate) in the aggregate-j on the farm-k.
- $\bar{r}_{ij}$: the average share of good-i in aggregate-j over all farms.
- $\ln P_{ij}^{k}$: the natural logarithm of the unit price for good-i in the aggregate-j on farm-k.
- $\overline{\ln p_{ij}}$: the average of the natural logarithm of the price of good-i in aggregate-j over all farms.

The index has a base of zero (the average of the sample) and for the farms that report zero values for an input or output, the average sample price was used in calculating the index.

The set of dependent and independent variables included in the supply system is given in Table 5.

Table 5: Base model system variables

Variable name	Description	Unit of measurement
Q_{mlk}	Total quantity of fluid milk produced	Litres
Q_{trd}	Total aggregate units of animals traded	Aggregated unit
Q_{fb}	Total aggregated units of purchased feed demanded	Aggregated unit
Q_{fs}	Total aggregated units of self-produced feed demanded	Aggregated unit
P_{mlk}	Unit price of a litre of milk	Rand / litre
P_{trd}	Price index for an aggregated animal unit traded	Rand / unit
P_{fb}	Price index for an aggregated unit of feed purchased	Rand / unit
P_{fs}	Price index for an aggregated unit of self-produced feed	Rand / unit
Smlk	Share of milk revenue in the restricted profit	
S_{trd}	Share of trade revenue in restricted profit	
S_{fb}	Share of purchased feed in restricted profit	
S_{fs}	Share of self produced feed in restricted profit	
MPRX	Index for management efficiency (base value is one)	Profit/ Fixed cost
LCAP	Livestock capital (average of beginning and ending stock)	Rand
LABR	Labour cost (cash, rations, payment in kind and grants)	Rand
Profit (π)	Restricted profit (Gross value of production – variable input cost)	Rand

3.8 SPECIFICATION OF THE EMPIRICAL MODEL

3.8.1 INPUT DEMAND AND OUTPUT SUPPLY EQUATIONS FOR THE NORMALISED QUADRATIC MODEL

Equation 20 shows the specification for the empirical normalised profit function. The derived supply and demand equations are represented Equation 21.

Equation 20:

$$\begin{aligned}\pi^* = \frac{\pi}{p_{trd}} &= \alpha_0 + \alpha_1 p_{mlk} + \alpha_2 p_{fb} + \alpha_3 p_{fs} \\ &+ \tfrac{1}{2}(\beta_{11} p_{mlk}^2 + \beta_{22} p_{fb}^2 + \beta_{33} p_{fs}^2) \\ &+ (\beta_{12} p_{mlk} p_{fb} + \beta_{13} p_{mlk} p_{fs} + \beta_{23} p_{fb} p_{fs}) \\ &+ (\beta_{1M} p_{mlk} z_{Mprx} + \beta_{2M} p_{fb} z_{Mprx} + \beta_{3M} p_{fs} z_{Mprx}) \\ &+ (\beta_{1C} p_{mlk} z_{Lcap} + \beta_{2C} p_{fb} z_{Lcap} + \beta_{3C} p_{fs} z_{Lcap}) \\ &+ (\beta_{1L} p_{mlk} z_{Labr} + \beta_{2L} p_{fb} z_{Labr} + \beta_{3L} p_{fs} z_{Labr})\end{aligned}$$

Equation 21:

$$\begin{aligned}Q_{mlk} &= \alpha_1 + \beta_{11} p_{mlk} + \beta_{12} p_{fb} + \beta_{13} p_{fs} + \beta_{1M} z_{Mprx} + \beta_{1C} z_{Lcap} + \beta_{1L} z_{Labr} \\ Q_{fb} &= \alpha_2 + \beta_{22} p_{fb} + \beta_{12} p_{mlk} + \beta_{23} p_{fs} + \beta_{2M} z_{Mprx} + \beta_{2C} z_{Lcap} + \beta_{2L} z_{Labr} \\ Q_{fs} &= \alpha_3 + \beta_{33} p_{fs} + \beta_{13} p_{mlk} + \beta_{23} p_{fb} + \beta_{3M} z_{Mprx} + \beta_{3C} z_{Lcap} + \beta_{3L} z_{Labr}\end{aligned}$$

Different combinations of the four equations were estimated. Each of the four was estimated by OLS; the group of three derived equations (Equation 21) were estimated separately from and jointly with the profit function.

3.8.2 SHARE EQUATION SPECIFICATION FOR THE TRANSLOG MODEL

The translog profit function for the two-output, two variable input and three quasi-fixed input case is represented in Equation 22. The derived share equations are given in Equation 23.

Equation 22:

$$\begin{aligned}
\ln \pi = {} & \alpha_0 + \alpha_1 \ln p_{mlk} + \alpha_2 \ln p_{fb} + \alpha_3 \ln p_{fs} + \alpha_4 \ln p_{trd} \\
& + \beta_M \ln z_{Mprx} + \beta_C \ln z_{Lcap} + \beta_L \ln z_{Labr} \\
& + \tfrac{1}{2}(\beta_{11} \ln p_{mlk}^2 + \beta_{22} \ln p_{fb}^2 + \beta_{33} \ln p_{fs}^2 + \beta_{44} \ln p_{trd}^2) \\
& + \beta_{12} \ln p_{mlk} \ln p_{fb} + \beta_{13} \ln p_{mlk} \ln p_{fs} + \beta_{14} \ln p_{mlk} \ln p_{trd} \\
& + \beta_{23} \ln p_{fb} \ln p_{fs} + \beta_{24} \ln p_{fb} \ln p_{trd} + \beta_{34} \ln p_{fs} \ln p_{trd} \\
& + \tfrac{1}{2}(\gamma_{MM} \ln z_{Mprx}^2 + \gamma_{CC} \ln z_{Lcap}^2 + \gamma_{LL} \ln z_{Labr}^2) \\
& + \gamma_{MC} \ln z_{Mprx} \ln z_{Lcap} + \gamma_{ML} \ln z_{Mprx} \ln z_{Labr} + \gamma_{CL} \ln z_{Lcap} \ln z_{Labr} \\
& + \gamma_{1M} \ln p_{mlk} \ln z_{Mprx} + \gamma_{1C} \ln p_{mlk} \ln z_{Lcap} + \gamma_{1L} \ln p_{mlk} \ln z_{Labr} \\
& + \gamma_{2M} \ln p_{fb} \ln z_{Mprx} + \gamma_{2C} \ln p_{fb} \ln z_{Lcap} + \gamma_{2L} \ln p_{fb} \ln z_{Labr} \\
& + \gamma_{3M} \ln p_{fs} \ln z_{Mprx} + \gamma_{3C} \ln p_{fs} \ln z_{Lcap} + \gamma_{3L} \ln p_{fs} \ln z_{Labr} \\
& + \gamma_{4M} \ln p_{trd} \ln z_{Mprx} + \gamma_{4C} \ln p_{trd} \ln z_{Lcap} + \gamma_{4L} \ln p_{trd} \ln z_{Labr}
\end{aligned}$$

Equation 23:

$$\begin{aligned}
S_{mlk} = {} & \alpha_1 + \beta_{11} \ln p_{mlk} + \beta_{12} \ln p_{fb} + \beta_{13} \ln p_{fs} + \beta_{14} \ln p_{trd} \\
& + \gamma_{1M} \ln z_{Mprx} + \gamma_{1C} \ln z_{Lcap} + \gamma_{1L} \ln z_{Labr} \\
S_{fb} = {} & \alpha_2 + \beta_{22} \ln p_{fb} + \beta_{12} \ln p_{mlk} + \beta_{23} \ln p_{fs} + \beta_{24} \ln p_{trd} \\
& + \gamma_{2M} \ln z_{Mprx} + \gamma_{2C} \ln z_{Lcap} + \gamma_{2L} \ln z_{Labr} \\
S_{fs} = {} & \alpha_3 + \beta_{33} \ln p_{fs} + \beta_{13} \ln p_{mlk} + \beta_{23} \ln p_{fb} + \beta_{34} \ln p_{trd} \\
& + \gamma_{3M} \ln z_{Mprx} + \gamma_{3C} \ln z_{Lcap} + \gamma_{3L} \ln z_{Labr} \\
S_{trd} = {} & \alpha_4 + \beta_{44} \ln p_{trd} + \beta_{14} \ln p_{mlk} + \beta_{24} \ln p_{fb} + \beta_{34} \ln p_{fs} \\
& + \gamma_{4M} \ln z_{Mprx} + \gamma_{4C} \ln z_{Lcap} + \gamma_{4L} \ln z_{Labr}
\end{aligned}$$

Similar to the Normalised Quadratic case, different combinations of the equations were estimated. The trade-income share equation was dropped from the supply system estimations to avoid singularity of the covariance matrix.

3.9 TESTING THE PROPERTIES OF THE PROFIT FUNCTION

Under the assumptions of profit maximising behaviour with a continuous and a twice-differentiable profit function, the parameters of the estimated equations must satisfy symmetry, convexity, monotonicity and homogeneity conditions.

3.9.1 NON-NEGATIVITY

The estimated input demand and output supplies and profit should be zero or positive. This was evaluated at the level of each farm. By definition, quantities are non-negative values. Similarly, a profit maximising farmer will rather produce zero output than to incur negative profits.

3.9.2 MONOTONICITY

This property requires that the profit function strictly increases in output prices and strictly decreases in input prices [Chambers, 1988; Capalbo *et al.*, 1988; Higgins, 1986]. This property is tested through evaluation of the first derivatives of the profit function with respect to input and output prices. In the translog case, this implies evaluation of the profit shares. For inputs, the first derivatives of the profit function with respect to the input price should be non-positive. The first derivatives of the profit function with respect to the output prices should be non-negative. Since the functions approximate the true profit function and the first derivatives are expressions in the levels of the variables, the evaluation is done at the point of approximation [Capalbo *et al.*, 1988]. In the normalised quadratic case, this implies setting the values of the variables to zero and for the translog function the values are set to one.

3.9.3 CONVEXITY

The necessary condition for convexity is that the Hessian matrix of second order derivatives of the profit function with respect to all prices be positive semi-definite. This implies that all the principal minors must have non-negative determinants {Capalbo *et al.*, 1988]. This follows from the fact that $\partial^2\pi/\partial p_i\partial p_i = \partial Q_i/\partial p_i > 0$ and $\partial^2\pi/\partial w_i\partial w_i = -\partial X_i/\partial w_i > 0$, making the profit function convex in input and output prices (i.e. output supply is upward sloping and input demand is downward sloping). Algebraically, the Hessian matrix is represented as follows:

Equation 24:
$$H = \begin{vmatrix} \frac{\partial^2 \pi}{\partial p_i \partial p_i} & \cdots & \frac{\partial^2 \pi}{\partial p_i \partial p_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial^2 \pi}{\partial p_n \partial p_i} & \cdots & \frac{\partial^2 \pi}{\partial p_n \partial p_n} \end{vmatrix}$$

3.9.4 HOMOGENEITY

The Wald-test was used to test for the homogeneity restrictions. The Normalised Quadratic profit function is homogeneous in prices, but not in fixed factors. For the translog profit function to be homogeneous, the symmetry condition ($\beta_{ij}=\beta_{ji}$ and $\gamma_{mn}=\gamma_{nm}$,)' the additivity restriction ($\Sigma_i\ \alpha_i=0$ and $\Sigma_m\beta_m=1$), as well as the condition that the sum of the coefficients of the squared and interaction terms are zero ($\Sigma_i\beta_{ij}=\Sigma_m\gamma_{mn}=\Sigma_i\gamma_{im}=\Sigma_m\gamma_{im}=0$) must hold. However, homogeneity in prices can also be imposed by normalising the translog profit function.

3.9.5 SYMMETRY

Symmetry is imposed due to the restricted sample size. Without the symmetry condition, there are not sufficient degrees of freedom in order to estimate all the parameters of the specified equations.

The methodology described is used to estimate different combinations of single equation and system specifications of which the results are reported in the following chapter (Chapter 4: Results).

CHAPTER 4: RESULTS OF THE EMPIRICAL ANALYSIS

4.1 OVERVIEW OF THE CHAPTER

Different combinations of profit-, supply- and demand equations, as well as estimation methods were employed, within the framework of profit maximising normalised quadratic and translog functions. In general, FIML estimation yielded very few significant coefficients. This casts doubt on the overall specification of the equations and systems. Consequently, OLS is used to evaluate the goodness of fit of each equation that would be included in the system. Although the system methods generally yield estimates that are more efficient, the results depend on the correct specification of the equations in the system. Thus, OLS results are used as a proxy to determine which equations are possibly causing contamination of the system.

This chapter reports tabulated[11] and graphical results of single equation OLS estimation (Section 4.2.1), of profit system results (Section 4.2.2) and a discussion of the structural tests and elasticity results. To avoid unnecessary repetition, the term "not rejected" is used without specification of the level of acceptance when the tested hypothesis cannot be rejected at the 1%-, 5%-, 10%- and 15%-level of acceptance. In all the other circumstances, the level of acceptance will be specified.

4.2 THE NORMALISED QUADRATIC

From Chapter 3: Methodology, Equation 20 and the derived input demand and output supply equations (Equation 21) were estimated and the results are reported in the following sections.

[11] Values larger than absolute ten are rounded up to the nearest integer; values less than absolute ten are rounded up to the nearest two decimals. Significance of coefficients is regarded up to a 15%-level of acceptance.

4.2.1 SINGLE EQUATION OLS RESULTS

4.2.1.1 NORMALISED QUADRATIC PROFIT FUNCTION

The Normalised Quadratic (NQ) profit function, Equation 20, was estimated with OLS. White's Heteroskedastic Consistent Variance Covariance Matrix Estimator (HETCOV) [White, 1980] was used to account for possible heteroskedasticity in the residuals (in the absence of heteroskedasticity, this estimator reduces to the usual covariance matrix estimator). The results are reported in Table 6.

Table 6: NQ Profit function estimated with OLS and HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	-280172	149941	-1.87	0.07
2	P^*_{MLK}	α_1	-1600882	2336949	-0.69	0.50
3	P^*_{FB}	α_2	2259143	2483672	0.91	0.37
4	P^*_{FS}	α_3	-424434	293130	-1.45	0.16
5	$(P^*_{MLK})^2$	β_{11}	-1480022	626291	-2.36	0.03
6	$(P^*_{FB})^2$	β_{22}	-372012	3009809	-0.12	0.90
7	$(P^*_{FS})^2$	β_{33}	1546	56448	0.03	0.98
8	$(P^*_{MLK})(P^*_{FB})$	β_{12}	790009	1528839	0.52	0.61
9	$(P^*_{MLK})(P^*_{FS})$	β_{13}	728827	234538	3.11	0.00
10	$(P^*_{FB})(P^*_{FS})$	β_{23}	-772165	323170	-2.39	0.02
11	$(P^*_{MLK})(Z_{MPRX})$	β_{1M}	1515763	963514	1.57	0.13
12	$(P^*_{MLK})(Z_{LCAP})$	β_{1C}	0.08	0.64	0.13	0.90
13	$(P^*_{MLK})(Z_{LABR})$	β_{1L}	0.10	9.72	0.01	0.99
14	$(P^*_{FB})(Z_{MPRX})$	β_{2M}	-1652753	1087730	-1.52	0.14
15	$(P^*_{FB})(Z_{LCAP})$	β_{2C}	0.52	0.73	0.72	0.48
16	$(P^*_{FB})(Z_{LABR})$	β_{2L}	0.10	11.70	0.01	0.99
17	$(P^*_{FS})(Z_{MPRX})$	β_{3M}	279987	167750	1.67	0.11
18	$(P^*_{FS})(Z_{LCAP})$	β_{3C}	-0.34	0.11	-3.10	0.00
19	$(P^*_{FS})(Z_{LABR})$	β_{3L}	2.03	1.14	1.79	0.08
20	Dependent Variable	π^*		R^2		0.93
21	Mean	379339		R^2-adjusted		0.89
22	Standard Deviation	411305		S.E. of regression		134947
23	Sample size	48		Akaike info criterion		26.75
24	Error Sum of Squares	5.28E+11		Schwarz criterion		27.50

The results in Table 6 are not consistent with the *a priori* expectations of coefficients' signs and magnitudes. For example: it was expected that the β_{ii}-coefficients would be positive for outputs and negative for inputs, since a well-behaved profit function is concave in output prices and convex in input prices. Apart from the fact that only β_{11}, β_{13} and β_{23} are statistically significant (at the 5%-level), the β_{11} and β_{33} coefficients have unexpected signs. The substantial negative value (and statistical significance) of the intercept (α_0) as well as the large negative value of α_1 cast doubt on the appropriateness of this equation (see sections 4.2.4 and 4.2.5 for a further discussion). The estimated equation apparently explains 89% (R^2-adjusted) of the variation in profits across firms. The residual (error) sum of squares, however, is large.

In Figure 1 observations are ranked according to ascending normalised actual profit. It is evident that the specification (fitted values) follows the same trend as the actual values, although the specified equation introduces more variation than that of the actual values. The H_0 of normality in the residuals was not rejected at the 15%-level (Jarque-Bera statistic = 4.38, prob = 0.11).

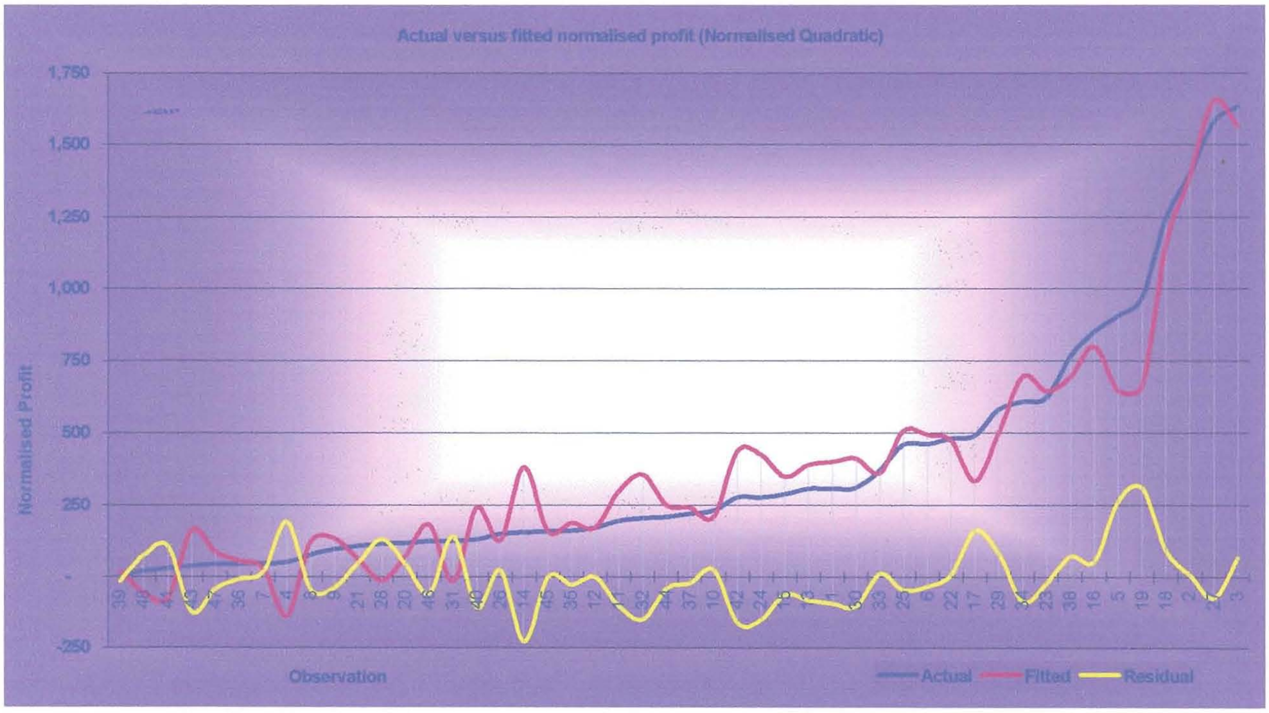

Figure 1: Normalised Quadratic Profit - result of OLS

4.2.1.2 NORMALISED QUADRATIC MILK SUPPLY

Although the specification of milk supply (Q_{MLK}) in Equation 21 provides a good fit (Adjusted $R^2 = 0.85$), it does not yield expected results. None of the price variables is significant (Table 7) –

only the livestock capital and labour quasi-fixed variables are statistically significant. The management proxy variable, however, indicates that improved management is associated with higher levels of milk production. The *a priori* expectation was that β_{11} would be significant and positive – the sign meets the expectations. In addition, it was expected that β_{12} (impact of purchased feed) and β_{13} (impact of self produced feed) would be negative – both are insignificant and only β_{13} is negative.

Table 7: NQ Milk Supply function estimated with OLS and HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_1	-187245	174961	-1.07	0.29
2	P^*_{MLK}	β_{11}	8370	97501	0.09	0.93
3	P^*_{FB}	β_{12}	-35192	126687	-0.28	0.78
4	P^*_{FS}	β_{13}	16150	26948	0.60	0.55
5	Z_{MPRX}	β_{1M}	87342	114255	0.76	0.45
6	Z_{LCAP}	β_{1L}	0.87	0.11	7.64	0.00
7	Z_{LABR}	β_{1C}	1.92	0.86	2.24	0.03
8	Dependent Variable	Q_{MLK}		R^2		0.87
9	Mean	627687		R^2-adjusted		0.85
10	Standard Deviation	514760		S.E. of regression		197643
11	Sample size	48		Akaike info criterion		27.36
12	Error Sum of Squares	1.60E+12		Schwarz criterion		27.63

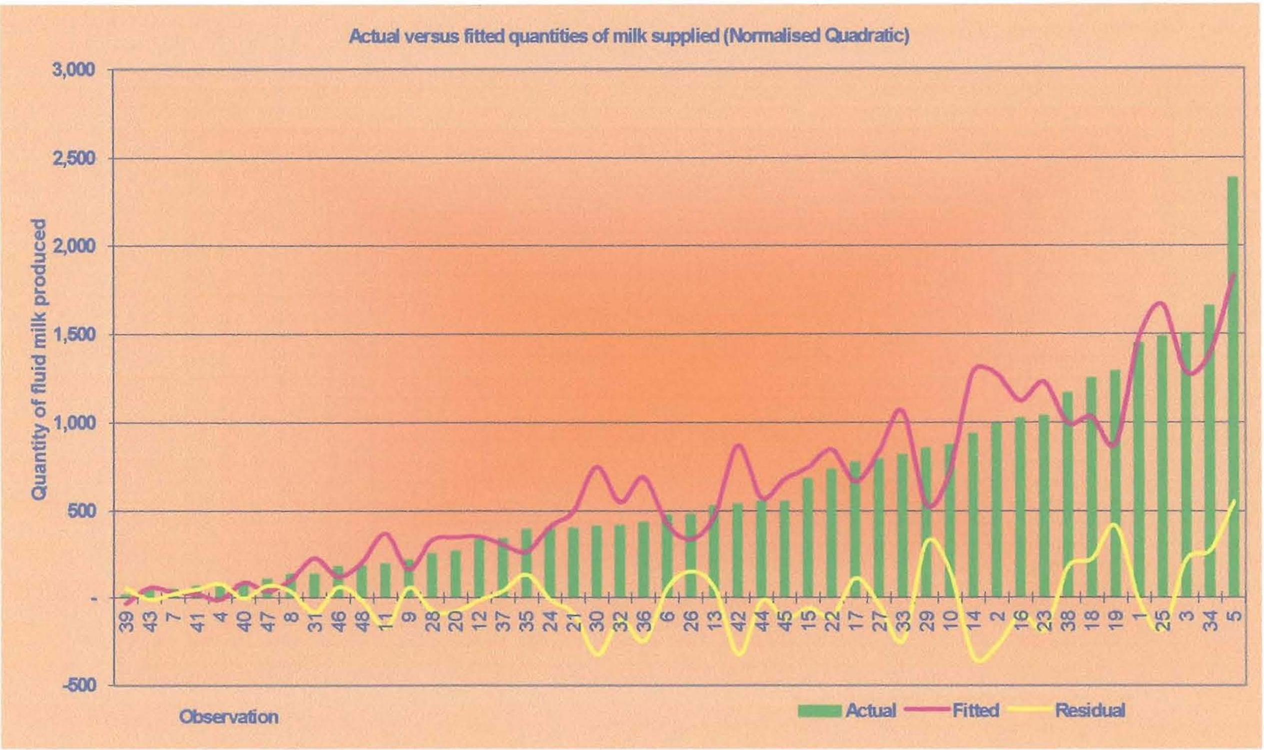

Figure 2: Normalised Quadratic - quantity of milk supplied

Figure 2 shows that although the fitted values follow the pattern of the actual quantities, there are much variation and a more erratic movement than the smooth increase in actual values. Due to the Jarque-Bera[12] statistic of 3.05 and probability of 0.22, the normality of residuals hypothesis is not rejected.

---

[12] Jarque-Bera is a test statistic for testing whether the series is normally distributed or not. The test statistic measures the difference of the skewness and kurtosis of the series with those from the normal distribution. Under the null hypothesis of a normal distribution, the Jarque-Bera statistic is distributed as χ^2 with 2 degrees of freedom. The reported Probability is the probability that a Jarque-Bera statistic exceeds (in absolute value) the observed value under the null—a small probability value leads to the rejection of the null hypothesis of a normal distribution.

4.2.1.3 NORMALISED QUADRATIC PURCHASED FEED DEMAND

An improvement is seen in the results of the estimated quantity of purchased feed equation (Q_{FB}).

Table 8: NQ Purchased Feed Demand function estimated with OLS and HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_2	95952	130103	0.74	0.47
2	P^*_{MLK}	β_{12}	159209	58180	2.74	0.01
3	P^*_{FB}	β_{22}	-205936	79078	-2.60	0.01
4	P^*_{FS}	β_{13}	-4359	19262	-0.23	0.82
5	Z_{MPRX}	β_{2M}	-132465	85987	-1.54	0.13
6	Z_{LCAP}	β_{2L}	0.66	0.07	8.90	0.00
7	Z_{LABR}	β_{2C}	0.50	0.35	1.41	0.17
8	Dependent Variable	Q_{FB}		R^2		0.86
9	Mean	357580		R^2-adjusted		0.84
10	Standard Deviation	353350		S.E. of regression		139363
11	Sample size	48		Akaike info criterion		26.66
12	Error Sum of Squares	7.96E+11		Schwarz criterion		26.93

From Table 8 it is clear that the price of milk affects the demand for purchased feed positively and the price of purchased feed has a decreasing effect on the demand for the input. The coefficients are also significant at a 1% probability level. The coefficient of the price of self-produced feed does not have the expected sign (for substitutes), but is statistically insignificant. The management proxy and livestock capital both show significant influences on the demand for purchased feed. In addition to this, the adjusted-R^2 indicates that 84% of the variation in purchased feed demand is explained by the specification.

From Figure 3, it is evident that the estimated derived demand equation moves with the actual values, but models more peaks and troughs than what occurred in the observed quantities of purchased feed for the sample.

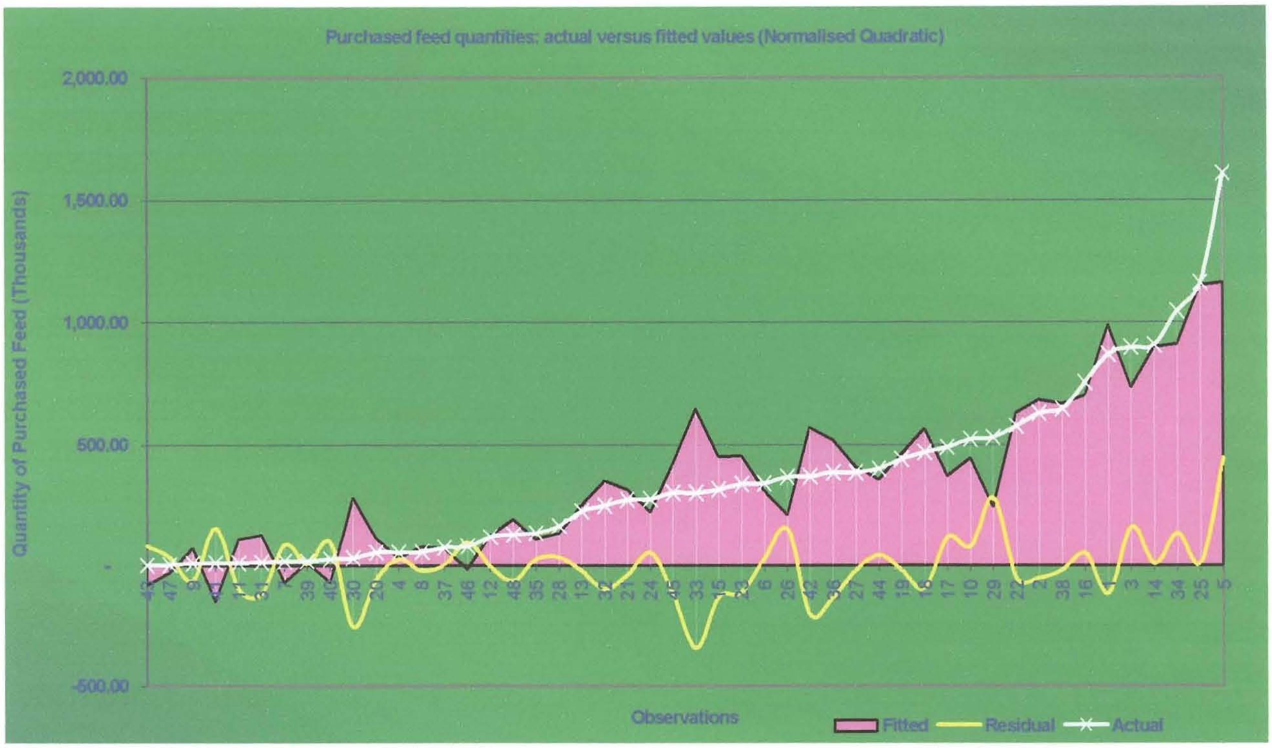

Figure 3: Normalised Quadratic - quantity of purchased feed utilised

4.2.1.4 NORMALISED QUADRATIC SELF-PRODUCED FEED DEMAND

In the case of the self produced feed demand (Table 9), only 58% of the between-farm variation is explained by the normalised quadratic specification of the demand function.

Table 9: NQ Self Produced Feed Demand function estimated with OLS and HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_3	59262	43680	1.36	0.18
2	P^*_{MLK}	β_{13}	-45828	49918	-0.92	0.36
3	P^*_{FB}	β_{23}	99760	64789	1.54	0.13
4	P^*_{FS}	β_{33}	-29972	7684	-3.90	0.00
5	Z_{MPRX}	β_{3M}	-25732	22768	-1.13	0.27
6	Z_{LCAP}	β_{3L}	0.18	0.04	4.06	0.00
7	Z_{LABR}	β_{3C}	-0.32	0.31	-1.05	0.30
8	Dependent Variable	Q_{FS}		R^2		0.58
9	Mean	121070		R^2-adjusted		0.52
10	Standard Deviation	96245		S.E. of regression		66779
11	Sample size	48		Akaike info criterion		25.19
12	Error Sum of Squares	1.83E+11		Schwarz criterion		25.46

Although the price of milk is not significant in this equation, it does have the expected sign, based on the results from Table 8, where purchased feed responded positively to an increase in milk prices. An *a priori* hypothesis was that purchased and self-produced feeds are substitutes. The latter results confirm this. Similarly, the significant β_{23} (at 15%-level) and β_{33} (at 1%-level) coefficients are consistent with the *a priori* expectations. Self produced feed demand responds positively to an increase in the price of purchased feed, and negatively to its own price.

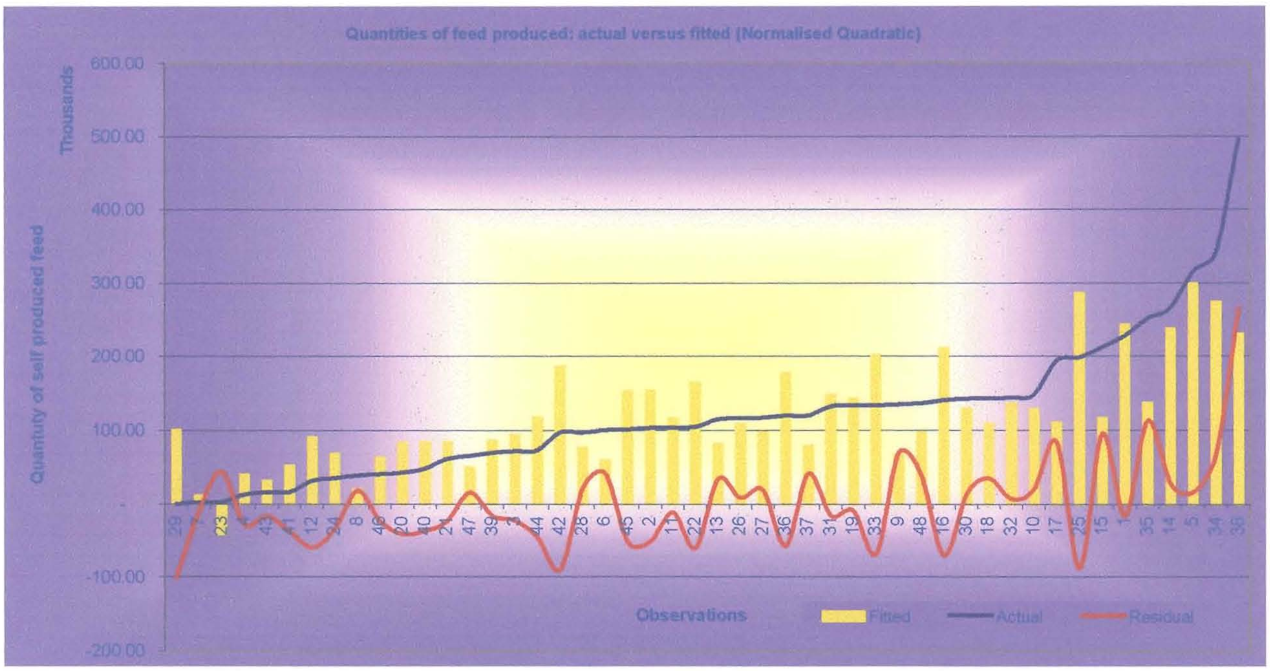

Figure 4: Observed versus fitted quantities of self-produced feed (Normalised Quadratic)

Figure 4 shows the poor explanatory power of the normalised quadratic derived demand equation in terms of self-produced feed. The fitted values follow an erratic pattern as opposed to the smooth pattern of the observed values. Consequently, substantial variation occurs in the residual values.

In Figure 5 and Figure 6 below, the respective actual and fitted values of the profit and derived demand and supply equations are graphed. In both figures (plotted in ascending magnitude of normalised profit), the same observations seem to cause deviation from the fitted pattern. There is no obvious trend in combinations of milk volume and feed use that indicates increasing profits in either the actual or the fitted series. Similarly, graphical inspection of the movement between normalised profit and the quasi-fixed variables yields no clear causational patterns.

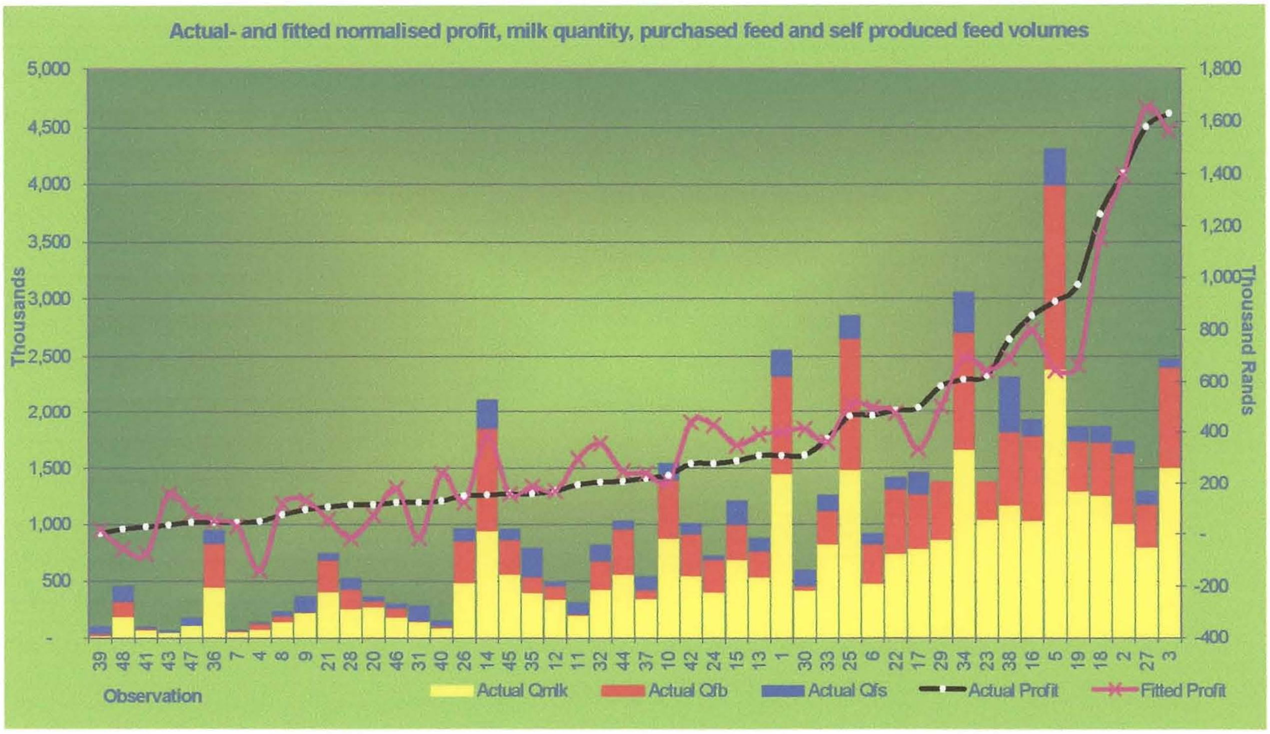

Figure 5: Actual and fitted normalised profit, and actual milk, purchased and produced feed quantities

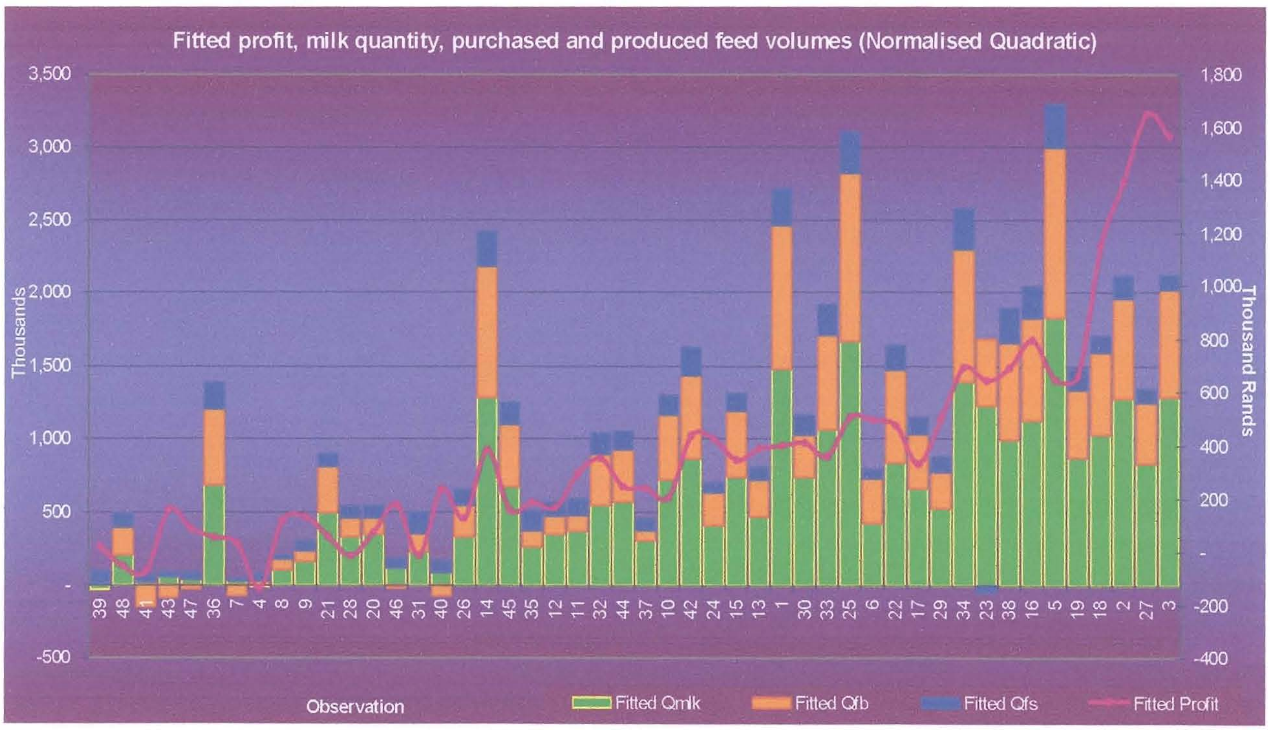

Figure 6: Fitted and actual normalised profit, and fitted milk, purchased and produced feed quantities.

The results from the single equation specification of the profit function are compared to those of the estimated demand and supply equations (Table 7 to Table 9). Wald 's coefficient test was used to establish whether the estimates differ significantly between the two OLS methods. In all cases, the null-hypothesis that the demand and supply equations' set of coefficients do not differ significantly from that of the profit function is rejected at the 5%-level.

4.2.2 *Normalised Quadratic Profit System Estimation Results*

Application of Zellner' s Iterative Seemingly Unrelated Regression method (ISUR) (Section 3.5.2) yielded more coefficients (Table 10) that are more significant than coefficients from the OLS estimations (Table 6 to Table 9).

The β_{ii}-coefficients are all significant. However, the β_{11}-coefficient is negative instead of positive. In addition, neither the β_{12} nor the β_{23} coefficients are statistically significant – only β_{13} is significant. The substantial negative value (and statistical significance) of the intercept (α_0) as well as the large negative value of α_1 is an indication that problems of misspecification, measurement errors, exclusion of important variables, data errors, or any combination of these problems influence the results. Similar to the OLS estimation results, specification of milk supply (Q_{MLK}) does not yield expected results. The milk price and self-produced feed price variables, as well as all the quasi-fixed variables are significant (Table 10). The management proxy variable indicates that improved management is associated with higher levels of milk production.

From the results of the estimated quantity of purchased feed equation (Q_{FB}), it follows that the price of milk affects the demand for purchased feed positively and the price of purchased feed has a decreasing effect on the demand for the input. The coefficient of the price of self-produced feed has the expected sign (for the hypothesis of substitution), but is statistically insignificant. The management proxy shows a significant influence on the demand for purchased feed: improved management is associated with more intense use of purchased feed.

Table 10: NQ Profit System estimated trough Iterative Seemingly Unrelated Regression method

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	-201065	59155	-3.40	0.00
2	P^*_{MLK}	α_1	-431870	84166	-5.13	0.00
3	P^*_{FB}	α_2	13725	64889	0.21	0.83
4	P^*_{FS}	α_3	-29039	45216	-0.64	0.52
5	$(P^*_{MLK})^2$	β_{11}	-95679	38672	-2.47	0.01
6	$(P^*_{FB})^2$	β_{22}	-149284	57011	-2.62	0.01
7	$(P^*_{FS})^2$	β_{33}	-24287	6592	-3.68	0.00
8	$(P^*_{MLK})(P^*_{FB})$	β_{12}	61729	46178	1.34	0.18
9	$(P^*_{MLK})(P^*_{FS})$	β_{13}	30217	9249	3.27	0.00
10	$(P^*_{FB})(P^*_{FS})$	β_{23}	12619	10039	1.26	0.21
11	$(P^*_{MLK})(Z_{MPRX})$	β_{1M}	395716	52907	7.48	0.00
12	$(P_{MLK})(Z_{LCAP})$	β_{1C}	0.07	0.04	1.83	0.07
13	$(P^*_{MLK})(Z_{LABR})$	β_{1L}	1.37	0.26	5.28	0.00
14	$(P^*_{FB})(Z_{MPRX})$	β_{2M}	59928	32276	1.86	0.07
15	$(P^*_{FB})(Z_{LCAP})$	β_{2C}	0.02	0.03	0.78	0.44
16	$(P^*_{FB})(Z_{LABR})$	β_{2L}	0.27	0.22	1.22	0.22
17	$(P^*_{FS})(Z_{MPRX})$	β_{3M}	52454	24483	2.14	0.03
18	$(P^*_{FS})(Z_{LCAP})$	β_{3C}	0.03	0.02	1.29	0.20
19	$(P^*_{FS})(Z_{LABR})$	β_{3L}	-0.40	0.20	-2	0.05
20	Dependent Variables	π^*, Q_{MLK}, Q_{FB}, Q_{FS}	Sample size	48		

In the case of the self-produced feed demand, the price of milk is significant and it has the expected sign - purchased feed responds positively to an increase in milk prices. An *a priori* hypothesis was that purchased and self-produced feeds are substitutes. This is confirmed by these results: despite the statistical insignificance of the β_{23}-coefficient, the sign is positive. Self produced feed demand responds positively to an increase in the price of purchased feed, and negatively to its own price. Higher levels of management is in this case also associated with higher levels of self-produced feed use – this is contrary to the substitutability findings, because purchased feed responds similarly to higher levels of management. According to these results, self-produced feed demand decreases with increased labour expenditure. Purchased feed, however, responds positively to increased labour expenditure – it seems that higher quality labour is associated with the use of purchased (expensive) feed.

Figure 7 shows the levels of milk production and input use associated with the estimated normalised profit. Higher profits are not necessarily associated with higher levels of milk production, or with specific ratios of input use. Based on these results, it seems that great variation exists in the production decisions between fluid milk producing units.

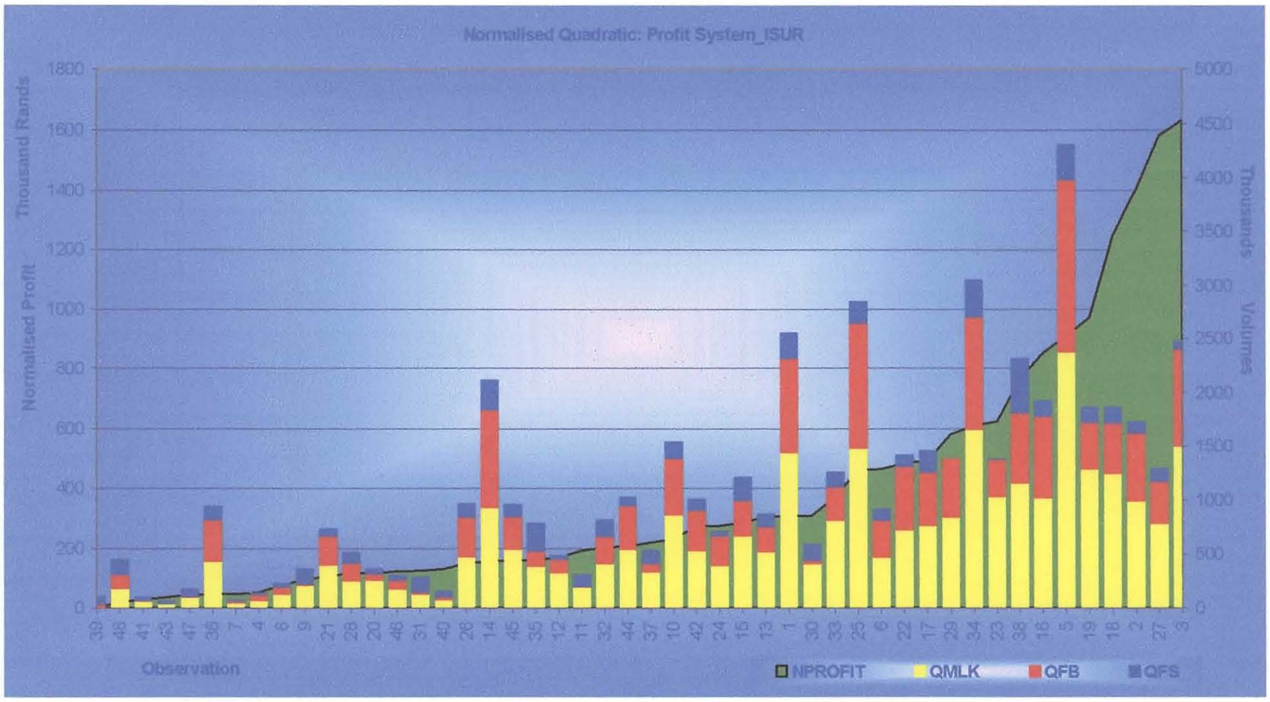

Figure 7: Estimated levels of milk production, input use and associated estimated normalised profit.

The results presented in Table 6 to Table 10 indicated that the quasi-fixed variables had a very significant relation with restricted normalised profit. Since this could be the cause for the unexpected signs of the price variables, it was decided to drop the livestock capital and labour variables, but keep the management proxy. The modified supply system was estimated with the SUR estimator [Zellner, 1962] and the results are presented in Table 11. More degrees of freedom were available due to the reduced number of parameters to be estimated.

Table 11: Modified NQ supply system

Line	Variable	Symbol	Coefficient	Std. Error	T-Statistic	Prob.
1	Constant	α_0	90851	32735	2.78	0.01
2	P^*_{MLK}	α_1	833220	305396	2.73	0.01
3	P^*_{FB}	α_2	-794149	219757	-3.61	0.00
4	P^*_{FS}	α_3	-212879	63690	-3.34	0.00
5	$(P^*_{MLK})^2$	β_{11}	216432	209180	1.03	0.30
6	$(P^*_{FB})^2$	β_{22}	451294	205623	2.19	0.03
7	$(P^*_{FS})^2$	β_{33}	33524	7927	4.23	0.00
8	$(P^*_{MLK})(P^*_{FB})$	β_{12}	-313058	188012	-1.67	0.10
9	$(P^*_{MLK})(P^*_{FS})$	β_{13}	-2474	31894	-0.08	0.94
10	$(P^*_{FB})(P^*_{FS})$	β_{23}	7635	25711	0.30	0.77
11	$(P^*_{MLK})(Z_{MPRX})$	β_{1M}	-104093	190728	-0.55	0.59
12	$(P^*_{FB})(Z_{MPRX})$	β_{2M}	258376	136037	1.90	0.06
13	$(P^*_{FS})(Z_{MPRX})$	β_{3M}	35653	38865	0.92	0.36
14	Dependent Variables		π^*, Q_{MLK}, Q_{FB}, Q_{FS}		Sample size	48

The results indicate a substantial improvement: the t-ratios improved and the coefficients of the milk price variables have the expected sign. Milk supply responds positively towards its price and negatively to increased feed prices.

4.2.3 *DISCUSSION OF THE RESULTS*

The results from sections 4.2.1 and 4.2.2 indicate that the normalised quadratic system results (Table 10) are generally better than the single equation results. It is likely that the unexpected results are caused by the specification of self-produced feed demand and the inherent problems associated with aggregation. Compared to the single equation results, more of the supply system variables showed significant influences on the normalised profit and on the supply and demand equations. The modified system (yielding more realistic results) was subsequently subjected to structural property tests to determine whether it conforms to the underlying economic theory.

4.2.4 TESTING THE STRUCTURAL PROPERTIES

4.2.4.1 NON-NEGATIVITY

In eight of the cases either negative profits or negative supply or demand quantities were estimated. None of these cases reported simultaneous negative profits or quantities. These results are not sufficient to classify the particular farms as non-profit maximising – small sample size bias, contamination due to aggregation and due to incorrect specification of supply or demand equations all contribute to reduced confidence in the estimation outputs.

4.2.4.2 MONOTONICITY

Evaluation of the first derivatives of the normalised profit function with respect to normalised input and output prices (at the point of approximation, Methodology, section 3.9.2) revealed that profit is monotonically increasing in milk prices ($\alpha_1 > 0$) and monotonically decreasing in purchased feed prices (α_2, $\alpha_3 < 0$).

4.2.4.3 CONVEXITY AND CONCAVITY

For convexity in all prices, it is required that the determinants of the principal minors (of the Hessian matrix of normalised profit to prices - H_{PP}) are non-negative, i.e. positive semi-definiteness of the Hessian matrix. The elements of the Hessian matrix are the β_{ij}-coefficients from Table 10:

$$H = \begin{bmatrix} \frac{\partial^2 \pi *}{(\partial P^*_{MLK})^2} & \frac{\partial^2 \pi *}{\partial P^*_{MLK} \partial P^*_{FB}} & \frac{\partial^2 \pi *}{\partial P^*_{MLK} \partial P^*_{FS}} \\ \frac{\partial^2 \pi *}{\partial P^*_{FB} \partial P^*_{MLK}} & \frac{\partial^2 \pi *}{(\partial P^*_{FB})^2} & \frac{\partial^2 \pi *}{\partial P^*_{FB} \partial P^*_{FS}} \\ \frac{\partial^2 \pi *}{\partial P^*_{FS} \partial P^*_{MLK}} & \frac{\partial^2 \pi *}{\partial P^*_{FS} \partial P^*_{FB}} & \frac{\partial^2 \pi *}{(\partial P^*_{FS})^2} \end{bmatrix} = \begin{bmatrix} 373857 & -434481 & -37738 \\ -434481 & 533709 & 38105 \\ -37738 & 38105 & 40783 \end{bmatrix}$$

$|H_1| = 373857 > 0$, $|H_2| = 10E+09 > 0$ and $|H_3| = 4E+14 > 0$, implying that H_{PP} is positive semi-definite (convexity in prices). The latter result is in accordance with the requirements for well-behaving profit functions.

4.2.4.4 HOMOGENEITY

Homogeneity in all prices is imposed through the functional form. The function is homogenous of degree zero in prices, but not in quasi-fixed factors.

4.2.4.5 SYMMETRY

Symmetry was imposed during estimation, due to the small sample constraints and symmetry can be seen from the Hessian matrix: $\beta_{ij} = \beta_{ji}$.

4.2.5 ELASTICITY CALCULATIONS

Table 12 reports the Marshallian elasticities (Equation 20) calculated from the different normalised quadratic estimations.

Table 12: Marshallian elasticities calculated from the different estimation results

Line	$E(q_i / p^*_j)$	P^*_{mlk}	P^*_{fb}	P^*_{fs}	Source
1	Q_{mlk}	-3.14	1.35	1.67	Table 6: OLS Normalised profit
2	Q_{fb}	2.94	-1.12	-3.11	Table 6: OLS Normalised profit
3	Q_{fs}	8.02	-6.85	0.02	Table 6: OLS Normalised profit
4	Q_{mlk}	0.19	0.04	0.19	Table 7: OLS Milk supply
5	Q_{fb}	0.59	-0.62	-0.02	Table 8: OLS Purchased feed demand
6	Q_{fs}	-0.50	0.89	-0.36	Table 9: OLS Self-produced feed demand
7	Q_{mlk}	-0.20	0.11	0.07	Table 10: ISUR Normalised profit system
8	Q_{fb}	0.23	-0.45	0.05	Table 10: ISUR Normalised profit system
9	Q_{fs}	0.33	0.11	-0.29	Table 10: ISUR Normalised profit system
10	Q_{mlk}	0.79	-0.74	-0.09	Table 11: ISUR Modified supply system
11	Q_{fb}	1.62	-1.60	-0.15	Table 11: ISUR Modified supply system
12	Q_{fs}	0.42	-0.34	-0.48	Table 11: ISUR Modified supply system

Line 2 indicates a plausible result: higher milk prices induce higher demand for purchased feed; own-price response is negative and cross-price response indicates that purchased and self-produced feed inputs are complements (confirmed in Line 5, Table 12). Line 6 also yields plausible results: self-produced feed demand decreases when milk prices increase (indicating a possible switch to purchased feeds) and it increases when purchased feed components become more expensive. Own-price response is negative.

From the modified system' results, milk supply elasticities are consistent with *a priori* expectations. The purchased and self-produced feed demand responses indicate complimentarity between the two inputs (contrary to the original profit system results), similar to the single equation results (Lines 2 and 3). Milk supply is consistently more intensive in purchased feed use.

Using the result from Table 12, with regard to the modified Normalised Quadratic Profit system (lines 10 to 12) and the Hicksian elasticity formulae from Equation 18 (Methodology chapter), the Hicksian input demand elasticities with respect to input prices are calculated as follows.

$$\{\eta_{lk}^{S}\} = \{\eta_{lk}\} - \{\eta_{lt}\} \times \{\eta_{th}\}^{-1} \times \{\eta_{tl}\}$$

$$= \begin{bmatrix} -1.65 & -0.15 \\ -0.34 & -0.48 \end{bmatrix} - \begin{bmatrix} 1.62 \\ 0.42 \end{bmatrix} \times [0.79]^{-1} \times [-0.74 \quad -0.09]$$

$$= \begin{bmatrix} -0.09 & 0.02 \\ 0.05 & -0.44 \end{bmatrix} = \begin{bmatrix} \eta_{FB,FB}^{S} & \eta_{FB,FS}^{S} \\ \eta_{FS,FB}^{S} & \eta_{FS,FS}^{S} \end{bmatrix}$$

The Hicksian responses confirm that both inputs are normal goods (demand decreases when prices increase) with highly inelastic compensated elasticities as opposed to the uncompensated (long run) elasticities. The inputs are gross complements, but net substitutes in the production process, with self-produced feed demand being more sensitive to purchased feed price changes than visa versa. This is in line with expectations since the price of purchased feed is determined in the open market, where the influence of self-produced feed prices play a comparatively small part. The short run (compensated) elasticities are less elastic than the long run elasticities, probably due to higher flexibility to change feeding and grazing patterns in the long-run.

The difference between uncompensated and compensated elasticities indicates the effect of the expansion process (movement to new production possibility frontiers) due to price changes and subsequent production shifts. The long-term (uncompensated) input demand responses are mainly a result of long-term adjustments.

Similarly, the Hicksian output supply elasticity with respect to output prices are as follows.

$$\{\eta_{th}^{S}\} = \{\eta_{th}\} - \{\eta_{tl}\} \times \{\eta_{lk}\}^{-1} \times \{\eta_{lt}\}$$

$$= [0.79] - [-0.74 \quad -0.09] \times \begin{bmatrix} -1.60 & -0.15 \\ -0.34 & -0.48 \end{bmatrix}^{-1} \times \begin{bmatrix} 1.62 \\ 0.42 \end{bmatrix}$$

$$= [0.04] \quad = \quad [\eta_{MLK,MLK}^{S}]$$

The short-run elasticity of milk supply with respect to its own price is positive, yet inelastic. The long-run response (0.79) is mainly due to contraction in supply (-0.83).

4.3 The Translog

4.3.1 Single equation OLS results

4.3.1.1 Translog Profit

This single equation (Equation 22) specification of the translog profit function succeeds in explaining 95% of the variation in the observed profits. Table 13 contains the estimation results. The results are evaluated as they pertain to the derived demand and supply equations.

Milk's share of profit is positively related to its own price (β_{11}), and to purchased feed price (β_{12}), but negatively to self produced feed prices (β_{13}) and the prices of trade animals (β_{14}). It is also negatively related to improved management (γ_{1M}), livestock capital (γ_{1C}) and labour expenditure (γ_{1L}). These results are contrary to the expectations, but they are statistically insignificant.

Coefficient β_{22} – the own price of purchased feed – is statistically significant and displays the expected sign. The share of purchased feed is positively related to milk prices and to self-produced feed prices, as expected, but also positively related to the price of traded animals – however, none of these are statistically significant. Decreased levels of profit share are associated with higher levels of management and labour expenditure.

Table 13: Translog Profit function estimated through OLS with HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	0.95	23	0.04	0.97
2	$Ln(P_{MLK})$	α_1	45	24	1.91	0.08
3	$Ln(P_{FB})$	α_2	-23	30	-0.77	0.46
4	$Ln(P_{FS})$	α_3	2.89	2.97	0.97	0.35
5	$Ln(P_{TRD})$	α_4	3.79	7.42	0.51	0.62
6	$Ln(P_{MLK})^2$	β_{11}	38	27	1.37	0.2
7	$Ln(P_{FB})^2$	β_{22}	-12	7.76	-1.53	0.15
8	$Ln(P_{FS})^2$	β_{33}	1.07	0.57	1.88	0.09
9	$Ln(P_{TRD})^2$	β_{44}	-0.03	0.77	-0.04	0.97
10	$Ln(P_{MLK})Ln(P_{FB})$	β_{12}	6.92	28	0.25	0.81
11	$Ln(P_{MLK})Ln(P_{FS})$	β_{13}	-3.04	3.05	-1.00	0.34
12	$Ln(P_{MLK})Ln(P_{TRD})$	β_{14}	-0.85	4.60	-0.18	0.86
13	$Ln(Z_{MPRX})$	β_M	-1.50	7.31	-0.21	0.84
14	$Ln(Z_{LCAP})$	β_C	1.92	3.71	0.52	0.61
15	$Ln(Z_{LABR})$	β_L	-2.32	1.29	-1.80	0.10
16	$Ln(Z_{MPRX})^2$	γ_{MM}	-7.62	5.90	-1.29	0.22
17	$Ln(Z_{LCAP})^2$	γ_{CC}	0.27	0.46	0.59	0.57
18	$Ln(Z_{LABR})^2$	γ_{LL}	0.66	0.43	1.54	0.15
19	$Ln(Z_{MPRX})Ln(Z_{LCAP})$	γ_{MC}	-1.16	0.97	-1.20	0.26
20	$Ln(Z_{MPRX})Ln(Z_{LABR})$	γ_{ML}	1.98	1.38	1.44	0.18
21	$Ln(Z_{LCAP})Ln(Z_{LABR})$	γ_{CL}	-0.36	0.39	-0.94	0.37
22	$Ln(P_{MLK})Ln(Z_{MPRX})$	γ_{1M}	-2.33	5.35	-0.44	0.67
23	$Ln(P_{MLK})Ln(Z_{LCAP})$	γ_{1C}	-3.78	2.74	-1.38	0.19
24	$Ln(P_{MLK})Ln(Z_{LABR})$	γ_{1L}	-0.09	1.60	-0.05	0.96
25	$Ln(P_{FB})Ln(Z_{MPRX})$	γ_{2M}	-7.89	8.21	-0.96	0.36
26	$Ln(P_{FB})Ln(Z_{LCAP})$	γ_{2C}	3.77	4.52	0.84	0.42
27	$Ln(P_{FB})Ln(Z_{LABR})$	γ_{2L}	-2.49	3.36	-0.74	0.47
28	$Ln(P_{FS})Ln(Z_{MPRX})$	γ_{3M}	-2.17	1.36	-1.6	0.14
29	$Ln(P_{FS})Ln(Z_{LCAP})$	γ_{3C}	-0.07	0.51	-0.13	0.9
30	$Ln(P_{FS})Ln(Z_{LABR})$	γ_{3L}	-0.07	0.76	-0.1	0.92
31	$Ln(P_{FB})Ln(P_{FS})$	β_{23}	1.85	2.82	0.66	0.52
32	$Ln(P_{FB})Ln(P_{TRD})$	β_{24}	2.13	4.75	0.45	0.66
33	$Ln(P_{FS})Ln(P_{TRD})$	β_{34}	0.42	0.72	0.59	0.57
34	$Ln(P_{TRD})Ln(Z_{MPRX})$	γ_{4M}	-0.17	1.60	-0.10	0.92
35	$Ln(P_{TRD})Ln(Z_{LCAP})$	γ_{4C}	-0.01	0.66	-0.02	0.99
36	$Ln(P_{TRD})Ln(Z_{LABR})$	γ_{4L}	-0.28	0.55	-0.51	0.62
37	Dependent Variable	$Ln(\pi)$		R^2		0.99
38	Mean	12.46		R^2-adjusted		0.95
39	Standard Deviation	1.17		S.E. of regression		0.26
40	Sample size	48		Akaike info criterion		0.21
41	Error Sum of Squares	0.73		Schwarz criterion		1.62

Self-produced feed' share in profit responds (significantly) negatively to its own price (β_{33}) and to the price of milk (β_{13}). Similarly, increased purchased feed prices (β_{23}) and increased prices for traded animals (β_{34}) would result in an increase in self-produced feed' s share of profit.

Trade income (S_{TRD}) decreases as the aggregate price increases (β_{44}) and when milk prices increase (β_{14}). When purchased and self-produced feed prices rise, the share of trade income in profit would increase (β_{24} and β_{34}). The response to increased levels of the specified quasi-fixed variables is negative in all cases (γ_{4M}, γ_{4C} and γ_{4L}).

Figure 8 shows the accuracy of the fitted equation. The fitted line follows the actual data very closely, but does introduce more peaks and troughs than what is actually observed. The errors (on a secondary scale) vary within a narrow range (0.6 and 1.3). The Jarque-Bera statistic, calculated for the H_0 of normality in the residuals, equals 3.41 at a 0.18-probability level. Thus, it is reasonable to assume normally distributed errors.

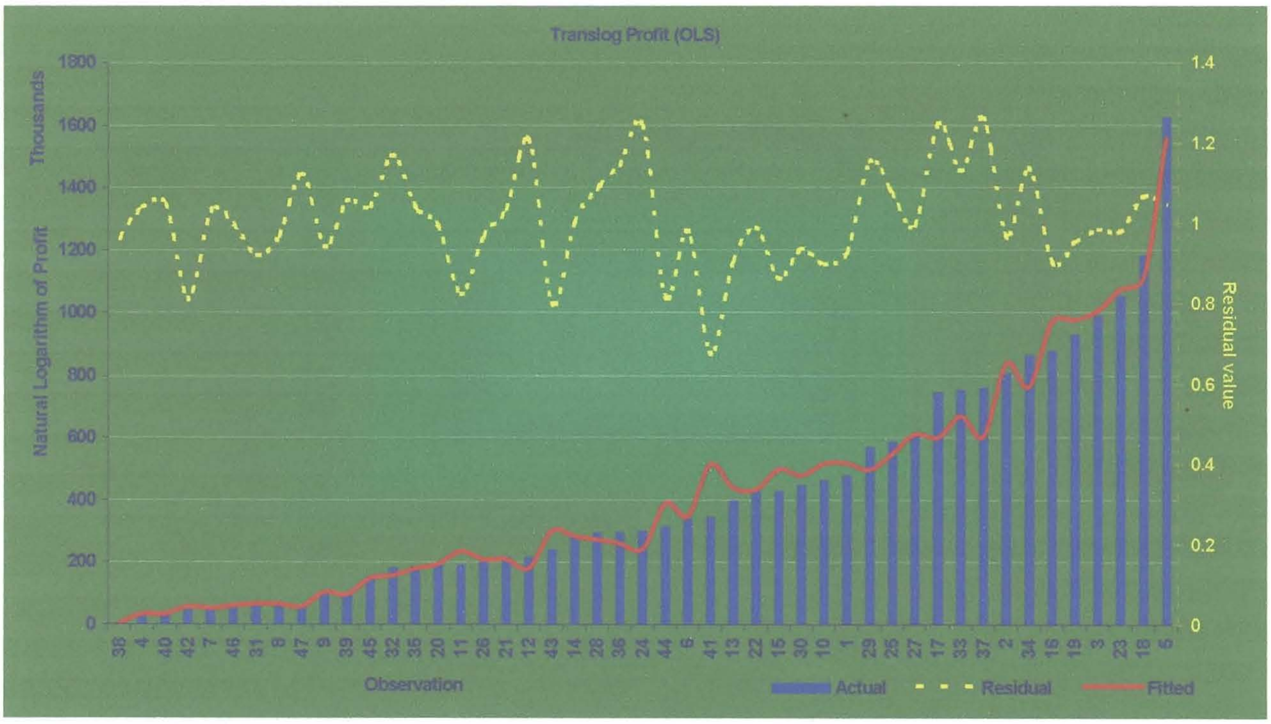

Figure 8: Actual and fitted values of profit from the OLS estimation of the translog profit function.

4.3.1.2 TRANSLOG MILK SHARE

The milk share equation, with an explanatory power of 78%, does not yield expected results. Firstly, the price of milk is negatively related to the supply of milk and increases in purchased and produced feed prices would cause increases in milk supply (although the coefficients are insignificant). Improved management and increased labour expenditure would decrease milk supply, while increases in livestock capital would increase milk supply. These results are summarised in Table 14 and Figure 9, below.

Table 14: Translog Milk Share function estimated through OLS with HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_1	0.89	0.96	0.93	0.36
2	$Ln(P_{MLK})$	β_{11}	-1.22	0.55	-2.21	0.03
3	$Ln(P_{FB})$	β_{12}	0.27	0.58	0.46	0.65
4	$Ln(P_{FS})$	β_{13}	0.10	0.13	0.80	0.43
5	$Ln(P_{TRD})$	β_{14}	0.11	0.16	0.69	0.50
6	$Ln(Z_{MPRX})$	γ_{1M}	-3.74	0.36	-10.33	0.00
7	$Ln(Z_{LCAP})$	γ_{1C}	0.54	0.13	4.14	0.00
8	$Ln(Z_{LABR})$	γ_{1L}	-0.41	0.11	-3.59	0.00
9	Dependent Variable	S_{MLK}		R^2		0.81
10	Mean	2.13		R^2-adjusted		0.78
11	Standard Deviation	0.86		S.E. of regression		0.41
12	Sample size	48		Akaike info criterion		1.19
13	Error Sum of Squares	6.44		Schwarz criterion		1.51

The fitted values follow the trend in the actual observations, but in most cases over or under estimate the actual values. The calculated Jarque-Bera statistic under the H_0 of normal residuals is 1.55 – which is significantly different from zero only at a 0.46- probability level. The null-hypothesis of normal residuals is not rejected.

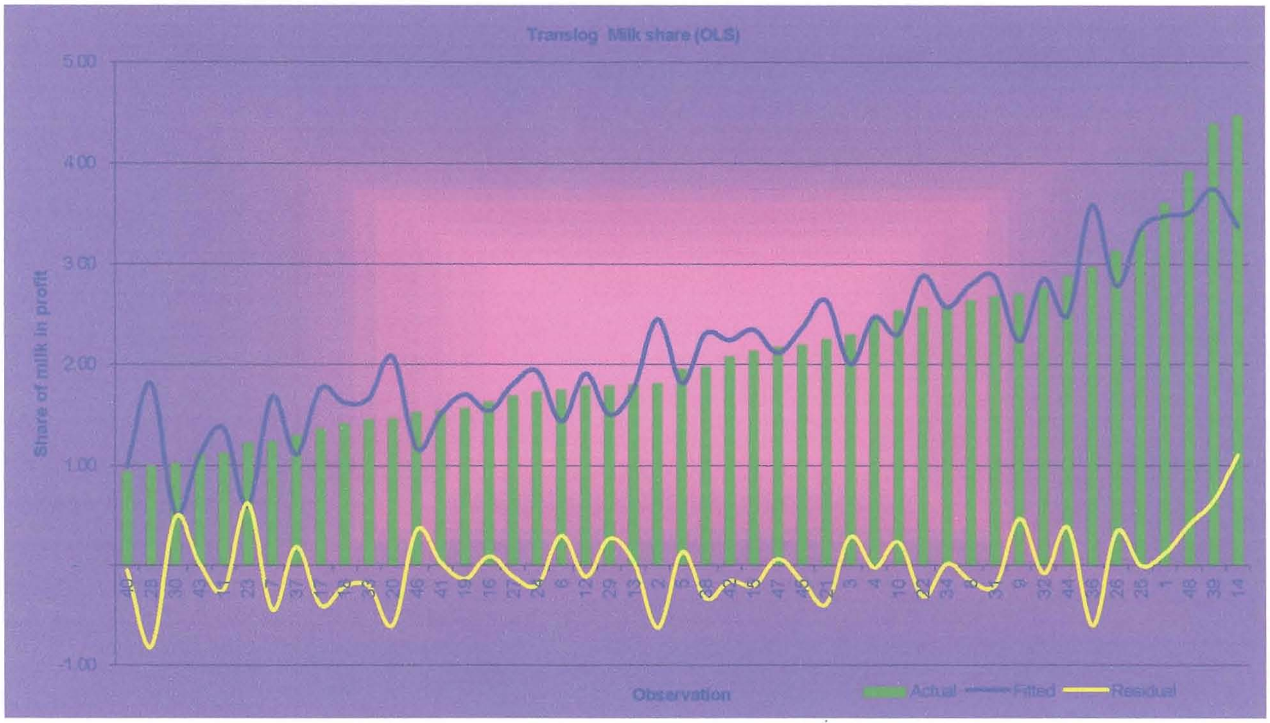

Figure 9: The actual and fitted shares of milk in restricted profit – OLS results

4.3.1.3 TRANSLOG PURCHASED FEED SHARE

In Table 15, the results of the purchased feed share equation is presented.

Table 15: Translog Purchased Feed Share function estimated through OLS with HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	$Ln(P_{FB})$	α_2	0.76	1.25	0.61	0.55
2	$Ln(P_{FB})$	β_{22}	-0.41	0.73	-0.56	0.58
3	$Ln(P_{MLK})$	β_{12}	0.29	0.79	0.37	0.71
4	$Ln(Z_{MPRX})$	γ_{2M}	2.82	0.48	5.91	0.00
5	$Ln(Z_{LCAP})$	γ_{2C}	-0.44	0.12	-3.64	0.00
67	$Ln(Z_{LABR})$	γ_{2L}	0.29	0.13	2.17	0.04
8	$Ln(P_{FS})$	β_{23}	0.02	0.14	0.17	0.87
9	$Ln(P_{TRD})$	β_{24}	-0.34	0.20	-1.72	0.09
10	Dependent Variable	S_{FB}		R^2		0.66
11	Mean	-0.94		R^2-adjusted		0.60
12	Standard Deviation	0.77		S.E. of regression		0.49
13	Sample size	48		Akaike info criterion		1.56
14	Error Sum of Squares	9.29		Schwarz criterion		1.87

Coefficient-β_{22} indicates the own-price response of the purchased feed share equation is negative, as would be expected. Milk price and self-produced price increases would increase the purchased feed share (β_{12} and β_{23}). Improved management and labour practices would increase the use of purchased feed, whilst increased expenditure on livestock capital would reduce the share of purchased feed. Figure 10[13] displays the actual versus fitted values from the estimated equation (Table 15). It is clear that observation to observation matching of fitted and actual values are quite poor, as is confirmed by the low adjusted-R^2 of 0.6.

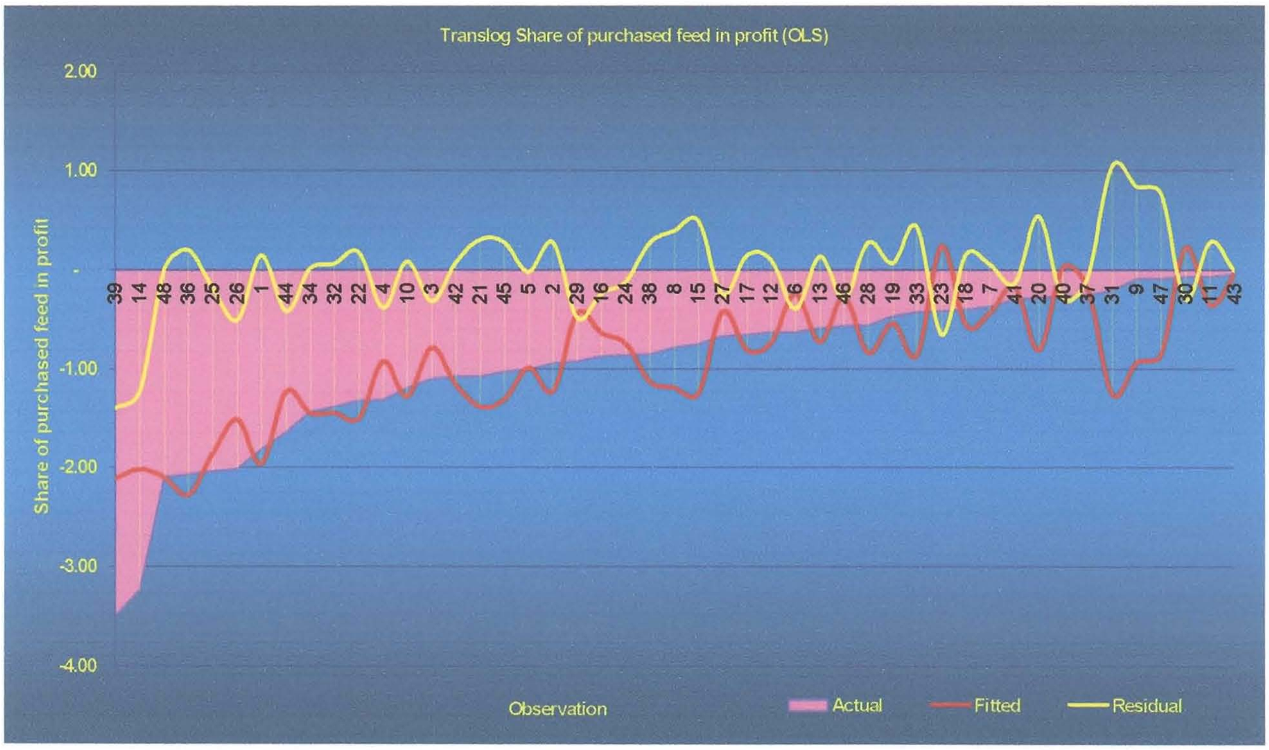

Figure 10: Actual and fitted purchased feed shares derived from the OLS single equation estimations.

[13] For theoretical accuracy, the input profit shares (negative shares of profit) are plotted as negative values - "increases in shares" refer to increases in absolute values.

4.3.1.4 TRANSLOG SELF-PRODUCED FEED SHARE

Self-produced feed' s share equation results are summarised in Table 16. Increased milk prices induce increased expenditure on self-produced feed and the latter increases when its own price rises. Increased purchased feed prices stimulate a decrease in expenditure on self-produced feeds. These results are not consistent with *a priori* expectations or with the results from the previous estimations. Management and labour is positively and significantly related to this input, while none of the price variables are significant. In addition, the adjusted-R^2 indicates that only 44% of the variation is explained by the estimated equation.

Table 16: Translog Self Produced Feed Share function estimated through OLS with HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_3	-2.81	1.44	-1.96	0.06
2	$Ln(P_{FS})$	β_{33}	0.09	0.15	0.62	0.54
3	$Ln(P_{MLK})$	β_{13}	1.30	1.02	1.28	0.21
4	$Ln(Z_{MPRX})$	γ_{3M}	1.83	0.55	3.35	0.00
5	$Ln(Z_{LCAP})$	γ_{3C}	-0.15	0.12	-1.2	0.24
6	$Ln(Z_{LABR})$	γ_{3L}	0.32	0.13	2.36	0.02
7	$Ln(P_{FB})$	β_{23}	-0.80	0.74	-1.09	0.28
8	$Ln(P_{TRD})$	β_{34}	0.001	0.12	0.01	0.99
9	Dependent Variable	S_{FS}		R^2		0.53
10	Mean	-0.51		R^2-adjusted		0.44
11	Standard Deviation	0.63		S.E. of regression		0.47
12	Sample size	48		Akaike info criterion		1.47
13	Error Sum of Squares	8.48		Schwarz criterion		1.78

Figure 11 portrays the goodness of fit. Clearly, the fitted values do not match the trend in the data over even a subset of the data range.

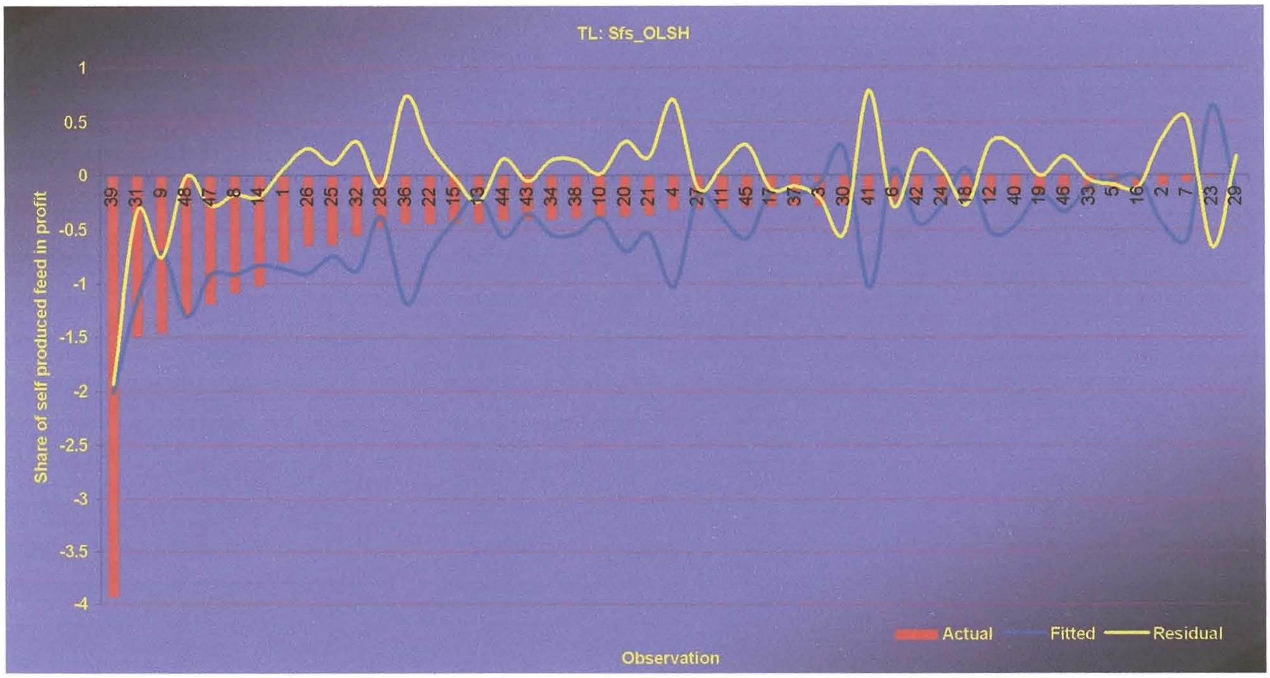

Figure 11: Actual and fitted self-produced feed shares resulting from OLS single equation estimation.

4.3.1.5 TRANSLOG TRADE INCOME SHARE

From the results in Table 17, it is clear that the trade income share equation does not provide an adequate explanation of the across-firm variation in trade income.

Table 17: Translog Trade Income Share function estimated through OLS with HETCOV

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_4	13.58	9.70	1.40	0.17
2	Ln(P_{TRD})	β_{44}	0.54	0.83	0.66	0.52
3	Ln(P_{MLK})	β_{14}	-7.57	5.52	-1.37	0.18
4	Ln(P_{FB})	β_{24}	5.90	5.78	1.02	0.31
5	Ln(P_{FS})	β_{34}	-1.12	1.13	-0.99	0.33
6	Ln(Z_{MPRX})	γ_{4M}	-5.55	4.44	-1.25	0.22
7	Ln(Z_{LCAP})	γ_{4C}	0.24	0.51	0.47	0.64
8	Ln(Z_{LABR})	γ_{4L}	-1.17	0.96	-1.22	0.23
9	Dependent Variable	S_{TRD}		R^2		0.31
10	Mean	0.81		R^2-adjusted		0.19
11	Standard Deviation	3.59		S.E. of regression		3.22
12	Sample size	48		Akaike info criterion		5.33
13	Error Sum of Squares	405.34		Schwarz criterion		5.65

None of the variables is statistically significant. The price variables show acceptable signs: own-price response is positive; response towards increased milk prices is negative and positive toward increased purchased feed prices. Improved management and increased expenditure on labour would reduce trade income, while increased investment in livestock would increase trade income.

Figure 12 confirms the poor fit. The equation severely over or under estimates the actual data. In addition, there is not much variation in the actual values, thus reducing the estimation results.

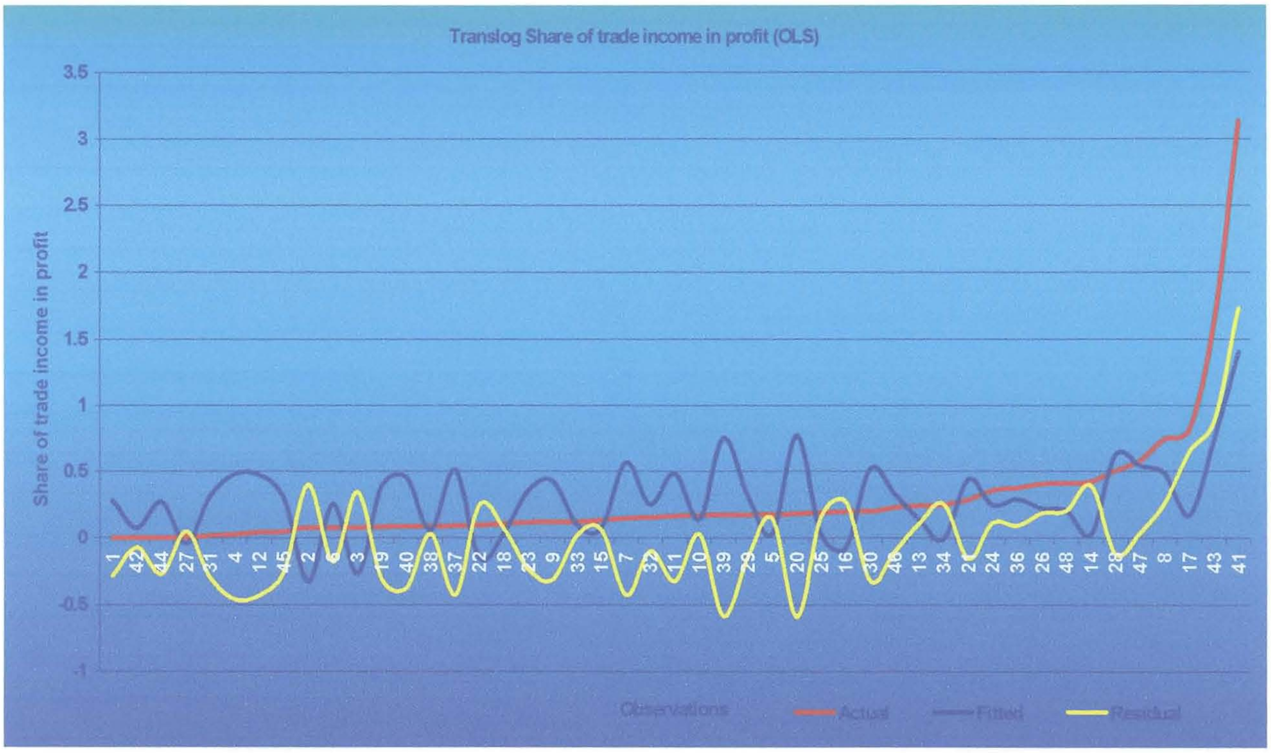

Figure 12: Actual and fitted values of trade income shares in restricted profit (OLS).

4.3.2 PROFIT SYSTEM ESTIMATION RESULTS

Various combinations of the derived demand and supply equations, with or without inclusion of the profit function were estimated. The most meaningful results were obtained from the system containing the profit function, the shares of milk, purchased and self-produced feed equations – estimated using Zellner' s iterative seemingly unrelated regression method (ISUR). The trade income share equation was omitted. The results are summarised in Table 18, and discussed based on the share equation implications.

Table 18: Translog Profit System estimated with the Iterative Seemingly Unrelated Regression method

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	4.59	8.09	0.57	0.57
2	$Ln(P_{MLK})$	α_1	1.31	0.88	1.49	0.14
3	$Ln(P_{FB})$	α_2	0.47	1.00	0.47	0.64
4	$Ln(P_{FS})$	α_3	-3.31	0.93	-3.55	0.00
5	$Ln(P_{TRD})$	α_4	0.91	2.34	0.39	0.70
6	$Ln(P_{MLK})^2$	β_{11}	-0.76	0.57	-1.35	0.18
7	$Ln(P_{FB})^2$	β_{22}	-0.07	0.58	-0.12	0.90
8	$Ln(P_{FS})^2$	β_{33}	-0.21	0.11	-1.82	0.07
9	$Ln(P_{TRD})^2$	β_{44}	-0.57	0.35	-1.65	0.10
10	$Ln(P_{MLK})Ln(P_{FB})$	β_{12}	-0.02	0.42	-0.04	0.97
11	$Ln(P_{MLK})Ln(P_{FS})$	β_{13}	0.27	0.10	2.77	0.01
12	$Ln(P_{MLK})Ln(P_{TRD})$	β_{14}	0.14	0.14	0.99	0.33
13	$Ln(Z_{MPRX})$	β_M	2.67	3.43	0.77	0.44
14	$Ln(Z_{LCAP})$	β_C	-0.69	1.51	-0.46	0.65
15	$Ln(Z_{LABR})$	β_L	0.86	1.04	0.82	0.41
16	$Ln(Z_{MPRX})^2$	γ_{MM}	-6.63	1.59	-4.16	0.00
17	$Ln(Z_{LCAP})^2$	γ_{CC}	0.16	0.15	1.07	0.29
18	$Ln(Z_{LABR})^2$	γ_{LL}	0.10	0.17	0.57	0.57
19	$Ln(Z_{MPRX})Ln(Z_{LCAP})$	γ_{MC}	0.36	0.60	0.60	0.55
20	$Ln(Z_{MPRX})Ln(Z_{LABR})$	γ_{ML}	-0.26	0.54	-0.47	0.64
21	$Ln(Z_{LCAP})Ln(Z_{LABR})$	γ_{CL}	-0.09	0.13	-0.71	0.48
22	$Ln(P_{MLK})Ln(Z_{MPRX})$	γ_{1M}	-3.36	0.27	-12.57	0.00
23	$Ln(P_{MLK})Ln(Z_{LCAP})$	γ_{1C}	0.48	0.11	4.42	0.00
24	$Ln(P_{MLK})Ln(Z_{LABR})$	γ_{1L}	-0.41	0.10	-4.03	0.00
25	$Ln(P_{FB})Ln(Z_{MPRX})$	γ_{2M}	2.56	0.32	8.06	0.00
26	$Ln(P_{FB})Ln(Z_{LCAP})$	γ_{2C}	-0.40	0.13	-3.11	0.00
27	$Ln(P_{FB})Ln(Z_{LABR})$	γ_{2L}	0.29	0.12	2.40	0.02
28	$Ln(P_{FS})Ln(Z_{MPRX})$	γ_{3M}	0.95	0.27	3.56	0.00
29	$Ln(P_{FS})Ln(Z_{LCAP})$	γ_{3C}	-0.03	0.12	-0.29	0.77
30	$Ln(P_{FS})Ln(Z_{LABR})$	γ_{3L}	0.29	0.12	2.47	0.01
31	$Ln(P_{FB})Ln(P_{FS})$	β_{23}	-0.14	0.12	-1.24	0.22
32	$Ln(P_{FB})Ln(P_{TRD})$	β_{24}	-0.34	0.17	-2.05	0.04
33	$Ln(P_{FS})Ln(P_{TRD})$	β_{34}	-0.09	0.15	-0.59	0.56
34	$Ln(P_{TRD})Ln(Z_{MPRX})$	γ_{4M}	0.51	0.51	1.00	0.32
35	$Ln(P_{TRD})Ln(Z_{LCAP})$	γ_{4C}	0.07	0.26	0.25	0.80
36	$Ln(P_{TRD})Ln(Z_{LABR})$	γ_{4L}	-0.23	0.20	-1.15	0.25
37	Dependent Variable	$Ln(\pi)$, S_{MLK}, S_{FB}, S_{FS}		Sample size	48	

Mixed results were obtained. While α_1 enters as a significant variable with the expected sign, the sign of β_{11} is contrary to expectations and the coefficient is insignificant. Both feed variables have significant β_{ii}-coefficients and their signs correspond to *a priori* expectations of own-price responses.

In the derived milk share equation, purchased feed prices induce negative supply responses, while self-produced feed price increases would lead to increased milk supply. Higher livestock trade prices would surprisingly cause increased milk supply. Management improvement and higher labour investments would reduce milk supply, while supply responds positively to increased livestock investment.

Evaluating the purchased feed share equation reveals that increased milk prices would reduce the demand for purchased feed inputs. Increases in self-produced feed prices and the trade prices of livestock would also reduce the demand for purchased feed. Conversely, improved management practices and higher labour expenses are associated with higher demand for purchased feed inputs. Increased livestock outlays would have a negative effect on the demand for purchased feed.

Self-produced feed shares would increase with increases in milk prices and with improved management practices and higher labour outlays. Increased livestock capital would reduce the demand for self-produced feed. Higher purchased feed prices would reduce the demand for self-produced feed – implying complementarities, not substitution between the two input groups. Higher livestock trade prices would force self-produced feed demand downwards.

Similar to the Normalised Quadratic, the highly significant quasi-fixed variables' coefficients together with unexpected signs for the price variables, prompted alternative specification of the system. Livestock capital and labour was dropped and homogeneity was imposed through normalisation of the profit function with the price of traded animals. The results of this process are presented in Table 19.

Table 19: Modified Normalised Translog profit system

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	11	0.25	44	0.00
2	$Ln(P_{MLK}/P_{TRD})$	α_1	2.02	0.20	10	0.00
3	$Ln(P_{FB}/P_{TRD})$	α_2	-0.68	0.18	-3.72	0.00
4	$Ln(P_{FS}/P_{TRD})$	α_3	-0.15	0.10	-1.51	0.13
5	$Ln(P_{MLK}/P_{TRD})^2$	β_{11}	0.96	0.52	1.85	0.07
6	$Ln(P_{FB}/P_{TRD})^2$	β_{22}	1.16	0.57	2.05	0.04
7	$Ln(P_{FS}/P_{TRD})^2$	β_{33}	0.28	0.11	2.46	0.02
8	$Ln(P_{MLK}/P_{TRD})Ln(P_{FB}/P_{TRD})$	β_{12}	-1.02	0.51	-1.98	0.05
9	$Ln(P_{MLK}/P_{TRD})Ln(P_{FS}/P_{TRD})$	β_{13}	-0.45	0.16	-2.74	0.01
10	$Ln(Z_{MPRX})$	β_M	3.85	0.76	5.03	0.00
11	$Ln(Z_{MPRX})^2$	γ_{MM}	-3.32	0.58	-5.73	0.00
12	$Ln(P_{MLK}/P_{TRD})Ln(Z_{MPRX})$	γ_{1M}	-0.28	0.30	-0.94	0.35
13	$Ln(P_{FB}/P_{TRD})Ln(Z_{MPRX})$	γ_{2M}	-0.10	0.27	-0.38	0.70
14	$Ln(P_{FS}/P_{TRD})Ln(Z_{MPRX})$	γ_{3M}	-0.69	0.18	-3.82	0.00
15	$Ln(P_{FB}/P_{TRD})Ln(P_{FS}/P_{TRD})$	β_{23}	0.37	0.14	2.75	0.01
37	Dependent Variable	$Ln(\pi/P_{TRD})$, S_{MLK}, S_{FB}, S_{FS}			Sample size	48

The α_1-coefficient enters as a significant variable with the expected sign; β_{11} is statistically significant, whilst also corresponding to *a priori* expectations. Both feed variables have significant β_{ii}-coefficients. In the derived milk share equation, purchased and self-produced feed prices induce negative supply responses. The management proxy is negatively related to milk supply.

In the derived purchased feed share equation reveals that increased milk prices would reduce the demand for purchased feed inputs. Increases in self-produced feed prices would increase the demand for purchased feed. Conversely, improved management practices and higher labour expenses are associated with decreased demand for purchased feed inputs. Self-produced feed shares would decrease with increases in milk prices and with improved management. Higher purchased feed prices would increase the demand for self-produced feed – implying substitution between the two input groups.

4.3.3 Discussion of the Results

Despite the high adjusted-R^2 (0.95) of the OLS estimation of the profit function (Table 13), the single equation OLS results for the share equations yielded coefficients with improved t-ratios. This improvement was downplayed by emergence of unexpected signs from the OLS estimation of the individual share equations. System estimation of the profit function and share equations produced overall improvements in variables' significance levels. However, it must be noted that the poor fit on the share of self-produced feed and on the share of trade income, casts doubt on the reliability of the system results. Yet, since the quantity of milk supplied and the level of feed administered are determined simultaneously with profit, it is believed that the system results should represent a more realistic scenario. The results from system estimation will be used to evaluate the structural properties of the profit system.

4.3.4 Testing the Structural Properties

4.3.4.1 Non-Negativity

In four (out of forty-eight) cases, negative input quantities were estimated. None of these cases reported simultaneous negative profits or quantities and these results are not sufficient to classify the particular farms as non-profit maximising – small sample size bias, contamination due to aggregation and due to incorrect specification of supply or demand equations all contribute to reduced confidence in the estimation outputs.

4.3.4.2 Monotonicity

From the original translog supply system (Table 18), the first derivatives of the profit function with respect to input and output prices (at the point of approximation, section 3.9.2) were evaluated. Profit is monotonically increasing in milk and livestock trade prices (α_1, α_4 > 0). Profit strictly decreases in self-produced feed prices, but not in purchased feed prices. The latter is thus a violation of profit maximisation requirements.

The normalised translog supply system yielded more theoretically accurate results. Evaluation of the first derivatives of the normalised translog profit function revealed that profit is monotonically increasing in milk prices ($\alpha_1 > 0$) and monotonically decreasing in purchased and self-produced feed prices (α_2, $\alpha_3 < 0$).

4.3.4.3 *CONVEXITY AND CONCAVITY*

For convexity of the non-normalised profit function in all prices, the modified[14] Hessian matrix of second order derivatives of normalised profit with respect to prices (H^*_{PP}) should have non-negative determinants for the principal minors. The elements of the modified Hessian matrix are ($\gamma_{ii}+\alpha_i^2-\alpha_i$) for the i^{th}-diagonal element, and ($\gamma_{ij}+\alpha_i\alpha_j$) for the off-diagonal elements [Capalbo, *et al.*, 1988]. The determinants $|H_1|$, $|H_2|$ and $|H_4|$ are negative, while $|H_3|$ is positive. The profit function is thus neither globally concave nor globally convex in prices. The latter result is contrary to the requirements for well-behaving profit functions. It is ascribed to the overall problems found in the data, such as small sample properties, aggregation bias and the cross-sectional nature of the data.

Stated algebraically:

$$H = \begin{bmatrix} \dfrac{\partial^2\pi}{(\partial P_{MLK})^2} & \dfrac{\partial^2\pi}{\partial P_{MLK}\partial P_{FB}} & \dfrac{\partial^2\pi}{\partial P_{MLK}\partial P_{FS}} & \dfrac{\partial^2\pi}{\partial P_{MLK}\partial P_{TRD}} \\ \dfrac{\partial^2\pi}{\partial P_{FB}\partial P_{MLK}} & \dfrac{\partial^2\pi}{(\partial P_{FB})^2} & \dfrac{\partial^2\pi}{\partial P_{FB}\partial P_{FS}} & \dfrac{\partial^2\pi}{\partial P_{FB}\partial P_{TRD}} \\ \dfrac{\partial^2\pi}{\partial P_{FS}\partial P_{MLK}} & \dfrac{\partial^2\pi}{\partial P_{FS}\partial P_{FB}} & \dfrac{\partial^2\pi}{(\partial P_{FS})^2} & \dfrac{\partial^2\pi}{\partial P_{FS}\partial P_{TRD}} \\ \dfrac{\partial^2\pi}{\partial P_{TRD}\partial P_{MLK}} & \dfrac{\partial^2\pi}{\partial P_{TRD}\partial P_{FB}} & \dfrac{\partial^2\pi}{\partial P_{TRD}\partial P_{FS}} & \dfrac{\partial^2\pi}{(\partial P_{TRD})^2} \end{bmatrix}$$

[14] The Hessian matrix is modified by dividing it through the vector of (π/p_ip_j)

$$\therefore H^{*}_{PP} = \begin{bmatrix} \beta_{11}+\alpha_1^2-\alpha_1 & \beta_{12}+\alpha_1\alpha_2 & \beta_{13}+\alpha_1\alpha_3 & \beta_{14}+\alpha_1\alpha_4 \\ \beta_{21}+\alpha_2\alpha_1 & \beta_{22}+\alpha_2^2-\alpha_2 & \beta_{23}+\alpha_2\alpha_3 & \beta_{24}+\alpha_2\alpha_4 \\ \beta_{31}+\alpha_3\alpha_1 & \beta_{32}+\alpha_3\alpha_2 & \beta_{33}+\alpha_3^2-\alpha_3 & \beta_{34}+\alpha_3\alpha_4 \\ \beta_{41}+\alpha_4\alpha_1 & \beta_{42}+\alpha_4\alpha_2 & \beta_{43}+\alpha_4\alpha_3 & \beta_{44}+\alpha_4^2-\alpha_4 \end{bmatrix}$$

$$= \begin{bmatrix} -0.35 & 0.60 & -4.07 & 1.33 \\ 0.60 & -0.32 & -1.70 & 0.09 \\ -4.07 & -1.70 & 14.06 & -3.10 \\ 1.33 & 0.09 & -3.10 & -0.65 \end{bmatrix}$$

The Hessian matrix of the normalised translog profit function is as follows:

$$H = \begin{bmatrix} \frac{\partial^2 \pi}{(\partial P^{*}_{MLK})^2} & \frac{\partial^2 \pi}{\partial P^{*}_{MLK} \partial P^{*}_{FB}} & \frac{\partial^2 \pi}{\partial P^{*}_{MLK} \partial P^{*}_{FS}} \\ \frac{\partial^2 \pi}{\partial P^{*}_{FB} \partial P^{*}_{MLK}} & \frac{\partial^2 \pi}{(\partial P^{*}_{FB})^2} & \frac{\partial^2 \pi}{\partial P^{*}_{FB} \partial P^{*}_{FS}} \\ \frac{\partial^2 \pi}{\partial P^{*}_{FS} \partial P^{*}_{MLK}} & \frac{\partial^2 \pi}{\partial P^{*}_{FS} \partial P^{*}_{FB}} & \frac{\partial^2 \pi}{(\partial P^{*}_{FS})^2} \end{bmatrix}$$

$$\therefore H^{*}_{PP} = \begin{bmatrix} \beta_{11}+\alpha_1^2-\alpha_1 & \beta_{12}+\alpha_1\alpha_2 & \beta_{13}+\alpha_1\alpha_3 \\ \beta_{21}+\alpha_2\alpha_1 & \beta_{22}+\alpha_2^2-\alpha_2 & \beta_{23}+\alpha_2\alpha_3 \\ \beta_{31}+\alpha_3\alpha_1 & \beta_{32}+\alpha_3\alpha_2 & \beta_{33}+\alpha_3^2-\alpha_3 \end{bmatrix}$$

$$\begin{bmatrix} 3.27 & -2.56 & -0.69 \\ -2.56 & 2.46 & 0.46 \\ -0.69 & 046 & 0.48 \end{bmatrix}$$

These results show that the determinants $|H_1|$, $|H_2|$ and $|H_3|$ are positive. The profit function is thus globally convex in prices (i.e. positive semi-definite). The latter result conforms to the requirements for a well-behaving profit function.

4.3.4.4 HOMOGENEITY

In the non-normalised translog supply system, homogeneity in all prices was not imposed, *a priori*, but tested for afterwards. The test results are reported in Table 20, below. The results are contradictory to such an extent that neither homogeneity in all prices, nor homogeneity in quasi-fixed factors could be established.

Table 20: Results of Wald Coefficient tests for homogeneity in the translog profit system

Hypothesis	Specification	χ^2-stat	p-value	Result
H_0: $\Sigma_i \alpha_i = 0$	c(2)+c(3)+c(4)+c(5)=0	0.47	0.49	Fail to reject H_0
H_0: $\Sigma_i \beta_{ij} = 0$	C(6)+C(10)+C(11)+C(12)=0 C(7)+C(10)+C(31)+C(32)=0 C(8)+C(11)+C(31)+C(33)=0 C(9)+C(12)+C(32)+C(33)=0	26.75	0.00	Reject H_0 at all levels
H_0: $\Sigma_m \gamma_m = 1$	C(13)+C(14)+C(15)=1	0.75	0.39	Fail to reject H_0
H_0: $\Sigma_i \gamma_{im} = 0$	C(22)+C(25)+C(28)+C(34)=0 C(23)+C(26)+C(29)+C(35)=0 C(24)+C(27)+C(30)+C(36)=0	1.85	0.61	Fail to reject H_0
H_0: $\Sigma_m \gamma_{im} = 0$	C(22)+C(23)+C(24)=0 C(25)+C(26)+C(27)=0 C(28)+C(29)+C(30)=0 C(34)+C(35)+C(36)=0	130.40	0.00	Reject H_0 at all levels
H_0: $\Sigma_m \gamma_{mn} = 0$	C(16)+C(19)+C(20)=0 C(17)+C(19)+C(21)=0 C(18)+C(20)+C(21)=0	66.93	0.00	Reject H_0 at all levels

The problem of homogeneity in prices was solved through the normalisation procedure performed on the translog profit function. Homogeneity was thus imposed in the normalised translog supply system.

4.3.4.5 SYMMETRY

Symmetry was imposed during estimation, due to sample size constraints. The symmetry can be seen from the Hessian matrix: $\beta_{ij} = \beta_{ji}$.

4.3.5 ELASTICITY CALCULATIONS

Table 21 reports the Marshallian elasticities (Equation 12) calculated from the various translog profit, share and system estimations. Single equation OLS estimation of the profit function produces system responses to price changes that are as follows (Table 21, lines 1 – 4). When milk prices rise, milk supply increases; purchased feed demand decreases and self-produced feed demand increases; the volume of traded livestock also increases. An upward shift in purchased feed prices increases milk supply, livestock supply for trade and purchased feed demand, but lowers self-produced feed demand.

Table 21: Elasticities calculated from the various estimation results for the Translog specification.

Line	E (q_i / p_j)	P_{mlk}	P_{fb}	P_{fs}	P_{trd}	Source
1	Q_{mlk}	18.85	2.28	-1.94	0.41	Table 13: OLS Profit
2	Q_{fb}	-5.18	10.75	-0.45	-1.45	Table 13: OLS Profit
3	Q_{fs}	7.92	-4.46	-3.56	0.01	Table 13: OLS Profit
4	Q_{trd}	1.09	1.71	-0.00	-0.23	Table 13:OLS Profit
5	Q_{mlk}	0.58	-0.82	-0.48	0.85	Table 14: OLS Milk share
6	Q_{fb}	1.84	-2.75	-0.09	1.16	Table 15: OLS Purchased feed share
7	Q_{fs}	-0.32	0.57	-1.70	0.80	Table 16: OLS Self-produced feed share
8	Q_{trd}	-7.28	6.40	-1.92	0.48	Table 17: OLS Trade income share
9	Q_{mlk}	0.79	-0.95	-0.40	0.87	Table 18: ISUR Profit system
10	Q_{fb}	2.17	-1.87	-0.38	1.16	Table 18: ISUR Profit system
11	Q_{fs}	1.63	-0.68	-1.13	0.97	Table 18: ISUR Profit system
12	Q_{trd}	2.32	-1.37	-0.64	-0.91	Table 18: ISUR Profit system
13	Q_{mlk}	1.70	-1.53	-0.73	N/a	Table 19: ISUR Normalised profit system
14	Q_{fb}	3.46	-3.41	-0.93	N/a	Table 19: ISUR Normalised profit system
15	Q_{fs}	2.98	-1.66	-2.16	N/a	Table 19: ISUR Normalised profit system

Milk supply responds negatively towards increased self-produced feed prices and both purchased feed and self-produced feed demand declines when the price increases. Higher livestock prices increase milk supply and self-produced feed demand, but decrease purchased feed demand and volume of livestock traded. The results in line 3 seem plausible. In the other cases (except for milk's own-price response, which is highly elastic), the own- and cross-price responses are contrary to economic theory. This response system indicates complementarities between purchased and self-produced feed inputs. Furthermore, increases in milk supply (stimulated by milk price increases) favour the use of self-produced feed inputs above purchased feed inputs.

When the results from the OLS regression on the single profit share equations are evaluated as a system (Table 21, lines 5 – 8), quite different conclusions are drawn. Milk still features as a normal good (positive own-price elasticity), but is much more inelastic in this system. Milk supply expansion, however, favours the use of purchased feeds in this case. Purchased feed inputs treat self-produced feed as a complement, but self-produced feed inputs treat purchased feed inputs as substitutes in the production process.

The system estimation results (Table 18) indicate that milk (line 9) is an inelastic normal good, which is intensive in the use of purchased and self-produced feed inputs in the production process. Both inputs have negative price elasticities of demand. The demand for purchased feed inputs is more elastic with respect to milk price changes than the demand for self-produced feeds (lines 10 and 11)– probably due to the commitment of land and other factors of production into the production process of the latter input. Milk supply response is inelastic towards input price changes, more so with respect to self-produced feed (line 9). While purchased feed' s response (line 10) is elastic towards its own price, it is inelastic with respect to self-produced feed prices – the same holds for self-produced feed response (line 11). The volume of traded animals' increase when milk prices rise (gross complements)– the response is highly elastic. Higher feed prices induce contractions in the supply of livestock – these results are consistent with the complimentarity between milk production and livestock trade. However, the negative price elasticity of livestock supply is contrary to expectations.

From lines 13 to 15, the normalised supply system poses milk as a normal good with an elastic long-run own-price response. Milk supply responds negatively to input price increases, especially towards purchased feed prices. Milk production is more intensive in the use of purchased feed: higher milk prices would induce larger demand increases for purchased feed than for self-produced feed inputs. All the own-price responses adhere to theoretical requirements for normal goods. The feed inputs are gross complements (long-run).

To compute the Hicksian input demand elasticities with respect to input prices, Table 21' s results (of the profit system, lines 9 to 12) are used in the formulae from Equation 18 (Chapter 3: Methodology).

$$\{\eta_{lk}^{S}\} = \{\eta_{lk}\} - \{\eta_{lt}\} \times \{\eta_{th}\}^{-1} \times \{\eta_{tl}\}$$

$$= \begin{bmatrix} -1.87 & -0.38 \\ -0.68 & -1.13 \end{bmatrix} - \begin{bmatrix} 2.17 & 1.16 \\ 1.63 & 0.97 \end{bmatrix} \times \begin{bmatrix} 0.79 & 0.87 \\ 2.32 & -0.91 \end{bmatrix}^{-1} \times \begin{bmatrix} -0.95 & -0.40 \\ -1.37 & -0.64 \end{bmatrix}$$

$$= \begin{bmatrix} 0.24 & 0.53 \\ 0.95 & -0.43 \end{bmatrix} = \begin{bmatrix} \eta_{FB,FB}^{S} & \eta_{FB,FS}^{S} \\ \eta_{FS,FB}^{S} & \eta_{FS,FS}^{S} \end{bmatrix}$$

The highly elastic long-run price elasticity of purchased feed demand (-1.87) is caused by a substantial expansion effect (2.11) - the change in input use due to a movement to a new production frontier – as opposed to the inelastic short-run response (0.24). Self-produced feed displays a similar pattern (expansion effect of 0.7). While the two inputs are gross complements, they are net substitutes. This is probably due to their simultaneous importance in the milk production process. Higher purchased feed prices induce a short-run switch to self-produced feeds, but this in counteracted by the long-run expansion of purchased feed use due to milk supply increases. In the same way, increased self-produced feed prices would cause purchased feed to replace self-produced feed inputs in the short–run, but this is then balanced by the expansion effect, albeit smaller than the expansion effect of purchased feed. Milk production is clearly more intensive in the use of purchased feeds. None of the inputs are regressive in the sense that the demands for them decrease as output prices increase.

The normalised translog supply system yields the following Hicksian input demand elasticities;

$$\{\eta_{lk}^{S}\} = \{\eta_{lk}\} - \{\eta_{lt}\} \times \{\eta_{th}\}^{-1} \times \{\eta_{tl}\}$$

$$= \begin{bmatrix} -3.41 & -0.93 \\ -1.66 & -2.16 \end{bmatrix} - \begin{bmatrix} 3.46 \\ 2.98 \end{bmatrix} \times \begin{bmatrix} 1.70 \end{bmatrix}^{-1} \times \begin{bmatrix} -1.53 & -0.73 \end{bmatrix}$$

$$= \begin{bmatrix} -0.31 & 0.56 \\ 1.00 & -0.89 \end{bmatrix} = \begin{bmatrix} \eta_{FB,FB}^{S} & \eta_{FB,FS}^{S} \\ \eta_{FS,FB}^{S} & \eta_{FS,FS}^{S} \end{bmatrix}$$

Long-run responses are dominated by expansion effects. The feed inputs are net substitutes in the production process. According to these results, the substitution effect is stronger when increases in purchased feed prices occur. In the long-run expansion in both inputs occur and the demand for the two components moves together.

Similarly, Hicksian output supply elasticities for the non-normalised profit function with respect to output prices are calculated as follows.

$$\{\eta_{th}^{S}\} = \{\eta_{th}\} - \{\eta_{tl}\} \times \{\eta_{lk}\}^{-1} \times \{\eta_{lt}\}$$

$$= \begin{bmatrix} 0.79 & 0.87 \\ 2.32 & -0.91 \end{bmatrix} - \begin{bmatrix} -0.95 & -0.40 \\ -1.37 & -0.64 \end{bmatrix} \times \begin{bmatrix} -1.87 & -0.38 \\ -0.68 & -1.13 \end{bmatrix}^{-1} \times \begin{bmatrix} 2.17 & 1.16 \\ 1.63 & 0.97 \end{bmatrix}$$

$$= \begin{bmatrix} -0.49 & 0.16 \\ 0.43 & -1.96 \end{bmatrix} = \begin{bmatrix} \eta_{MLK,MLK}^{S} & \eta_{MLK,TRD}^{S} \\ \eta_{TRD,MLK}^{S} & \eta_{TRD,TRD}^{S} \end{bmatrix}$$

Milk price elasticity of supply (0.79) indicates that price changes induce short–run contraction in milk supply (-0.49), followed by contraction effect (-1.28). Livestock trade is a complimentary process that exhibits short-run substitution for milk production (0.43), but this is countered by a substantial contraction effect (-1.89). In the same way, milk production substitutes for trade in the short run (due to trade price increases), but its long-run contraction effect overshadows the substitution effect.

The normalised translog supply system produces a Hicksian output supply elasticity of –0.08 (calculated as follows).

$$\{\eta_{th}^{S}\} = \{\eta_{th}\} - \{\eta_{tl}\} \times \{\eta_{lk}\}^{-1} \times \{\eta_{lt}\}$$

$$= [1.70] - [-1.53 \quad -0.73] \times \begin{bmatrix} -3.41 & -0.93 \\ -1.66 & -2.16 \end{bmatrix}^{-1} \times \begin{bmatrix} 3.46 \\ 2.98 \end{bmatrix}$$

$$= [-0.08] = [\eta_{MLK,MLK}^{S}]$$

This implies that short-run response to milk price increases is supply reducing, albeit a very in-elastic response. The highly elastic long-run response (1.70) is a result of the substantial contraction in supply (-1.78) following the short-run response.

4.4 Choice of most appropriate functional form

Before introduction of the modified supply systems, the results of sections 4.2.4 and 4.3.4 favoured the translog profit system (as estimated using Zellner' s Iterative Seemingly Unrelated method). However, the results of both systems led to rejection of the essential monotonicity and convexity properties and both systems suffer from aggregation, small sample and missing data problems.

On the contrary, introduction of the two alternative specifications for the Normalised Quadratic and Translog supply systems (also estimated with the ISUR method), produced results that are consistent with profit maximising producer behaviour. The long-run responses in the modified Normalised Quadratic system are more in-elastic than the Marshallian responses from the modified Normalised Translog system. In contrast, the Normalised Translog Hicksian responses are more elastic than the Normalised Quadratic's short-run responses.

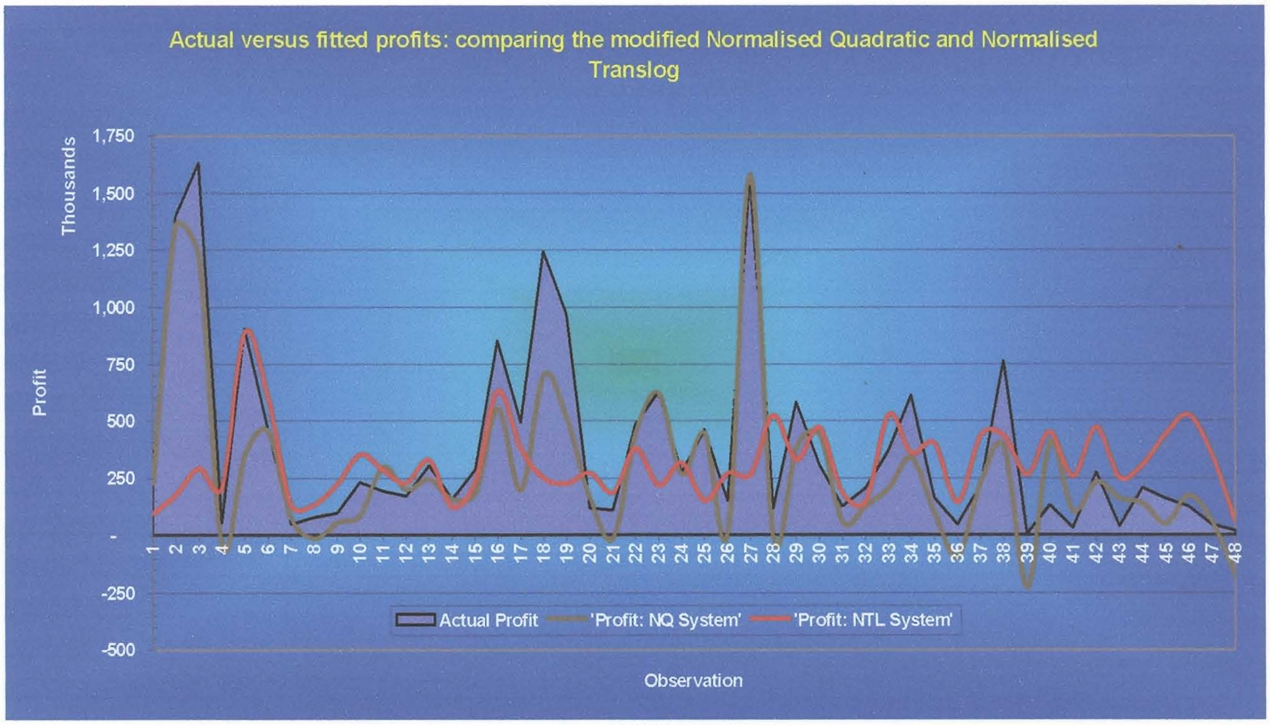

Figure 13: Comparing the Normalised Quadratic and Normalised Translog profit with actual profit levels

The Normalised Quadratic offers a closer correspondence with observed values.

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

5.1 SUMMARY

Despite the relative importance of the South African dairy sector in the country' agriculture, very little analysis has been done and published on the structure of dairy production and on the response of dairy farmers to price and other policy changes. This is partly due to the industry's apparent reluctance to make data available to academic institutions that have the capacity, resources and interest in performing the required analyses. This situation seems to be changing and it is a positive movement for the industry and academia.

Supply response studies take many forms and the complexity of agricultural supply response as opposed to studies on consumer demand only contributes to the diversity in methods of analysis. A predominant method of supply response analysis that is employed in many empirical studies pertaining to milk production, is econometric estimation of the parameters of the production process through the use of Duality theory, whereby cost or profit functions (rather than production functions) are fitted to data from farm or regional cost surveys (time-series, cross-sectional or panel data). This approach has many computational and estimation advantages over normative or programming methods and over direct econometric estimation of production functions.

For this study, the profit function approach was chosen. Two of the most frequently used functional specifications of profit functions, the Normalised Quadratic and the Translog forms, were applied to the data. In addition, both single equation estimation techniques (OLS) and system estimation techniques (ISUR and FIML) were employed. Those structural properties that were not imposed during estimation were tested afterwards. Due to the small sample size and some missing price observations in the data, as well as the substantial demand on degrees of freedom required by the functional specifications, aggregation of inputs and outputs were necessary. The maintained hypothesis was that farmers are profit maximising agents operating in unregulated markets. Each farm was treated as a multi-input multi-output production unit. The outputs were fluid milk and an aggregate of traded livestock. Variable inputs comprised of two aggregates: aggregated purchased feed and aggregated self-produced feed. The quasi-fixed variables that were considered are livestock capital, total farm labour and a proxy for management efficiency.

Out of all the estimation results for the initial specifications, those from the ISUR application to the translog system of profit and profit share equations yielded the most plausible and consistent results. Symmetry was imposed in both the Normalised Quadratic and Translog systems. The former system imposed homogeneity, while the results from the latter lead to the rejection of homogeneity. In both systems, convexity of profit with respect to all prices was rejected. Monotonicity was rejected in the case of only a small number of farms and two farms were excluded from the analysis due to negative restricted profits. An important note, however, pertains to the substantial number of statistically insignificant coefficients, of which many displayed unexpected signs and magnitudes. This is an indication that substantial improvement should be possible in terms of specifying the profit system.

Consequently, alternative specifications were tested. As a first step, the translog system was normalised by the price index of traded livestock, similar to the Normalised Quadratic. The specifications of both the Normalised Quadratic and Normalised Translog in which livestock and labour quasi-fixed variables were dropped produced the best results. The results of both specifications conformed to theoretical requirements for well-behaved profit functions. Uncompensated- and compensated price elasticities of supply and demand were calculated. These elasticities should be interpreted as an example of the type of answers analyses and data similar to that of this study could yield.

In milk production purchased and self-produced feed inputs were gross complements and net substitutes, according to both the Normalised Quadratic and Normalised Translog supply system specifications. The normalised translog system indicated substantial expansion effects in input demand, while both systems indicated contraction effects for milk supply as a result of milk price changes. Milk production was more intensive in purchased feed use than in self-produced feed use. Finally, input demand was much more price elastic in the short- and long-run than output supply.

The parameters of the quasi-fixed variables showed significant influences on all the profit share equations, except in the self-produced feed' s profit share response to livestock capital input, and for all quasi-fixed variables in the livestock trade profit share. Increased management and higher labour expenditures, as they were defined in this study, led to a decrease in milk's share of profit, contrary to the expectation that higher management efficiency would result in more profitable milk production and livestock trade activities. From the modified systems' results, improved management would reduce milk supply and input demand in the Normalised Translog case. However, the Normalised Quadratic results indicated that improved management increases milk supply and the demand for purchased feed inputs, whilst reducing the demand for self-produced feed inputs.

These inconclusive results indicate that substantial improvement in specification and estimation could be achieved if the data set was expanded in terms of size and detail on prices and quantities of inputs and trading activities.

5.2 Conclusions and Recommendations

This study was intended to be a platform upon which future dairy supply response studies can build. From the outset, the data dictated what can be done, assumed and reported.

In a time in South Africa were public agricultural research expenditure decreases annually, it is important that research issues are jointly identified and defined by the industry and the researchers - thereby limiting the need for resource expensive and duplicative surveys and experiments. For sound and useful analysis and prediction purposes, it is imperative that the industry and research institutions nurture a partnership in which information sharing and confidentiality are paramount.

Only when this prevails can researchers access the required detailed information on prices, input use strategies, farming goals, physical quantities of input use, timing of production activities, risk coping strategies and expectation formation that would negate the need for elaborate and unrealistic assumptions that are currently incorporated in analyses.

The quality of results is partly ascribed to the quality of the data that it is based on. In the dairy sector, substantially more detail is required for useful analyses and where this detailed data exists, it is important that analysts gain access to it – for the benefit of the industry as a world market competitor. In the absence of data, the industry and researchers should collaborate on developing surveys, managing the information and dissemination of results to the industry.

Possible improvements in existing available data are:

- Larger samples
- Time-series data or panel data (balanced or unbalanced)
- Unit cost of inputs, valued at market prices or opportunity cost; unit prices of all traded animals; unit prices of animal products (milk, butter, fat, etc.)
- Farm level records of climatic conditions (rainfall, temperatures)
- Farm level specification of technologies used (e.g. feedlot, grazing, combination, automated milking methods, manual methods, etc.)
- Type and quantity of labour actually utilised in production as opposed to employed labour.
- Uniform quality ratings of resources (grazing land, herd quality, labour quality, etc.).
- Stock patterns within and between seasons, and
- Detail on the allocation of variables (i.e. feed, labour, etc) to different farm enterprises.

International literature on the economics of dairy production, -processing and supply response provides many ideas for short or more intensive studies pertaining to the South African dairy sector. At the risk of sounding redundant, the problem of data access remains the most inhibiting factor. As much as this study tried to show the potential use of existing data, it is also a call for increased co-operation between the industry and the academic profession in serving the needs of the dairy sector.

The results from this study suggest that dairy producers in South Africa are rational profit maximisers who use resources efficiently to the point where the marginal returns are zero. They allocate bought and self-produced feed components as substitutes in the short-run but treat them as complements in the long-run. The intensity of purchased feed use is higher than that of self-produced feed use. This has implications for the animal feed sector in terms of confirming dairy farmers' preferences for scientifically formulated feed components. It also suggests increased pressure on the international competition for already limited natural animal protein sources (fish meal, bone meal, etc.). Analysis of this apparent preference should be checked against time series data, also of other economic variables such as exchange rates, natural animal protein prices, maize prices and investment in animal feed research. In addition, disaggregated modelling of the self-produced and purchased components is necessary to evaluate the substitution status between components within and between the two broad classifications.

Milk supply shows an inclination to contract over time. Hence, this study's results suggest that increased milk prices will not stimulate expansion of the industry. Again, this should be checked against time series data and international patterns of herd size expansion, productivity increases and decreasing producer concentration. Very useful information can be obtained if similar analysis is conducted for different production regions (given the high geographic diversity) and different groups of producers (based on technology preferences or size of operations) to establish what effects input and output price changes might have on short and long term production dynamics.

Supply analysis, as it was performed here, provides testable hypotheses about producer behaviour, and a basis from which supply and demand elasticities for dairy products can be computed for policy simulation and analysis, thus enabling the dairy sector to be proactive in its response to international and local economic stimuli.

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ANNEXURE A: DATA SUMMARY

	Minimum	Average	Maximum	Zeroes
INVESTMENT IN DAIRY CATTLE				
28/02/1998				
Cows				
Number of cows in milk	11.00	94.16	225.00	-
Value per cow in milk	1,350.00	3,713.00	8,000.00	-
Cows in milk total	28,000.00	365,597.00	1,272,000.00	-
Number of cows dry and steaming up	2.00	24.94	96.00	-
Value per cow dry and steaming up	1,350.00	3,719.00	8,000.00	-
Cows dry and steaming up total	7,500.00	93,435.00	288,000.00	-
Heifers				
Number in calf	-	24.40	120.00	2.00
Value per heifer in calf	-	2,775.00	7,000.00	2.00
Total for heifers in calf	-	67,349.00	227,500.00	4.00
Number of heifers 12 - 24 months	-	32.30	167.00	2.00
Value per heifer 12 - 24 months	-	2,294.68	17,500.00	2.00
Heifers 12 - 24 months total	-	65,133.00	334,000.00	5.00
Number of heifers born to 12 months	-	41.44	174.00	1.00
Value per heifer born to 12 months	-	992.35	4,000.00	1.00
Heifers born to 12 months total	-	39,053.24	261,000.00	3.00
Bulls and oxen				
Number of full grown bulls and oxen	-	2.29	25.00	2.00
Value per bul and ox	-	4,511.43	10,000.00	2.00
Full grown bulls and oxen total	-	5,828.00	32,500.00	17.00
Number of bulls and oxen 12 - 24 months	-	12.62	35.00	2.00
Value per bul and ox 12 - 24 months	-	1,338.46	3,000.00	2.00
Bulls and oxen 12 - 24 months total	-	4,497.00	56,000.00	39.00
Number of bulls and oxen, born - 12 months	1.00	34.45	130.00	-
Value per bul and ox, born - 12 months	100.00	629.55	4,000.00	-
Bulls and oxen born - 12 months total	-	7,873.00	72,000.00	28.00
Total value as on 28/02/1998	53,150.00	648,765.24	1,804,500.00	-
CAPITAL INVESTMENT LIVESTOCK	55,450.00	635,980.44	1,804,500.00	-
DIVISION OF LAND	**66.00**	**361.93**	**629.00**	**-**
IRRIGATION				
PASTURE				
Type				
Ha	0.60	20.53	70.00	-
Value/ha land	1,000.00	4,044.44	15,000.00	-
Production cost/ha pasture	750.00	1,784.72	3,200.00	-
Type				
Ha	4.00	16.89	80.00	-
Value/ha land	2,000.00	4,666.67	12,000.00	-
Production cost/ha pasture	600.00	1,742.50	2,500.00	-
Type				

Ha	4.00	10.25	20.00	-
Value/ha land	2,500.00	6,250.00	12,000.00	-
Production cost/ha pasture	900.00	1,875.00	2,500.00	-
Type				
Ha				
Value/ha land				
Production cost/ha pasture				
TOTAL VALUE LAND (I PASTURE)	-	51,706.00	570,000.00	32.00
TOTAL PRODUCTION COST I PASTURE	-	24,098.50	350,000.00	32.00
TOTAL HECTARE IRRI PASTURE	-	11.25	120.00	32.00
HAY				
Type				
Ha	1.00	18.67	30.00	-
Value/ha land	1,500.00	2,666.67	3,500.00	-
Production cost/ha hay	350.00	1,150.00	2,000.00	-
Type				
Ha	10.00	10.00	10.00	-
Value/ha land	1,500.00	1,500.00	1,500.00	-
Production cost/ha hay	450.00	450.00	450.00	-
Type				
Ha				
Value/ha land				
Production cost/ha hay				
Type				
Ha				
Value/ha land				
Production cost/ha hay				
TOTAL VALUE LAND (I HAY)	-	2,920.00	90,000.00	47.00
TOTAL PRODUCTION COST HAY	-	965.00	33,000.00	47.00
TOTAL HECTARES IRRI HAY	-	1.32	35.00	47.00
SILAGE				
Type				
Ha	10.00	37.67	80.00	-
Value/ha land	1,650.00	1,883.33	2,000.00	-
Production cost/ha silage	1,200.00	1,600.00	2,000.00	-
Type				
Ha				
Value/ha land				
Production cost/ha silage				
TOTAL VALUE LAND (I SILAGE)	-	4,450.00	160,000.00	47.00
TOTAL PRODUCTION COST SILAGE	-	4,176.00	160,000.00	47.00
TOTAL HECTARES IRRI SILAGE	-	2.26	80.00	47.00
CONCENTRATES				
Type				
Ha				
Value/ha land				
Production cost/ha concentrates				
TOTAL VALUE LAND (I CONCENTRATES)	-	-	-	50.00

TOTAL PRODUCTION COST CONCENTRATES	-	-	-	50.00
TOTAL HECTARES IRRI CONCENTRATES	-	-	-	50.00
DRY LAND	**66.00**	**361.93**	**629.00**	**-**
PASTURE				
Type				
Ha	5.00	42.46	130.00	-
Value/ha land	350.00	2,001.79	8,000.00	-
Production cost/ha pasture	300.00	943.02	6,900.00	-
Type				
Ha	3.00	33.58	70.00	-
Value/ha land	350.00	2,388.46	8,000.00	-
Production cost/ha pasture	200.00	574.33	1,481.32	-
Type				
Ha	4.00	135.25	500.00	-
Value/ha land	200.00	1,887.50	6,000.00	-
Production cost/ha pasture	75.00	441.25	1,000.00	-
Type				
Ha	6.00	43.00	80.00	-
Value/ha land	350.00	375.00	400.00	-
Production cost/ha pasture	125.00	187.50	250.00	-
TOTAL VALUE LAND (D PASTURE)	-	82,326.00	1,040,000.00	22.00
TOTAL PRODUCTION COST D PASTURE	-	26,967.75	217,692.40	22.00
TOTAL HECTARE DRYLAND PASTURE	-	45.05	740.00	22.00
HAY				
Type				
Ha	3.00	55.82	300.00	-
Value/ha land	100.00	1,494.64	6,000.00	-
Production cost/ha hay	50.00	624.13	2,000.00	-
Type				
Ha	2.00	49.35	150.00	-
Value/ha land	100.00	1,753.85	6,000.00	-
Production cost/ha hay	50.00	533.33	950.00	-
Type				
Ha	12.00	31.00	50.00	-
Value/ha land	1,000.00	1,500.00	2,000.00	-
Production cost/ha hay	450.00	550.00	650.00	-
Type				
Ha				
Value/ha land				
Production cost/ha hay				
TOTAL VALUE LAND (D HAY)	-	59,258.00	558,000.00	22.00
TOTAL PRODUCTION COST D HAY	-	23,359.54	171,150.00	22.00
TOTAL HECTARES D HAY	-	45.33	450.00	22.00
SILAGE				
Type	-	-	-	1.00
Ha	-	41.65	100.00	1.00
Value/ha land	-	1,514.81	3,000.00	1.00
Production cost/ha silage	350.00	1,345.10	6,000.00	-
Type				

Ha	12.00	16.00	20.00	-
Value/ha land	1,000.00	1,000.00	1,000.00	-
Production cost/ha silage	950.00	1,075.00	1,200.00	-
TOTAL VALUE LAND (D SILAGE)	-	38,805.00	270,000.00	24.00
TOTAL PRODUCTION COST D SILAGE	-	31,054.00	240,000.00	24.00
TOTAL HECTARES D SILAGE	-	23.13	100.00	24.00
CONCENTRATES				
Type	-	-	-	1.00
Ha	-	36.19	200.00	1.00
Value/ha land	-	1,265.00	2,500.00	1.00
Production cost/ha concentrates	550.00	1,169.08	2,100.00	-
Type				
Ha	21.00	21.00	21.00	-
Value/ha land	2,000.00	2,000.00	2,000.00	-
Production cost/ha concentrates	550.00	550.00	550.00	-
Type				
Ha				
Value/ha land				
Production cost/ha concentrates				
TOTAL VALUE LAND (D CONCENTRATES)	-	19,483.43	300,000.00	31.00
TOTAL PRODUCTION COST D CONCENTRATES	-	18,306.00	192,500.00	31.00
TOTAL HECTARES D CONCENTRATES	-	14.89	200.00	31.00
NATURAL PASTURE	**66.00**	**361.93**	**629.00**	**-**
Ha	-	156.42	575.00	1.00
Value/ha land	200.00	1,995.35	30,000.00	-
Total value	-	154,572.00	630,000.00	8.00
TOTAL LAND USED FOR DAIRY	10.00	277.56	950.00	-
HA RENTED	12.00	56.75	225.00	-
CAPITAL INVESTMENT LAND	16,000.00	413,520.43	1,428,000.00	-
FIXED IMPROVEMENTS				
Milking parlor				
Area	60.00	159.71	350.00	-
Present value	5,000.00	67,099.29	400,000.00	-
Replacement value	25,000.00	92,263.64	225,000.00	-
Feed shed				
Area	16.00	364.33	1,350.00	-
Present value	2,000.00	81,397.44	800,000.00	-
Replacement value	15,000.00	89,111.11	300,000.00	-
Dip				
Present value	-	4,250.00	10,000.00	1.00
Replacement value	-	5,000.00	10,000.00	1.00
Crush-pen				
Present value	500.00	5,478.85	20,000.00	-
Replacement value	1,000.00	9,750.00	40,000.00	-
Kraal				
Present value	-	9,222.00	50,000.00	1.00
Replacement value	-	15,062.50	80,000.00	1.00
Silage storage				
Present value	2,000.00	11,538.10	60,000.00	-
Replacement value	5,000.00	19,000.00	80,000.00	-

Water provision				
Present value	1,000.00	24,748.75	250,000.00	-
Replacement value	1,300.00	16,866.67	100,000.00	-
Calf housing				
Present value	-	7,562.05	50,000.00	1.00
Replacement value	-	10,656.80	60,000.00	1.00
Labour housing				
Present value	3,000.00	99,281.08	750,000.00	-
Replacement value	3,000.00	112,916.67	900,000.00	-
Fencing dairy				
Present value	2,000.00	41,866.67	180,000.00	-
Replacement value	4,000.00	29,287.50	120,000.00	-
Other (present value)	500,000.00	500,000.00	500,000.00	-
Other (replacement value)				
TOTAL FIXED IMPROVEMENTS (PRESENT)	15,000.00	271,494.70	1,520,500.00	-
TOTAL FIXED IMPROVEMENTS (REPLACEMENT)	-	194,514.40	1,366,000.00	16.00
EQUIPMENT	**66.00**	**361.93**	**629.00**	**-**
Electronic feeder				
Present value	20,000.00	20,000.00	20,000.00	-
Replacement value	30,000.00	30,000.00	30,000.00	-
Feeding facilities				
Present value	-	10,235.37	65,000.00	2.00
Replacement value	-	13,192.19	60,000.00	2.00
Milking machine				
Fabricate				
Handling system				
Number of points	4.00	7.87	16.00	-
Present value	1,000.00	50,208.33	500,000.00	-
Replacement value	10,000.00	93,625.00	600,000.00	-
Milk tanks				
Number	-	1.83	4.00	1.00
Total capasity	1.00	4,184.15	20,000.00	-
Present value	2,200.00	41,860.87	180,000.00	-
Replacement value	12,000.00	75,218.75	200,000.00	-
AI equipment				
Present value	-	2,575.00	8,500.00	3.00
Replacement value	-	4,180.00	10,000.00	2.00
Power generator KW	11.00	22.60	45.00	-
Present value	-	9,866.67	65,000.00	9.00
Replacement value	-	12,266.67	65,000.00	6.00
Feeding equipment				
Present value	1,500.00	42,187.50	290,000.00	-
Replacement value	3,000.00	74,448.28	495,000.00	-
Irrigation equipment				
Present value	-	56,504.78	350,000.00	3.00
Replacement value	-	52,407.14	250,000.00	3.00
Bakkie/truck %	5.00	62.56	100.00	-
Present value	5,000.00	69,040.00	331,000.00	-
Present value dairy	700.00	43,600.00	331,000.00	-
Replacement value	50,000.00	155,823.50	600,000.00	-
Replacement value dairy	-	67,925.20	600,000.00	16.00
Tractors and implements %	2.00	80.89	100.00	-

Present value	10,000.00	111,372.34	650,000.00	-
Present value dairy	-	86,876.00	650,000.00	3.00
Replacement value	35,000.00	278,156.22	1,600,000.00	-
Replacement value dairy	-	128,321.98	1,200,000.00	18.00
Workshop equipment %	1.00	56.41	100.00	-
Present value	300.00	10,233.33	50,000.00	-
Present value dairy	-	5,517.30	50,000.00	9.00
Replacement value	1,000.00	16,249.96	60,000.00	-
Replacement value dairy	-	4,449.99	60,000.00	25.00
Computer %	-	61.00	100.00	2.00
Present value	-	3,112.50	6,500.00	1.00
Present value dairy	-	983.20	5,000.00	27.00
Replacement value	-	7,131.58	12,000.00	1.00
Replacement value dairy	-	1,751.00	12,000.00	32.00
TOTAL EQUIPMENT (PRESENT)	26,500.00	300,203.70	1,374,000.00	-
TOTAL EQUIPMENT (REPLACEMENT)	-	383,175.18	2,155,800.00	16.00
GROSS VALUE OF PRODUCTION	**66.00**	**361.93**	**629.00**	-
PRODUCT INCOME				
Milk price in R/liter	0.80	1.24	1.52	-
Quantity of milk delivered	2,504.00	582,506.54	2,372,500.00	-
Value of milk delivered	2,003.20	759,466.26	3,179,150.00	-
Quantity of milk for household consumption	365.00	1,832.60	9,125.00	-
Value of milk for household consumption	-	2,181.96	11,497.50	1.00
Quantity of milk for labourers	-	7,065.81	28,500.00	1.00
Value of milk for labourers	-	7,662.27	37,050.00	8.00
Quantity of milk for calves	-	15,299.75	43,800.00	1.00
Value of milk for calves	-	13,841.59	55,890.00	15.00
Quantity milk privately sold	-	18,817.57	108,000.00	2.00
Value of milk privately sold	1.26	27,033.48	189,000.00	-
Total quantity of milk	21,455.00	606,663.83	2,382,355.00	-
Value of milk	22,527.75	789,099.44	3,192,355.70	-
TRADING INCOME				
LIVESTOCK SOLD				
Number of cows	-	19.93	84.00	1.00
Value per cow	-	21,001.37	410,944.00	1.00
Total value of cows	-	49,801.58	410,944.00	10.00
Number of heifers	-	7.78	20.00	1.00
Value per heifer	-	24,192.83	200,000.00	1.00
Total value of heifers	-	7,524.96	200,000.00	42.00
Number of calves	-	33.07	100.00	1.00
Value per calf	25.00	757.83	7,500.00	-
Total value of calves	-	11,807.58	150,000.00	22.00
Number of bulls and oxen	1.00	24.58	95.00	-
Value per bul and ox	70.00	4,750.65	40,000.00	-
Total value of buls and oxen	-	7,682.45	60,000.00	31.00
TOTAL VALUE OF LIVESTOCK SOLD	-	76,816.57	614,944.00	4.00
LIVESTOCK PURCHASED				
Number of cows	8.00	24.86	100.00	-
Value per cow	2,350.00	3,623.08	6,000.00	-
Total value of cows	-	11,440.32	300,000.00	43.00
Number of heifers	2.00	3.50	5.00	-
Value per heifer	860.00	3,180.00	5,500.00	-

Total value of heifers	-	584.40	27,500.00	48.00
Number of calves				
Value per calf				
Total value of calves	-	-	-	50.00
Number of bulls and oxen	1.00	1.00	1.00	-
Value per bul and ox	800.00	2,700.00	5,000.00	-
Total value of buls and oxen	-	216.00	5,000.00	46.00
TOTAL VALUE PURCHASED	-	12,240.72	300,800.00	39.00
SLAUGHTERED				
Number for household	1.00	1.89	3.00	-
Value for household	1,350.00	3,255.26	7,000.00	-
Number for labourers	-	4.73	25.00	1.00
Value for labourers	-	9,363.33	75,000.00	1.00
Value slaughtered	-	4,128.57	75,000.00	26.00
OTHER INCOME				
EXPENCES	**66.00**	**361.93**	**629.00**	-
DIRECTLY ALLOCATED COST				
SELF PRODUCED FEED				
Concentrates quantity	-	132.50	450.00	1.00
Concentrates total	-	41,292.86	192,500.00	1.00
Hay quantity	38.00	1,662.17	8,000.00	-
Hay total	1,650.00	41,681.12	189,200.00	-
Silage quantity	-	2,462.50	12,000.00	1.00
Silage total	-	62,050.00	240,000.00	1.00
Pastures total	-	62,398.84	253,693.00	1.00
Total other such as rests and groundnut hay	-	22,373.45	120,000.00	3.00
Total self produced feed	-	126,939.96	380,000.00	1.00
PURCHASED FEEDS				
Concentrates quantity	-	13,858.14	275,000.00	2.00
Concentrates total	-	335,968.19	1,440,000.00	1.00
Hay quantity	10.00	202.74	480.00	-
Hay total	1,350.00	100,470.93	397,000.00	-
Silage quantity	-	105.00	180.00	2.00
Silage total	-	32,400.00	70,000.00	2.00
Licks and minerals quantity	-	2,964.15	20,000.00	2.00
Licks and minerals total	240.00	8,505.23	29,976.00	-
Milk surrogates quantity	-	3,185.71	25,410.00	2.00
Milk surrogates total	-	24,249.11	172,900.00	1.00
Self produced milk for calves	-	14,124.07	55,890.00	14.00
Total purchased feeds and surrogates	2,007.50	362,735.95	1,636,800.00	-
Total feeds	19,832.00	489,675.91	1,856,800.00	-
Vet and medicine	600.00	26,181.48	101,500.00	-
AI cost	-	20,651.57	84,000.00	2.00
Wash and sterilising agents	400.00	8,157.89	42,000.00	-
Rent of milk tank				
Marketing cost of livestock	128.00	5,699.54	25,412.00	-
Sundry (telephone, milk recording etc)	100.00	5,743.22	50,000.00	-
TOTAL VARIABLE COST	21,132.00	544,982.32	2,021,300.00	-
NON DIRECT ALLOCATED COST				
LABOUR (excluding hired management)				
Number of full day labourers	-	7.12	28.00	1.00
Cash receipts and bonuses	1,800.00	47,741.87	276,000.00	-

Rations (excluding milk and meat from dairy)	768.00	7,294.56	44,750.00	-
Other (for example medical, clothes etc)	50.00	2,908.80	13,500.00	-
Farm produce labour	-	10,471.27	112,050.00	6.00
TOTAL LABOUR	-	64,320.27	316,103.00	1.00
Hired management (Salary and benefits)	12,000.00	24,290.50	48,000.00	-
Rent for dairy animals	-	-	-	1.00
Electricity	80.00	14,180.79	77,000.00	-
Fuel and lubricants (excluding production of feed)	150.00	9,605.13	48,000.00	-
MAINTENANCE AND REPARATIONS				
Milk equipment	100.00	7,764.28	35,000.00	-
Tools, implements and equipment	-	16,977.80	118,000.00	1.00
Fixed improvements	-	7,163.57	79,160.00	2.00
Insurance and licences	-	7,036.86	65,500.00	1.00
TOTAL FIXED COST	3,550.00	123,193.46	602,103.00	-
DEBT				
Bank overdraft %	17.50	19.67	22.50	-
Bank overdraft amount	-	103,203.17	299,152.00	1.00
Interest on bank overdraft	-	7,369.34	56,261.60	32.00
Account at trade creditors %	17.00	20.66	27.00	-
Trade creditors amount	26,400.00	84,256.83	264,682.00	-
Interest trade creditors	-	2,703.32	48,966.17	42.00
Land interest %	17.00	18.88	24.00	-
Land amount	13,800.00	203,423.75	450,000.00	-
Interest on land	-	9,159.90	78,750.00	38.00
Fixed improvements interest %	20.00	20.00	20.00	-
Fixed improvements amount	100,000.00	100,000.00	100,000.00	-
Interest on fixed improvements	-	400.00	20,000.00	49.00
Equipment interest %	17.50	20.12	22.00	-
Equipment amount	10,000.00	180,592.43	694,741.00	-
Interest on equipment	-	9,873.37	138,948.20	37.00
Dairy herd interest %	10.00	19.60	24.00	-
Dairy herd amount	30,000.00	104,000.00	190,000.00	-
Interest on dairy herd	-	1,812.00	26,400.00	45.00
Carry over debt interest %				
Carry over debt amount				
Interst on carry over debt	-	-	-	50.00
TOTAL INTEREST	-	31,317.94	214,553.26	26.00
ALGEMEEN				
GENERAL INFORMATION	**66.00**	**361.93**	**629.00**	**-**
Average number of cows in herd	13.00	117.31	298.00	-
Average number of cows in milk	11.00	92.04	225.00	-
Ha for dairy	10.00	277.56	950.00	-
Liter milk/year	21,455.00	606,663.83	2,382,355.00	-
Number of labourers	-	6.69	28.00	4.00
CAPITAL INVESTMENT				
Land	16,000.00	413,520.43	1,428,000.00	-
Fixed improvements	15,000.00	271,494.70	1,520,500.00	-
Land and fixed improvements	34,500.00	685,015.13	2,250,500.00	-
Land and fixed improvements per ha	878.99	3,717.22	19,446.43	-
Equipment and machinery	26,500.00	300,203.70	1,374,000.00	-

Livestock	55,450.00	635,980.44	1,804,500.00	-
TOTAL INVESTMENT	170,250.00	1,621,199.27	4,480,500.00	-
LIABILITIES				
Short term	-	67,695.10	553,203.00	25.00
Medium term	-	62,965.88	794,741.00	32.00
Long term	-	48,821.70	450,000.00	38.00
TOTAL LIABILITIES	-	179,482.68	1,135,404.00	23.00
GROSS VALUE OF PRODUCTION	104,156.25	104,156.25	104,156.25	-
Product income	22,527.75	789,099.44	3,192,355.70	-
Trading income	(15,920.00)	94,191.45	431,794.00	1.00
Other	-	-	-	50.00
TOTAL: GROSS VALUE OF PRODUCTION	34,391.20	883,290.90	3,485,855.70	-
VARIABLE COST				
FEEDING				
Self produced	-	126,939.96	380,000.00	1.00
Purchased	2,007.50	362,735.95	1,636,800.00	-
TOTAL FEEDING	19,832.00	489,675.91	1,856,800.00	-
VET AND MEDICINE	-	25,134.22	101,500.00	2.00
AI COST	-	15,282.16	84,000.00	15.00
WASH AND STERILISING	-	7,668.42	42,000.00	3.00
RENT OF MILK TANK	-	-	-	50.00
MARKETING COST	-	1,937.84	25,412.00	33.00
SUNDRY	-	5,283.76	50,000.00	4.00
TOTAL VARIABLE COST	21,132.00	544,982.32	2,021,300.00	-
FIXED COST				
LABOUR				
Cash	-	45,832.20	276,000.00	2.00
Rations (including farm produce)	-	16,161.03	118,050.00	2.00
Other	-	2,327.04	13,500.00	10.00
TOTAL LABOUR COST	-	64,320.27	316,103.00	1.00
Electricity	-	11,750.31	77,000.00	5.00
Fuel and lubricants	-	8,644.62	48,000.00	5.00
MAINTENANCE AND REPARATIONS				
Milking equipment	-	7,453.70	35,000.00	2.00
Fixed improvements	-	6,303.94	79,160.00	8.00
Equipment, implements, tractors etc	-	14,600.91	118,000.00	8.00
Insurance and licences	-	6,192.44	65,500.00	7.00
TOTAL FIXED COST	3,550.00	119,266.20	602,103.00	-
FOREIGN FACTOR COST (FFC)				
Rent on land	18,000.00	49,221.33	107,664.00	-
Rent on livestock	-	-	-	50.00
Hired management	-	2,914.86	48,000.00	44.00
INTEREST PAYABLE ON:				

Short term liabilities	-	10,072.67	105,227.77	29.00
Medium term liabilities	-	12,085.37	160,948.20	33.00
Long term liabilities	-	400.00	20,000.00	49.00
TOTAL INTEREST	-	22,558.04	185,968.10	26.00
TOTAL FOREIGN FACTOR COST	-	28,426.18	268,612.20	24.00
PROFITABILITY ANALYSIS				
GROSS VALUE OF PRODUCTION	34,391.20	883,290.90	3,485,855.70	-
VARIABLE COST	21,132.00	544,982.32	2,021,300.00	-
MARGIN ABOVE FEED COST	(102,588.00)	393,614.98	1,629,055.70	-
GROSS MARGIN	(149,588.00)	338,308.57	1,464,555.70	-
FIXED COST	3,550.00	119,266.20	602,103.00	-
TOTAL COST (EXCLUDING FFC)	30,931.00	664,248.52	2,284,134.50	-
NET FARM INCOME	(175,228.00)	219,042.38	1,201,721.20	-
FOREIGN FACTOR COST	-	28,426.18	268,612.20	24.00
FARM PROFIT	(216,528.00)	190,616.20	1,093,136.20	-

ANNEXURE B: EVIEWS 3.1 SYSTEM ESTIMATION METHODS

This Annexure outlines the System Estimation Methods utilised in the EViews Version 3.1 software, which has been applied in this study.

Ordinary Least Squares

- Minimizes the sum-of-squared residuals for each equation in the system.
- Accounts for any cross-equation restrictions on the parameters of the system.
- If there are no such restrictions, the method is identical to estimating each equation using single-equation ordinary least squares.

Cross-Equation Weighting

- Accounts for cross-equation heteroskedasticity by minimizing the weighted sum-of-squared residuals.
- The equation weights are the inverses of the estimated equation variances, and are derived from unweighted estimation of the parameters of the system.
- This method yields identical results to unweighted single-equation least squares if there are no cross-equation restrictions.

Seemingly Unrelated Regression

- Estimates the parameters of the system, accounting for heteroskedasticity, and contemporaneous correlation in the errors across equations.
- Estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system.
- EViews estimates a more general form of SUR than is typically described in the literature, since it allows for cross-equation restrictions on parameters.

Weighted Two-Stage Least Squares

- The weighted two-stage least squares (WTSLS) estimator is the two-stage version of the weighted least squares estimator.

- WTSLS is an appropriate technique when some of the right-hand side variables are correlated with the error terms, and there is heteroskedasticity, but no contemporaneous correlation in the residuals.
- EViews first applies TSLS to the unweighted system, enforcing any cross-equation parameter restrictions.
- Results from this estimation are used to form equation weights, based upon the estimated equation variances.
- If there are no cross-equation restrictions, these first-stage results will be identical to unweighted single-equation TSLS.

THREE-STAGE LEAST SQUARES

- Three-stage least squares (3SLS) is the two-stage least squares version of the SUR method.
- It is an appropriate technique when right-hand side variables are correlated with the error terms, and there is both heteroskedasticity, and contemporaneous correlation in the residuals.
- EViews applies TSLS to the unweighted system, enforcing any cross-equation parameter restrictions.
- These estimates are used to form an estimate of the full cross-equation covariance matrix that is used to transform the equations to eliminate the cross-equation correlation. TSLS is applied to the transformed model.

FULL INFORMATION MAXIMUM LIKELIHOOD (FIML)

- Full Information Maximum Likelihood (FIML) estimates the likelihood function under the assumption that the contemporaneous errors have a joint normal distribution.
- Provided that the likelihood function is correctly specified, FIML is fully efficient.

GENERALIZED METHOD OF MOMENTS (GMM)

- Belongs to a class M-estimators that are defined by minimizing some criterion function.
- GMM is a robust estimator in that it does not require information of the exact distribution of the disturbances.
- GMM estimation is based upon the assumption that the disturbances in the equations are uncorrelated with a set of instrumental variables.
- Estimator selects parameter estimates so that the correlations between the instruments and disturbances are as close to zero as possible, as defined by a criterion function.

- By choosing the weighting matrix in the criterion function appropriately, GMM can be made robust to heteroskedasticity and/or autocorrelation of unknown form.
- Many standard estimators, including all of the system estimators provided in EViews, can be set up as special cases of GMM.