Contracts in cattle production in Ghana: their nature, and effects on input use and technical efficiency G.Y. Ameleke 2018

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Godwin Yao Ameleke

Propositions

1. Only fixed-wage contracts will ensure the significant intensification of cattle production.

   (this thesis)

2. A kraal owner's education stifles efficiency in cattle production rather than promoting it.

   (this thesis)

3. If developing countries learn from their history, their development will be faster.

4. The quest for ever increasing efficiency in animal production can be more harmful than beneficial for human health.

5. Most African states are only concerned with science education, while they do not care about generating indigenous scientific knowledge.

6. The worst enemy of economic development is impunity.

Propositions belonging to the thesis, entitled: Contracts in cattle production in Ghana: their nature, and effects on input use and technical efficiency

Godwin Yao Ameleke

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Contracts in cattle production in Ghana: their nature, and effects on input use and technical efficiency

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Dedicated to the memory of my late father, Ben Ameleke

Table of Contents

CHAPTER 1

General introduction

1.1 Background

Rising incomes and urbanization in developing countries are increasing the demand for food especially meat and milk (Delgado, 1999). It poses the need to increase the output of animal products. Productivity levels in existing livestock production systems are typically low in developing countries, thus attempts to increase meat and milk production require steps to improve farm efficiency and productivity. In Ghana, cattle contributes the largest portion (at least a half) of the total economic value of livestock raised by households (GSS, 2008, GSS, 2014). Therefore, improvements in cattle production can contribute significantly to satisfying the growing demand for animal products.

Cattle production in Ghana is based predominantly on extensive systems which depends on minimal housing and grazing on natural pasture (Oppong-Anane, 2006). Often, cattle in a kraal are owned by multiple owners. According to Oddoye (2001), in some parts of the Accra Plains one person owned all cattle in less than a third of all kraals, two to five people owned cattle in at least half of the kraals, and more than five people owned cattle in the rest of the kraals. Cattle productivity under this production system is linked to factors like the natural environment, including rainfall patterns and cattle breeds, how production is organised, production practices, and motives for keeping cattle. A description of these features of the production system is provided in the next paragraphs.

Generally, indigenous breeds of cattle are kept. These breeds include the West African Short Horn (WASH) and a cross between the WASH and zebu breeds, which is known as Sanga (Otchere and Okantah, 2001). The Sanga has become an established breed in its own right. Attempts by the state to introduce exotic breeds such as the Friesian and Jersey have not been successful due to their ill-adaptation to the tropical climatic conditions. Local breed improvement, using semen from exotic breeds, has also been tried. However, this has not been successful. The resulting cross-breeds have to be under intensive production systems, but most farmers are unable to deal with this.

Herd sizes are generally small and range between 10 to 50 head in northern Ghana and 50 to 200 head in southern Ghana (Otchere and Okantah, 2001). The herd owner, who may be the household head if the cattle belongs to a family, usually constructs a kraal, an enclosure in which cattle are kept, or acquires appropriate space for the cattle to pass the night. Often, the kraal is close to the herd owner or kraal owner's compound. During the day, the cattle are herded to the rangeland or natural pastures to graze. In Ghana, the extensive system is largely sedentary and agro-pastoral with limited transhumance (Otchere and Okantah, 2001). The kraal owner uses either family labour or hired labour to herd the cattle in the rangeland; he himself prefers to work on his crop farm, especially during the farming season. In return for providing herding services, the herdsman receives remuneration in kind or cash or both. In-kind rewards include entitlement to milk, food provisions, and periodic award of a heifer. The kraal owner performs an overall managerial function by making decisions regarding breeding and input use, and hiring and supervision of herdsmen. External input use is low in the extensive production system, but efforts are made to acquire veterinary drugs and vaccines for disease and parasite control.

Other people who want to keep cattle, but do not have the space or labour to keep them, entrust their cattle with herd owners who already have a kraal and the required labour force. Cattle owners keeping their cattle with a kraal owner come to certain agreements regarding the duties of the kraal owner and the remuneration he may receive. The latter includes share of calves and cash. People who entrust their animals to a kraal owner for upkeep may be relatives, friends or complete outsiders. Often, they are public and civil servants who reside in urban areas. They wish to keep cattle as a form of saving or store of wealth to be used as security for emergencies or as security towards their pension. They may visit the kraal occasionally to see how their cattle are doing.

Production under the extensive system sometimes is market oriented. Young bulls may be removed from the herd to further grow and fatten them for the market. Cattle owners often target seasonal markets, which occur during festive occasions when demand for fattened bulls is high. Crop residues and by-products from agro-processing are used to feed the bulls. Crop residues are also fed to animals when natural pasture is scarce, especially during the dry season in areas where livestock population is dense (Karbo and Agyare, 2002, Konlan et al., 2015). Milk generally is a by-product of cattle production, since the local breeds have low milk yield. However, it is an important source of food for many herdsmen for whom it is a major component in their family's diet. Surplus milk is sold fresh or processed into cottage cheese (*wagashie*) for consumption at home or sale.

The Ministry of Food and Agriculture (MoFA) is the ministry of state that oversees issues related to animal production in the country. The ministry implements its activities through three key directorates: the Animal Production Directorate (APD), the Veterinary Services Directorate (VSD), and the Extension Services Directorate (ESD). The APD is generally responsible for implementing government policy on livestock, breed improvement, forage and pasture development and stock water development, while the VSD deals with disease control, vaccine production and laboratory services. The ESD is responsible for agricultural technology diffusion. The ministry collaborates with the country's universities and research institutions to perform its mandate.

1.2 Problem statement

As indicated earlier, three key actors are engaged in extensive cattle production: the kraal owner, the cattle owner, and the herdsman. The kraal owner is at the centre and has contractual arrangements with the other two parties. These arrangements have several implications for cattle production. First, they provide incentives for the parties to apply their best effort. Second, they provide incentives for the use of material inputs and thereby influence productivity and efficiency in cattle production. The general questions that arise from this perspective include the following: What is the nature and what are the drivers of the contracts in cattle production in Ghana? What is the impact of the contract conditions on input use and efficiency of cattle production?

Unfortunately, the study of contracts in relation to incentive problems in livestock production in developing countries is scanty. Studies concerning agricultural contracts abound, but the bulk of these focus on sharecropping (Allen and Lueck, 2004, Allen, 1985, Basu, 1992, Braverman and Stiglitz, 1986, Eswaran and Kotwal, 1985, Hallagan, 1978, Newbery, 1977, Sen, 2011, Sengupta, 1997, Shetty, 1988, Singh, 2000, Stiglitz, 1974). Insofar as contracts have been studied in relation to livestock production, many of the studies deal with production in developed countries and are often concerned with vertical integration or contract farming (Dries et al., 2009, Dries and Swinnen, 2004, Hennessy, 1996, Key, 2004, Reimer, 2006). This thesis uses mostly primary data to investigate the nature of contracts in cattle production in Ghana and their implications for productivity and efficiency. It contributes to several strands of the literature by examining the role of uncertainty and trust in the choice of implicit versus explicit contracts, the effect of contract type on long-term and short-term productivity-enhancing investment, and the efficiency in cattle production and its sources. Before stating the thesis' specific research questions, we present a brief overview of the relevant literature.

A contract may be defined as an agreement between parties regarding exchange of goods and services. Thus, contracts can be made for labour services, land, material inputs, and goods. Contracts relating to labour can take the form of an agreement between an employer and an employee, and contracts relating to land include land rental arrangements. In contract farming, investors usually supply material inputs to farmers to produce goods such as crops and livestock for them, and they buy the goods from farmers once these are harvested. Contracts can differ with respect to their duration and the form of remuneration. Contract duration can be classified as short term or long term. The remuneration of a performer, hired by an employer or owner of an asset, can be a fixed amount in cash or in kind, a variable amount that depends on performance, or a combination of the two. Alternatively, an asset owner can rent his asset to a tenant to operate it, keep the proceeds, and pay him a fixed rent. An asset owner could also allow a tenant on his asset to operate the it, and they both share the output. For instance, in crop agriculture, a landowner can cultivate his land all by himself, or hire labour for all or some the tasks on the land and pay him a fixed wage. The land owner may also hire a tenant to operate the land and collect a fixed rent from him (tenant), or share output with him. Accordingly, we could have a fixed-wage contract, fixed-rent contract, or sharecropping contract between a land owner and another party who operates the land. Contracts often require exchange of information between parties. Yet, there can be asymmetry in this information: one party may not have full information about the other. In particular, it may be too costly or even impossible for a party to verify whether the other gave his best effort. Environmental uncertainties contribute to the difficulty of verifying if any shortfall in performance could be due to low effort, inadequate material inputs, or environmental shocks.

Contracts have been analysed within different frameworks, including principal agent theory, transaction cost theory, and property rights theory (Kim and Mahoney, 2005). The focus of each theory is different. Principal agent theory recognizes the problem of information asymmetry that could hamper a principal. It studies the creation of incentives that would lead agents to give their best, so that the principal can maximize his payoffs. Transaction cost theory acknowledges the incomplete nature of contracts arising from bounded rationality (limitations on information, cognitive ability, and time to take decision). It studies governance structures that can deal with problems arising from issues such as information asymmetry, asset specificity, and opportunism (Williamson, 1989). Cost is incurred when these governance structures are put in place and operated. Thus, transaction cost economics involves the comparison of the costs of alternative governance structures. In the case of opportunism, monitoring measures may be instituted to reduce it. Alternatively, contractors or principals can take steps to build trust or forge deeper relationships with parties to increase their chances of being trustworthy (Ensminger, 2001). Property rights theory is concerned with the ownership, use and transfer rights to assets. When property rights are not clearly defined or are insecure, it leads to externalities (costs or benefits emanating from economic activity that affect someone who did not take part in the activity). Thus, when such costs are not borne, or benefits are not appropriated by the parties generating them, the level of economic activity will be such that social welfare is not maximized. Consequently, property rights theory seeks to find the allocation of property rights that will maximize social welfare and minimize distributional conflicts.

Explanations that have been given for the influence of contracts on input use or investment include Marshallian inefficiency and insecurity of property rights. Marshallian inefficiency arises when a party undersupplies input to a production process. This could be because the party receives only a fraction of the marginal product contributed by the input. Thus, share contracts are predicted to be inefficient. Insecurity of property rights implies that parties are not sure whether they are able to appropriate the benefits arising out of their investment. For instance, land tenancy arrangements in which a tenant can be evicted before all the benefits accruing from his investment, in say soil conservation measures, have been realised by him, will discourage the tenant from making such investments (Banerjee and Ghatak, 2004). Distinction has also been made between long-term and short-term productivity-enhancing inputs or investments (Abdulai et al., 2011, Beekman and Bulte, 2012, Besley, 1995). Hence, it is expected that contract types will influence the use of these inputs differently.

Efficiency of a production process connotes the avoidance of waste. This can be achieved by minimizing the level of inputs used to produce a given output, or by maximizing output with given levels of inputs (Fried et al., 2008). Various methods have been used to measure efficiency, including parametric and non-parametric methods. The latter include Data Envelopment Analysis, which involves mathematical programming, while parametric methods include Deterministic and Stochastic Frontier analysis and make use of econometric methods. Stochastic Frontier Analysis allows the simultaneous estimation of the efficiency and its determinants (Battese and Coelli, 1995).

Most of the current knowledge on contractual arrangements in cattle production, especially arrangements between kraal owner and herdsmen, comes from the Anthropology and Geography literature on pastoralists. Studies on West Africa have focused on the Fulbe (Fulani) pastoralists and dealt with several issues: the relationship between herding arrangement and range management or productivity, the shift in ownership of livestock from pastoralists to other people (Turner, 2009, Turner and Hiernaux, 2008), conflicts between herdsmen and farmers (Bassett, 1994, Moritz, 2010, Tonah, 2003, Tonah, 2006), and the link between livestock transfers and social security (Dijk, 1994). Nevertheless, a lot remains to be learned about the nature of contractual arrangements in cattle production in tropical Africa. For instance, what are the types of agreements reached? What are the terms of these agreements and how might they lend themselves to analysis using contract theory?

Several factors have been shown to influence agrarian contracts that ultimately influence productivity. These include risk and incentives (Newbery, 1977, Stiglitz, 1974), hidden information (Hallagan, 1978), moral hazard (Eswaran and Kotwal, 1985, Reid, 1976), limited liability (Basu, 1992, Shetty, 1988), and transaction cost (Allen and Lueck, 1993). Yet, most of these studies have focused on contracts in crop agriculture. Little attention has been devoted to the study of contracts in livestock production especially in developing countries. However, it has been noted that contracts in livestock production are plagued with moral hazard (Binswanger and McIntire, 1987). Often these problems are ameliorated by high levels of trust and long-term relationships (Ensminger, 2001). Whereas in developed countries contracts are more formal, written and governed by formal legal procedures, in developing countries they are mostly informal, verbal and governed by social norms. A recent contribution by Tadesse et al. (2016) investigated factors that influence participation and choice of contracts in Ethiopia. They showed that contracts in cattle production enable rural communities and households to deal with imperfection in land, labour, credit and insurance markets. However, their analysis is based on only two key players in livestock production: the livestock tenant and the livestock lord, akin to the tenant and landowner in the land rental market. In this thesis, we consider three key players: the herdsman, the kraal owner and the cattle owner. This could mean the existence of a wider variation in contracts that need to be looked at. Additionally, the agroecological differences between Ethiopia and Ghana imply differences in resource endowments and environmental uncertainties, which could shape livestock contracts differently in the two countries.

Contracts are important because they influence incentives for the supply of inputs. Several studies have tested the theoretical prediction that share contracts are less efficient than fixed-rent contracts or owner cultivation (Deininger et al., 2013, Ghebru and Holden, 2015, Jacoby and Mansuri, 2009, Laffont and Matoussi, 1995, Shaban, 1987). However, the superiority of fixed-rent contracts and owner cultivation over sharecropping is mixed. Studies that differentiate between inputs or investments that are long-term or short-term productivity-enhancing have shown that contract types influence these categories of inputs or investments differently (Abdulai et al., 2011, Beekman and Bulte, 2012). Generally, contract types or land tenure arrangements that enhance tenure security are more likely to engender long-term productivity-improving investment than short-term productivity improving investment. Nevertheless, the evidence so far is related to land productivity-improving investments. Will the story be the same for livestock productivity-improving investments?

As mentioned earlier, in order to increase production of animal products one of the steps required is to improve efficiency of production. Thus, it is critical that the levels of inefficiency in livestock production and their sources are identified. There is a lot of literature on efficiency studies of developing countries' agriculture. Yet, the bulk of these studies are related to crop production (Ahmed et al., 2002, Bravo-Ureta and Pinheiro, 1993, Helfand and Levine, 2004, Thiam et al., 2001). Nevertheless, there is an emerging economic literature on livestock production in tropical Africa, though at the moment this is still scanty (Otieno et al., 2014, Temoso et al., 2015). The role of contract type as a source of technical inefficiency, especially regarding livestock production, has hardly been investigated. Furthermore, the few studies that have investigated technical efficiency in cattle production in Africa have used data from the eastern and southern parts of the continent.

From the foregoing the following questions can be raised: First, what is the nature of the contracts in cattle production in Ghana? Second, what factors drive these production contracts? Third, what are the incentive effects of contracts on input use in cattle production? Fourth, how efficient is cattle production in Ghana and what are the sources of inefficiency?

1.3 Objectives of the study

The primary objective of the study is to identify contract types, explain their existence, analyse the effects of contract types on incentives for input use and, more generally, efficiency in cattle production in Ghana. The specific objectives include the following:

- To ascertain the nature of contracts in cattle production and explain their occurrence.
- To analyse the influence of potential production loss, trust, and risk aversion on the choice of implicit versus explicit contracts in cattle production.
- To analyse the influence of contract types on input use.
- To estimate technical efficiency in cattle production and ascertain its sources.

1.4 Study Area

We consider cattle production contracts under different agro-ecological conditions. Six agro-ecological zones occur in Ghana: the Rain Forest, Deciduous Forest, Forest to Savannah Transitional zone, Coastal savannah, Guinea savannah and the Sudan savanna (Fig 2.1). Among these zones, the Guinea, Sudan and Coastal savannah zones and the Transitional zone, are well known for cattle production. Rainfall amounts and distribution in the zones vary. The Transitional zone has the highest annual rainfall amount followed by the Guinea , the Sudan and the Coastal savannah (MOFA, 2013). Compared to the Guinea and Sudan savannah zones which have unimodal rainfall distribution, the Transitional and the Coastal zones have bimodal rainfall distribution. The Guinea and Sudan savannah have more dry months than the Transitional zone and Coastal savannah. In the Guinea and Sudan savannahs, rainfall usually starts from April and ends in September. In the zones with bimodal rainfall, the major rains typically occur from April to July and the minor season rains occur from September to October. The varying number of dry months and rainfall distribution in each zone leads to differences in environmental uncertainty, which in turn results in production risk differences.

1.5 Methodology

The study employs an empirical methodology to answer the research questions and address its objectives. Primary data was collected and combined with complementary data from experiments and secondary sources. The specific methodological designs and empirical strategies that were used to address the objectives are as follows:

Question 1: What is the nature of contracts in cattle production in Ghana?

To ascertain the nature of contracts in cattle production in Ghana, we conducted a survey of kraal owners, cattle owners, and herdsmen linked to kraals in 11 districts in Ghana. These districts were spread across four agro-ecological zones prominent for cattle production. About 342 kraals from over 50 villages in the 11 districts were sampled in total. Responses were elicited from all actors regarding their duties and remunerations. Contracts were characterised by type of remuneration, as duties were standard. Additionally, drivers of these contracts were discussed based on established contract theories. The survey of individuals associated with kraals (the sampling unit) allowed the collection of data from representative kraals and generated quantitative information such as the distribution of contract types.

Question 2: What is the role of potential production loss, trust, and risk aversion on implicit contract choice?

To analyse the influence of potential production loss, trust, and risk aversion, we formulated a model to derive hypotheses regarding the influence of these variables on the choice of contract type. We distinguished between implicit and explicit contract. In implicit contracts, the kraal owner's remuneration was not specified in advance, but was dependent on future production outcomes. In explicit contracts, the kraal owner's remuneration was specified in advance. Then, we combined experimental and survey data to investigate the role of trust, potential production loss, and risk aversion on the choice for implicit contracts. We played trust games between cattle owners and kraal owners in two agro-ecological zones to measure generalised trust of the participants regarding other people in their communities. Unlike survey-based measures of trust, which say how people will behave given certain situations, experimental methods allow the measurement of trust based on actual behavior (Glaeser et al., 2000). We estimated a series of categorical choice models to establish the relationship between the choice of contract type on the one hand and trust, potential production loss, and risk aversion on the other.

Question 3: What are the incentive effects of contracts on input use in cattle production?

To analyse the influence of contract type on input use, we modelled cattle production as a dynamic process in which inputs could be classified as short-term or long-term productivity-enhancing. We showed that contracts influence use of the two types of inputs differently. Next, we used survey data to investigate the effect of contract type on input use. We regressed short-term and long-term productivity-enhancing inputs on contract type. Noting that contract type could be endogenous, we searched for valid instruments but failed to find one. Thus, we considered the relationships estimated as correlational and not causal. Nevertheless, movements in coefficients and R^2 values indicated that the results were mostly not driven by omitted variable bias. Distinguishing between short-term and long-term productivity-enhancing inputs and identifying the influence of contract type on them is useful. It makes possible the targeting of measures to improve short-term and long-term productivity.

Question 4: What are the levels and sources of efficiency in cattle production?

To ascertain the levels and sources of technical efficiency, we employed stochastic frontier analysis, introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977). We used cross-sectional survey data augmented with secondary data on some independent variables for our analysis. The stochastic frontier approach (SFA) accounts for noise and allows the simultaneous estimation of efficiency and their sources (Battese and Coelli, 1995). Generally, the SFA is preferred to Data Envelopment Analysis (DEA), an alternative method for estimating efficiency, since the latter does not account for noise nor estimate efficiency and its sources simultaneously. Knowledge of efficiency levels and their sources are important in formulating strategies to address possible low efficiency levels in various production processes.

1.6 Outline of thesis

The rest of the thesis is organised as follows. Chapter 2 lays the foundation for the remaining chapters by characterising contract types in cattle production and investigating factors that shape them. Chapter 3 then proceeds to investigate the influence of factors including trust, potential production loss, and risk aversion on the choice of implicit contracts. In Chapter 4, we analyse the influence of contact type on input use in cattle production. Chapter 5 estimates efficiency levels in extensive cattle production and continues to investigate the sources of efficiency. Chapter 6 provides the key conclusions and general discussion of the findings.

CHAPTER 2

The nature and drivers of contracts in cattle herding and management: the case of Ghana

ABSTRACT

We study the nature of contracts in cattle production and explain their existence in specific locations using agency and transaction cost theory. In their study of pastoral groups, especially those in West Africa, anthropologists have referred to contracts in cattle production including herding contracts. However, few studies have analysed these contract types with the view of explaining their existence. We found two categories of contracts: cattle owner – kraal owner (CK) contracts and kraal owner - herdsman (KH) contracts. Contracts in each of these two categories can be explicit, with the reward given by the cattle owners to kraal owners explicitly specified, or implicit and unspecified. The existence of CK contracts are explained both in terms of agency theory (risk and incentive tradeoffs) and transaction cost theory (low specificity of production assets, environmental uncertainty, and monitoring cost). We also found that difficulty in measuring performance and monitoring cost associated with curbing herdsman's opportunism and hidden information regarding herdsmen's skills provide explanations for the existence of KH contracts.

Key words: cattle production, cattle owners, kraal owners, herdsmen, contracts, transaction cost, agency theory

2.1 Introduction

Contracts in agricultural production are important worldwide including Sub-Saharan Africa. For the parties involved, they may provide incentives that influence productivity and investment decisions. Such productivity may be indicated by crop output per hectare of land, average daily weight gain of livestock per kilogramme of feed intake, and daily milk yield per animal. Investment decisions may comprise land improvement, tree planting, pasture cultivation, construction of wells and dams, acquisition of farm houses, and farm equipment. In Sub-Saharan Africa, just as in other parts of the world, contracts occur both in crop production and livestock production. Crop production contracts, which often include land rental or land tenancy contracts, usually occur as share cropping, fixed-land rental, or fixed-wage contracts between a landlord and a tenant (Ackerberg and Botticini, 2002, Eswaran and Kotwal, 1985, Laffont and Matoussi, 1995, Sen, 2011). Livestock production contracts frequently occur as arrangements between livestock owners and herdsmen, and between livestock owners doubling as herd managers and other livestock owners.

Generally, three sets of studies have been conducted regarding contracts in crop production. The first set of studies are theoretical studies that try to explain why different contract types exist (Allen, 1985, Basu, 1992, Eswaran and Kotwal, 1985, Ghatak and Pandey, 2000, Hallagan, 1978, Muthoo, 1998, Newbery, 1977, Reid, 1976, Sen, 2011, Stiglitz, 1974). The second set of studies investigate the influence of contracts on productivity in crop production (Jacoby and Mansuri, 2009, Jahnke, 1982, Laffont and Matoussi, 1995, Shaban, 1987). The third set of studies investigates the link between contracts (or land use rights) and land improvement decisions in crop production (Abdulai et al., 2011, Goldstein and Udry, 2008, Place and Hazell, 1993, Zhang and Aboagye Owiredu, 2007).

In livestock production in Sub-Saharan Africa, knowledge on contracts has mainly come out of studies on pastoralists. Studies on West-Africa have focused on herding arrangements among the Fulbe (Fulani) pastoralists of the Semi-arid agro-climatic zone (Bassett, 1994, Dijk, 1994, Driel, 1999, Moritz et al., 2011, Turner, 2009, Turner and Hiernaux, 2008). Knowledge on herding contracts in the region has come from the study of four main issues: the link between herding arrangements and range management; the shift in ownership of livestock from pastoralists to other people, and its effect on rangeland productivity (Toulmin, 1992, Turner, 2009, Turner and Hiernaux, 2008); conflicts between herdsmen and farmers (Bassett, 1994, Moritz, 2010, Tonah, 2003, Tonah, 2006); and the link between livestock transfers and social security (Dijk, 1994).

There has been little research of contracts in livestock production regarding why contracts exist and what is their influence on livestock productivity and investment. Some explanation for the existence of cattle production contracts has been provided by Binswanger and McIntire (1987). They explain cattle entrustment in semi-arid, land-abundant areas, where a cattle owner entrusts his cattle into the care of another person, in terms of two factors. First is the need for transhumance. The cattle owner usually is a crop farmer too. He prefers to stay at home to cultivate his land, while other people herd his cattle in distant lands in search of pasture. Second is the economies of scale in herding larger numbers of animals. It makes a cattle owner willing to take the herds of his neighbours alongside his own to the grazing field in return for some reward. Binswanger and McIntire (1987) then predict how the institution of cattle entrustment will change as population density, external migration and trade increase. Another, more recent, contribution by Tadesse et al. (2016) shows that cattle sharing and rental contracts in Ethiopia are a response to imperfect credit and insurance services. In any case, given that there are only few studies on contracts in livestock production in Sub-Saharan Africa, more research could help to improve our understanding, especially under sedentary herding in the sub-humid zone in Sub-Saharan Africa including Ghana.

Also, studies on pastoralism in West Africa have tended to focus only on contracts between a herdsman and a kraal owner (Bassett, 1994, Tonah, 2003, Tonah, 2006). Yet often the kraal owner, as a cattle owner himself, is an intermediary between his herdsmen and one or more cattle owners who have animals in his kraal. Here the functions of a kraal owner are the same as those of a herd patriarch in Turner (1999), a herd manager in Turner and Hiernaux (2008), and an independent owner and intermediary in Moritz et al. (2011)[1]. By overlooking the kraal owner's intermediary role, the study of contracts between kraal owners and cattle owners who entrust their animals into the care of these kraal owners has largely been neglected so far. The kraal owner's role has simply been lumped together with herdsmen's role. In studying contracts, we think it is crucial to distinguish between kraal owner-herdsman contracts and cattle owner-kraal owner contracts, since these involve different sets of contractual arrangements that provide different sets of rules and incentives to the parties. Besides, different factors could be at play in defining the arrangements. For instance, risk aversion may influence the cattle owner-kraal owner contract to a greater degree than the kraal owner-herdsman contract.

The foregoing gives rise to the following questions. First, what is the nature of contracts in cattle production in Sub-Saharan Africa, drawing a distinction between the rights and obligations of herdsmen versus kraal owners and those of cattle owners versus kraal owners? Second, how can we explain contract types in cattle production using contract theory? In this study, we try to answer these questions for the case of Ghana. Specifically, we will describe the existing contracts in cattle production in Ghana, and examine how the structure and composition of cattle production contracts can be related to agency theory and transaction cost theory. For this we carried out surveys among kraal owners, herdsmen, and cattle owners in four main agro-ecological zones of Ghana.

The rest of this chapter is structured as follows. Section 2.2 provides an overview of cattle production in Ghana. Section 2.3 provides the conceptual framework of this study and reviews the major contract theories. Section 2.4 presents the methodology underlying the data collection. Section 2.5 presents the results of our surveys and Section 2.6 discusses them. Section 2.7 concludes.

2.2 Cattle production in Ghana

In Ghana, cattle production is done in different parts of the country using mainly a traditional or extensive system of production. Cattle is often owned by farmers and individuals engaged in other occupations. Thus, parties involved in production come to some agreements to enable production take place. Ghana lies in the Sub-humid agro-climatic zone and the functions of livestock in existing production systems vary. These functions could be the same or different from livestock functions in the Semi-arid agro-climatic zone of West Africa. The contribution of livestock to overall agricultural output in the economy is small, 1.3 percent in 2014 (GSS, 2015), but important. According to GSS (2014), over four million households in Ghana own livestock. These livestock provide valuable nutrients in the form of protein for households and manure and draught animal power for crop production, reduce income risk associated with crop failure, and facilitate accumulation of wealth to finance both planned and unplanned expenditure (Moyo and Swanepoel, 2010).

Cattle production is done mainly in the Guinea savannah, Sudan savannah, and the Coastal savannah, though the forest to savannah Transitional zone is becoming increasingly important for cattle production (Fig 2.1). The Guinea savannah zone corresponds approximately to three administrative regions in the

[1] We view the kraal owner, herd patriarch, and herd manager as the same when they serve as intermediaries between another cattle owner and a herdsman.

north of Ghana: Upper West region, Northern region, and Upper East region. The Sudan savannah zone is a relatively small area in the north-east corner of the Upper East Region. The Coastal savannah, which is in south of Ghana, stretches across three regions: Central Region, Greater Accra region, and Volta region, all of which are boarded to the south by the sea, Gulf of Guinea. The Transitional zone, which is in the middle of Ghana, comprises mainly the Brong-Ahafo region, but portions of it are the northern parts of Ashanti and Eastern regions. The proportions of total cattle population in the agro-ecological zones were 64% in the Guinea and Sudan zone, 15% in the Coastal savannah, and 10% in the Transitional zone, based on regional cattle population from the last livestock census conducted in 1996. Recent livestock population figures are projections of this data set, and we think the proportions of breeds have not changed much. All the cattle production zones in Ghana fall under the sub humid agro-climatic zone. By contrast, the major cattle production areas in West Africa fall within the semi-arid and climatic zone.

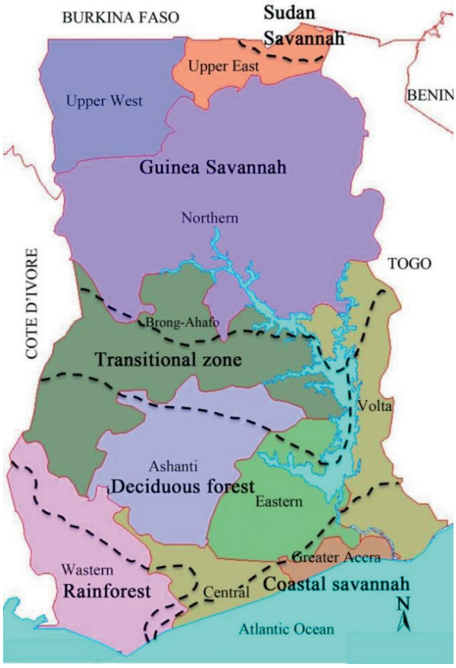

Fig 2.1: Agro-ecological zones and administrative regions of Ghana
Source: Kemausuor et al. (2013)

The agro-ecological zones have varying rainfall distribution and landscape. The mean annual rainfall and the number of rainy days in these zones support crop production (Table 2.1). Rainfall distribution is bimodal in the Transitional and Coastal savannah, leading to a major and minor season for crop farming. However, it is unimodal in the Guinea savannah and the Sudan savannah with a single cropping season. The Coastal savannah is characterised by low plains, particularly, the Accra plains. The Guinea and Sudan savannah also have extensive flat lands. The Transitional zone has a combination of forest and savannah. The southern part of this zone has a topography that is fairly rolling with valleys and peaks, while its northern portions consist of undulating and flat land. There are very low cattle numbers in the humid zone of Ghana (evergreen forest and deciduous forest) due to the incidence of trypanosomiasis, which adversely affects cattle production.

Table 2.1. Characteristics of agro-ecological zones of Ghana

Zone	Proportion of total land area (%)	Rainfall (mm)	Length of major season (days)	Length of minor season (days)	Dominant land use systems	Main food crops
Evergreen Forest	3	2200	150-160	100	Forest, plantations	Roots, plantain
Deciduous Forest	3	1500	150-160	90	Forest, plantations	Roots, plantain
Transitional zone	28	1300	200-220	60	Annual food and cash crops	Maize, roots, plantain
Coastal Savannah	2	800	100-110	50	Annual food crops	Roots, maize
Guinea Savannah	63	1100	180-200	-	Annual food and cash crops, livestock	Sorghum, maize
Sudan Savannah	1	1000	150-160	-	Annual food crops, livestock	Millet, sorghum, cowpea

Source: AQUASTAT 2005

Cattle production in Ghana occurs mostly in arable areas under pastoral systems. Though crop production is the main form of land use in all the agro-ecological zones in the country, pure grazing systems can be found in the savannah and transitional zones. The production system is mainly extensive, relying on natural pasture and little external input. According to Otchere and Okantah (2001), the West African Shorthorn (WASH) is the most populous breed, constituting over 60 percent of the cattle population. Over the years, the WASH has been crossed with zebu cattle, especially the white Fulani, to form a cross called Sanga. The Sanga are bigger than the WASH and used for both beef and milk production. Additionally, there are more intensive systems of production that use crosses from local cattle and exotic breeds like the Friesian, and pure breeds like the Jersey. Since the crosses and pure breeds are not well adapted to the climate, they are not taken out to graze like the local breeds. Instead, forage is cut and brought to them. Milk is a major output of the more intensive production systems, which are located close to large towns and cities where fresh milk is in high demand, both for direct consumption and for processing into dairy products. However, cattle numbers in these intensive production units are almost negligible compared with the numbers involved in the extensive production system.

Three main players can be identified in cattle production in Ghana: a kraal owner, a cattle owner, and a herdsman. A kraal owner is a person who owns cattle and has space and or housing (i.e., a kraal) to keep cattle. A cattle owner is someone who has a few cattle but no facilities or labour for keeping them, and therefore entrusts the animals into the care of a kraal owner. A herdsman is someone who has skills for herding cattle as they graze. In grazing systems, cattle are fed on naturally growing pasture which requires that cattle are herded. Most cattle farmers are also crop farmers who usually employ their own labour on their farms and often use family labour to herd cattle. Alternatively, herdsmen can be hired to herd cattle (Otchere and Okantah, 2001, Otchere et al., 1997).

The functions of livestock production in Ghana are similar to those existing in other parts of tropical Africa. These functions include the output, input, asset, and socio-cultural functions (Jahnke, 1982). In Ghana, cattle is mostly kept for meat and to a lesser extent for milk. Manure from cattle is often used as an input in crop production to improve soil fertility. Additionally, bullocks are sometimes used for ploughing or animal traction. The asset function also appears to be prominent. People in formal employment sometimes keep cattle as a form of saving towards retirement and adverse income shocks. This is also the case for crop-livestock farmers who depend on crop sales for their regular income and view cattle as saving to be used in time of need. By contrast, in the arid agro-ecological zones of tropical Africa, where it is too dry to produce crops, milk forms a major output of the livestock production systems, and households rely on it for subsistence (Jahnke, 1982). However, in the sub-humid agro-ecological zone the output function of cattle is not as important as in the arid zone, because here farmers rely more on crops for subsistence. The socio-cultural function of cattle production appears quite important as cattle is sometimes used for customary and religious ceremonies. This is especially true in the Guinea and Sudan agro-ecological zones, where cattle is used as bride price.

Cattle production contributes to the Ghanaian economy in several ways. This includes local meat production, which was a modest 16% of total domestic meat production in 2012 (MOFA, 2013). It also contributes to domestic milk production, part of which is consumed by farm families at home, and the rest sold as fresh milk in peri-urban markets for direct consumption or further processing into dairy products such as local cheese and yogurt (Omore et al., 2004). Sometimes people eat cow hide as food, but it is also used in the handicraft industry for the production of various items such as sandals and drums.

2.3 Conceptual framework and review of contract theories

In this section, we first present our conceptual framework for the contractual arrangements in cattle production. Hereafter we review the major contract theories, including agency and transaction cost theories that could apply to contract types in cattle production.

2.3.1 Conceptual framework

Contracts are agreements that entail duties that are to be performed by parties to contracts (principals and agents) and the rewards for undertaking such duties. Thus, contracts are often present in many principal agent relationships, including those between landowners and farmers, employers and employees, shareholders and chief executives, and businesses and their suppliers. As indicated earlier, we distinguish between kraal owner-herdsman contracts and cattle owner-kraal owner contracts.

Let us now specify these two contractual arrangements in cattle production a bit further to explain our empirical categorisation of contracts. We envisage these arrangements as an employer-employee relationship, where the latter performs duties at the request of the former in return for some reward. The first arrangement is between a kraal owner and a herdsman. Here, the herdsman has the duty of herding cattle to find fodder and water in the rangeland. He brings the cattle back to the kraal in the evening and ensures that they are secure till the next morning when the routine is repeated. We consider this duty as standard for all herdsmen. The kraal owner rewards the herdsman in kind or in cash (Delgado, 1979, Delgado and McIntire, 1982, Driel, 1999, Hill, 1964, Jahnke, 1982). In-kind rewards may include milk, an animal (usually at the end of the contract period), food, and health care provision. The herdsman sometimes receives remuneration directly from a cattle owner, called a kraal fee, whenever the latter removes an animal from the kraal for sale or otherwise. However, this occurs infrequently, and the fee is small, so we will ignore this in our categorisation of contracts. Kraal owners can use family labour for herding or hire labour outside of the family for herding.

The second arrangement is between a kraal owner and another cattle owner. The kraal owner now is responsible for hiring a herdsman, breeding, and other farm management decisions regarding the cattle that have been entrusted to him. Additionally, he updates the cattle owner about the status of his animals from time to time. These duties are standard, but there may be variations in the level of his responsibility for financing veterinary care cost for a cattle owner's animals and cost of hiring a herdsman. The cattle owner rewards the kraal owner for keeping his animals by sharing the calves that are delivered by his cattle with the kraal owner. In lieu of sharing calves with him, he may also pay the kraal owner cash. The cattle owner usually leaves the selection of a herdsman and all dealings with him to the kraal owner. However, occasionally, when he visits the kraal, he may bring some gifts either in cash or kind to the herdsman.

Duration and negotiation of contracts can be viewed as additional elements of both contracts. Cattle can be entrusted to a kraal owner for a definite or indefinite period of time. Similarly, a herdsman can be employed for a fixed number of years or an indefinite period. Some herdsmen may prefer a fixed contract period, while others prefer the duration of their contract to be left open-ended. The duration of a contract can be negotiated when it is fixed, just as the rewards involved in a contract can be negotiated.

Typically, contracts have been studied within two frameworks: agency theory and transaction cost theory. We review elements of these theories as follows.

2.3.2 Agency theory

Agency theory analyses the arrangement between a principal and an agent (Grossman and Hart, 1983, Hölmstrom, 1979, Holmstrom and Milgrom, 1991, Laffont and Martimort, 2009). The principal normally assigns tasks to the agent and sets other terms of the contract including the agent's remuneration. Often, agents possess information on their (potential) performance of the task, yet the principal is not privy to this information when he is engaging an agent. This situation of information asymmetry between the principal and the agent could take two forms: hidden information and hidden action. Hidden information implies that the principal does not know the type of agent he is dealing with. For instance, the principal may not know if he is dealing with a high-productivity or low-productivity person when he is hiring workers, or with a low-risk or high-risk consumer if he is selling insurance. To overcome this problem of hidden information, the principal could design a contract that provides incentives for an agent to reveal his true type (if it is too costly for him to stay uninformed). This works if the benefits of a certain contract for a high-quality agent are higher than for a low-quality agent, and at the same time the benefits of a certain alternative contract for a low-quality agent are higher than for a high-quality agent. Thus, it is possible to separate the two types of agents such that they each receive contracts suited to their type. Hidden action means that the principal cannot observe the employee's effort and thus whether he works adequately. However, if the principal knows how effort is correlated with the conditions of the contract, he could design a contract that provides the necessary incentives for the agent to perform well. Moreover, when the agent is risk averse, a risk-neutral principal could design a contract that insures the agent against output risks and by doing so earn an implicit risk premium by adapting the terms of the contract to his favour.

Agricultural contracts have often been explained as responses to hidden action (moral hazard) and hidden information (adverse selection) problems. For example, sharecropping agriculture is thought of as a solution to moral-hazard problems. In the landlord-tenant relationship, the tenant supplies effort that is not observable. This effort influences output, but the level of effort cannot be inferred from output, since it can be influenced by weather and other environmental uncertainties. To ensure that the tenant does not undersupply effort, the landlord designs a share contract where the tenant receives a fraction of the realised output. As long as this share of output gives the tenant a level of utility higher than what he can attain elsewhere, he accepts the contract. Sharecropping also serves as a risk-sharing mechanism and is a trade-off between incentive provision and risk sharing (Newbery, 1977, Stiglitz, 1974). Fixed-rent contracts offer a tenant greater incentives to supply inputs than sharecropping, since he receives his full marginal product compared to just a fraction of the marginal product under sharecropping. Yet fixed-rent contracts expose the tenant to the full risk in the event of crop failure. When crop fails, the tenant's income is completely wiped out or reduced greatly, but he still has to pay his full rent. Under sharecropping, however, he gives only a proportion of realised output to the landlord as rent, and if there is no output, he pays nothing. In this case, the landlord shares risk with the tenant. All this implies that a risk-averse tenant prefers sharecropping to fixed-rent contracts.

Another example of responses to moral-hazard problems in agriculture is when both tenant and landlord provide unobservable inputs to the production process. This leads to a double-sided incentive problem which also could be resolved with share contracts (Eswaran and Kotwal, 1985). If a risk-neutral tenant is better able to provide one particular input while his risk-neutral landlord is better able to supply another input, then a partnership between the two in which they share output is the optimum arrangement.

An example of an adverse-selection problem is the situation where a tenant's ability is only known to himself and not to his landlord. The problem could be solved if the landlord can design a menu of contracts suited to tenants of particular abilities and thereby get them to accept contracts best suited to them (Allen, 1985, Hallagan, 1978). Thus, he can design a fixed-rent contract for a tenant of high ability or productivity and a sharecropping contract for a tenant of low ability or productivity. The high-ability tenant knows that he can generate a marginal product high enough to cover the rent and yield a surplus high enough to attract him, so he accepts it. A low-ability tenant will not accept the fixed-rent contract, because his net marginal product after covering the rent is too low to attract him. Hence the landlord offers a menu of contracts and, through self-selection, tenants of different abilities accept different contracts. This could explain the coexistence of fixed-rent and sharecropping contracts.

2.3.3 Transaction cost theory

Transaction cost theory focuses on the transactions among parties to a contract (Kim and Mahoney, 2005, Williamson, 1989). There are several dimensions of transactions, including the frequency with which they occur, the type of uncertainty to which they are subjected, and asset specificity. Uncertainty has three dimensions (Williamson, 1989): 1. uncertainty that arises from changing states of nature; 2. uncertainty that arises from lack of communication between contract parties; and 3. behavioural uncertainty arising from strategic behaviour of parties when they interact (Williamson, 1989). Asset specificity is defined as the ease of moving assets to alternative uses without sacrificing productive value. Williamson (1989) also distinguishes between different types of asset specificity including: 1. Site specificity which arises from location of a firm in proximity of related firms to economise on inventory and transportation. 2. Human asset specificity which emanates from learning by doing. 3. Physical asset specificity which is related to nature of equipment used for production.

Transaction cost arises when not all contingencies can be specified in a contract (making them incomplete), creating opportunistic tendencies of parties. The incompleteness of contracts demands for appropriate governance structures to ensure that parties act in ways that maximize mutual benefits. The transaction cost approach involves comparison of costs of alternative governance mechanisms.

Asset specificity influences transaction cost. The more specific an asset is, the more difficult it is to use the asset in other transactions. Consequently, the need for safeguards is greater if asset specificity rises. These safeguards imply different governance mechanism and costs. High asset specificity also makes internal organization rather than outsourcing preferable. Accordingly, the higher the asset specificity is, the more efficient it is to conclude transactions internally. When asset specificity is low then the asset can be deployed to alternative uses, hence suppliers can aggregate various demands of many buyers to achieve economies of scale and lower cost. Under lower asset specificity and consequent lower costs, assets are contracted from market (Williamson, 1989).

Transaction cost also arises from measurement problems. For example, Holmstrom and Milgrom (1991) argue that in situations where it is difficult to value productive assets, contract type will depend on which party owns the returns from these assets. When the principal owns the returns, the optimal contract for the agent will have incentives that prevent him from abusing the assets. When the agent owns the returns from the asset, however, the optimal contract will have incentives that prevent him from using the asset too cautiously. Barzel (1982) also notes that when it is less difficult to measure performance, lump-sum arrangements are preferred. When measurement difficulties increase, it could be too costly to reach an appropriate estimation of the lump-sum.

The existence of agricultural contracts, especially share cropping, has been explained using mainly agency theory, as illustrated earlier. However, a few studies have also used transaction cost theory to explain some aspects of sharecropping. For instance, Allen and Lueck (1993) show that input cost shares in crop share contracts between farmers and landowners in Nebraska and South Dakota were associated with the cost of measuring and dividing the ownership of such inputs or assets. Thus, it was more common to share the cost of inputs such as fertilizer and seed, while it was more common for one party to the contract to own assets such as buildings, combine harvesters, and tractors, since the cost of measuring and dividing the ownership of such assets was probably excessive.

Thus, the characteristics of the parties to a contract create a role for agency theory to explain the nature of contracts. The parties could have varied risk preferences, be prone to moral hazard, or have information about their qualities that is private to them. Transaction cost theory can also be used to explain contracts in cattle production, because several sources of transaction cost can be found in the process. Sources of transaction cost include environmental uncertainty, opportunism, asset specificity, or measurement problems. Environmental uncertainty relates to the distribution of rainfall and the number of rainfall months in the different agro-ecological zones. Opportunism is prevalent in many relationships, but this can be reduced depending on whether one is dealing with a party who is a family member or non-family member. Assets, especially material inputs, used in cattle production are not highly specialised and therefore have low asset specificity. Measurement problems could be associated with both sharing of production inputs, including veterinary inputs, and labour cost, and measurement and sharing of output such as milk.

2.4 Methodology

In this section, we present details of the sampling and data collection procedures that were used. Furthermore, we present procedures used to analyse the data.

2.4.1 Sampling procedures

A multi-stage stratified random sampling procedure was used to select kraal owners, cattle owners, and herdsmen. Districts were selected and a list of kraal owners in the districts were made.

2.4.2 Selection of districts

We selected two or three districts from each of the four agro-ecological zones known for cattle production, namely the Guinea savannah, Sudan savannah, Transitional zone, and the Coastal savannah (Appendix 2.1 Table A1). Three districts were chosen from the Guinea Savannah, as it is the biggest zone known for cattle production. Three districts were also picked from the Transitional zone, because this zone is becoming increasingly important for cattle production. In the Coastal savannah, we selected three districts. However, two districts were chosen from the Sudan savanna, which is the smallest savannah zone in Ghana. These districts are assumed to be representative of the various agro-ecological zones in terms of rainfall characteristics and cattle production systems, because they have similar features as the zones to which they belong, as described in Section 2.

2.4.3 Selection of kraal owners, cattle owners, and herdsmen

In the various districts, lists of known kraal owners were prepared with the assistance of local veterinary technicians and agricultural extension agents. The number of kraal owners identified and listed in each district was between 60 and 130. The kraal owners were identified largely from records of mass vaccinations. Kraal owners were also identified through the familiarity of the veterinary technicians and agricultural extension officers with them, as a result of the close working relationships they have. Using these lists, we randomly selected 40 kraal owners from each district for personal interviews. However, not all kraal owners were available to be interviewed. Consequently, data was collected from a total of 342 kraal owners across the country. A herdsman who worked for a selected kraal owner and one cattle owner who had entrusted his cattle into the care of this kraal owner were also selected for face-to-face interviews.

Consequently, from each kraal, three respondents were interviewed: the kraal owner, a herdsman, and a cattle owner. In the case of more than one herdsman, the most senior one was interviewed since he was deemed to be the most knowledgeable. If there was more than one cattle owner, the first one who was available was interviewed. Nonetheless, there were some kraals where it was difficult to get the herdsmen and cattle owners for interviews. A total of 260 cattle owners and 284 herdsmen were interviewed across all the agro-ecological zones. Since we were interested in studying management arrangements between contracting parties, we did not include kraal owners who herded their own cattle in the sample frame, because they did not have a counterpart herdsman. Also, we tried interviewing all three parties connected to a kraal. Hence, we made sure, as much as possible, that kraals were included in the sampling frame that had all three parties, or at least two. Often there are multiple owners of cattle in a particular herd (Hill, 1970, Okantah et al., 1999, Otchere and Okantah, 2001). Thus, it is quite easy to get at least two parties in a kraal. Despite the exclusion of kraal owners who herded their own cattle, our sample is still representative of the majority of kraals or kraal owners in the population who do not herd their own cattle.

2.4.4 Data collection and procedure

Data was collected through the use of structured questionnaires. Prior to the questionnaire preparation, four experts (a past Director of Animal Production Department of the Ministry of Food and Agriculture (MoFA) in Ghana, a Regional Livestock Officer of MoFA, a Livestock Officer of the Animal Research Institute (ARI), Ghana, and a former herdsman also of ARI) were interviewed for a general description of prevailing contracts. Based on their reports, questionnaires were prepared. We then trained enumerators in two districts (Atebubu-Amantin and Ejura-Sekyedumase) and pretested the questionnaires there. Based on the responses during pretesting, the questionnaires were revised. Next, a team of enumerators in each district were trained again and then the questionnaires were administered from January 2014 to March 2014. Questionnaire administration in Ada West was done in July 2015 due to logistical constraints.

Data of the three sets of respondents (kraal owners, cattle owners, and herdsmen) were entered into Microsoft Excel spreadsheets and exported to IBM SPSS Statistics version 20 for further processing and analysis. We analysed contract characteristics based on kraal owners' responses. The responses from relevant herdsmen and cattle owners were used to cross-check kraal owners' responses. In the case of inconsistencies, we used responses from the respondent category that we deemed better informed to answer the particular question. For instance, though both herdsmen and kraal owners were asked to comment on production indicators, we assumed that the herdsmen were better informed of these indicators. In situations where data was missing for the kraal owner, especially regarding contract parameters, responses from the relevant cattle owner and herdsman provided the data to fill the gap. We used descriptive statistics, including frequencies and percentages, to summarise the information. Also, we crosstabulated some variables to assess the association between them. The significance and strength of these associations were tested using the chi square test. Questionnaires completed during pretesting were not included in the final sample.

2.5 Survey results

In this section, we present the results of the survey regarding the nature of contracts in cattle production.

2.5.1 Characteristics of contracts in cattle production

As indicated, we identified two sets of contracts, namely between kraal owner and herdsman (KH contracts) and between kraal owner and cattle owner (CK contracts).

2.5.2 Characteristics of cattle owner - kraal owner (CK) contracts

CK contracts were of two kinds. One kind had the remuneration given by a cattle owner to the kraal owner specified at the beginning of the contract and agreed to. The other kind had the remuneration to the kraal owner not explicitly specified at the inception of the arrangement. We refer to the first and second kind of contracts as explicit and implicit contracts, respectively. Approximately 60 percent of the sampled CK contracts were explicit contracts. The kraal owner's duties were generally standard, with some variations in responsibility for input financing. These variations are accounted for in a cattle owner's rewards to a kraal owner.

In the explicit CK contracts, remuneration by a cattle owner consisted of two components. The first was the share of the cattle owner's animals (calves). Calves sharing could go this way: when a cattle owner's cow produces an offspring the first time, the offspring (calf) belongs to him. However, when that same cow calves a second time, the calf is given to the kraal owner. The second component of a cattle owner's remuneration was the periodic (usually monthly) fixed payment, and subsidies paid to the kraal owner to finance material inputs such as drugs for veterinary care or the herdsman's upkeep. The fixed payment was often cash. The subsidies were related to duties performed by the kraal owner, including employing a herdsman and remunerating him and providing veterinary care for the cattle. Thus, the subsidies comprised contributions to the kraal owner to cover part of these expenses. The contributions were in cash or kind. In-kind contribution for a herdsman's upkeep could be food provisions. Alternatively, the herdsman could be assisted to cultivate a piece of land for himself. Such assistance could include ploughing the land for him free of charge.

The CK contracts we found showed a different mix of compensations, and their frequencies varied across zones (Table 2.2). These contracts - fixed payment in cash with or without subsidies, share contracts with or without subsidies, input subsidy only and unspecified contracts - were significantly associated with the zones ($\chi^2(9)$ =284.25, p=0.01). This association of contracts with zones was relatively strong (Cramer's V = 0.54). Whereas fixed payment in cash (with or without input subsidy) was not observed in the Coastal savannah and only a few times in the Guinea savannah, and Sudan savannah, it was quite prominent in the Transitional zone. Share contracts, with or without input subsidy, occurred the most in the Coastal savannah, followed by the Transitional zone; they were virtually absent in the Guinea and Sudan savannah. Contracts with only input subsidy were mostly found in the Guinea savannah, followed by the Transitional zone, and the Sudan savannah; these contracts were negligible in the Coastal savannah (Table 2.2).

Table 2.2 Distribution of cattle owner-kraal owner contract types by agro-ecological zone (percentage)

	Agro-ecological zone				
Contract Type	Coastal	Guinea	Sudan	Transi-tional	Total
Fixed payment in cash	0	8.1	5.4	11.9	6.2
Fixed payment in cash plus input subsidy	0	0	1.4	18.6	3.7
Share contract	65.4	1.8	0.0	11.9	18.6
Share contract plus input subsidy	28.2	0.9	1.4	6.8	5.2
Input subsidy	0	30.6	13.5	25.4	18.3
Unspecified contracts	6.4	58.6	78.4	25.4	44.4
Total percentage	100	100	100	100	100
Total number of kraals	78	111	74	59	322

Source: Field data

The proportion of cattle owners who contributed to the care or payment of herdsmen was low in the Coastal savannah (5%). This was a little higher in the Guinea savannah (46%), the Sudan savannah (67%), and the Transitional zone (15%). There was significant association between agro-ecological zones and receipt of subsidy for care of herdsmen ($\chi^2(3)$ = 29.12, p=0.01). The association was relatively strong (Cramer's V = 0.47, p = 0.01). Contributions from cattle owners to the repairs or construction of animal house was not widespread. Whereas no such contribution was reported in the Coastal savannah and Sudan savannah, there were some observations, though very few, in the Guinea savannah (3%) and Transitional zones (10%). The most important component of input subsidy was a contribution towards veterinary care of cattle. This was highest in the Transitional zone (56%), followed by the Guinea savannah (33%) zone and Coastal savannah zone (29%). It was lowest in the Sudan savannah (9%). The association between agro-ecological zone and kraal owner receipt of subsidy for veterinary care was significant ($\chi^2(3)$ = 30.36, p=0.01), and the association was moderately strong (Cramer's V = 0.31, p=0.01).

The set of contracts for which the remuneration given by cattle owner to the kraal owner were not specified were quite high in the sample (Table 2.2). In the Guinea savannah and the Sudan savannah, unspecified contracts even formed the majority of contracts. Unspecified contracts occurred the least in the Coastal savannah, while a quarter of contract types in the Transitional zone also had this feature.

Also, kraal owner's contract type was significantly associated with his receipt of subsidy for care or payment of herdsmen (χ^2 = 33.61, p=0.01)[2] and with his receipt of subsidy for veterinary care ($\chi^2(3)$ = 138.0, p=0.01). The strengths of the respective associations were relatively strong (Cramer's V = 0.51, p=0.01), and strong (Cramer's V = 0.69, p=0.01). Over eighty percent of those kraal owners who received subsidy for care or payment of herdsmen and more than half of kraal owners who received subsidy for veterinary care had input subsidy only contracts.

Table 2.3 reports on the sharing proportions under share contracts. First of all, almost half of the explicit contracts involved the sharing of calves. Kraal owners got either one out of every three calves or one out of every two calves. The majority of kraal owners under share contracts in the Coastal savannah had one out of two animals. The frequency of share contracts was negligible in the Guinea and Sudan savannah, since not more than two cases of share contracts were observed in each zone. Giving one out of every three calves to the kraal owner occurred more in the Transitional zone than in the Coastal savannah. The share of calves received by kraal owners was associated with whether the zone was Coastal or Transition (Fisher's exact test, p=0.01). This association was relatively strong (Cramer's V=0.46, p=0.01). In some cases, in the Coastal savannah, there was only one round of calves sharing; the next rounds of calves belonged to the cattle owner. This was found in the Ada West district, for example.

Table 2.3 Distribution of calves sharing by agro-ecological zone (percentages)

	Agro-ecological zone				
Kraal owner's share	Coastal	Guinea	Sudan	Transi-tional	Total
One half (1/2)	73	50	100	9	54
One third (1/3)	27	50	0	91	36
Total percentage	100	100	100	100	100
Total number of kraals	70	2	1	11	84

Source: Field data

Often, kraal owners who received calves as compensation also got a share of the proceeds from the sale of cattle. A pre-determined share of sales proceeds was agreed upon by the majority of cattle owners in the Coastal savannah. The sharing of sales proceeds was less common in the other zones and least common in the Guinea savannah, followed by the Transitional zone, and Sudan savannah (Table 2.4).

Table 2.4: Distribution of the sharing of cattle sales proceeds with kraal owners by agro-ecological zone(percentage)

	Agro-ecological zone			
	Coastal	Guinea	Sudan	Transitional
Kraal owners receiving predetermined share of sales	91	4	14	8
Total zonal observation	75	104	66	49

Source: Field data

[2] Twenty-five percent of cells have expected counts less than five.

Kraal fees are a prominent feature of the rewards for herdsmen, though this is occasional and not large. Cattle owners sometimes paid these kraal fees through kraal owners when they removed animals from the kraal for sale. The fees were paid in the majority of cases in the Coastal savannah, Guinea savannah, and Transitional zone; this practice occurred only a little in the Sudan savannah (Table 2.5). Herdsmen were the sole beneficiaries of kraal fees in most cases in each zone: Coastal savannah (95%), Guinea savannah (100%), and Transitional zone (97%).

Table 2.5: Distribution (percentage) of kraal owners receiving kraal fees, on behalf of herdsmen, by agro-ecological zone

	Agro-ecological zone			
	Coastal	Guinea	Sudan	Transitional
Kraal owners receiving kraal fees	58	91	10	70
Total zonal observation	74	107	67	50

Source: Field data

The duration of most (89%) contracts in the sample was indefinite, although this varied in frequency across the zones. Even when contracts are disaggregated into zones, most contracts in each zone had indefinite contract periods (Table 2.6).

Table 2.6: Distribution (percentage) of kraal owners who had indefinite contract durations with cattle owners by agro-ecological zone

	Agro-ecological zone			
	Coastal	Guinea	Sudan	Transitional
Kraal owners offering indefinite contract periods	96	100	80	57
Total zonal observation	56	67	49	23

Source: Field data

2.5.3 Characteristics of kraal owner and herdsman (KH) contracts

Also among KH contracts, we found contracts in which the remuneration given by the kraal owner to the herdsmen was specified or explicitly agreed and contracts in which the remuneration to the herdsman was not specified explicitly. In the latter case, the herdsman's rewards were not explicitly agreed and appeared to be tacit. However, such unspecified contracts were in the minority in the sample (3%). We also characterized KH contracts with respect to the duration of the agreements. One set of contracts, which were usually short term, had the duration given, while the second set of contracts had an indefinite contract period.

The specified rewards to the herdsmen were of two kinds: (1) offering the milk harvest and (2) a fixed payment, which was in cash or in kind (other than milk). Fixed payments of cash were usually monthly payments. Fixed payments in kind were of two types: regular periodic payments in kind, especially food and animals, and the award of a breeding animal to the herdsman after the expiration of his contract. It is not unusual for kraal owners to make periodic deliveries of bags of rice or quantities of other cereal meals to herdsmen. Giving the entire milk output could be the only reward, or it could be supplemented by a fixed payment in cash or kind.

Herdsmen received the entire milk output in the majority of the contracts in the Coastal savannah, Transitional zone, and Guinea savannah; it occurred in less than half of the contracts in the Sudan savannah (Table 2.7). Offering the milk output was almost always combined with fixed payments in cash or kind. Payment with only milk output occurred to a very small extent in the Coastal savannah. However, KH contracts with only fixed payment, both in cash or kind, were observed in slightly high percentages only in the Coastal savannah and the Sudan savannah. It hardly occurred in the Guinea savannah and the Transitional zone.

Table 2.7: Distribution of kraal owner-herdsman contract types by agro-ecological zone (percentage)

	Agro-ecological zone				
Contract Type	Coastal	Guinea	Sudan	Transi-tional	Total
Milk output	1.3	0.0	0.0	0.0	0.3
Milk output plus fixed payment in cash	1.3	10.8	0.0	6.3	5.3
Milk output plus fixed payment in kind	37.5	37.5	26.0	14.3	30.6
Milk output plus fixed payment in cash and kind	25.0	50.0	7.8	77.8	39.7
Fixed payment in cash	0	0	1.3	0	0.3
Fixed payment in kind	28.7	0.8	55.8	1.6	20.0
Fixed payment in cash and kind	3.8	0.0	1.3	0	1.2
Unspecified contract	2.5	0.8	7.8	0	2.6
Total percentage	100	100	100	100	100
Number of kraals	80	120	77	63	340

Source: Field data

Fixed payment contracts whether in cash or kind occurred in all zones. The proportion of unspecified contracts varied across zones, but was pretty low. Although the occurrence of this contract type was low, it occurred the most in the Sudan savannah, followed by the Coastal savannah. It was virtually non-existent in the Guinea and Transitional zones. The association of KH contracts - milk with or without fixed payments, fixed payment only in kind or cash, and unspecified contracts - with agro-ecological zones was significant ($\chi^2(6) = 131.26$, p=0.01). The association was relatively strong (Cramer's V = 0.44).

The occurrence of the various components of fixed payment in kind (food provision, or award of an animal after a specified period of work ranging from six months to four years) varied also (Table 2.8). Most kraal owners provided herdsmen with food in all the agro-ecological zones. Alternatively, herdsmen were assisted by kraal owners to produce food that they consumed at home, usually by providing equipment or finance to plough their land. However, few kraal owners did across all the agro-ecological zones. Giving a heifer (breeding animal) to a herdsman as fixed payment, after a given period, occurred relatively much in the Coastal savannah. The practice was also found in the Transitional zone, but only few times; it was almost absent in the Guinea and Sudan savannah. A heifer could be given after 3 to 4 years in the Coastal savannah, whereas the duration could be as short as 6 months in the Transitional zone.

Table 2.8: Distribution of components of fixed payment in kind to herdsmen (percentage)

	Agro-ecological zone			
Components of fixed payments	Coastal	Guinea	Sudan	Transitional
Food	95	84	89	89
Assistance to farm	3	12	9	5
Heifer	50	0	1	8
Total number of observations	80	120	79	63

Source: Field data

A herdsman's remuneration generally depended on whether he was family of the kraal owner or hired. The association of herdsman type with herdsman's remuneration - milk with or without fixed payment, fixed payment only in cash or kind, and unspecified contracts - were significant ($\chi^2(2)$ = 84.31, p=0.01). The relationship was relatively strong (Cramer's V = 0.50). Herdsmen who were family members mostly received fixed payments in cash or in kind, whereas hired herdsmen often received in addition to some fixed payment also milk output (Table 2.9). The combination of fixed payments and milk output among family herdsmen accounted for about a third of KH contracts. Often, they took only enough milk for their household use.

Table2.9 Relationship between type of kraal owner – herdsman contract and type of labour (percentages)

	Type of labour used for herding			
Contract type	Family labour	Hired labour	Herder is both family and hired	Total
Milk output	0	0.4	0	0.3
Milk output plus fixed payment in cash	1.5	6.3	0	5.3
Milk output plus fixed payment in kind	20.6	33.3	0	30.7
Milk output plus fixed payment in kind and cash	11.8	46.3	100	39.5
Fixed payment in cash	1.5	0	0	0.3
Fixed payment in kind	51.5	12.2	0	1.2
Fixed payment in kind and cash	2.9	0.7	0	2.7
Unspecified	10.3	0.7	0	2.7
Total percentage	100	100	100	100
Number of kraals	68	270	1	339

Source: Field data

The kraal owner and herdsman were asked whether the terms of their agreement were negotiated between them. Herdsmen also had the chance to say something about the offer that was given to them. The negotiations focused on whether a herdsman would be entitled to all milk harvested and whether any fixed payment would be in cash and how much. Also, contract duration could be part of the negotiation. Contract terms were negotiated in the Coastal savannah in over half of the cases. However, negotiations occurred less in the rest of the agro-ecological zones (Table 2.10).

Table 2.10 Negotiation on kraal owner – herdsman contracts by agro-ecological zone (percentage)

	Agro-ecological zone				
Contract negotiation	Coastal	Guinea	Sudan	Transi-tional	Total
Terms were negotiated	60.0	44.3	29.9	32.7	39.8
Terms were not negotiated	40.0	55.7	70.1	67.3	60.2
Total percentage	100	100	100	100	100
Number of kraals	75	115	77	52	289

Source: Field data

Whereas duration was fixed in most contracts in the Coastal savannah and the Transitional zone, this was not so in the Guinea savannah and Sudan savannah (Table 2.11). In these cases where the duration was not fixed, the contract duration was both unspecified and indefinite – A herdsman could work in a specific kraal for decades. It could continue until one party decides to terminate it for one reason or another. The duration for KH contracts which occurred most frequently in the sample when this was fixed was 3-4 years. However, the mean duration of fixed duration KH contracts was higher in the Coastal savannah (3.6 years) than in the Transitional zone (1.7 years). The proportion of herdsmen whose contract durations were fixed was very low in the Guinea and Sudan savannah. Yet, the mean durations in the two zones were relatively high, 5.3 and 2.6 years respectively.

Table 2.11 Distribution of the duration of kraal owner-herdsman contracts by agro-ecological zone (percentage)

	Agro-ecological zone				
Duration of agreement (Years)	Coastal	Guinea	Sudan	Transi-tional	Total
1 – 2	3.0	0	7.7	42.4	9.0
3 – 4	56.7	1.4	15.4	12.1	23.2
5 – 7	3.0	2.8	0	0	1.9
Indefinite	37.5	95.8	79.5	45.5	65.9
Total percentage	100	100	100	100	100
Number of kraals	67	72	39	33	211

Source: Field data

2.6 Discussion

We discuss our findings in this section. First, we discuss the types of contracts we find in cattle production. Second, we discuss major drivers of cattle production contracts drawing on insights from agency and transaction cost theory.

2.6.1 Cattle owner - kraal owner contracts (CK) and their drivers

Types of CK contracts

We have found two sets of CK contracts, depending on whether the remuneration of the cattle owner to the kraal owner was specified or not. Among the specified contracts, we could distinguish between three broad types: fixed-payment contracts, share contracts, and input subsidization contracts. The first two could have input subsidization in addition. The CK contract is similar to the livestock owner-herd manager contract discussed by Turner and Hiernaux (2008) and Turner (1999), where a livestock owner entrusted his animals into the care of a herd manager. The latter provides services similar to the kraal owner, such as ensuring that animals were grazed, treated for illnesses, and managed for optimum reproductive performance. According to Turner and Hiernaux (2008), the herd manager could be paid a wage or receive entrustments of animals . The wage corresponds to the fixed payments we found. The entrustments conferred entitlement to milk, which the herd manager or kraal owner could in turn pass on to his herdsmen, wholly or partially. Moritz et al. (2011) mentioned that kraal owners obtained other forms of compensation in addition to their right to milk, but it is not clear what the role of calves sharing was with regard to this.

Calves-sharing contracts and sharecropping contracts are similar, since output is shared between the principal and agent in both cases. Yet, they have some differences too. For instance, whereas in sharecropping the tenant and landlord share output from the same season, in calves-sharing arrangements the cattle owner and the kraal owner receive their share of output in different seasons. There is simultaneous receipt of output by both parties in sharecropping, while there is sequential receipt of outputs in calves in calves sharing contracts. When output shares are received simultaneously by the parties, output risk is even for each party. However, when parties receive their shares of output in different seasons (sequentially) the level of output risk could differ.

Fixed-rent contracts, where the kraal owner rents cattle and pays the cattle owner cash, were not found. Two reasons could account for this. We have argued that one main function of keeping cattle is to accumulate wealth to serve as an insurance substitute (Binswanger and McIntire, 1987). The cattle owner whose main goal is to grow his herd is less likely to rent his cattle to a kraal owner for cash. Additionally, it is possible that animals rented out will be abused and lost.

In most agro-ecological zones, we found the coexistence of at least two contract types. Yet, particular contract types were dominant in particular agro-ecological zones. Whereas calves-sharing contracts were the majority in the Coastal savannah, unspecified contracts were the majority in the Guinea and Sudan Savannah. Features of the agro-ecological zones could account for such geographical distribution of contracts. The agro-ecological zones differ in rainfall distribution and months of rainfall, which leads to differences in environmental uncertainty. We shall turn our attention to the relationship between environmental uncertainty and contract types presently.

Drivers of CK contracts

In the subsidy-only contract, the cattle owner (CO) provides cash for input acquisition for his cattle. The kraal owner (KO) may not receive cash rewards but is often entitled to by-products such as milk and manure. The KO is entrusted with cattle by several COs. This arrangement can be explained using transaction cost theory. The transaction involved here is cattle concentration, which enables the aggregation of the individual demands by COs for herding services and other production inputs. This achieves economies of scale (Binswanger and McIntire, 1987). Some of the inputs that are used in the production process include veterinary drugs and services, which have low specificity. COs require almost the same inputs, hence it makes sense to acquire these in bulk rather than each CO making individual purchases for his animals. When the KO receives contributions from the COs and buys inputs in bulk, he could obtain some discounts. Thus, the low specificity of assets facilitates aggregation of demand, leading to economies of scale (Williamson, 1989). Additionally, it is cheaper if the KO transports all the inputs in one go than if COs purchase their own inputs and deliver them to the KO. Also, it is cheaper to locally concentrate cattle and look for a common herdsman to take care of them than for each cattle owner to employ his own herdsman. This is made easier by the fact that COs have only small herds. Herd sizes are particularly small in the Guinea and Sudan savannah (Otchere and Okantah, 2001), which explains why this contract type is predominant in these zones. Monitoring subsidy-only arrangements to ensure that the KO performs his duties are likely to be easier in the Guinea and Sudan savannah, because the outside options of parties in these zones are fewer than in the Coastal savannah and in the Transitional zone.

In unspecified contracts, the KO takes major decisions including cattle breeding and management of herdsmen. What the KO receives as remuneration is not specified explicitly, but the CO rewards him with cattle from time to time. In transaction cost theory terms, the transaction involved here is the mutual sharing of risk, which allows CO and KO to deal with environmental uncertainties. Unspecified contracts are found mostly in the Guinea and Sudan savannah, where rainfall distribution has a single peak, resulting in longer dry seasons. Environmental uncertainty in these zones is greater than in the Coastal savannah and Transitional zone with their bimodal rainfall patterns. Sharing of calves between CO and KO is the typical way of remunerating the KO in locations like the Coastal savannah where environmental uncertainty is lower. Since individual herds of COs are small, there is a time lag between the period one party receives his share and when the other party does – calves sharing is on rotational basis. If this sharing arrangement is adopted under harsh environmental conditions such as low rainfall and consequent scarcity of feed, as occurs in the Guinea and Sudan savannah, a party can easily lose his share of calves and have his gain eroded. We interpret the occasional reward of the KO with an animal that occurs under unspecified contracts as a way of circumventing a possible loss of his share. Calves are accumulated and reared for a period of time, and the CO then rewards the KO out of those that survived. Hence, in contrast to rotational sharing as pertains in the Coastal savannah, we see the occasional rewards of animals, after several periods, under unspecified contracts as a form of remuneration where parties implicitly insure themselves against severe environmental losses. Problems of mutual trust are solved by the long-term nature of the relationship between the parties.

Calves-sharing contracts with or without input contribution by the CO were found predominantly in the Coastal savannah and to some extent in the Transitional zone. Calves sharing can be explained by agency theory, while the associated sharing of input cost can be explained by the CO's ability to monitor the KO's use of his inputs. In principle, the relationship between CO and KO is prone to moral hazard. Output of calves does not only depend on the KO's effort but also, for instance, on availability and quantity of forage and environmental conditions. A share contract offers the KO incentives to do his best and, if he is risk averse, might also provide him with some insurance. As mentioned earlier, under calves-sharing contracts, some COs contributed to input provision while others did not. Those who contributed could have had better ability to monitor the use of the inputs. The ability of COs to monitor KOs probably depends on their outside options. More outside options for COs may imply fewer visits to the kraal where they have entrusted their animals. Because COs have more outside options in the Coastal savannah than in the Transitional zone, the monitoring problem prevails particularly in the former zone. This is in line with our result that the majority of kraal owners under a share contract in the Coastal savannah have one half of the share as opposed to one-third in the Transitional zone, since a larger share for the kraal owner is likely to imply a higher contribution of him to inputs. It also agrees with the result that the proportion of share contracts where the CO provides subsidy for labour and veterinary care inputs, which are major components of inputs, is higher in the Transitional zone than in the Coastal savannah This observations regarding input contribution and share of output received is in line with Bardhan and Rudra (1980).

The duration of most contracts including share contracts was indefinite. An indefinite duration of contracts facilitates the feasibility of calves-sharing contracts. First, it makes the rotational-sharing arrangement feasible. A cow calves for the first time after approximately three years, and the calving interval could be as high as three years. Hence, if each party is to have his turn at getting his share of output, then the contract duration must be long. If the kraal owner is entitled to the third calf, and not the second, then he must wait even longer. If they are to have multiple turns at sharing output from the same cow, then the duration must be even much longer. Second, it reduces moral hazard in the arrangement. Since sharing of output is repeated, there is opportunity to punish a party that deviates from the terms of the contract. Binswanger and McIntire (1987) noted that CK contracts were prone to moral hazard and potential theft problems, therefore, these contracts should be of a long-term nature. Turner and Hiernaux (2008) also found that entrustments were generally made for an indefinite period of time and that entrustments of animals were much more common with cattle than small stock.

Fixed-wage contracts are relatively uncommon. This could also be explained by the CO's ability to monitor. In the Coastal savannah, they do not even occur at all. Paying fixed wages means that the CO needs to be sure that the KO puts in his best efforts. In the Coastal savannah, COs have relatively many outside options as compared with the Guinea and Sudan savannah, which makes the cost of monitoring relatively high and so the offering of fixed-wage contracts unlikely. This agrees with Binswanger and McIntire (1987) who observe that an animal owner will opt for wage labour only if he can supervise the care given to his animals.

2.6.2 Kraal owner – herdsman (KH) contracts and their drivers

Types of KH contracts

We have also found two sets of KH contracts. Contracts in which the remuneration of the kraal owner to the herdsman were explicitly specified and contracts that did not have any specifications. In some specified contracts, the herdsman was rewarded with the entire milk harvest, often in combination with fixed payment in kind or cash.

We view milk as an output, although secondary to live animal output, that could be shared. Often the herdsman had complete entitlement to milk, while the kraal owner took nothing. This finding agrees with Toulmin (1992) who found that the herdsman had complete entitlement to milk, however this was only on specific days of the week while the kraal owner was entitled to milk the rest of the days. The finding that herdsmen were paid with only milk in the Coastal savannah, although this related to only a small proportion of herdsmen in the zone, is supported by Hill (1964). She observed that normally in the Accra plains (which is a large part of the Coastal savannah) herdsmen's only remuneration was the milk collected from the herd. Payment with milk is also consistent with observations by earlier studies (Moritz et al., 2011, Tonah, 2003, Tonah, 2006, Toulmin, 1992, Turner, 1999, Turner and Hiernaux, 2008).

The compensation of herdsmen with milk and fixed payments like animals, food and clothes agrees with observations by Dijk (1994). Driel (1999) also observed that the form of compensation for herdsmen in northern Benin included part of the milk harvest and offspring. He further noted that the portion of milk given to the herdsman varied across regions. In other specified contracts, the herdsman got no milk but only a fixed payment in kind or cash. The few instances where the herdsman was not rewarded in any form was associated more with the use of family labour for herding than hired labour.

Contracts in which the herdsman received a heifer as reward at the end of a contract period were found especially in the Coastal savannah. These contracts also had a fixed duration. Here, the herdsman could leave the herding business and get back to school or find some other employment, or extend his contract for another period. The heifer could be considered as start-up capital for the young herdsman to begin his own cattle business.

In all studied regions, there were cases where the contracts had no fixed duration. In these cases, the herdsmen considered herding as a long-time employment, perhaps a way of life. This could have been due to fewer alternative employment avenues for them. This is especially true for herdsmen who belong to the Fulani ethnic group. Dijk (1994) and Turner and Hiernaux (2008), who studied herding arrangements among the Fulbe or Fulani in West Africa, observed that herding contracts could be long- lasting or indefinite. Most members of the Fulani ethnic group have specialized skills in herding cattle and virtually depend on animals for their livelihood. In other parts of West Africa, especially in the Sahel zone, herdsmen were hired on short-term bases for periods of about six months to look after transhumant herds (Bassett, 1994). Only few contracts were found that had a fixed duration of less than one year. This could be because the cattle herds in Ghana, as such the sub humid zone, are mostly sedentary herds.

Drivers of KH contracts

As indicated earlier, a KO rewarded herdsmen in two main forms: 1. entitlement to the entire milk harvest with occasional cash and food provisions; 2. non-milk fixed payments in the form of cash, food provisions, or animals. We found that payment of herdsmen with milk was associated more with hired herdsmen than with familial herdsmen, whereas it was the other way around with non-milk fixed payments. We will forward an explanation based on transaction cost theory to explain these differences in remuneration. Although hired herdsmen were mostly paid in milk, some of them received non-milk payments. To deal with the contract differences among hired herdsmen, we will propose an explanation using agency theory.

The key transaction engaged in by KO and herdsman is the exchange of the latter's labour for pay. Inherent to this relationship is moral hazard. This is particularly the case when hired labour is used for herding as opposed to family labour. According to Holmstrom and Milgrom (1991), when performance is not easily measured and the agent owns returns to the asset, he should be incentivised in such a way that he is not too cautious with the use of the asset. Extending this to cattle, we note that it is difficult to measure or verify the quantity of milk harvested from cattle accurately, since only partial milking is done. Partial milking means that the herdsman is expected to leave some milk in the cows for calves to suckle. The KO can allow the hired herdsman to keep a high proportion of milk harvested or the entire harvest from cows as his remuneration. The herdsman's entitlement to milk makes him employ his best skills to herd cattle to obtain adequate nutrition, because the better the nutrition of cattle the better their reproductive performance and milk output. Having ensured that cattle have adequate nutrition, the herdsman is not cautious about extracting milk from the animals as there are sufficient quantities to meet his needs without detrimental consequences for cows and calves. However, if the KO pays the herdsman cash in lieu of milk, when there is opportunity for herdsmen to harvest the milk, the KO will not be able to stop him since it is costly to monitor them. The occasional cash and food provisions to a herdsman who has entitlements to milk often results from feed scarcity due to adverse environmental conditions. Under such situations, the KO supplements milk remuneration with cash or food.

Non-milk fixed payments were associated with the use of family labour for herding. We remarked that family labour is probably associated less with moral hazard than is hired labour. Consequently, it is less likely that a familial herdsman will secretly harvest milk from cows or engage in over-harvesting of milk with detrimental consequences for cow and calves. Hence, the KO can keep the milk for himself and feeding of calves, and offer low powered incentive payments to the herdsman. This could explain why herdsmen who are family members receive non-milk fixed payments such as animals.

Although a majority of hired herdsmen were paid in milk, some of them received non-milk fixed payments such as cash, food, and animals. To explain this variation, we turn to agency theory. The key is that, although the productive skills of familial herdsmen are pretty observable to a kraal owner, this typically does not hold for unrelated, hired herdsmen. The latter presumably have hidden information regarding their productive skills. The kraal owner can design different contracts targeted at specific skill types of herdsmen and create self-selection on the part of herdsmen. He designs different pay packages tailored to suit herdsmen of particular skill types. These pay packages have two components: a milk component and a non-milk component. The non-milk component includes cash and kind payments such as food and animals. A pay package with a high milk component and low non-milk component is targeted at a high-ability herdsman, while a pay package with a low milk component and high non-milk component is targeted at a low-ability herdsman. We see the package with the high milk component as a share contract, because the pay is related to output, and the package with the low milk component as a wage contract. Now, the high-ability herdsman typically prefers the pay package with the high milk component, because he knows he can take good care of the cattle to produce adequate milk for him as food and income and feed for the calves (more on this below). The low-ability herdsman typically knows he cannot take care of the cattle well enough to produce adequate milk for his subsistence and still leave enough for the calves. Besides, he cannot utilize milk as food or marketable commodity as well as the high-ability herdsman. Thus, the low-ability herdsman prefers the pay package with the low milk component. In sum, by offering a menu of different pay packages, the kraal owner is able to learn the ability of his herdsmen before hiring.

We may add a few words on the typical differences between high-ability and low-ability herdsmen. High-ability herdsmen are often people who see cattle herding as a way of life. Such long-term devotion to cattle herding makes these herdsmen very skilled (Binswanger and McIntire, 1987). They depend on milk as a major component of their diet and often receive milk as their remuneration (Jahnke, 1982). Young men pick up herding skills from their parents and relatives. They depend heavily on cow milk for food and sell the surplus for cash. Thus, they acquire tolerance for lactose in milk and skills for handling and processing the surplus. However, low-ability herdsmen are unlikely to see cattle herding as a way of life. Hence, they do not have incentives to acquire a lot of herding skills, and they themselves or the women in their households may not have high skills in handling and processing skills. They also do not tolerate milk as well as the high-ability herdsman. Whereas high-ability herdsmen can use unsold milk as food, low-ability herdsmen are limited in doing so. Also, the latter have low handling and processing skills to add value to surplus milk. These make their cost of accepting milk as payment higher.

2.7 Conclusion

The objectives of this study have been to ascertain the nature of contracts in cattle production in Ghana and to explain existing contract types. We found two categories of contracts: cattle owner-kraal owner (CK) contracts and kraal owner- herdsman (KH) contracts. Each category could be grouped into explicit contracts, in which the remunerations of parties are explicitly specified, and unspecified contracts, in which remunerations are not explicitly specified. Explicit CK contracts comprised share contracts under which the cattle owner gives a share of calves to the kraal owner, subsidy-only contracts, under which the cattle owner only compensates the kraal owner for expenses incurred on the former’s cattle, and fixed-wage contracts under which the cattle owner pays the kraal owner a fixed wage in cash or kind. Explicit

KH contracts comprised milk payment and non-milk payment contracts. We tried to explain these findings with agency and transaction cost theory.

Subsidy-only contracts were explained largely by low input asset specificity; the same inputs are required for all cattle. Hence, large volumes of the same inputs are handled at any given time leading to cost savings because of the economies of scale in the acquisition and transportation of material inputs. The predominance of unspecified contracts in zones with single rainfall peaks, and therefore a long dry season with high environmental uncertainty (Guinea and Sudan savannah), were explained by the high cost kraal owners incur when a calf dies, due to feed scarcity, and the opportunity to share this risk with the cattle owner. Further, the occurrence of fixed-wage payments in particular zones was explained by the lower cost of monitoring associated with such zones. The association of hired herdsmen with milk payment and familial herdsmen with non-milk payment contracts was explained by pointing at the difficulty of measuring performance and adequate monitoring, and hidden information that herdsmen often possess regarding their herding skills. The observation that some hired herdsmen, though a minority, received non-milk fixed payments was explained by the possibility that a kraal owner designs a menu of contracts tailored to herdsmen's abilities. Thus, each herdsman selects a contract type which matches his herding abilities. High-ability herdsmen receive milk payment contracts and low-ability herdsmen receive non-milk fixed payment contracts. A feature common to the explanations of KH contracts, based on difficulty in performance measurement and monitoring cost of herdsmen's opportunism, and herdsmen's hidden information, is the ability of herdsmen to ensure that the cattle they herd obtain adequate nutrition from grazing.

Our explanations for the existence of specific contract types in particular zones are more suggestive than definitive, since we are unable to go beyond the establishment of associations to causality. In the subsequent chapters, we will use more rigorous methods to verify the drivers of some contract types. Knowledge of these drivers and how they influence incentives can provide information for policy formulation aimed at improving the incentives for productivity-enhancing input use and investment in cattle production. Ultimately, this can lead to increased output of meat, milk and other livestock products and thereby meet the growing demand for livestock products.

Appendix 2.1

Table A1 Study locations

Agro-ecological zone	Districts
Coastal savannah	Ningo Prampram
	South Tongu
	Ada West
Guinea savannah	Saboba
	Wa West
	Wa Municipal
Sudan savannah	Garu-Tempane
	Pusiga
Transitional zone	Atebubu- Amantin
	Ejura - Sekyere
	Kintampo North

Source: Field data

CHAPTER 3

Implicit contracts as mutual insurance in cattle production in Ghana

ABSTRACT

Potential production loss, trust, and risk aversion can affect the choice of contract type between a cattle owner and kraal owner. We formulate a model which yields hypotheses regarding the influence of potential production loss, trust, and risk aversion on the choice of contract type. Using survey and experimental data sets from Ghana we find some support for the hypotheses. We show that in accordance with our theoretical predictions potential production loss, and trust are positively correlated to the choice for implicit cattle owner- kraal owner contracts. We see implicit contracts as a way through which parties to the contract insure each other against potential production loss. The correlation between education, our measure of outside options and risk aversion, and the choice for implicit contracts is negative also conforming to our prediction. We suggest that future research investigates the need for other insurance alternatives for cattle production in Ghana especially in areas of high potential production loss.

3.1 Introduction

In Sub-Saharan Africa, cattle production contracts can be categorised into two main types: kraal owner - herdsman (KH) contracts, and cattle owner - kraal owner (CK) contracts (Moritz et al., 2011, Turner, 1999). The kraal owner is a person who owns cattle and has a place of his own where he keeps his cattle. In the case of KH contracts, a kraal owner hires a herdsman to take cattle for grazing. In the case of CK contracts, a cattle owner who has no place of his own to keep cattle or a herdsman to herd them entrusts his animals into the care of a kraal owner.

CK contracts can be classified further as implicit and explicit contracts. Implicit contracts are long-term arrangements between two parties that are defined contingent on production outcomes (Azariadis, 1975, Baker et al., 2002). In explicit contracts, the agent's rewards are agreed ex ante and do not vary regardless of production outcomes. Contracts between a kraal owner and a cattle owner include fixed-wage payments by the cattle owner to the kraal owner and share contracts, where the proportion of calves (output) shares received by the kraal owner are agreed ex ante. Calves sharing is rotational: the cattle owner gets the first calf delivered by a cow he has entrusted into the care of a kraal owner, while the kraal owner gets the second calf delivered by the same cow under his care. This cycle of sharing is repeated indefinitely. Cattle owners usually entrust multiple cows into the care of kraal owners and each cow is subject to the agreed sharing arrangement. In implicit contracts, the cattle owner waits for a number of periods (at least two periods) to observe output and then rewards the kraal owner accordingly. These rewards are determined ex post, after he has obtained all the available information about production outcomes. It is not unusual for a cattle owner to give animals to the kraal owner as part of his rewards after several periods.

The existence of specific contracts in specific areas appears to be a puzzle. In Ghana, explicit CK contracts, especially rotational calves-sharing contracts, tend to be concentrated in the Coastal savannah, while implicit CK contracts are common in Guinea and Sudan savannahs. The Guinea and Sudan savannah are more prone to drought than the Coastal savannah. When drought occurs, it leads to crop production loss. Crop production loss is often accompanied by drying of natural pastures. Consequently, droughts which lead to production loss and scarcity of natural pastures increase livestock mortality especially in cases where livestock production is sedentary. An issue that arises from the foregoing is the following: Can differences in potential production loss and therefore the need for mutual insurance explain the existence of implicit and explicit contracts in cattle production across regions?

The drivers of explicit contracts in agriculture are quite well known. It is expected that if a principal (cattle owner) is risk neutral, then he will offer a wage contract to the kraal owner which the former will accept if it meets his reservation wage. If the kraal owner is risk averse, then risk and incentive considerations will make the cattle owner offer a share contract (Newbery, 1977, Stiglitz, 1974). The incentive concerns stem from the non-observability of the agent's action, making the principal design a contract for the agent to give his best effort (Hölmstrom, 1979). Share contracts will also occur if both the cattle owner and kraal owner are risk averse (Eswaran and Kotwal, 1985). Yet, implicit contracts in which the kraal owner's reward do not appear to be clearly specified are also found.

Nevertheless, some explanations have been provided for the existence of implicit contracts. For example, Azariadis (1975) and Baily (1974) explain that additional uncertainties or risk can lead to the emergence of implicit contracts that serve as insurance for agents. In situations where the principal is wealthy and risk neutral, he can provide insurance at a premium to the agent who is faced with uncertainty. More recent studies have attempted to estimate the sensitivity of wages to idiosyncratic shocks (Guiso et al., 2005, Kátay, 2016). If both parties involved in a transaction or contract face some risky situation, then they can agree to share risk or provide mutual insurance to each other (Fafchamps and Lund, 2003, Murgai et al., 2002). Risk pooling is possible among small clusters such as relatives and friends (Fafchamps, 2011, Fafchamps and Lund, 2003, Murgai et al., 2002). Appropriate risk pooling can also occur along ethnic ties (Grimard, 1997). These suggest that trust and kinship elements could be at play in risk pooling or mutual insurance. Trust could be generalised, relating to how a person looks at the rest of the world, or localised, which is personalised trust between relatives. As an instance of personalised trust, Ensminger (2001) observes that in East Africa, kraal owners sometimes marry their daughters to their herdsmen in a bid to introduce stronger bonds between them and reduce moral hazard on the part of the herdsman. Several channels of risk pooling have been observed (Bhattamishra and Barrett, 2010, Fafchamps, 2011). Fafchamps (2011), for instance, refers to risk-sharing channels such as gifts and transfers (including livestock), funeral societies, labour pooling, and fostering of children.

In this chapter, we model implicit CK contracts as mutual insurance against the additional risk that emanates from rotational sharing of calves (output) and derive hypotheses. In a round of sharing, one party can lose his animal while in a subsequent round the other does not. If both parties agree to pool risk, they can accumulate animals in a round and share what is available at the end. Cattle owners often keep multiple animals with their kraal owners, and this accumulation of animals applies to all calves delivered by the multiple cows that a cattle owner keeps with the kraal owner. Our main hypothesis is that the choice for implicit contracts is positively correlated with potential production loss, trust levels, and risk aversion.

We use primary data from Ghana to show empirically that potential production loss is positively correlated with the occurrence of implicit contracts. This means that in the face of high potential production loss, parties to a cattle owner-kraal owner contract share risk as a form of mutual insurance. We also show that trust is positively correlated with the occurrence of implicit contracts. We also observe that implicit contracts are positively correlated with regions where environmental and economic scarcity is highest. The correlation between the probability of a person engaging in implicit contracts and his education is negative.

Substantial knowledge on cattle production in Sub-Saharan Africa especially West Africa has been generated by anthropologists and geographers. They have sought to understand how pastoralists' way of life revolve around cattle. Additionally, they have studied herder arrangements and how they influence the environment (Moritz et al., 2011, Toulmin, 1992, Turner, 1999, Turner and Hiernaux, 2008), herder farmer conflicts (Moritz, 2010, Tonah, 2003, Tonah, 2006) and how livestock transfers occur, and social security (Dijk, 1994). With the exception of a few studies including Ensminger (2001) and Tadesse et al. (2016) cattle production arrangements have hardly been studied using contract theory framework. If these arrangements provide insurance to overcome the inherent risk in the production environment, then perhaps more effective ways of providing insurance can be investigated and implemented. This will go a long way to reduce poverty, as people who might suffer losses become protected. Livestock insurance schemes exist in other parts of Africa, particularly East Africa. Thus, a better understanding of the arrangements in West Africa might provide information regarding whether similar schemes can be implemented in the region.

The rest of the chapter is organised as follows. We model contracts in cattle production as implicit contracts and derive hypotheses in Section 3.2. Then in Section 3.3, we provide an empirical strategy for investigating the implications of the model. Our results are presented and discussed in Section 3.4. Finally, in Section 3.5, we draw conclusions.

3.2 Theory

In a cattle owner (CO) kraal-owner (KO) contract, hereafter called the contract, the CO (principal) gives his animals to the KO (agent) to be cared for. The CO can remunerate the KO in several ways. He can pay the KO a fixed wage, give him a share of his calves, or leave the KO's payment unspecified ex ante and reward him based on future production outcomes.

When a share contract is agreed upon, the CO and KO take turns at appropriating calves delivered by the CO's cow. Given that the production environment has variable weather, which in turn influences natural pasture availability, a calf could die or lose its value significantly due to scarcity of pasture. Thus, under share contracts in which the CO and the KO share calves on rotational basis, a set of possible production outcomes results when each party has had the chance to receive output after a round of two periods. First, both parties could lose their calves. Second, the CO's calf could survive while the KO loses his. Third, the CO could lose his calf while the KO's survives. Fourth, both parties' calf could survive. We refer to contracts in which the KO's remuneration is specified explicitly as explicit contracts. Thus, we see share contracts in which the KO's remuneration is explicitly specified as explicit contracts.

Let us denote the value of a calf by y, the value of the loss from the animal by $L\ (L \leq y)$, and the probability that a party does not suffer a loss by π. Then the four production outcome possibilities can be represented by the ordered pairs in set A,

$$A = \{(y-L, y-L), (y, y-L), (y-L, y), (y, y)\}.$$

The first and second elements of an ordered pair are the payoffs obtained by the CO and the KO, respectively, in the two consecutive periods.

Under contracts where the remuneration of the KO is not specified ex ante, it is common for the CO to reward the KO with calves after several years. Essentially, the CO observes production outcomes for several periods and then rewards the KO. This reward could be considered as flowing from an implicit arrangement. The two parties reach an agreement such that over the several periods (we use two periods for tractability) when one party suffers production loss and the other does not, the party that does not suffer the loss shares his output with the one who does. We refer to this arrangement in which the KO's remuneration is dependent on outcomes as implicit contracts.

This way of relying on one another to smooth production outcomes in the face of uncertainties constitutes mutual insurance. It could be argued that implicit contracts are a form of explicit contract in which output is accumulated for a period and split between the cattle owner and the kraal owner. Nevertheless, there is some difference, which is that pooling offers insurance to both parties, compared to sequential sharing. The insurance element of pooling is a key feature of implicit contracts. Also, it is conceivable to have an arrangement where the order of appropriation of calves by the CO is alternated for different cows. However, in situations where COs have several cows, such an arrangement could be difficult to implement or monitor. Different orders of calf appropriation for different cows introduces extra complications which could present problems, since written records are hardly kept by the parties to the contract. Besides, all the CO's cows may not be acquired at the same time, which means that although the order of appropriation will be different for two cows, the timing of the appropriation from the two cows could coincide. Above all, we do not find such alternating orders of appropriation in practice, which perhaps points to the near impracticality of implementing such an arrangement under the prevailing management systems. Thus, we disregard the possibility of this option for sharing.

The CO needs to trust that if he splits his share of the output (income) with the KO when the latter faces a production loss, the KO will reciprocate by splitting his share of the output when he, the CO, also faces similar loss. Trust comprises both selfish motives, under which the trustor expects that the trustee will reciprocate any gesture he makes towards him, and altruistic motives, under which there is no expectation of reciprocation from the trustee. A party to an implicit contract wants to be assured that his partner is committed to the contract. Commitment to the contract also means that, first, the KO will account faithfully for all animals accumulated over the two periods and, second, the CO will reward the KO fairly. We will show that when trust is too low, an implicit contract will not be adopted.

We do not focus on asymmetric information and moral hazard. Asymmetric information arises when information on KO's ability which is private to him influences the loss of animals. Asymmetric information also occurs when a party has private information regarding his risk of refusing to abide by the sharing arrangements. Moral hazard arises when the KO does not give his best effort which results in the loss of animals. We ignore asymmetric information and moral hazard, so that we can attribute losses fully to environmental factors. Also, the assumptions make the model tractable.

Below we derive the expected utility and variance of the utility of a party to the contract under both explicit and implicit contracts and make comparisons. We will show that if trust is too low, implicit contracts will not be reached.

3.2.1 Expected payoff and variance of payoff of explicit contracts – uninsured

Consider a contract in which a CO has entrusted one cow into the care of a KO. Suppose the CO and KO have a (rotational) share contract where the CO takes the first calf (in period 1) and the KO takes the second calf the next time the same cow calves (in period 2). Thus, the CO obtains one calf over the two periods.

The CO's expected utility under an explicit contract, (U^E) can be written as

$$U^E = \pi U(y) + (1-\pi)U(y-L) \tag{1}$$

Where π $(0 < \pi < 1)$ is the probability that the CO (or the KO) does not suffer animal loss and earns income y. When he suffers animal loss of value L, he obtains a net income of $y - L$. The payoff y can be interpreted as high output in the absence of production shock. The loss L can be viewed as the difference between high output, when the calf survives and is in good condition, and low output, when the animal dies or loses condition due to a production shock.

The explicit contract has expected payoff $(\bar{y}^E)$

$$\bar{y}^E = \pi y + (1-\pi)(y-L) = y - (1-\pi)L, \tag{2}$$

and the variance of the expected payoff (V^E) is

$$V^E = \pi\big(y - (y-(1-\pi)L)\big)^2 + (1-\pi)\big(y - L - (y-(1-\pi)L)\big)^2 = \pi(1-\pi)L^2. \tag{3}$$

3.2.2 Expected payoff and variance of payoff of implicit contract – insured

The CO's expected utility of an implicit contract (U^I) with probability p that the KO will remain committed to the contract, $0 \leq p \leq 1$, is given by

$$U^I = \pi[(1-\pi)U(y-\alpha L) + \pi U(y)] + (1-\pi)[(1-\pi)U(y-L) + \pi\{pU(y-L+\alpha L) + (1-p)U(y-L)\}]. \tag{4}$$

where α $(0 < \alpha \leq \frac{1}{2})$ is the share of the loss that the CO transfers to the KO who has incurred the loss. Equation (4) takes account of two possible states - whether the CO suffers production loss or not - and in each state, he considers whether the KO has also suffered production loss or not. First, when the CO does not suffer production loss, with probability π, he faces the prospect of the KO facing production loss, in which case he transfers αL to him. However, the KO can also escape production loss with probability π, in which case the CO does not transfer anything to the KO. Second, when the CO does suffer production loss, with probability $(1-\pi)$, the KO can also suffer production loss with probability $(1-\pi)$, so he does not receive any transfer from the KO. However, when the CO suffers production loss, but the KO does not, with probability π, he receives a transfer of αL from the KO. He receives this transfer with a probability p and earns an income of $y - L + \alpha L$ or fails to receive it with probability $1-p$ and earn only $y - L$. Note that $\alpha = \frac{1}{2}$ implies full insurance.

In Appendix 3.2, we show that this contract has the expected payoff $(\bar{y}^I)$

$$\bar{y}^I = \bar{y}^E - (1-\pi)(1-p)\alpha\pi L \tag{5}$$

and the variance of the expected payoff (V^I) is

$$V^I = V^E \cdot \left[1 - 2\alpha + 2\alpha^2 + (1-p)\alpha\left\{2\pi - \alpha\left(1 + \pi(1-\pi)(1-p)\right)\right\}\right]. \tag{6}$$

3.3.3 Comparison of explicit and implicit contracts

Let us compare the outcomes of the two types of contracts. First, from (5), we see that expected payoffs are the same in the case of complete trust $(p = 1)$. Otherwise the explicit contract yields a higher expected payoff. Therefore, in the case of risk-neutrality, explicit contracts are preferred; only if trust is complete the CO is indifferent. In the case of risk aversion, the variances play a role too. Suppose first that trust is complete $(p = 1)$. From (5) it follows that $\bar{y}^I = \bar{y}^E$. Moreover, from (6) it follows that

$$V^I = V^E \cdot [1 - 2\alpha + 2\alpha^2] < V^E\ . \tag{7}$$

For example, in the case of full insurance and so losses are shared equally $(\alpha = \frac{1}{2})$, implicit contracts have only half of the variance of explicit contracts $\left(V^I = \frac{V^E}{2}\right)$. Consequently, in the case of risk aversion and complete trust, implicit contracts are strictly preferred.

For the case when trust is incomplete $(p < 1)$, we note that the effect of trust on the variance of the implicit contract is

$$\frac{\partial V^I}{\partial p} = V^E \cdot [\alpha^2 - 2\alpha\pi + 2(1-p)\alpha^2\,\pi(1-\pi)]\ . \tag{8}$$

The derivative depends on parameters, but it can be shown that a sufficiency condition for $\frac{\partial V^I}{\partial p} < 0$ is $\pi \geq \frac{1}{2}$. In this case, therefore, higher trust reduces the variance of the implicit contract and thus promotes the acceptance of such contracts relative to explicit contracts. Hence, in the case of risk averse CO and incomplete trust $(p < 1)$, we know that $\bar{y}^I < \bar{y}^E$ but a comparison of the variances depends on parameters. Moreover, if $V^I < V^E$, this procedure cannot give us the final decision of a CO.

Therefore, we now proceed in an alternative, but straightforward way to examine the case of risk aversity (so U is strictly concave). Let Δ denote the difference between the expected utility under an implicit contract and that under an explicit contract, so $\Delta = U^I - U^E$. Then using (4) and (1)

$$\Delta = \pi(1-\pi)[-U(y) + U(y - \alpha L) + pU(y - (1-\alpha)L) - pU(y - L)]. \tag{9}$$

Setting $\Delta = 0$ and solving for p gives the critical p^* for which a risk-averse CO is indifferent:

$$p^* = \frac{U(y) - U(y - \alpha L)}{U(y - (1-\alpha)L) - U(y - L)}. \tag{10}$$

Thus, if $p > p^*$ he prefers the implicit contract, and if $p < p^*$ he prefers the explicit contract. This is consistent with the above finding that if $p = 1$, he prefers the implicit contract. Note that threshold p^* does not depend on the probability of production loss (π). Further, $p^* > 0$ (in the case of risk neutrality, $p^* = 1$) and, note that because $U(y - (1-\alpha)L) \le U(y - \alpha L)$ if $\alpha \le \frac{1}{2}$, $p^* < 1$.

To examine the effect of the size of the production loss L and also the effects of the parmeters on the adoption of implicit contract, it is convenient to consider the following general utility function with relative risk aversion (indicated by $\theta \in (0,1)$):

$$U(x) = x^{1-\theta}. \tag{11}$$

For this specification, the threshold (10) becomes

$$p^* = \frac{y^{1-\theta} - (y - \alpha L)^{1-\theta}}{(y - (1-\alpha)L)^{1-\theta} - (y - L)^{1-\theta}}. \tag{12}$$

Numerical examples suggest that if L (or $\frac{L}{y}$), θ, or α increases, then p^* falls (see Appendices 3.3a and 3.3b). Hence, if the (relative) size of the potential production loss increases, then p^* falls. If the CO's relative risk aversion increases, then also p^* falls. And if the share of loss that is transferred to the party incurring the loss increases, p^* falls. This means that, first, those for whom losses loom larger tend to prefer implicit contracts. Second, more risk-averse CO's tend to prefer implicit contracts, i.e., are less hindered by a lack of trust – they can tolerate a lower level of trust more. Third, as the insurance cover or benefit derived from insurance increases, preference for implicit contract also increases.

In making the choice to adopt an implicit contract, the KO has similar considerations as the CO. The variables y, L, and π and the parameter α may be the same for both the CO and KO. However, the parameter θ may differ leading to a different p^*. The probability that the CO and the KO engage in an implicit contract depends on the trust levels of the CO and the KO being greater than their respective p^*. Let us assume that there exists a subpopulation of COs and a subpopulation of KOs, and each subpopulation has a distribution of trust levels. Further assume that the distribution of trust for each sub-group is independent of the other. Then the probability that a CO and a KO randomly engage in an implicit contract depends on the product of their trust levels each of which should be greater than the critical trust level, p^*, which is assumed to be the same for each sub-group. Thus, the likelihood of the two adopting an implicit contract increases when both or one of the p^* fall. Similarly, the effects of the size of KO's production loss and parameters on the choice of implicit contract are the same as those of the CO in the earlier analysis.

We consider that the trust levels of both the KO and the CO matter, because it is consistent with our observation that the KO and CO face a symmetric bargaining situation - one must rely on the other when one faces a production loss and the other does not suffer a loss. It could be argued that because the KO has all the animals in his custody, he has a stronger bargaining position and therefore has full trust that the CO cannot renege on their sharing agreement. In this case, it is the trust level of the CO that matters. Nevertheless, we think the symmetric bargaining situation is plausible. If for any reason, KO trust only, or CO trust only should be considered the relevant trust variable, the evidence we wish to show regarding the positive correlation between trust and implicit contract choice could be weakened somewhat, but not negated entirely.

The theoretical model supports the following hypotheses: First, higher levels of CO or KO trust are positively correlated with the adoption of implicit cattle production contracts. Second, higher levels of potential production loss are positively correlated with the adoption of implicit contracts. Third, more risk-averse cattle owners and kraal owners are more likely to adopt implicit contracts.

3.3 Empirical strategy

3.3.1 Data

We combine cross-sectional primary data (survey and experimental data) and secondary data to address our objectives. The primary data were collected from cattle owners and kraal owners in two agro-ecological zones, the Guinea savannah and the Coastal savannah in 2015. The secondary data concerns crop loss events occurring in various regions of Ghana. This data was obtained from a report on Ghana's agricultural sector risk assessment by Choudhary and D'Alessandro (2015).

The survey elicited data for characterising the contract types kraal owners and cattle owners were engaged in. Respondents were interviewed by Agricultural Officers fluent in the local languages of their areas and knowledgeable in agricultural practices there. They were asked questions pertaining to the terms of their contracts including remunerations and duties. Additionally, questions were asked to obtain information on their socio-economic characteristics. One hundred people were surveyed. Contracts were characterised based mainly on the remuneration a cattle owner gives to a kraal owner for taking care of his cattle. For this survey, we could distinguish share contracts and non-share contracts. Under share contracts the cattle owners rewarded the kraal owner with a share of the cattle for taking care of the former's cattle. The non-share contracts were largely unspecified contracts in which kraal owners' rewards were not specified explicitly, and some subsidy-only contracts where the cattle owner financed all input requirements including contributing to paying or caring for the herdsman and paying for all veterinary care related to his cattle.

Contract types were associated with agro-ecological zones. In the Coastal savannah, nearly all contracts were calves-sharing contracts while the rest were unspecified. In the Guinea savannah, almost all contracts were non-share contracts. The association of contracts with agro-ecological zones presents challenges for subsequent regression analysis.

We re-categorised the share and non-share contracts as implicit and explicit contracts respectively. As mentioned earlier, we see explicit contracts as contracts where the kraal owner's rewards are explicitly specified and implicit contracts as contracts where the kraal owner's rewards are not explicitly mentioned beforehand. Also, we have suggested that implicit contracts have inherent properties that provide mutual insurance against potential production loss. Thus, our goal here is to distinguish between contract types which have this property and those that do not.

We present summaries of the key variables in Table 3.1. Half of the respondents are engaged in non-share (implicit) contracts. On average, cattle owners have about four years of schooling (row 3), or just primary school education.

A common proxy for risk aversion is wealth, although it can be measured with error and thus creates problems of endogeneity bias in subsequent estimations in which it is used. Education, income, and wealth have been found to be highly correlated (Guiso and Paiella, 2008, Halek and Eisenhauer, 2001, Outreville, 2014). Thus, Guiso and Paiella (2008) used education as an instrument for wealth and showed that risk aversion is a decreasing function of wealth. Also, a review by Outreville (2015) indicates that from a causality point of view, highly educated investors tend to be less risk averse, but there could be selection such that less risk averse individuals choose higher education. Brunello (2002) goes a step further and uses risk aversion as an instrument for schooling in an earnings regression; estimating a reduced form equation, he found that years of schooling was negatively correlated with risk aversion. In sum, education could be a candidate for a proxy of risk aversion.

Table 3.1. Summary statistics of key variables

Variable	**N**	**Mean**	**S.D**	**Min**	**Max**
Trust	100	3.68	1.78	0	8
Contract type dummy (implicit = 1)	100	0.51	0.502	0	1
Education	100	4.84	5.32	0	18
Number of crop loss events	3	11.92	5.32	6	16

Field data

Trust data was obtained from trust games. We conducted the trust games following Berg et al. (1995) and Bouma et al. (2008). The game was played between a pair of players, a sender (player A) and a receiver (player B). Each player played only one role. Both player A and player B received cash endowments of eight Ghana cedis (GHC 8.00) each (about two US dollars at the time). The amount was slightly higher than the minimum daily wage of GHC 7.00 in 2015. The game goes as follows: Player A sends an amount $\mathrm{GHC}\, S\ (0 \leq S \leq 8)$; S is an integer. The experimenter triples the amount sent by player A before sending it to player B. Player B returns $\mathrm{GHC}\, R\ (0 \leq R \leq 3S)$; R is an integer. So player A earns $\mathrm{GHC}\,(8 - S) + R$, while player B earns $\mathrm{GHC}\, 3S - R$. The amount sent (S) is the measure of trust (see, e.g., Berg et al. (1995) and Bouma et al. (2008)).

The game was implemented in the Guinea savannah zone (Wa West district) and the Coastal savannah zone (South Tongu and Ada West districts) between June and August, 2015. One hundred (100) pairs of players participated in the games, 48 pairs coming from the Guinea savannah zone and 52 pairs coming from the Coastal savannah zone. We invited a kraal owner and another person who owned and kept cattle in the former's kraal to come to a designated venue to play the game on a specified day at a given time. General instructions and trust game instructions were given in the local language of the area.

Participants were then divided into two groups of kraal owners and cattle owners. Groups were randomly selected to be senders and receivers, but we ensured that equal numbers of kraal owners and cattle owners played the role of senders and receivers as this was more convenient and appeared fair to both parties. Senders randomly picked numbers that indicated who they were paired with from the other group. Players were told that they would play the game with a person from the other group, but they did not know exactly who they were playing with. They were then called one by one to go to the experimenter to play the game. Players were informed that they would be paid their earnings after one week, which was adhered to. We consider the amount sent in the trust game, our proxy for trust, as generalised trust rather than local trust because the games were largely between community members, and not strictly between relatives. After the experiment, each participant was surveyed to collect information on demographic characteristics and the contract types they were engaged in.

Table 3.1 presents the key variables obtained from the experiment and the follow up survey. The mean amount sent in the trust game is approximately half of the cash endowment given to the sender (GHC 3.68 out of GHC 8.00). Fig 3.1 also shows the distribution of the amount sent by agro-ecological zone, which shows that a greater percentage of senders sent higher amounts in the Guinea savannah. Appendix 3.4 also shows that the mean amount sent is higher in the Coastal savannah than in the Guinea savannah.

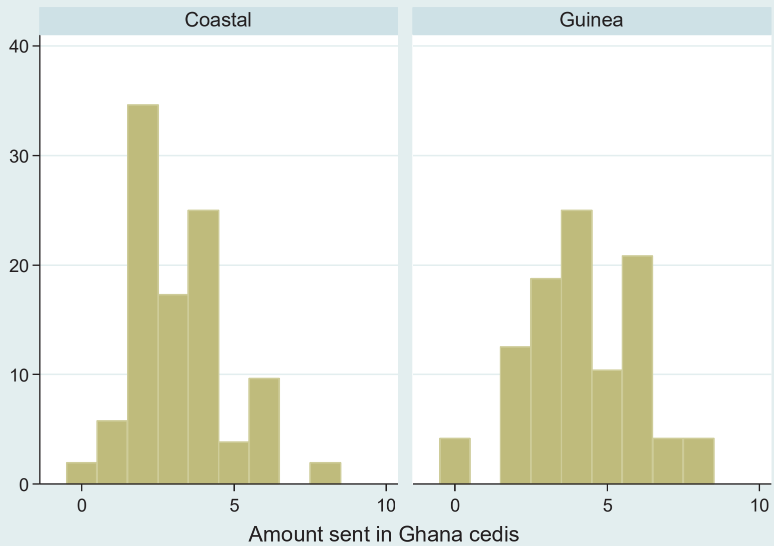

Fig. 3.1: Amount sent in Ghana cedis by agro-ecological zone

Data on production loss events was obtained from a publication, Choudhary and D'Alessandro (2015). This publication is based on work done by the Agricultural Risk Management Team of the World Bank to assess Ghana's agricultural sector risk. They analyzed adverse production events by crops and region and reported the incidence of such events over the period 1981-2010. Drought, floods, bushfires, pest and diseases were considered the drivers of adverse production events. The most common driver was drought. This data set allowed us to construct a measure of the number of crop loss events for our study areas. We did this by using the regional data to represent data for each district we surveyed (Appendix 3.1, Table B1). In each case, we adjusted our computation of crop loss events by considering only crops grown in the districts (agro-ecological zones) we surveyed, even if other crops were considered in the regions the districts (agro-ecological areas) belong to (Appendix 3.1, Table B2). The agro-ecological zones are areas of the country with specific climate that influences the vegetation and production systems. Table 3.1 shows the summaries of the number of production loss events in row 4.

3.3.2 Empirical strategy

Our goal is to analyse the relationship between contract types on the one hand and trust, potential production loss, and risk aversion on the other. We do this by estimating a series of equations using the complementary data sets from surveys and experiments. Since the dependent variable (contract type) is binary, we conduct logistic regressions for all the equations.

First, we estimate the relationship between contract type (C) engaged in by the contract party (cattle owner or kraal owner) i in agro-ecological zone j and the potential production loss (L) he faces, his risk aversion (R), and his trust level (T), while controlling for agro-ecological zone, Z, (13). The random error term is denoted as e. The zone takes the value 1 when it is the Coastal savannah and zero when it is the Guinea savannah. Also, the dependent variable is a dichotomous variable which indicates whether the contract type is implicit (and takes on a value one) or explicit (and takes on a value zero).

$$C_{ij} = b_0 + b_1 L_{ij} + b_2 R_{ij} + b_3 T_{ij} + b_4 Z_{ij} + e_{ij} \quad (13)$$

In accordance with the theoretical model, we expect that trust level of a party will be positively associated with the probability of observing implicit contracts. Similarly, an increase in potential production loss is likely to be associated with an increase in the probability of observing implicit contracts. The more risk averse a party is the higher the probability that he will be engaged in an implicit contract.

We use the number of crop loss events as a proxy for potential production loss in cattle by assuming that this number is proportionate to the size of production losses. Potential production loss in cattle can be linked to crop losses because losses of calves could be linked to the weather and therefore the availability of grass or natural pasture as feed for the animals. In times of bad weather, crops fail, and pasture does not grow well, thus crop loss events can be correlated with dying and unavailability of grass. Scarcity of pasture often leads to the starvation of animals and possible death, especially in young animals (Wymann et al., 2006).

Data on livestock assets and herd size could serve as measures for wealth. However, we find these to be quite noisy. Although education is correlated with risk aversion, it is not necessarily a strong proxy for risk aversion. Nevertheless, we include it as an explanatory variable for choice of contract. Education is measured as the number of years of schooling by the cattle owner. A continuous variable for years of schooling is created by noting the level of education attained by an individual and estimating the number of years required to attain such a level.

The amount sent by a cattle owner or a kraal owner in our trust games is used as a proxy for his trust. Recall that we have trust data for both cattle owners and kraal owners.

We estimate equation (13) using logistic regression. However, there is separation in the dataset. Separation usually occurs when there are no events (outcome = 0) in one of two groups of a binary variable. In such situations, maximum likelihood regressions lead to infinite or zero estimates of odd ratios (Heinze, 2006). In order to overcome this problem we adopt the penalised maximum likelihood procedure suggested by Firth (1993). The procedure reduces small-sample bias in maximum likelihood estimates and produces finite, consistent estimates of the parameters. We obtain a user written programme, firthlogit, and implement the procedure in STATA 13 to estimate the equation. An alternative procedure, exact logistic regression, can also be used, but is much more computationally intensive, relying on much more computer memory than firthlogit.

Two more equations are estimated by omitting certain variables of (13). Because agro-ecological zone captures everything that varies across the zones including trust and production loss, and therefore obscures insights from the model, we estimate a second equation without agro-ecological zone. A third equation is estimated by omitting the risk variable, since the proxy we used (education) could be controversial, for it not commonly used as a proxy for risk aversion.

3.4 Results and discussions

Table 3.2 presents the results of the estimations of the three equations. In column 1, we show firthlogit regression of contract type on trust, potential production loss, and education, while controlling for agro-ecological zone. Both the trust and potential production loss variables have insignificant correlation with the probability of engaging in implicit contracts. As indicated earlier, agro-ecological zones capture most things that vary across the zones and hence could be obscuring the relationship between trust and potential production loss on the one hand and engagement in implicit contracts on the other. However, education has a significant negative correlation with implicit contracts, indicating that higher education reduces the adoption of an implicit contract. We view education as a means to improve one's economic or outside options, which in turn could make one less risk averse. This is also in conformity with our expectation that more risk averse individuals will increasingly prefer implicit contracts.

When agro-ecological zone is dropped from the model and estimated by logistic regression, trust does have significant positive correlation with the engagement in implicit contracts (column 2). This agrees with our hypothesis that the adoption of implicit contracts becomes more likely when trust is greater. Also, potential production loss has significant positive correlation with having implicit contracts (column 2), which also agrees with our hypothesis that higher potential production losses increase the preference for implicit contracts. Education is still significant and negatively correlated with the occurrence of implicit contracts.

Table 3.2: Categorical choice regressions of implicit contract on trust, potential production loss, and risk aversion

	Dependent variable is contract type		
	Firthlogit regression	Logistic regression	Logistic regression
	(1)	(2)	(3)
Trust	-0.215	0.428**	0.392***
	(0.335)	(0.202)	(0.198)
Potential production loss	-0.180	0.446***	0.522***
	(0.199)	(0.099)	(0.101)
Education	-0.259**	-0.269***	-
	(0.126)	(0.075)	-
Coastal	-8.655***	-	-
	(2.848)	-	-
Constant	9.789**	-5.816***	-7.972***
	(4.497)	(1.618)	(1.711)
N	100	100	100
Ll	-24.782	-3.33	-32.6

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

When both agro-ecological zone and education are removed from the model, and estimated by logistic regression, trust and potential production loss are still significantly correlated with implicit contracts (column 3).

Potential production loss could be a source of uncertainty in production outcomes for kraal owners. Such uncertainties can be insured by a risk-neutral principal, in this case the cattle owner (Azariadis, 1975, Baily, 1974, Kátay, 2016). However, the cattle owner could also be prone to similar uncertainties in production outcomes. Furthermore, the cattle owner could also be risk averse. Hence, the two parties could take action to mutually insure each other. Such mutual insurance is replete in the developing world including Ghana (Bhattamishra and Barrett, 2010, Fafchamps, 2011, Fafchamps and Lund, 2003, Grimard, 1997, Murgai et al., 2002).

The probability of observing implicit contracts is less in the Coastal savannah compared to the Guinea savannah (column 1), which is our base agro-ecological zone and has a higher estimated production loss events (Appendix 3.1, Table B2). Elements of the agro-ecology of the Coastal savannah, such as lower environmental resource scarcity, could be driving down trust, which in turn lead to a lower preference for implicit contracts as hypothesized. This agrees with our finding (Fig 3.1) that trust levels were lower in the Coastal savannah than in the Guinea savannah.

The high levels of trust in the Guinea savannah are not likely to be accidental. In fact, Acedo-Carmonia and Gomilla (2015) found that general trust or social cohesion was higher in regions where environmental resources are scarce. Incidentally, they analysed trust and cooperation networks in northern Ghana, in areas spanning both the Guinea and Sudan savannah, and Oaxaca, Mexico. They found that there was more generalised trust in northern Ghana, a region with less resources and economic prosperity, than in Oaxaca, a region with more resources and economic prosperity.

The Guinea savannah has harsher environmental conditions than the Coastal savannah. Although the Guinea savannah has more total annual rainfall than the Coastal savannah, the rainfall distribution is unimodal in the Guinea savannah, while it is bimodal in the Coastal savannah. Hence, there are two cropping seasons in the Coastal savannah, while there is only one cropping season in the Guinea savannah. Consequently, there are more dry months in the Guinea savannah than in the Coastal savannah. Thus, it is conceivable that the higher trust levels found in the Northern savannah are associated with the higher environmental resource and economic scarcity in this region. This in turn is likely to be associated with the greater occurrence of implicit contracts in the Guinea and Sudan savannah, as compared with the Coastal savannah. Also, in northern Ghana, lack of help from persons in one's trust networks is seen as betrayal of trust (Acedo-Carmona and Gomila, 2015), which suggests that trust is positively correlated with cooperation, mutual help, and mutual insurance .

Furthermore, the finding of higher trust levels in the Guinea savannah (a harsher environment) than in the Coastal savannah (a less harsh environment) is consistent with Vollan (2008), who in southern Africa observed higher trust in harsher environmental conditions (lower grazing resource areas) than in less harsh environments (higher grazing resources). Prediger et al. (2011) analysed levels of cooperation in different resource scenarios (using common pool resource games) and found that cooperation was higher in low resource (harsher) regions. This is similar to our finding that the probability of adopting implicit contracts, which requires cooperation and trust from parties, is higher in low resource or harsher environments.

Generalised trust has been shown to be positively correlated with participation in formal institutions such as stock markets (Georgarakos and Pasini, 2011, Guiso et al., 2004, Guiso et al., 2008) and labour markets (Tu and Bulte, 2010). The institutions we consider, implicit and explicit contracts in cattle production, are largely informal institutions. Yet, we find that even within informal institutions generalised trust is more likely to be positively correlated with implicit contracts than explicit contracts. Our theoretical model, which forms the basis for our hypothesis in relation to trust and contract choice, predicts that implicit contracts require higher trust thresholds to be met than explicit contracts.

3.5 Conclusion

Potential production loss, trust, and risk aversion can affect the choice of contract type by parties engaged in a cattle owner-kraal owner contract. We formulate a model which yields hypotheses regarding the influence of potential production loss, trust, and risk aversion on the choice of contract type. Using survey and experimental data from Ghana, we show that in accordance with our hypothesis potential production loss is positively correlated to the choice of implicit cattle owner-kraal owner contracts. We see implicit contracts as a way through which parties to the contract insure each other against potential production loss. Also, we demonstrate that trust is positively correlated with the choice of implicit contracts, and the correlation between education and the choice of implicit contract is negative. We associate increase in education with reduction in risk aversion which in turn is associated with reduction in the choice of implicit contracts. We suggest that future research investigates the need for other insurance alternatives for cattle production in Ghana especially in areas of high potential production loss. Additionally, we suggest that future research investigates the effect of contract type on input use and productivity. We study the influence of contract type on input use and efficiency in the next chapters.

Appendices

Appendix 3.1

Table B1: Potential production loss – number of crop loss events - by region and crop (1992-2008)

	Number of crop loss events per crop (1992 – 2008)								
Region	Maize	Rice	Cassava	Yams	Plantain	Ground-nuts	Millet	Sorghum	Total
Ashanti	2	-	1	3	1	-	-	-	7
Brong-Ahafo	3	4	1	1	2	-	-	-	11
Greater-Accra	5	5	4	-	-	-	-	-	14
Northern	2	4	4	4	-	5	3	4	26
Upper East	6	6	2	-	-	4	6	4	28
Upper West	3	1	5	3	-	1	3	-	16
Volta	1	2	3	3	1	-	-	-	10

Source: Chaudhary and D'Alessandro 2015 – (Compiled from Appendix A – Regional risk profiles)

Table B2. Potential production loss – number of crop loss events by region and adjusted for crops not typical of districts surveyed in the region (1992-2008)

		Number of crop loss events by region adjusted for crops not typical of zone (1992-2008)								
Region	District	Maize	Rice	Cassava	Yams	Plantain	Ground-nuts	Millet	Sor-ghum	Total
Ashanti	Ejura-Sekyere-dumase	2	-	1	3	-	-	-	-	6
Brong-Ahafo	Atebubu, Kintampo-North	3	4	1	1	-	-	-	-	9
Greater-Accra	Ningo-Prampram	5	5	4	-	-	-	-	-	14
Northern	Saboba	2	4	4	4	-	5	3	4	26
Upper East	Pusiga, Garu	6	6	2	-	-	4	6	4	28
Upper West	Wa Municipal, Wa West	3	1	5	3	-	1	3	-	16
Volta	South Tongu	1	2	3	-	-	-	-	-	6

Source: Adapted from Chaudhary and D'Alessandro 2015 – (Compiled from Appendix A – Regional risk profiles)

Appendix 3.2 Derivation of expected payoff and variance of payoff of implicit contract

Derivation of $\bar{y}^I = y^E - (1-\pi)(1-p)\pi\alpha$

Well,

$$\bar{y}^I = \pi[(1-\pi)(y-\alpha L)+\pi y] + (1-\pi)[(1-\pi)(y-L)+\pi\{p(y-L+\alpha L)+(1-p)(y-L)\}]$$
$$= y-(1-\pi)L-(1-\pi)(1-p)\pi\alpha L$$
$$= \bar{y}^E-(1-\pi)(1-p)\pi\alpha L$$

using $\bar{y}^E = y-(1-\pi)L$.

Derivation of $V^I = V^E \cdot \left[1-2\alpha+2\alpha^2+(1-p)\alpha\{2\pi-\alpha(1+\pi(1-\pi)(1-p))\}\right]$.

Well,

$$V^I = \pi(1-\pi)[(y-\alpha L-y^I)]^2$$
$$+\pi^2[y-y^I]^2$$
$$+(1-\pi)^2[(y-L)-y^I]^2$$
$$+(1-\pi)\pi p[(y-L)+\alpha L-y^I]^2$$
$$+(1-\pi)\pi(1-p)[(y-L)-y^I]^2$$

Using $y^I = y-(1-\pi)(1+(1-p)\pi\alpha)L$, we find after some manipulations:

$$V^I = \pi(1-\pi)L^2\{1-2\alpha+\alpha^2+(1-p)\alpha[2\pi-\alpha(1+\pi(1-\pi)(1-p))]\}$$
$$= V^E\cdot\{1-2\alpha+\alpha^2+(1-p)\alpha[2\pi-\alpha(1+\pi(1-\pi)(1-p))]\}.$$

Appendix 3.3a: Numerical analysis of effect of potential production loss (L) on threshold level of trust (p^*)

	y	θ	α	L	p^*
Fix $y,\theta,\alpha;\alpha=0.5$	100	0.5	0.5	10	0.974
	100	0.5	0.5	20	0.946
	100	0.5	0.5	30	0.915
	100	0.5	0.5	40	0.881
	100	0.5	0.5	50	0.843
	100	0.5	0.5	60	0.800
	100	0.5	0.5	70	0.750
Fix $y,\theta,\alpha;\alpha=0.4$					
	100	0.5	0.4	10	0.969
	100	0.5	0.4	20	0.935
	100	0.5	0.4	30	0.899
	100	0.5	0.4	40	0.859
	100	0.5	0.4	50	0.815
	100	0.5	0.4	60	0.765
	100	0.5	0.4	70	0.708
Fix $y,\theta,\alpha;\alpha=0.3$					
	100	0.5	0.3	10	0.964
	100	0.5	0.3	20	0.925
	100	0.5	0.3	30	0.883
	100	0.5	0.3	40	0.837
	100	0.5	0.3	50	0.787
	100	0.5	0.3	60	0.732
	100	0.5	0.3	70	0.668

Appendix 3.3b: Numerical analysis of effect of risk aversion (θ) on threshold level of trust (p^*)

	y	θ	α	L	P^*
Fix $y, L, \alpha; \alpha = 0.5$	100	0.2	0.5	10	0.990
	100	0.3	0.5	10	0.984
	100	0.4	0.5	10	0.979
	100	0.5	0.5	10	0.974
	100	0.6	0.5	10	0.969
	100	0.7	0.5	10	0.964
	100	0.8	0.5	10	0.959
Fix $y, L, \alpha; \alpha = 0.4$					
	100	0.2	0.4	10	0.987
	100	0.3	0.4	10	0.981
	100	0.4	0.4	10	0.975
	100	0.5	0.4	10	0.969
	100	0.6	0.4	10	0.963
	100	0.7	0.4	10	0.957
	100	0.8	0.4	10	0.951
Fix $y, L, \alpha; \alpha = 0.3$					
	100	0.2	0.3	10	0.985
	100	0.3	0.3	10	0.978
	100	0.4	0.3	10	0.971
	100	0.5	0.3	10	0.964
	100	0.6	0.3	10	0.957
	100	0.7	0.3	10	0.950
	100	0.8	0.3	10	0.943

Appendix 3.4: Summary statistics: Education by agro-ecological zone

	Observations	**Means**	**Std. Dev.**	**Min**	**Max**
Coastal	52	7.981	4.747	0	18
Guinea	48	1.438	3.881	0	13

CHAPTER 4

Contract types and incentives for input use: evidence from cattle production in Ghana

ABSTRACT

Incentive effects of contracts in agriculture have been investigated empirically a few times in the last decades. Yet, the evidence of these effects is still mixed. We contribute to this literature by studying the incentive effects of contract types on input use using data from cattle production in Ghana. Regressing input use on contract types and controlling for agro-ecological zones, farm and farmer characteristics, we find some evidence that contract types are differently correlated with input types. Specifically, we show that generally fixed-wage contracts show higher correlation with short-term productivity-enhancing input use than calves-sharing contracts. However, the correlations between contract types and long-term productivity-enhancing inputs are insignificant. A better understanding of the incentive effects of contract types is likely to lead to the formulation of better policies and strategies to enhance the uptake of new technology and thereby improve agricultural productivity.

4.1 Introduction

Theoretical studies on contract theories abound and have provided several testable hypotheses on the incentive effects of contracts, and what optimal contracts should look like (Allen, 1985, Baker et al., 2002, Basu, 1992, Newbery, 1977, Rothschild and Stiglitz, 1976, Stiglitz, 1974). Later empirical studies have sought to test these hypotheses, but the results have depended on the ability to control for unobserved heterogeneity in order to avoid endogeneity problems (Chiappori and Salanié, 2002). One's inability to do this could lead to conclusions that are opposite to predictions of theory. (Ackerberg and Botticini, 2002, Banerjee and Ghatak, 2004, Paarsch and Shearer, 1999). In modelling the incentive effects of contracts, the contract variable could itself be endogenous requiring the use of instrumental variables.

Recently, empirical studies have emerged to provide tests of these hypotheses on theories of contracts including sharecropping (Deininger et al., 2013, Ghebru and Holden, 2015, Jacoby and Mansuri, 2009, Kassie and Holden, 2007, Laffont and Matoussi, 1995, Shaban, 1987). Regarding empirical studies on sharecropping, the majority have focused on share-cropper productivity debate. Yet, the evidence of the superiority of own-cultivation and fixed-rent contracts to sharecropping contracts is mixed (Jacoby and Mansuri, 2009). A few studies have also investigated whether kin relationship between a landlord and sharecropping tenant improves productivity. Whereas Sadoulet et al. (1997) found that this relationship can lead to improvement in efficiency, Kassie and Holden (2007) found that it decreases efficiency or productivity. Other studies (Abdulai et al., 2011, Beekman and Bulte, 2012) have categorised input use or investment into those that enhance short-term productivity and others that enhance long-term productivity. The emerging evidence is that contract type influences the use of input types or investment differently. The bulk of these studies have focused on contracts pertaining to crop agriculture. Yet, similar contracts exist in livestock production, including cattle production. An issue that arises from the foregoing is: do contracts in livestock production influence the use of different inputs differently?

Livestock production contracts abound in Sub-Saharan Africa and other developing countries. These contracts have been referred to as herding contracts or livestock entrustments (Binswanger and McIntire, 1987, Moritz et al., 2011, Tonah, 2006, Toulmin, 1992, Turner, 2009). For this study, we focus on cattle production arrangements in Ghana. Two broad categories of contracts exist in cattle production in Ghana and other parts of tropical Africa: kraal owner-herdsman contracts and cattle owner-kraal owner contracts. The kraal owner is a cattle owner who has facilities for cattle production, whereas a herdsman is someone who is engaged by a kraal owner to take cattle for grazing. A cattle owner who has no facilities or time for cattle production entrusts his animals into the hands of a kraal owner for caretaking.

The cattle owner-kraal owner contracts can take four broad forms. First, we have fixed-wage contracts with or without subsidies. The cattle owner (the principal) can pay the kraal owner (the agent) a fixed wage and take full charge of input supply. This fixed wage could come with compensation or subsidies for expenses that the kraal owner incurs on the principal's cattle. Generally, under fixed-wage contracts the owners take charge of input supply; hence we refer to fixed-wage contracts alternatively as owner-input-supply arrangements later in the Chapter. Second, we have calves-sharing contracts with or without subsidies. In this contract type the cattle owner shares the calves delivered by his cow with the kraal owner as a way of remunerating him. The cattle owner could also compensate or subsidise the kraal owner for expenses he has incurred on his cattle. Third, we have subsidy-only contracts in which the cattle owner only compensates the kraal owner for the expenses he has incurred on his animals. As noted in Chapter 2, the kraal owner may obtain some benefits from manure and milk. Fourth, contracts could be entirely unspecified, in which case the kraal owner's reward for taking care of animals for the cattle owner is not specified ex ante. It is also not clear whether the cattle owner compensates the kraal owner for expenses he incurs on the former's animals. There is a fifth candidate for contract type, where the kraal owner could rent cattle from the cattle owner, but we do not observe this, probably because rented cattle can be abused.

We argue that the subsidy-only contract approaches the fixed-wage contract (where the cattle owner supplies all inputs) in terms of the incentives they provide for material input use. Similarly, unspecified contracts can be viewed as being close to calves-sharing contracts and have similar incentive effects. Hence, we recategorise the four contracts as two contract types. The first is the owner-input-supply arrangement, which is an aggregate of fixed-wage contracts and subsidy-only contracts. The second category is the calves-sharing contract, which is an aggregate of calves-sharing and unspecified contracts. In Chapter 3, we argued that unspecified contracts could be viewed as implicit contracts with insurance against production loss built into it.

These contractual arrangements between cattle owner and kraal owner influence the kraal owner's incentives to apply external inputs in cattle production. Traditionally, cattle is produced using extensive methods. This involves minimal housing and sending cattle to the rangeland for grazing. Little external inputs are used, although sometimes veterinary care is provided for the animals. Providing supplementary feeding for cattle is not the norm. However, some farmers provide supplementary feed to selected animals to grow and fatten them for the market. Besides, state institutions responsible for research and agriculture have been making efforts to get cattle farmers to use external inputs such as supplementary feed, especially in the dry season when there is little grass on the rangeland. These institutions also engage in veterinary care interventions in a bid to boost the productivity of the animals. The extent to which kraal owners and cattle owners use these external inputs could be influenced by the contract type they have. The effect of contract type on behaviour in agriculture is still mixed (Jacoby and Mansuri, 2009). Furthermore, there is little evidence of contracts' incentive effects in livestock production.

Therefore, the primary objective of this chapter is to analyse the effect of contract types in cattle production on external inputs use. Contracts in cattle production and their influence on input use have not been analysed much, as far as we know. A recent contribution is by Tadesse et al. (2016), who studied cattle sharing and rental contracts in Ethiopia, East Africa. Nonetheless, their main focus was on factors that influence participation and choice of contracts. We use survey data obtained from four agro-ecological zones where cattle production occurs most for our analyses. We characterise cattle production contracts using this data and also obtain the levels of input use. We consider cattle as a capital good (Jarvis, 1974) and model cattle production as a dynamic process in order to obtain testable hypotheses regarding the effect of contract type on input use. We employ categorical data models to estimate the effect of contract type on input use. We do not simply look at Marshallian inefficiency of contract types. We look beyond this by assessing the property rights or contract security effects of contract types and how these affect the use of long-term and short-term productivity-enhancing inputs (see for instance Abdulai et al. (2011), Beekman and Bulte (2012), and Besley (1995))

We show that generally there is higher correlation of the probability of using short-term productivity-enhancing inputs with owner-input-supply than with calves-sharing contracts. This is in conformity with the alleged Marshallian inefficiency of output-sharing arrangements, where there is less intense use of inputs. However, there was no significant correlation between owner-input-supply arrangements and long-term productivity-enhancing input use.

This study is relevant for several reasons. First, we contribute to the empirical literature on the incentive effects of contracts. Second, the results of this study can guide policy formulation to boost cattle or beef production. For instance, in order to increase beef production, incentives could be created that encourage the making of owner-input-supply arrangements, because these particularly enhance the use of external feed inputs. The government could promote private pasture cultivation through its agricultural and research institutions, remove bottlenecks to land acquisition, and create avenues for loanable funds for interested farmers. The measures could create an enabling environment for cattle owners to take advantage of to intensify cattle production.

The rest of this chapter is organised as follows: In Section 4.2, we provide an overview of cattle production in Ghana. This is followed by a brief review of the literature on agricultural contracts and incentives in Section 4.3. In Section 4.4, we construct a simple dynamic model of cattle production in order to derive testable hypotheses. In Section 4.5, we specify our econometric model and empirical strategy, outline our survey and data collection methods, and describe the data. Our results and discussions are presented in Section 4.6 and our conclusions are in Section 4.7.

4.2 Cattle production system and input use

In this section, we describe cattle production in Ghana, in particular, production methods, farmers' production goals, production environment, and supporting institutions. We seek to describe cattle production in a way that clarifies the kind of inputs that are used in the production process and the environment in which they are used.

Extensive methods are used for cattle production. Thus, minimal housing is provided for the cattle and they feed on natural pasture. Such housing could be simple enclosures, made from wood, where cattle are kept at night. Herdsmen herd the cattle in the open range to look for pasture to feed on. Feed supplementation is not practiced often. External or purchased inputs are mostly for veterinary care. The type of veterinary practices that farmers engage in include vaccinations, deworming, and acaride application against ticks. Cattle farmers are mostly agro-pastoralists and combine crop production with livestock production. Cattle do not usually trek very long distances from their abode in search for grass. Hence, cattle production in Ghana involves little transhumance and is mostly sedentary.

Reasons for keeping cattle vary among cattle owners. Often farmers keep livestock as saving or a way of accumulating wealth. They sell some of their animals when they have to make some emergency expenditure. Yet, production is sometimes market oriented. In this case, they select young bulls which they provide supplementary feed in order to quicken their growth and fatten them for peak demand periods especially during religious festivals. Milk is more of a by-product from cattle production. No extra feed is provided to the animals to boost their milk yield beyond what they obtain from grazing on natural pasture.

There are several arrangements for keeping cattle in Ghana. Some cattle owners have a place where they keep their animals and manage the upkeep of their animals themselves – they are called the kraal owners in this thesis. Other cattle owners have a few animals but have no space or time to take care of them. These cattle owners entrust their cattle into the care of a kraal owner. The kraal owners have a duty to hire a herdsman who will herd the cattle to the natural pastures daily. They may also finance external inputs used in the production process such as veterinary care inputs. Sometimes cattle owners supply all the external input requirements for their cattle and contribute to pay the herdsman. They mostly remunerate kraal owners in one of two ways. It can be a fixed wage, in which case the cattle owner finances all inputs, or a share of calves that is given to the kraal owner.

Cattle is produced mostly in the Northern (Guinea and Sudan) and Southern (Coastal) savannahs and in the Transitional zone in the middle of the country. The Northern savannahs have more total annual rainfall than the Southern savannah, but the distribution of rainfall in the Northern savannahs is unimodal, while it is bimodal in the Southern savannah. Also, the Transitional zone has a double rainfall peak. The Northern savannahs also have longer dry season periods (seven months) than the Southern savannah (five months) and Transitional zone (five months). These different rainfall regimes have implications for natural pasture availability throughout the year for cattle production and disease burden. For instance, feed scarcity is higher in the Northern savannahs and could lead to greater starvation of animals in the dry season. Also, Walker and Koney (1999) found that the Guinea savannah had the widest variety of tick species and the most infestation among all the agro-ecological zones.

Governmental institutions and non-governmental organisations exist to deal with challenges and development of the livestock sub-sector. For instance, research institutions generate or adapt new technologies and transfer them to farmers in collaboration with extension agents and agricultural officers. Non-governmental organisations are also involved in dissemination of new technologies in livestock production including small and large ruminants.

4.3 Contracts and incentives

In this section, we outline reasons why contracts might influence behaviour of agents in a principal-agent relationship and lead to undersupply of inputs by the agent if it his duty to take care of inputs. Incentive effects of contracts in cattle production have hardly been analysed. Therefore, we provide some evidence of the effects of contracts on incentives to use inputs in crop production. Then we explore some factors that might improve the incentive effects of contracts. Finally, we look at some categorisation of input types and how different contracts might influence their use.

Contract types have different effects on input use. Under a fixed-rent contract, tenants are expected to supply inputs at the optimum level since they are the residual claimants of output. Under output share contracts, however, an agent could undersupply inputs since he claims only a fraction of the output while supplying all the inputs. Nonetheless, it is thought that if the agent's input supply level can be enforced, and monitoring is costless, then optimum levels of input supply can be achieved (Johnson, 1950, Otsuka et al., 1992). Similarly, under fixed-wage contracts, the landlord being the owner-operator has the incentive to supply inputs at the right levels since he receives all the output. Nevertheless, it is possible for owner-supplied inputs to be misapplied or diverted by hired labour. Such diversion could be prevented or reduced by monitoring and supervision, especially when the owner does not live very far from his farm.

Some empirical studies have sought to test the superiority of owner-operated farms and fixed-rent contracts to share contracts. For instance, Shaban (1987) showed that output and input intensities were greater on owned land than sharecropped land of the same household. Also, Laffont and Matoussi (1995) showed that sharecropping tenants with lower output shares have lower efficiency.

Several factors are thought to improve efficiency in output-sharing contracts. First, when input costs are shared in proportion to the output share between the principal and the agent, the optimal level of input use is approached (Allen and Lueck, 1993, Braverman and Stiglitz, 1986). Second, a landlord's threat of evicting a tenant if he undersupplies inputs ensures that the latter uses inputs at optimal levels, though the threat to the security of his tenure could discourage him from investing in durable inputs (Banerjee and Ghatak, 2004). Third, kinship relationship between a landlord and his tenant can lead the kin tenant to supply inputs at optimal levels (Sadoulet et al., 1997). This improvement in efficiency could be because of altruistic feelings between them, but also because of an implicit insurance arrangement between them where one comes to the other's aid when he is down. Fourth, monitoring and supervision have also been found to improve productivity in share cropping (Jacoby and Mansuri, 2009).

Recently, distinction has been made between inputs that influence short-term productivity and long-term productivity (Abdulai et al., 2011, Beekman and Bulte, 2012, Besley, 1995). For instance, Abdulai et al. (2011) found that fixed-rent contracts influenced short-term productivity-improving inputs (mineral fertilizer) more than long-term productivity-enhancing inputs (organic manure). Beekman and Bulte (2012) also found that tenure security influences long-term productivity-enhancing investment (terracing) but not short-term productivity enhancing-investment (fertilizer use).

We observe four main contract types in cattle production. As mentioned earlier, these are fixed-wage contracts, calves-sharing contracts, subsidy-only contracts, and unspecified contracts. This categorisation of contract types is based mainly on the remuneration and compensations (subsidies) for expenditure on inputs received by the kraal owner as an employee of the cattle owner.

In the fixed wage contract, the cattle owner supplies all the inputs and is also the residual claimant of output. Additionally, he rewards the kraal owner with a fixed wage for managing the animals in the kraal including the kraal owner's hiring of a herdsman. The arrangement is similar to the owner operator we find in the sharecropping literature. The cattle owner, just like the owner-operator, can reduce diversion of inputs supplied by him through monitoring.

In subsidy-only contracts too, the cattle owner is largely responsible for financing input use. These inputs include veterinary care of his animals and contribution to the payment of a herdsman. We assume that this contract type approaches owner-input-supply arrangements because the cattle owner contributes almost all the input, Nevertheless the kraal owner is allowed to appropriate milk and manure from the animals.

In calves-sharing contracts, the cattle owner and the kraal owner share the former's calves in an agreed proportion. When the share proportion is one half, then the cattle owner is entitled to the first calf delivered by his cow and the kraal owner to the second calf delivered by the same cow. Thus, sharing is rotational. In calves-sharing contracts the kraal owner usually has the duty of financing input supply. However, the cattle owner may make some contribution or provide subsidy towards input financing by the kraal owner.

In the unspecified contracts, it is the kraal owner who largely finances the inputs. Yet, his rewards are not explicitly agreed on beforehand. Usually the cattle owner observes the stream of outputs over a period of time and then rewards the kraal owner based on this. Unspecified contracts could be considered as implicit contracts based on pay-for-performance but with insurance built into it (see Chapter 3). Instead of rotational sharing, as in calves-sharing contracts, animals are accumulated over a period and the kraal owner is rewarded at the end. Accumulating output over a period before rewarding the kraal owner ensures that the incomes of both the cattle owner and the kraal owner are smoothed. They are insured against any weather shocks that could erode one's income should payments take place every period. We find that this contract type occurs often among kin.

However, we are interested in the incentives each contract type gives for resource or material input use (rather than labour or effort). Thus, we can recategorise the four contract types into two types in terms of who finances input use and how much output this person is entitled to. As indicated earlier, subsidy-only contracts approach the owner-input-supply arrangement in terms of the incentives they provide for material input use. Similarly, unspecified contracts can be viewed as being close to calves-sharing contracts. In both contracts calves are shared, only in the case of unspecified contracts sharing occurs after animals have been accumulated over a period. Thus, these two contracts exert similar incentive effects. Therefore, we redefine owner-input-supply contracts as the aggregate of owner-input-supply and subsidy-only contracts, and share contracts as the aggregate of calves-sharing and unspecified contracts. As noted earlier, inputs have been categorised into short-term and long-term productivity-enhancing inputs.

4.4 Modelling input use and contracts in cattle production

In this section, we model cattle production as a dynamic process and derive some testable hypotheses on how contract type can influence input use. We show that input can be classified as short-term or long-term productivity-enhancing. Furthermore, it is shown that the use of short-term productivity-enhancing inputs is higher under owner-input-supply arrangements than under calves-sharing arrangements, while the use of long-term productivity-enhancing inputs is not different under the different contract types.

We do not emphasise the incentive effects of contracts on labour and pasture supply, since there is not much scope for the kraal owner to manipulate the levels of these inputs. He generally requires the services of at most a few herdsmen. One herdsman is usually enough to take care of all the cattle in a kraal. If a herd is very large, then an additional herdsman could be required, so that the herd is split between the two herdsmen for easy management. The quality of the herdsman matters though. This means that he needs to be experienced in the knowledge of good grazing grounds and can ensure that the cattle graze adequately and are protected. Nevertheless, such quality indicators are difficult to measure. Pasture grows naturally, and its availability is determined by natural events such as rainfall rather than by decisions of the kraal owner. The use of purchased inputs, however, is a variable that the kraal owner can manipulate, and it is often necessary that purchased inputs such as veterinary care inputs are used for good results.

A major motive for keeping cattle is asset accumulation, which is then fallen on in times of need. The stock of cattle (K) comprises stocks of female (K_f) and male (K_m) cattle. The female cattle together with a few selected bulls constitute the breeding stock, which are maintained to ensure that the herd grows. Each period the herd size increases because of new births, but also decreases due to offtakes and mortalities. We assume equal numbers of births of female and male cattle at a rate of b each. The mortality rate in the absence of veterinary care is given by $\bar{m}$, while applying more veterinary care per cow leads to a marginal reduction in this rate by m_o. Labor and natural pasture also influence the mortality rate, but we hold these factors constant. A small proportion λ_y of the stock of male cattle not intended to be used for breeding and a similar proportion λ_y of the stock of female cattle, including old cows that have recorded significantly reduced reproductive performance, are periodically removed for sale and consumption. Also, a fraction λ_q $(\lambda_q > \lambda_y)$ of the male stock (usually young bulls) is removed, fattened, and sold. These animals are fed crop residues and by-products from agro-processing such as cassava peels and waste from local beer brewing. The purpose of such intensive supplementary feeding and care of the animals is to make them gain weight and attract good prices when they are sold during high-demand periods such as religious festivities.

A cattle owner and a kraal owner collaborate in cattle production based on two main arrangements. First, the cattle owner and the kraal owner can have a calves-sharing contract in which the cattle owner keeps a share δ of calves delivered by his cows and gives a share $(1-\delta)$ to the kraal owner as his remuneration. The share (δ) is taken as given by both parties, determined by local norms and traditions. Second, the cattle owner can pay the kraal owner a fixed wage, which also is assumed to be exogenous, and keep all calves delivered by his cows for himself. In both arrangements, the kraal owner has access to the milk and manure produced by the cattle, which could provide him some incentive to provide inputs. Moreover, both the cattle owner and the kraal owner have the choice of providing purchased inputs such as veterinary care inputs and supplementary feed on top what the animals derive from grazing on natural pasture.

We ignore moral hazard to allow the kraal owner to add more inputs if he chooses to do so. In reality, especially under calves-sharing arrangements, it is possible for the kraal owner to give the impression of assuming responsibility for input provision, while he will not provide inputs in the required quantities and frequency. Such responsibility for input provision goes with some remuneration. The cattle owner may not be able to tell if this responsibility of the kraal owner has been carried out adequately. Thus, the kraal owner can enjoy the reward that goes with such responsibility but refuse to carry the duties out well, thereby creating a moral hazard situation.

In Appendix 4.1, we show that, under these assumptions, the steady state stocks of female (K_f^*) and male (K_m^*) cattle are given by

$$K_f^* = \alpha_f(\gamma)V_f \text{ with } \alpha_f(\gamma) := \frac{m_0}{\bar{m}+\lambda_y-[\gamma\delta+1-\gamma]b}\,, \tag{1}$$

and

$$K_m^* = \alpha_{m1}(\gamma)V_f + \alpha_{m2}V_m$$

$$\text{with } \alpha_{m1}(\gamma) := \frac{[\gamma\delta+1-\gamma]b\alpha_f(\gamma)}{\bar{m}+\lambda_y+\lambda_q} \text{ and } \alpha_{m2} := \frac{m_0}{\bar{m}+\lambda_y+\lambda_q}, \tag{2}$$

where V_f and V_m are the quantities of veterinary care applied to the female and male stocks, and parameter γ takes on a value of one (1) when the type of contract is a share contract and zero (0) when it is a fixed-wage arrangement.

Results (1) and (2) show that both steady-state stocks of cattle are a linearly increasing function of veterinary care, which is a result of our assumption that the mortality rate depends linearly on veterinary care per cow (see (3) in appendix 4.1). This linearity implies, in equilibrium, either zero veterinary care or maximum veterinary care is chosen, depending on contract type. The cattle stocks depend on contract type and are lower under a share contract (in the case of equal veterinary care), since only the calves that accrue to the cattle owner lead to accumulation of cattle. Also, cattle stock is an increasing function of the marginal reduction in mortality (m_0) achieved through veterinary care, while offtake reduces stock.

In a steady state, the removal of cattle from the stock for sale or consumption is given by

$$Y = \lambda_y\left[K_f^* + K_m^*\right]. \tag{3}$$

These batches of animals (Y), which are removed every period, are produced by grazing them on natural pasture only. The average price of calves and animals that are removed for sale is p_y.

Also, each period another batch of young bulls $(\lambda_q K_m^*)$ are removed from the male stock and fed supplementary feed to fatten them for sale. The supplementary feed includes crop residues and by-products from agro-processing. The final total weight of the fattened bulls (Q) is a strictly increasing function of supplementary feed. In order to achieve a closed-form solution, we assume a specific functional form for the relationship between the final weight and supplementary feed, which is given by

$$Q = \lambda_q K_m^* \sqrt{1+S_m} \tag{4}$$

where the variable S_m denotes supplementary feed given to young bulls. Thus, without supplementary feeding the final weight of the bulls remains the same as in the beginning. This is given by the number of animals times weight per animal, which is normalised to one kilogramme. Supplementary feed can be obtained at a unit price p_s, while the selling price of a fattened animal is p_q.

Note that, since veterinary care input increases the steady-state level of stock, it can be seen as a long-term output-enhancing input. Supplementary feed, on the other hand, just alters the weight of a given number of animals, so this can be considered a short-term productivity-enhancing input. Note that we do not supplement cows, hence we do not consider milk as an output of supplementation.

Veterinary care can be obtained at a price p_v as long as it does not exceed a certain quantity $\overline{V}$. For tractability, it is assumed that beyond this level the price of veterinary care becomes exorbitant. This assumption is necessary because, as indicated above, the steady-state stock of cattle is linearly increasing in veterinary care. This is plausible if we consider that beyond a certain level of veterinary care, the cost of care, including fees of veterinary professionals, becomes excessive. We further simplify by assuming that male and female stock receive veterinary care in a fixed proportion such that the male stock receives a share μ of the total supplied care (V) and the female stock receives the share $1-\mu$. This reduces the number of variables and allows us to concentrate on the total quantity of veterinary care, $V := V_f + V_m$.

Based on these assumptions, we can now proceed to derive the payoffs of the cattle owner and the kraal owner. These payoffs depend on each other because one's marginal returns to providing veterinary care and supplementary feed are influenced by what the other supplies. In particular, granting that the cattle owner will be the one who determines the type of contract, his choice will depend on the input decisions of the kraal owner under each type of contract. Hence, we have a strategic situation. We model this as a Stackelberg game and solve it by backward induction.

Let us indicate the endogenous variables of the cattle owner with superscript c and those of the kraal owner with superscript k. The cattle owner has three decision variables. He has to choose between offering the kraal owner a fixed-wage contract at a given acceptable wage (w) and a share contract where he only keeps a share δ of the calves. This comes to determining $\gamma^c \in \{0,1\}$. Further, the cattle owner has to decide on the amount of veterinary care, $V^c \leq \overline{V}$, and on the amount of supplementary feed, $S_m^c \geq 0$. The kraal owner has only two decision variables: the amount of veterinary care he wants to provide, $V^k \leq \overline{V}$, and the amount of supplementary feed, $S_m^k \geq 0$. As indicated above, the total amount of applied veterinary care is limited, $V^c + V^k \leq \overline{V}$.

The cattle owner's payoff function is given by

$$\pi^c\Big((V^c, S_m^c, \gamma^c)\,;(V^k, S_m^k)\Big) :=$$

$$p_y \lambda_y \overline{\alpha}(\gamma^c)[V^c + V^k] + p_q \lambda_q \alpha_m(\gamma^c)[V^c + V^k]\sqrt{1 + S_m^c + S_m^k} - r(V^c, V^k, \gamma^c) - V^c p_v - S_m^c p_s \tag{5}$$

where

$$\alpha_m(\gamma^c) := (1-\mu)\alpha_{m1}(\gamma^c) + \mu\alpha_{m2}$$

$$\overline{\alpha}(\gamma^c) := (1-\mu)\alpha_f(\gamma^c) + \alpha_m(\gamma^c)$$

$$r(V^c, V^k, \gamma^c) := \gamma^c(1-\delta)b(1-\mu)\alpha_f(\gamma^c)[V^c + V^k]\beta p_y + (1-\gamma^c)w$$

with $0 < \beta, \mu < 1$ and positive prices $p_y, p_q, p_v, p_s > 0$. The cattle owner's payoff thus is equal to his revenues from sale of cattle, both non-fattened and fattened (first two terms), minus the cost he incurs in remunerating the kraal owner under a share contract or a fixed wage contract (third term) and the cost he incurs on veterinary care inputs and supplementary feed (last two terms). Parameter β is a coefficient attached to the price (p_y) of mature cows to reflect the fact that the value of a calf is a fraction of that of a mature animal. Therefore, the quantity βp_y indicates the value of a calf given out to the kraal owner as payment.

The kraal owner's payoff function is given by

$$\pi^k\Big((V^k, S_m^k); (V^c, S_m^c, \gamma^c)\Big) := r(V^c, V^k, \gamma^c) + \theta\overline{\alpha}(\gamma^c)[V^c + V^k] - V^k p_v - S_m^k p_s \tag{6}$$

with $\theta \geq 0$. The kraal owner's payoff includes the remuneration by the cattle owner and the earnings from milk and manure, measured as a proportion θ of the stock of cattle, which he obtains under each type of contract, minus his expenditure on veterinary care inputs and supplementary feed.

Both the cattle owner and the kraal owner seek to maximize their individual payoffs. We assume that they engage in a two-stage Stackelberg game with perfect information where the cattle owner moves first, and the kraal owner follows. So in the first stage, the cattle owner chooses the contract type $\gamma^c \in \{0,1\}$ and his inputs, $V^c \in [0, \overline{V}]$ and $S_m^c \in R^+$. In the second stage, depending on the contract type he is offered and the inputs provided, the kraal owner responds by choosing his levels of veterinary care, $V^k \in [0, \overline{V} - V^c]$, and supplementary feed, $S_m^k \in R^+$. The backward induction solution to the game is presented in Appendix 4.1.

In solving this game, we restrict ourselves to equilibria with strictly positive total input quantities $(S_m^c + S_m^k, > 0,\ V^c + V^k > 0)$. The use of veterinary care inputs is almost a must so that diseases do not wipe out the herd. It is possible for supplementary feeding to be zero if maginal returns to feeding are too low as compared with marginal costs, but for the current exposition, we assume positive total supplementary feed inputs. In the appendix, we indicate that a unique Stackelberg equilibrium exists and that the prevailing type of contract particularly depends on parameters as the wage rate (w) and the share (δ). Here we are interested in the properties of each type of equilibrium. The following proposition holds (for a proof, see Appendix 4.1):

Proposition: *Suppose a Stackelberg equilibrium (SE) with strictly positive inputs (veterinary care and supplementary feed inputs).*

- *If the kraal owner's marginal return to providing veterinary care is greater than the price of veterinary care inputs, then he will provide all veterinary care requirements $(\overline{V})$; otherwise the cattle owner will provide all the requirements $(\overline{V})$.*
- *Only the cattle owner will provide supplementary feed. The amount of supplementary feed will be highest in the case of an SE with a fixed-wage contract.*

These results can be explained as follows. Veterinary care leads to increase in cattle stock. Under share contracts, both the cattle owner and the kraal owner share in the increase in cattle stock. Hence, both have incentive to provide veterinary care inputs. If one party does not provide veterinary care, the other will do so. Similarly, the cattle owner and the kraal owner both have incentive to provide veterinary care under fixed-wage contracts. Under fixed-wage contracts the kraal owner does not have a share of the increase in stock, but he receives by-products of the stock, which may induce him to supply veterinary care too. However, as implied by the proof in the appendix, the value of this by-product is likely to be lower than the value of his share of stock under share contracts. Therefore, he is more likely to provide veterinary care inputs under share contracts than under fixed-wage contracts.

The marginal return to providing supplementary feed, which is used exclusively for feeding young bulls, is virtually nil for the kraal owner, because he does not receive any part of the returns from supplementary feeding. It is true that supplementary feeding of bulls will lead to some increase in manure production, but the bulk of the manure comes from the natural pasture component of total feed intake by the bulls. Additionally, manure generated by the rest of the stock emanates from exclusively feeding on natural pasture. Thus, the kraal owner will not provide supplementary feed, which leaves the cattle owner to take care of supplementary feed requirements. Further, the steady state-male stock is higher under a fixed-wage contract than under a share contract, because the cattle owner does not share his calves with the kraal owner under the former contract. Hence, the return to providing supplementary feed is higher under a fixed-wage contract, which explains the higher amount of supplementary feed under this contract type.

Elsewhere in this chapter, we refer to fixed-wage contracts as owner-input-supply arrangements to reflect the property that owners supply all the inputs.

Hypotheses

Two main hypotheses are formulated to test predictions from the preceding theoretical analysis. First, feed supplement use is higher under owner-input-supply arrangements than under calves-sharing arrangements. Second, the probability of using veterinary care inputs is the same under owner-input-supply arrangements than under calves-sharing arrangements. For individual components of supplementary feed (minerals and crop-residues), and veterinary care inputs (dewormers, acaricides, and vaccination) the respective hypotheses stated above apply also.

4.5 Empirical strategy and data

We present our empirical strategy for input use estimation and data in this section.

4.5.1 Empirical strategy

Input use is modeled using binary choice models. We define a variable y_i which takes a value of 1 or 0 depending on whether or not an input is used in the kraal or herd of kraal owner i. We assume that inputs are applied uniformly across cows to prevent diseases and control parasites. However, when particular animals require treatment, they are isolated and treated as required. Assume that the decision to use inputs is based on a latent variable y_i^* which is a function of a vector of explanatory variables (X_i) including kraal owner characteristics, farm or cattle related characteristics, agro-ecological zone, and contract types, and unobserved heterogeneity such that

$$y_i^* = X_i'\lambda + \varepsilon_i \tag{10}$$

where λ is a vector of parameters and

$$y_i = 1 \qquad if\ y_i^* > 0$$

$$y_i = 0 \qquad if\ y_i^* \leq 0.$$

The probability that a particular input is used is

$$P\{y_i = 1\} = P\{y_i^* > 0\} = P\{X_i'\lambda + \varepsilon_i > 0\} = P\{-\varepsilon_i < X_i'\lambda\} = F(X_i'\lambda)$$

where F denotes the distribution function of the error term $-\varepsilon_i$. The model is estimated using the maximum likelihood approach.

The dependent variable, input use, includes use of supplementary feed or routine veterinary care such as deworming, acaricide application against ticks, and vaccination of cattle against diseases. Feed supplement use is a binary variable; hence we regress it on contract type using logit. However, the other dependent variable, veterinary care input use (*vetcare*), which is a composite of deworming, acaricide application and vaccination, is considered to be a continuous variable; hence we regress it on contract type using ordinary least squares. Kraal owner characteristics include age and education, while farm characteristics include herd size, cattle breed, and contact with agricultural officers. Zonal characteristics include rainfall distribution, which influences herbage growth and availability.

We are interested in the aggregate level of input use in the production process in order to boost productivity. Nonetheless, the party that supplies input is often clear, depending on the contract type involved. Under fixed-wage contracts, we expect the cattle owner to supply inputs and under share contracts, either party could supply. In our theoretical model, only bulls receive supplementary feed. Milk-producing cows depend on grazing on natural pasture. Their milk output is influenced by the stock of female cattle which is in turn influenced by veterinary care inputs, not supplementary feeding. The returns to supplementary feeding are almost nil for the kraal owner.

4.5.2 Dealing with potential endogeneity of the contract variable

Contract choice could be an endogenous variable in the empirical model. If so, we cannot say that contract choice causes input use. The endogeneity problem could arise from omitted variables. In order to reduce this problem, we have included key explanatory variables and dummies for agroecological zones to take care of some unobserved heterogeneity or omitted variables. We assess the extent to which omitted variable bias could be driving the effect of contract type by observing movements in coefficients of the contract type variable in the regression of input use with and without other explanatory variables (controls), but controlling for agro-ecological zones (Altonji et al., 2005, Bellows and Miguel, 2009, González and Miguel, 2015, Oster, 2017). González and Miguel (2015) and Oster (2017) estimate the bias adjusted coefficient (β^*) using the equation

$$\beta^* = \tilde{\beta} - \left(\beta^0 - \tilde{\beta}\right)\frac{R_{max} - \tilde{R}}{\tilde{R} - R^0} \tag{11}$$

where $\tilde{\beta}$ and β^0 are coefficients of contract type in the regression on input use with and without the controls respectively; $\tilde{R}$ and R^0 are the R^2 values with and without controls respectively; and R_{max} is the upper bound of R^2 assuming no omitted variable bias. Oster (2017) recommends the estimation of R_{max} as $1.3\tilde{R}$. R_{max} is less than 1 due to measurement errors in dependent variables. Thus, we estimate the interval of coefficients of contract type $[\beta^*, \tilde{\beta}]$ which is commensurate with the level of omitted variable bias accounted for by R_{max}, the difference between $\tilde{R}$ and R^0 and change in the estimated coefficients. If this interval does not include zero, then it is an indication that omitted variables are relelatively unimportant and therefore unlikely to drive the results.

This endogeneity could also arise from reverse causality, meaning that input use in turn influences contract choice. One solution to the endogeneity problem is to carry out instrumental variable regression. This approach necessitates the search for and use of valid instruments. For an instrument to be valid, it must satisfy three conditions. First, it has to be randomly assigned or exogenous. Second, it must satisfy the exclusion restriction. That is, an instrument should not be an explanatory variable in the equation of interest. Third, it has to be correlated with the endogenous variable. In our case, the instrument should not be in the equation specifying input use in terms of other variables. Two instruments come to mind: language and cattle owner's distance of cattle to the kraal/farm.

There are about 50 non-mutually intelligible languages spoken in Ghana, but almost all of these can be grouped into two major languages: the Kwa and the Gur of the Niger-Congo phylum (Anyidoho and Dakubu, 2008). The Kwa languages are spoken in the southern portion of the country while the Gur languages are spoken in the northern parts of the country. It is possible that social norms might have developed along language lines and in turn influenced contract type. When we disaggregate contract types into four: fixed-wage, subsidy-only, share, and unspecified contracts, the Kwa language appears to be highly correlated with share contracts, which are predominant in southern Ghana. However, when we combine share and unspecified contracts as share contracts, and fixed-wage and subsidy-only contracts as owner-input-supply arrangements, this correlation with share contracts vanishes. In short, we do not find any significant correlation between language and our dichotomous categorisation of contracts into share and owner-input-supply contracts. Language might be randomly distributed across our respondents, and it meets the exclusion restriction also, but it is not significantly correlated with the endogenous variable contract type. Hence language cannot be a valid instrument for contract type.

The distance from a cattle owner's home to the kraal could influence his monitoring ability of the input he supplies to the kraal owner for use on his animals. We expect that when this distance is short, a cattle owner is more likely to choose a contract in which he supplies all the input; when the distance is long, he is more likely to choose a contract that gives incentives to keep kraal owners to their obligations. This is in line with Abdulai et al. (2011), who use distance of the land owner to the plot as an instrument for contract type. The cattle owner's distance to the kraal is unlikely be a candidate variable in the input use equation and hence satisfies the exclusion restriction. These distances are also likely to be random. However, we do not find any significant correlation between contract type and the cattle owner's distance to the kraal. Hence, this variable also fails to be a valid instrument.

Perhaps, reverse causality could be from wealth to input use and then to contract type. If so, we could find an instrument for wealth and use this as an instrument for contract type. Following this path, we constructed a wealth variable from non-cattle livestock and poultry assets. Nevertheless, this also is not significantly correlated with input use. Thus, we do not attempt to search for instruments for it.

Having failed to find a valid instrument that will help resolve the possible endogeneity problem related to contract type, we carry on with our analysis and discussion of the relationship between input use and contract type with the caveat that we interpret this relationship as correlational and not causal.

4.5.3 Data

We use survey data for our analyses in this study. We surveyed kraal owners, cattle owners, and herdsmen from four agro-ecological zones in Ghana. These zones include the Guinea savannah, Sudan savannah, Coastal savannah and the Transitional zone, all of which are noted for cattle production. Furthermore, we selected three districts each from the Guinea savannah, Coastal savannah, and the Transitional zone, and two districts from the Sudan savannah. Next, we selected kraals randomly from a list of kraals prepared by veterinary technicians and agricultural extension officers in the various districts. From each kraal we aimed to interview the kraal owner, a cattle owner who kept cattle with the kraal owner for care-taking, and a herdsman who herded animals in the grazing fields. We interviewed these three people separately using structured questionnaires. The interviewers were veterinary technicians and agricultural extension agents in the various districts. Since these officers were knowledgeable of farmers' activities relating to cattle production, they could easily recognize unreasonable responses and so limit inaccurate responses and measurement errors. The survey methodology is presented in detail in section 2.4.

With regards to this study, we asked a variety of questions on their farm and farmer characteristics, contract terms between a cattle owner and a kraal owner, and input use by the kraal owner. The farmer characteristics include age of the kraal owner, and the number of years of schooling he has had. The farm characteristics include the kraal owner's herd size, and whether he has contact with agricultural officers. Regarding input use by the kraal owner, we sought to know what inputs he used, including mineral salt licks, common salt, crop residues, and cereal bran, and if he undertook certain routine veterinary care practices such as vaccination, deworming, and acaricide application against ticks. In relation to all input use, we also sought to obtain information of how frequently he undertook these practices and at what cost in monetary terms. We obtained responses from 342 kraal owners in total.

The summary statistics of our key variables are presented in Table 4.1. The mean age of kraal owners was 57 years. They had an average of 5 years of schooling and a mean herd size of 72 animals (cattle). Approximately, 83 percent of kraal owners had contact with agricultural extension agents or veterinary technicians. Use of feed supplements is a composite variable indicating whether feed supplement is used in a farm/herd or not. Varying proportions of kraal owners used different inputs in different proportions. For instance, 58 percent of kraal owners indicated they used feed supplements in general, while 40 percent used mineral supplements, and 26 percent used crop residues including agro-industrial by-products like rice bran and cassava peels. Use of veterinary inputs is another composite variable indicating the use of veterinary care inputs. The use of veterinary input variable sums up responses regarding whether vaccination, control of worms, and control of ticks are done in farm/herd or not. Thus, the use of veterinary input variable ranges between zero (no veterinary input is used) and three (all three veterinary inputs are used). Specifically, 70 percent of kraal owners vaccinated their animals, 65 percent of them dewormed their animals, and 43 percent applied acaricides to control ticks.

Table 4.1. Summary statistics of main variables

Variable	N	Mean	SD	Min	Max
Age of kraal owner	342	57.19	16.09	23	95
Education	342	4.81	5.40	1	19
Herd size	332	71.83	77.88	8	600
Contact with extension agents	339	0.83	0.38	0	1
Use of supplements	338	0.58	0.49	0	1
Use of minerals	340	0.40	0.49	0	1
Use of crop residues	342	0.26	0.44	0	1
Use of veterinary inputs	334	1.78	0.98	0	3
Vaccinations	335	0.70	0.46	0	1
Deworming	334	0.65	0.48	0	1
Use of acaricides against tick	334	0.43	0.50	0	1
Number of cattle owners	305	3.45	3.25	1	20
Cattle owner’s herd size	244	12.97	11.15	1	95

Source: Field data

The level of use of different inputs can vary based on the relationship between the inputs. For instance, if two inputs are substitutes then the use of one of them could reduce the use of the other. Similarly, if two inputs are complements, then when the use of one input increases the use of the other increases too. The specific supplements are minerals (salt lick) and crop residues. Minerals licks are products manufactured to provide major and minor nutrients to the animals. Some farmers also give common salt to the animals to provide some of these minerals. Crop residues are the leaves and stalks of crops that are left over from harvests. Some materials (cassava peels, maize and rice bran) obtained from the processing of food crops, often referred to as agro-industrial by-products, are also considered as crop residue. These crop residues are a source of roughage, fibrous material that adds bulk, and perhaps some carbohydrates and protein to the animal's diet. Thus, minerals and crop residues are not substitutes. It is also not clear if minerals and crop residues can be considered as complements. Whereas minerals could be considered a necessity and used all year round, crop residues are used seasonally when natural pasture availability reduces. In order to have minerals, one must purchase them with cash. However, crop residues could be obtained free of charge from one's own farm or a neighbour's farm, or purchased for a small fee. Additionally, the user of crop residues may incur some cost to transport the materials to where they will be used. Also, the three veterinary practices, vaccinations, deworming and acaricide application, are not substitutes as each solves a different problem. These practices can be done by the kraal owner or by a veterinary officer. Thus, drugs (dewormers, and acaricides) for worm and tick control are procured by farmers and self-administered. These drugs can also be administered by a veterinary officer for a fee. Vaccinations are usually carried out by veterinary officers for a fee also. The absence of these relationships among the inputs implies it is legitimate to estimate the use of these inputs using single equation methods.

Table 4.1 further reports that, on average, three to four cattle owners have their cattle in a kraal, and the average number of animals they bring in is 13. Given the mean number of animals owned by one person (12.97), the mean number of other cattle owners having animals in a particular kraal (3.45), and mean herds size in a kraal (71.83), the proportion of animals owned by all other cattle owners is 62 percent of the total herd size in a kraal. Therefore, cattle owners together have the majority of cattle in a kraal. Often, the cattle owners with cattle in the same kraal have similar contracts with the kraal owner. Thus, we assume that input use in a kraal is influenced by the contract type which pertains in the kraal. If cattle owners in a kraal had different contract types, this would require data on input use per cattle owner. However, this is not the case. Differential treatment of cattle by the kraal owner is possible. However, this is mitigated by the fact that he risks getting treated animals re-infected by untreated ones in the kraal. Regarding supplementary feeding of bulls, he can isolate his animals and feed them separately.

With respect to contract terms, we asked questions on the duties of a kraal owner towards a cattle owner, and the obligations of a cattle owner to a kraal owner. Based on the responses we characterised the contracts broadly into fixed-wage contracts (with or without input subsidy), calves-sharing contract (with or without input subsidy), input subsidy only contracts, and unspecified contracts. Fixed-wage payments can be in cash or in kind. Calves-sharing contracts involve the sharing of calves between a cattle owner and a kraal owner such that they take turns to appropriate calves from a particular cow. Subsidies involve the partial compensation of the kraal owner by the cattle owner for expenses the former has incurred or will incur in future. Unspecified contracts have kraal owners' rewards not specified ex ante and it is not clear if subsidies are provided to the kraal owner either.

For the purpose of assessing the incentive effects of contract types for material input use, instead of effort, we redefine these contract types as in Section 4.3. The owner-input-supply arrangement is recategorised as the aggregate of fixed-wage and subsidy-only contracts, and the calves-sharing contract as the aggregate of calves-sharing and unspecified contracts (based on the similarity of their incentive effects on material input use). We present the distribution of contract types, based on this recategorisation, by agro-ecological zone in Table 4.2. In the Coastal savannah zone all contracts are share contracts, while in the other zones we find both contract types. In the Guinea and Sudan savannah, the majority of contracts are share contracts.

Table 4.2: Distribution of cattle owner – kraal owner (recategorised) contracts by agro-ecological zone (frequency and column percentages)

	Agro-ecological zone				
Contract type	Coastal	Guinea	Sudan	Transitional	Total
Owner-input-supply	0	43	15	33	91
	0.00	38.47	20.27	55.93	28.26
Share	78	68	59	26	231
	100	61.26	79.73	44.07	71.74
Total	78	111	74	59	322
	100.00	100.00	100.00	100.00	100.00

Source: Field data

As noted above, cattle owners together own the majority of cattle in a kraal (about 62 percent). In the particular instance of calves-sharing contracts (original categorisation), an average of 5.5 persons own cattle in a kraal while the mean number of cattle owned by one person and the total herd size in a kraal are 13.37 and 89.4, respectively. Thus, together all cattle owners own about 80 percent of all animals in a kraal in which the contract type is calves-sharing (Appendix 4.2).

4.6 Results and discussion

In this section we present three sets of results. The first set of results looks at the relationship between aggregate inputs use (feed supplement use and veterinary care input use) and contract types. Feed supplements represent short-term productivity-improving while veterinary care inputs represent long-term productivity-improving inputs. The second and third sets of results look at the relationship between specific feed supplements and specific veterinary care inputs and contract types respectively.

Table 4.3 presents the first set of results from regressing supplementary feed and veterinary care inputs on contract type, with agro-ecological zone fixed effects. In each case one specification has no other controls (columns 1 and 4) while another has controls for farm and farmer characteristics (columns 2 and 5). The owner-input-supply arrangement has a significant positive correlation with the probability of feed supplements, but a negative though insignificant correlation with veterinary care inputs, with or without controls in each case. Hence, compared to the calves-sharing contract, the owner-input-supply arrangement is associated with more feed supplement use, whereas there is no significant difference between contract types with respect to use of veterinary care inputs. Column 3 shows the interval of coefficients obtained using R_{max}, and movements in coefficients and R^2 values. The interval excludes zero, which suggests that omission variable bias is not driving the effect of contract type on supplementary feed use.

Feed supplements are likely to increase current output, in this case meat, more than veterinary care inputs, which particularly influence long-term productivity such as animal survivability. Furthermore, kraal owners who are usually responsible for input provision in calves-sharing contracts may have only a small share (if any) in the sales proceeds of animals that the cattle owner may sell. Thus, the incentive for supplementary feed use is correlated more with owner-input-supplier contracts than calves-sharing contracts. Under the latter, a cow must live long enough to allow each party to the contract to take his

Table 4.3 Regression of input use on contract type with calves-sharing contracts and Coastal Savannah as base

	Supplementary feed			Veterinary care		
	(1) Without controls	(2) With controls	(3) Interval	(4) Without controls	(5) With controls	(6) Interval
Owner-input-Supply	1.069^{**}	1.085^{**}	[1.085, 1.34]	-0.030	-0.064	[-0.064, -0.185]
	(0.460)	(0.461)		(0.126)	(0.119)	
	$[0.204]^{**}$	$[0.202]^{**}$				
	(0.083)	(0.086)				
Guinea	2.515^{***}	2.780^{***}		-0.780^{***}	-0.722^{**}	
	(0.622)	(0.659)		(0.267)	(0.273)	
Sudan	1.194^{**}	1.694^{***}		-1.206^{***}	-1.006^{***}	
	(0.541)	(0.569)		(0.282)	(0.277)	
Transitional	0.985^{*}	1.083^{*}		0.011	0.144	
	(0.580)	(0.584)		(0.269)	(0.276)	
Age		-0.003			0.007^{*}	
		(0.011)			(0.004)	
Education		0.026			0.011	
		(0.034)			(0.010)	
Herd size		0.004^{**}			0.000	
		(0.002)			(0.001)	
Contact with ext. officers		0.243			0.450^{**}	
		(0.379)			(0.201)	
Constant	-1.204^{***}	-1.850^{**}		2.333^{***}	1.436^{***}	
	(0.400)	(0.802)		(0.202)	(0.326)	
N	319	309		314	303	
R^2	0.192	0.213		0.260	0.284	
F				7.784	5.547	
Ll	-175.639	-166.311		-392.425	-371.740	

Standard errors in parentheses; values in the square brackets in columns 1 and 2 are marginal effects.
* $p < .1$, ** $p < .05$, *** $p < .01$

turn at getting a calf from the cow. Besides, kraal owners do not get the first turn to appropriate a calf from a cattle owner's cow he is caring for. Thus, a kraal owner who has a calves-sharing contract could be more interested in applying more of long-term productivity-enhancing inputs, such as veterinary drugs and vaccines, than short-term output-enhancing inputs, such as feed supplements, to ensure that cows live long enough to produce many calves for them to have their share too.

These results agree with our theoretical predictions and other findings. First, the results are consistent with our hypotheses that the use of short-term productivity-increasing inputs is more associated with owner-input-supply contracts, where the cattle owner supplies all inputs, than with calves-sharing contracts, while we do not expect any correlation of long-term productivity-enhancing inputs with contract type. Secondly, the findings are also in line with Abdulai et al. (2011), who show that owner-operators (in land rental contracts) are more likely to apply long-term productivity-enhancing inputs but not short-term productivity-enhancing inputs, and Beekman and Bulte (2012), who show that tenure security is correlated more with long-term productivity improvement (erosion management) and not with short-term productivity improvement (fertilizer use). The common thread here is that if the returns to expenditure can be secured, that expenditure will be made. Also, age and contact with agricultural officers have a significant positive correlation with *vetcare* inputs but not with feed supplements.

Input use is to some extent associated with agro-ecological zones. In the Guinea and Sudan savannah there is more use of feed supplements as compared with the Coastal savannah, but with veterinary care inputs this is just the opposite. Supplements comprise crop residues such as crop herbage left on farms after harvest and agro-industrial by products such as maize and rice bran. These are used especially in the Sudan and Guinea savannah in times of feed scarcity and to fatten livestock (Konlan et al., 2015). The negative correlation of veterinary care inputs with the Sudan and Guinea savannahs cannot be readily explained. Unbundling this composite input into vaccination, deworming, and deticking may suggest some explanations.

The results of regressing feed supplement categories on contract type with agro-ecological zone fixed effects are shown in Table 4.4. For each supplement category, there are two regressions: one with no

Table 4.4. Logit regression of supplements on contract type with calves-sharing contract and Coastal savannah as base

	Minerals			Crop residues		
	(1) Without controls	(2) With controls	(3) Interval	(4) Without controls	(5) With controls	(6) Interval
Owner-input-Supply	0.898^{***}	1.011^{***}	[1.011, 8.323]	0.218	0.098	[-2.062, 0.098]
	(0.321)	(0.341)		(0.366)	(0.334)	
	$[0.154]^{***}$	$[0.170]^{***}$		[0.034]	[0.149]	
	(0.058)	(0.060)		(0.057)	(0.050)	
Guinea	2.033^{***}	2.204^{***}		0.657	0.843	
	(0.654)	(0.659)		(0.787)	(0.759)	
Sudan	-1.832^{*}	-1.391		2.800^{***}	3.107^{***}	
	(0.936)	(0.877)		(0.650)	(0.701)	
Transitional	0.738	0.830		2.181^{***}	2.323^{***}	
	(0.561)	(0.586)		(0.670)	(0.689)	
Age		-0.001			-0.012	
		(0.012)			(0.015)	
Education		0.025			0.012	
		(0.029)			(0.033)	
Herd size		0.003^{*}			-0.000	
		(0.002)			(0.003)	
Contact with ext. Officers		0.070			0.404	
		(0.519)			(0.475)	
Constant	-1.278^{***}	-1.856^{**}		-2.681^{***}	-2.519^{**}	
	(0.444)	(0.876)		(0.519)	(0.997)	
N	320	309		322	311	
R^2	0.280	0.291		0.177	0.180	
F						
Ll	-155.902	-148.480		-151.328	-143.644	

Standard errors in parentheses, values in the square brackets in columns 1,2,4 and 5 are marginal effects.
* $p < .1$, ** $p < .05$, *** $p < .01$

controls and the other with controls for farm and farmer characteristics (columns 1 and 4). Contract type has positive correlation with mineral use with or without controls (columns 1 and 2). This correlation of owner-input supply contracts with minerals use is significant at the one percent level. The interval of coefficients corresponding to the R_{max} and movements in R^2 excludes zero (column 3), indicating that omission variable bias is not driving the result. However, there is no significant correlation between owner-input-supply contracts and crop residue use. This means that there is no difference in the use of crop residues under the two types of contracts.

Most of the specific input categories are associated with agro-ecological zones (Tables 4.4). Regarding feed supplements, we find that in the Guinea savannah minerals are more used than in the Coastal savannah. It is not clear why there is more mineral use in the Guineas savannah. The use of crop residues is significantly higher in the Sudan savannah and Transitional zone than in the Coastal savannah (see also Appendix 4.3). Two reasons could account for this. First, the Sudan savannah is the driest zone in the country with a dry season that stretches over seven months. In five of the driest months, average total rainfall during the period 1980-2010 is only 20mm, compared to 156mm in the Coastal savannah and 180mm in the Transitional zone (Appendix 4.4). Hence, in the Sudan savannah, the use of crop residues to supplement feed obtained from grazing could be critical for body condition and survival of animals. Crop residues, including agro-industrial by-products such as rice bran (from rice processing) and cassava peels from cassava (processing), are generally marketed. The stem and leaves of crops left over after harvest can be obtained free of charge, but some expense has to be incurred to move them from the field to where they will be fed to the animals. The residues are used to fatten animals for sale and to supplement the diet of animals in the dry season when natural pasture is scarce. Thus, crop residues and agro-industrial by-products are used during periods of feed scarcity, especially in areas of high animal density such as portions of the Upper East region, which fall within the Sudan agro-ecological zone (Konlan et al., 2015). Second, in the case of the Transitional zone, the greater use of crop residues could be linked to its availability. In this zone a lot of food stuffs such as cassava are produced because of the favourable rainfall and its bi-modal distribution (Appendix 4.4). This makes the availability of by-products such as cassava peels obtained from cassava processing easily available.

Also, we unbundle veterinary care inputs and regress the various categories on contract type with agro-ecological zone fixed effects and no other controls in one specification (columns 1, 4, & 7), but with controls for farm and farmer characteristics in another specification (2, 5, & 8), (Table 4.5). We find that vaccination is correlated with owner-input supply arrangements without controls (5 percent level) and with controls (10 percent level). This means that vaccination occurs more under owner-input-supply arrangements. However, deworming is not significantly correlated with owner-input supply contracts, but deticking is negatively correlated with the owner input supply contract (5 percent level). Thus, deticking occurs less under owner-input-supply contracts. The intervals of coefficients (columns 3 and 9) exclude zero, meaning that the influence of owner-input-supply arrangements on vaccination and deticking are not driven by omission level bias. Being components of veterinary care and long-term productivity-enhancing inputs, it was expected that contract type will not be significantly correlated with vaccination, deworming and deticking. Only the influence of contract type on deworming agrees with our expectation. The lower (higher) use of acaricides under owner-input-suppliers (calve-sharing contracts) could be attributed to the effect of the input use. Acaricides are applied to control ticks which are ecto-parasites and therefore are observable on the body of animals when they occur. This observability of the effect of treatment could encourage kraal owners under calves-sharing contracts to pay more attention to it, thus the positive (negative) association with calves-sharing contracts (owner-input-suppliers). The effect of vaccination on animals could be more difficult to observe outwardly. Why vaccination is greater under owner-input-supply arrangements than under calves-sharing contracts, contrary to our expectation, is not immediately clear.

Table 4.5. Logit regression of veterinary care input use on contract types with calves-sharing contract and Coastal savannah zone as base

	Vaccination			De-wormers			Acaricides		
	(1) Without controls	(2) With controls	(3) Interval	(4) Without control	(5) With controls	(6) Interval	(7) Without controls	(8) With controls	(9) Interval
Owner-input-	0.668**	0.592*	[0.411, 0.592]	-0.241	-0.343	[-0.343, -0.580]	-0.722**	-0.707**	[0.503, -0.707]
Supply	(0.340)	(0.318)		(0.355)	(0.346)		(0.310)	(0.314)	
	[0.120]**	[0.104]*		[-0.046]	[-0.064]		[-0.113]**	[-0.109]**	
	(0.061)	(0.058)		(0.069)	(0.066)		(0.054)	(0.055)	
Guinea	0.442	0.733		-1.573**	-1.509**		-2.165***	-2.223***	
	(0.772)	(0.778)		(0.624)	(0.706)		(0.663)	(0.713)	
Sudan	-1.310*	-0.758		-0.816	-0.557		-4.221***	-3.930***	
	(0.671)	(0.674)		(0.604)	(0.702)		(0.765)	(0.821)	
Transitional	-0.642	-0.312		1.743**	2.094**		-0.166	-0.038	
	(0.713)	(0.736)		(0.841)	(0.834)		(0.653)	(0.707)	
Age		0.017*			0.016			0.004	
		(0.010)			(0.010)			(0.012)	
Education		0.055*			0.019			-0.003	
		(0.031)			(0.034)			(0.027)	
Herd size		0.000			-0.002			0.002	
		(0.002)			(0.001)			(0.002)	
Contact with Ext. officers		0.766			1.153**			0.538	
		(0.490)			(0.481)			(0.416)	
_cons	1.012**	-1.108		1.305***	-0.640		1.472***	0.572	
	(0.510)	(0.874)		(0.427)	(0.762)		(0.463)	(0.835)	
N	315	304		314	303		314	303	
R^2	0.090	0.103		0.155	0.178		0.310	0.317	
Ll	-176.196	-166.390		-172.423	-162.194		-148.137	-141.488	

Standard errors in parentheses, values in square brackets in columns 1, 2, 4,5, 7 and 9 are marginal effects.
* $p < .1$, ** $p < .05$, *** $p < .01$

Regarding the specific veterinary care practices (Table 4.5), the probability of using vaccines does not differ by agro-ecological zone. This could be because cattle vaccination has been widely promoted in the country such that most cattle owners appreciate its importance. Thus, most farmers vaccinate their animals. The Livestock Development Project (2002-2010) afforded cattle owners the opportunity for free vaccinations (AfDB, 2012). After the completion of the project farmers had to pay out of the pocket for these vaccinations. Veterinary doctors or technicians often provide vaccination services for a fee. In cattle production, the expenses that have to be made to vaccinate animals are more than justified. If a farmer ignores such vaccinations, the consequences could be serious. For instance, in Ghana, vaccinations are done to prevent diseases such as Contagious Bovine Pleuropneumonia (CBPP) and anthrax. CBPP can devastate cattle herds when it strikes. Infected herds have to be slaughtered as a control measure. Thus, a cost-effective way of avoiding these losses is to immunize the animals through mass vaccinations. Anthrax can also lead to loss of animals, and it can also be transferred from animals to man with dire outcomes. Yet, this can also be prevented through vaccination.

The use of acaricides to control ticks (deticking) is significantly lower in the Guinea savannah and the Sudan savannah than in the Coastal savannah. However, it is difficult to explain why this is so. According to Walker and Koney (1999), the Guinea savannah has the widest variety of tick species and the most frequent infestations in Ghana, followed by the moist semi-deciduous zone and the coastal grassland and ticket (Coastal savannah). This leads us to expect that the control of ticks would be greater in the Guinea savannah.

Deworming occurs significantly more in the Transitional zone and significantly less in the Guinea savannah as compared with the Coastal savannah. This could be explained by the fact that worm infestation increases with rainfall amount and distribution (Blackie, 2014). The Guinea savannah with a single rainfall peak has a longer dry season than the Transitional zone and Coastal savannah. Though both the Transitional zone and the Coastal savannah zone have double rainfall peaks, the Transitional zone has more total annual rainfall than the Coastal savannah. Veterinary drugs for deworming and tick control are mostly manufactured formulations that can be purchased on the market. Some cattle farmers use ethno-veterinary medicine to control worms and other animal diseases, but a lot of them use orthodox veterinary drugs. Routine veterinary care practices including vaccinations, deworming and tick control are important in cattle production. Worm and tick infestations in cattle can also lead to significant production losses and possible death of animals. Whereas worm infestations in animals can lead to loss of appetite and weight, tick infestations can lead to diseases which affect animal health and growth. On the whole, the consequences of non-vaccination of animals can be more devastating to cattle herd than lack of deworming and tick control.

4.7 Conclusion

We set out to investigate the effect of contract types in cattle production on incentives for input use. In order to achieve our objective, we model cattle production as a dynamic process and show that inputs can be classified as short-term and long-term productivity-enhancing inputs. Specifically, we show that veterinary care inputs are long-term productivity-enhancing inputs since they increase the steady state stock of cattle. Supplementary feed can be considered a short-term productivity-enhancing input since it only changes the weight of a given number of animals. Furthermore, we formulate two main hypotheses to test predictions from the model. First, feed supplement use is higher under owner-input-supply arrangements than under calves sharing arrangements. Second, the probability of using vetcare inputs is neither higher nor lower under owner-input-supply arrangements than under calves-sharing arrangements. In order to test these hypotheses, we carry out regressions of input use on contract type, controlling for agro-ecological zones, farm and farmer characteristics. We find that generally short-term productivity-enhancing inputs are more likely to be used under owner-input-supply arrangements (fixed-wage contracts) than under calves-sharing contracts. However, there is no significant difference in long-term productivity-enhancing input use under owner-supplier arrangements compared to calves share contracts. Also, the use of inputs is correlated with agro-ecological zone. When we unbundle inputs, the results are mixed for both individual feed supplements and veterinary care inputs. The use of minerals is significantly higher with owner-input-supply contracts than calves-sharing contracts as predicted, but there is no difference in the use of crop residues under owner-input-supply contracts and calves-sharing contracts. Vaccinations are significantly positively correlated with owner-input-supply arrangements, contrary to our expectation. Deworming is not correlated with owner-input-supply contracts, while the use of acaricides is significantly negatively correlated with owner-input-supply contracts, also contrary to expectation.

Generally, we learn that to enhance feed supplementation, owner-input-supply arrangements must be encouraged or promoted. Under calves-sharing contracts there is little or no incentive to spend on feed supplementation of bulls. To the extent that cattle owners are only interested in building their stocks of cattle, the owner-input supply and calve-sharing contracts provide similar incentives for input use. Given that owner-input-supply contracts are common in the Guinea and Sudan savannah and to some extent in the Transitional zone, the promotion of feed supplementation in these zones is likely to succeed.

The empirical analysis was based partly on the observation that all cattle owners who had cattle in a particular kraal had the same contract type with their kraal owner. Thus, input use per kraal would reflect the contract type that pertains therein. However, input use per cattle owner might be preferred if this data were available. This could also lead to the generation of panel data and the use of panel data methods of analysis, which is likely to yield more robust results. Thus, future studies could collect data on input use per cattle owner for the analysis of the correlation between input use and contract type.

Appendices

Appendix 4.1. Derivation of results

Derivation of results (1) and (2)

Let $\phi := \gamma\delta + (1-\gamma)$. The dynamics of $K_{f,t}$ and $K_{m,t}$ can be written as

$$K_{f,t+1} = K_{f,t} + \phi b K_{f,t} - m K_{f,t} - \lambda_y K_{f,t} \tag{1}$$

$$K_{m,t+1} = K_{m,t} + \phi b K_{f,t} - m K_{m,t} - \lambda_y K_{m,t} - \lambda_q K_{m,t} \tag{2}$$

To arrive at closed-form solutions for the steady state stocks, we assume that mortality rate m depends negatively on V/K according to a function *h* defined by

$$h\left(\frac{V}{K}\right) := \begin{cases} \overline{m} - m_0 \dfrac{V}{K} & \text{if } \dfrac{V}{K} \leq v \\ \dfrac{V}{K} + \underline{m} & \text{if } \dfrac{V}{K} \geq v \end{cases} \tag{3}$$

with $0 < m_0 v < \overline{m} - \underline{m}$ and v such that h is continuous (v is the positive root of a quadratic equation). Moreover, we assume for relevance

$$\underline{m} < \phi b - \lambda_y < \overline{m} - m_0 v. \tag{4}$$

A steady state requires $K_{f,t+1} = K_{f,t}$ and $K_{m,t+1} = K_{m,t}$. So K_f^* is found by solving for $K_{f,t}$:

$$h\left(\frac{V}{K_{f,t}}\right) = \phi b - \lambda_y. \tag{5}$$

By (4), this becomes

$$\overline{m} - m_0 \frac{V}{K_{f,t}} = \phi b - \lambda_y \tag{6}$$

which yields result (1) in the main text.

Similarly, K_m^* is found by solving for $K_{m,t}$:

$$h\left(\frac{V}{K_{m,t}}\right) K_{m,t} = \phi b K_f^* - (\lambda_y + \lambda_q) K_{m,t}. \tag{7}$$

Suppose a solution has $V_m/K_{m,t} \leq v$. Then, using (3), it must hold that

$$\overline{m} K_{m,t} - m_0 V_m = \phi b K_f^* - (\lambda_y + \lambda_q) K_{m,t}. \tag{8}$$

which yields result (2) in the main text. Noting that, with $V_f = \sigma V_m$, we have

$$\frac{V_m}{K_m^*} = \frac{\overline{m} + \lambda_y + \lambda_q}{\sigma \phi b \alpha_f(\gamma) + m_0} = \frac{\overline{m} + \lambda_y + \lambda_q}{\sigma \phi b \left(\dfrac{m_0}{\overline{m} + \lambda_y - \phi b}\right) + m_0}, \tag{9}$$

the condition $V_m/K_m^* \leq v$ is satisfied for σ large enough (it can be verified that this has $\sigma > 1$). Note that $\sigma = (1-\mu)/\mu$.

Proof of Proposition 1

We solve backwards by considering first the choice of the kraal owner and then that of the cattle owner.

Kraal owner. So suppose that, in the first stage, the cattle owner has set (V^c, S_m^c, γ^c). This gives two cases, depending on whether a share contract is offered $(\gamma^c = 1)$ or a wage contract $(\gamma^c = 0)$.

(1) Share contract. So fix the cattle owner's actions as $(V^c, S_m^c, 1)$. A kraal owner k chooses $V^k \in [0, \overline{V} - V^c]$ and $S_m^k \geq 0$ so as to maximize

$$\pi^k\big((V^k, S_m^k); (V^c, S_m^c, 1)\big)$$

$$= r(V^c, V^k, 1) + \theta\overline{\alpha}(1)[V^c + V^k] - V^k p_v - S_m^k p_s$$

$$= \left[(1-\delta)b(1-\mu)\alpha_f(1)\beta p_y + \theta\overline{\alpha}(1)\right][V^c + V^k] - V^k p_v - S_m^k p_s \,. \tag{10}$$

Hence, $S_m^k = 0$. Further, $V^k > 0$ only if

$$(1-\delta)b(1-\mu)\alpha_f(1)\beta p_y + \theta\overline{\alpha}(1) > p_v. \tag{11}$$

Hence (throughout it is assumed that if one is indifferent between more than one input level, the lowest amount is chosen),

$$V^k = \begin{cases} 0 & \text{if (11) does not hold} \\ \overline{V} - V^c & \text{if (11) holds} \end{cases} \tag{12}$$

We denote these solutions by $S_m^k(1)$ and $V^k(1)$.

(2) Wage contract. So fix the cattle owner's actions as $(V^c, S_m^c, 0)$. A kraal owner k chooses $V^k \in [0, \overline{V} - V^c]$ and $S_m^k \geq 0$ so as to maximize

$$\pi^k\big((V^k, S_m^k); (V^c, S_m^c, 0)\big)$$

$$= r(V^c, V^k, 0) + \theta\overline{\alpha}(0)[V^c + V^k] - V^k p_v - S_m^k p_s$$

$$= w + \theta\overline{\alpha}(0)[V^c + V^k] - V^k p_v - S_m^k p_s \tag{13}$$

Again, $S_m^k = 0$. Further, $V^k > 0$ only if

$$\theta\overline{\alpha}(0) > p_v. \tag{14}$$

Hence,

$$V^k = \begin{cases} 0 & \text{if (14) does not hold} \\ \overline{V} - V^c & \text{if (14) holds} \end{cases} \tag{15}$$

We denote these solutions by $S_m^k(0)$ and $V^k(0)$.

Cattle owner. Let the results (12) and (15) be summarized by $V^k(\gamma^c) = \Psi_{\gamma^c}(V^c)$, and recall $S_m^k(\gamma^c) = 0$ $(\gamma^c = 0,1)$. We first determine the highest payoff per contract type.

(1) Share contract. A cattle owner c chooses $V^c \in [0, \overline{V}]$ and $S_m^c \geq 0$ so as to maximize

$$\pi^c\big((V^c, S_m^c, 1); \Psi_1(V^c), 0\big)$$

$$= p_y\lambda_y\overline{\alpha}(1)[V^c + \Psi_1(V^c)] + p_q\lambda_q\alpha_m(1)[V^c + \Psi_1(V^c)]\sqrt{1 + S_m^c} - r(V^c, \Psi_1(V^c), 1) - V^c p_v - S_m^c p_s$$

$$= \left[p_y\lambda_y\overline{\alpha}(1) + p_q\lambda_q\alpha_m(1)\sqrt{1 + S_m^c} - (1-\delta)b(1-\mu)\alpha_f(1)\beta p_y\right]\left[V^c + \Psi_{\gamma^c}(V^c)\right] - V^c p_v - S_m^c p_s \tag{16}$$

or,

$$\pi^c\big((V^c, S_m^c, 1)\,;\Psi_1(V^c), 0\big) = \begin{cases} A & \text{if} \quad (11) \text{ does not hold} \\ B & \text{if} \quad (11) \text{ holds} \end{cases} \tag{17}$$

where

$$\text{A} := \left[p_y\lambda_y\overline{\alpha}(1) + p_q\lambda_q\alpha_m(1)\sqrt{1+S_m^c} - (1-\delta)b(1-\mu)\alpha_f(1)\beta p_y\right]V^c - V^c p_v - S_m^c p_s$$

$$\text{B} := \left[p_y\lambda_y\overline{\alpha}(1) + p_q\lambda_q\alpha_m(1)\sqrt{1+S_m^c} - (1-\delta)b(1-\mu)\alpha_f(1)\beta p_y\right]\overline{V} - V^c p_v - S_m^c p_s$$

Suppose (11) does not hold. By differentiating A with respect to V^c, we find that if

$$p_y\lambda_y\overline{\alpha}(1) + p_q\lambda_q\alpha_m(1) - (1-\delta)b(1-\mu)\alpha_f(1)\beta p_y > p_v, \tag{18}$$

then (denoting solutions by $S_m^c\,(\gamma^c)$ and $V^c(\gamma^c)$)

$$V^c(1) = \overline{V} - V^k(1) = \overline{V}. \tag{19}$$

Further, by differentiating A with respect to S_m^c, we find that if

$$\frac{p_q\lambda_q\alpha_m(1)\overline{V}}{2} > p_s, \tag{20}$$

then

$$S_m^c\,(1) = \left(\frac{p_q\lambda_q\alpha_m(1)\overline{V}}{2p_s}\right)^2 - 1 > 0. \tag{21}$$

Suppose (11) holds. By differentiating B with respect to V^c, we see immediately that

$$V^c(1) = 0. \tag{22}$$

Further, by differentiating B with respect to S_m^c, we find that if (20) holds, then again (21) applies.

(2) Wage contract. A cattle owner c chooses $V^c \in [0,\ \overline{V}]$ and $S_m^c \geq 0$ so as to maximize

$$\begin{aligned} &\pi^c\big((V^c, S_m^c, 0)\,;\Psi_0(V^c), 0\big) \\ &= p_y\lambda_y\overline{\alpha}(0)[V^c + \Psi_0(V^c)] + p_q\lambda_q\alpha_m(0)[V^c + \Psi_0(V^c)]\sqrt{1+S_m^c} - r(V^c, \Psi_0(V^c), 0) - V^c p_v - S_m^c p_s \\ &= \left[p_y\lambda_y\overline{\alpha}(0) + p_q\lambda_q\alpha_m(0)\sqrt{1+S_m^c}\right][V^c + \Psi_0(V^c)] - w - V^c p_v - S_m^c p_s \end{aligned} \tag{23}$$

or,

$$\pi^c\big((V^c, S_m^c, 0)\,;(\Psi_0(V^c), 0)\big) = \begin{cases} A' & \text{if} \quad (14) \text{ does not hold} \\ B' & \text{if} \quad (14) \text{ holds} \end{cases} \tag{24}$$

where

$$A' := \left[p_y\lambda_y\overline{\alpha}(0) + p_q\lambda_q\alpha_m(0)\sqrt{1+S_m^c}\right]V^c - w - V^c p_v - S_m^c p_s$$

$$B' := \left[p_y\lambda_y\overline{\alpha}(0) + p_q\lambda_q\alpha_m(0)\sqrt{1+S_m^c}\right]\overline{V} - w - V^c p_v - S_m^c p_s$$

Suppose (14) does not hold. By differentiating A' with respect to V^c, we find that if

$$p_y\lambda_y\overline{\alpha}(0) + p_q\lambda_q\alpha_m(0)\sqrt{1+S_m^c} > p_v\,, \tag{25}$$

then

$$V^c(0) = \overline{V} - V^k(0) = \overline{V}. \tag{26}$$

Further, by differentiating A' with respect to S_m^c, we find that

$$\frac{p_q \lambda_q \alpha_m(0)\overline{V}}{2} > p_s, \tag{27}$$

then

$$S_m^c\,(0) = \left(\frac{p_q \lambda_q \alpha_m(0)\overline{V}}{2p_s}\right)^2 - 1 > 0. \tag{28}$$

Suppose (14) holds. By differentiating B' with respect to V^c, we see immediately that

$$V^c(0) = 0. \tag{29}$$

Further, by differentiating B' with respect to S_m^c, we find that if (27) holds, then again (28) applies.

Now recall our focus on Stackelberg equilibria (SE) with strictly positive quantities of inputs. Then the above can be summarized as follows:

- Suppose an SE with a share contract.
  (1) If (11) holds, then $V^c(1) = 0$ and $V^k(1) = \overline{V} - V^c(1) = \overline{V}$.
  (2) If (11) does not hold (and so (18) holds), then $V^k(1) = 0$ and $V^c(1) = \overline{V} - V^k(1) = \overline{V}$.
  (3) $S_m^k\,(1) = 0$ and $S_m^c\,(1) = \left(p_q \lambda_q \alpha_m(1)\overline{V}/2p_s\right)^2 - 1$.

- Suppose an SE with wage contract
  (1) If (14) holds, then $V^c(0) = 0$ and $V^k(0) = \overline{V} - V^c(0) = \overline{V}$.
  (2) If (14) does not hold (and so (25) holds), then $V^k(0) = 0$ and $V^c(0) = \overline{V} - V^k(0) = \overline{V}$.
  (3) $S_m^k\,(0) = 0$ and $S_m^c\,(0) = \left(p_q \lambda_q \alpha_m(0)\overline{V}/2p_s\right)^2 - 1$.

- Because $\alpha_m(1) < \alpha_m(0), S_m^c\,(1) < S_m^c\,(0)$.

This proves proposition 1.

Finally, we compare the optimal payoffs of the cattle owner under both types of contracts using the first two bulleted results. In the case of a share contract,

$$\pi^c\big((V^c, S_m^c, 1)\,; \Psi_1(V^c), 0\big)$$
$$= \Big[p_y \lambda_y \overline{\alpha}(1) + p_q \lambda_q \alpha_m(1)\sqrt{1 + S_m^c(1)} - (1-\delta)b(1-\mu)\alpha_f(1)\beta p_y\Big]\overline{V} \;- V^c(1)p_v \;- S_m^c(1)p_s \tag{30}$$

with $V^c(1) = 0$ if (11) holds and otherwise $V^c(1) = \overline{V}$. In the case of a wage contract,

$$\pi^c\big((V^c, S_m^c, 0)\,; \Psi_0(V^c), 0\big) \;= \Big[p_y \lambda_y \overline{\alpha}(0) + p_q \lambda_q \alpha_m(0)\sqrt{1 + S_m^c(0)}\Big]\overline{V} - w \;- V^c(0)p_v \;- S_m^c(0)p_s \tag{31}$$

with $V^c(0) = 0$ if (14) holds and otherwise $V^c(0) = \overline{V}$. Depending on conditions (11) and (14), this implies four configurations for which we have to determine the optimal contract and so the existence and nature of the Stackelberg equilibrium. Instead of this tedious but straightforward exercise, we just make two observations.

First, it is immediately seen that a Stackelberg equilibrium with a share contract obtains if wage w is sufficiently high. Second, because $\overline{\alpha}(1) < \overline{\alpha}(0)$ and

$$p_q \lambda_q \alpha_m(1)\sqrt{1 + S_m^c}(1)\,\overline{V} - S_m^c(1)p_s < p_q \lambda_q \alpha_m(0)\sqrt{1 + S_m^c}(0)\,\overline{V} - S_m^c(0)p_s \tag{32}$$

a wage contract yields a higher payoff if

$$w + V^c(0)p_v < (1-\delta)b(1-\mu)\alpha_f(1)\beta p_y\overline{V} + V^c(1)p_v, \tag{33}$$

so it is just a matter of suitable parameterization to obtain a Stackelberg equilibrium with a wage contract.

Appendix 4.2: Summary statistics by contract type

Variable	Obs	Mean	Std. Dev.	Min	Max
Fixed payment Contract					
Number of other owners (*nothown*)	31	2.78	2.40	1	11
Cattle owner's herd size (*cohdsz1*)	29	11.41	8.12	2	38
Proportion of cattle owner's herd (*cohdszprop1*)	27	0.26	0.167	0.036	0.67
Kraal owner's herd size (*kherdsize1*)	30	56.27	38.29	15	180
Share contract					
Number of other owners (*nothown*)	88	5.5	4.56	1	20
Cattle owner's herd size (*cohdsz1*)	51	13.37	15.90	1	95
Proportion of cattle owner's herd (*cohdszprop1*)	51	0.21	0.20	0.005	0.85
Kraal owner's herd size (*kherdsize1*)	88	89.44	102.55	14	600
Subsidy-only contract					
Number of other owners (*nothown*)	59	2.36	1.88	1	8
Cattle owner's herd size (*cohdsz1*)	53	13.09	10.10	2	50
Proportion of cattle owner's herd (*cohdszprop1*)	52	0.27	0.18	0.020	0.83
Kraal owner's herd size (*kherdsize1*)	57	61.56	50.50	8	256
Unspecified contract					
Number of other owners (*nothown*)	126	2.72	1.98	1	11
Cattle owner's herd size (*cohdsz1*)	103	13.17	9.70	1	53
Proportion of cattle owner's herd (*cohdszprop1*)	98	0.26	0.19	0.015	0.96
Kraal owner's herd size (*kherdsize1*)	138	69.16	79.42	8	500

Source: Field data

Appendix 4.3. Input use by agro-ecological zone

Variable	Obs	Mean	Std. Dev	Min	Max
Coastal savannah					
Use of supplements	80	0.225	0.420	0	1
Use of minerals	80	0.213	0.412	0	1
Use of crop residues	80	0.063	0.244	0	1
Vaccinations	77	0.714	0.455	0	1
Deworming	77	0.792	0.408	0	1
Guinea savannah					
Use of supplements	118	0.822	0.384	0	1
Use of minerals	118	0.729	0.446	0	1
Use of crop residues	120	0.117	0.322	0	1
Vaccinations	117	0.855	0.354	0	1
Deworming	116	0.422	0.496	0	1
Sudan savannah					
Use of supplements	78	0.564	0.499	0	1
Use of minerals	79	0.051	0.221	0	1
Use of crop residues	79	0.557	0.500	0	1
Vaccinations	79	0.481	0.503	0	1
Deworming	79	0.620	0.488	0	1
Transitional zone					
Use of supplements	62	0.581	0.497	0	1
Use of minerals	63	0.476	0.503	0	1
Use of crop residues	63	0.413	0.496	0	1
Vaccinations	62	0.677	0.471	0	1
Deworming	62	0.952	0.216	0	1

Source: Field data

Appendix 4.4: Rainfall by agro-ecological zone

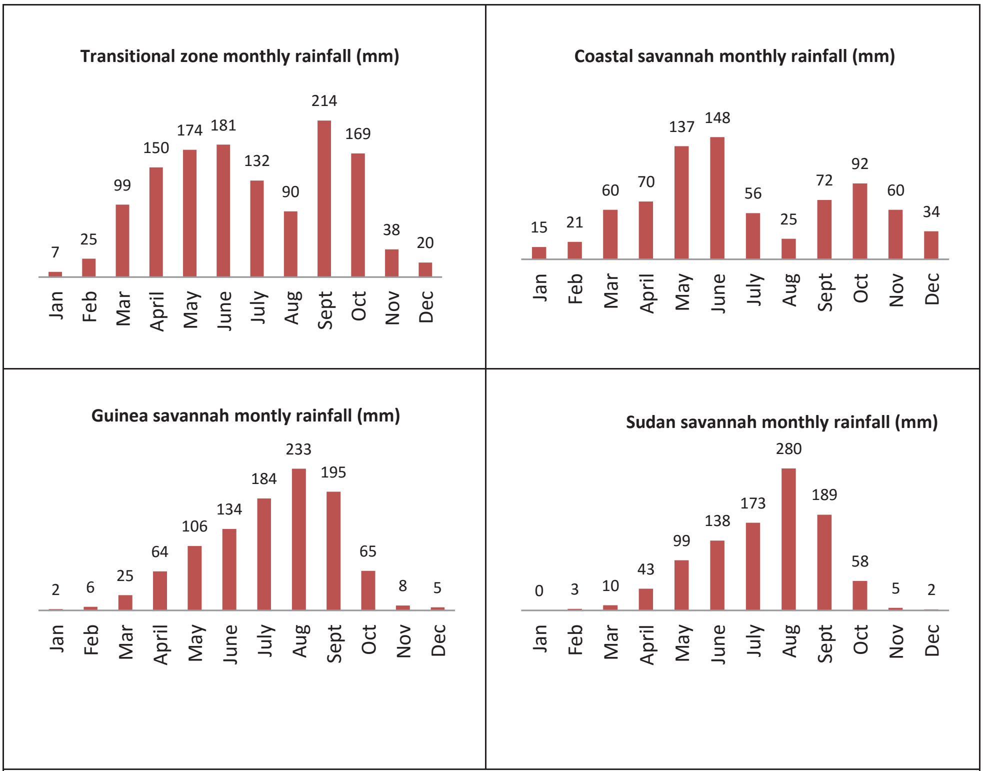

Fig 1a. Monthly rainfall distribution by agro-ecological zone (1980-2010)

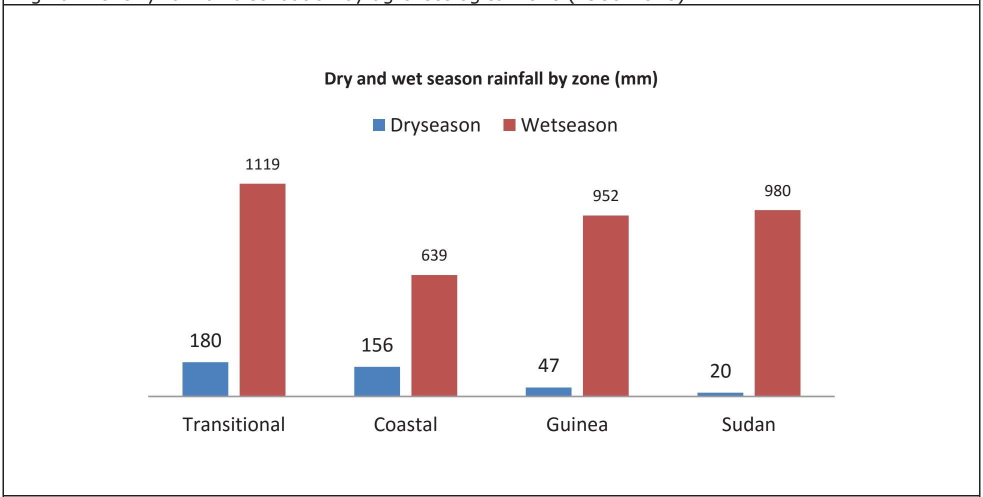

Fig 1b. Total rainfall in wet and dry seasons by agro-ecological zone

CHAPTER 5

Technical efficiency of extensive cattle production in Ghana

ABSTRACT

We estimate technical efficiency in extensive cattle production in Ghana and analyse sources of technical efficiency using stochastic frontier analysis. We find low mean technical efficiency scores between 0.64 and 0.67 for agro-ecological zones. Also, the spread of the scores were wide among farms within zones, suggesting that there is still much room for efficiency improvements in cattle production. Livestock density and wet season rainfall were associated with inefficiency. We find an unexpected positive effect of kraal owner's education on inefficiency, which could mean that the higher educated, because of having more outside options, devote less time to cattle management. Also, contrary to existing studies, we learn that contract type does not matter for efficiency as incentives of both the principal and the agent are aligned. It was shown that extensive cattle production exhibits constant returns to scale in some zones but not in others. Hence productivity improvements in farms in some cases will not depend on the scale of the farm but on improvements in technology and efficiency. We view this study as providing more evidence of technical efficiency in extensive cattle production, especially in Tropical Africa, and isolating some of the sources of inefficiency.

5.1 Introduction

The need to ensure food security in the world, especially in developing countries, requires that farm productivity is improved constantly. Variations in productivity can stem from differences in technology, scale of operation, operating efficiency, and the environment in which production occurs (Fried et al., 2008). Often, interventions made by external agents to improve productivity in food production in developing countries involve the introduction of new technology. However, the adoption of new technologies for food production is not sufficient to achieve increased food production. When new technologies are adopted they must be used efficiently. Furthermore, new technologies may be expensive. Hence, if producers are inefficient in the use of existing technologies, taking steps to increase efficiency may be a cost-effective way to increasing productivity. Thus, many studies have been carried out to assess efficiency in food production, including crops and livestock production (Ahmed et al., 2002, Battese and Coelli, 1995, Cabrera et al., 2010, Hadley, 2006, Helfand and Levine, 2004, Huang et al., 2016, Kompas and Che, 2006, Kumbhakar et al., 1991, Samarajeewa et al., 2012, Villano et al., 2010).

Livestock production can be based on intensive or extensive methods. In the tropics, extensive livestock production systems are predominant. In Ghana, and much of Sub-Saharan Africa, the extensive system involves rudimentary housing and the grazing on natural pasture for nutrition. Usually a herdsman is engaged by a kraal owner, a cattle owner who has space and facilities to rear cattle, to herd his cattle to the rangelands to feed on natural pasture and search for water to drink. Often other cattle owners who have a few cattle but no space, time or labour to take care of them, entrust their cattle to a kraal owner to keep for them. Consequently, the contractual relationships between herder, kraal owner and cattle owners could crucially influence incentives for input use and ultimately productivity and efficiency of cattle production. A few studies have been conducted to show that contract types impact on efficiency and productivity in agriculture. For instance, (Shearer, 2004) showed that when workers were paid piece rates instead of fixed wages, it engendered 20 percent gain in productivity in tree planting. Laffont and Matoussi (1995) showed that efficiency was lower when the tenant's share of output was lower. However, contrary to theoretical prediction, Kassie and Holden (2007) found higher land productivity on sharecropped plots than on tenants own plots. Also, Ahmed et al. (2002) found that efficiency was lower with sharecropping than owner-cultivation. In the case of Helfand and Levine (2004), the effect of sharecropping, compared to owner-cultivation, on efficiency was mixed.

We distinguish between two sets of contractual arrangements, one between a kraal owner and a cattle owner and another between a kraal owner and a herdsman. For the former, we define two contract types: the owner-input-supply arrangement, in which the cattle owner supplies all inputs to the kraal owner and keeps all the calves from his cows for himself, and calves-sharing contracts, in which the cattle owner shares his calves with the kraal owner and may not supply inputs. For the latter relationship between kraal owner and herdsman, we define two contract types based on herdsman remuneration: one in which the herdsman receives milk as his major remuneration, and another in which he receives a heifer after his contract expires.

Although new technologies and intensive production systems are being promoted, the extensive nature of the production system, especially for ruminant livestock, is likely to remain for a long time. Research institutions collaborating with other agricultural institutions generate technologies such as improved cattle breeds and methods for establishing and managing sown pasture, which are intended for adoption by cattle farmers. However, the use of such technologies and methods, which involve some intensification of livestock production, are capital intensive. This can be a major limitation to the adoption of such systems. Besides, concerned groups such as animal welfare advocates are pushing for less intensive livestock production methods. Therefore, it is critical that before considering technical change in extensive livestock production systems in developing countries, we assess the levels of inefficiency and their sources. This means comparing performance of each farm in a group against the best in the group.

Most studies of extensive livestock production systems have been done for countries in the sub-tropic and temperate zones (Cabrera et al., 2010, Hadley, 2006, Huang et al., 2016, Moreira and Bravo-Ureta, 2010, Samarajeewa et al., 2012). Only few studies have investigated efficiency in extensive livestock production systems in the tropics (Otieno et al., 2014, Seré and Doppler, 1981, Temoso et al., 2015). The paucity of efficiency studies on extensive livestock production systems is in part due to unavailability of reliable data; record keeping by farmers is poor if it is done at all.

The objective of this chapter is to measure efficiency of extensive cattle production systems in various agro-ecological and assess the influence of contract types on inefficiency using data from Ghana. We emphasise calf production which is the foundation for beef production. Our interest in calves as output is similar to Samarajeewa et al. (2012) and Rakipova et al. (2003) who consider weaned calf as the primary output of cow-calf operations. Also, indigenous cattle breeds which we deal with in this study are poor milk producers. Hence, aside getting enough milk for calves to feed on, milk production is not a major concern for most cattle owners. We use survey data from 288 cattle farms or kraals in Ghana. Stochastic frontier analysis is used to measure efficiency and identify their sources.

We find a mean technical efficiency score between 0.64 and 0.67 for the different zones together with a wide spread of scores within zones. This suggests that there is still much room for efficiency improvements in cattle production in Ghana. Also, we show that the cattle production function exhibits constant returns to scale in some zones, but decreasing returns to scale in others. This result rules out productivity gains via changes in the scale of production for zones with constant returns to scale, and thus reinforces the need for improvements in efficiency and technology if productivity is to be increased. Sources of technical inefficiency were difficult to identify. However, for the Guinea/Sudan savannah, increases in livestock density increased inefficiency, while increases in wet season rainfall decreased inefficiency. Also, we find an unexpected positive relationship between kraal owner's education and inefficiency for the pooled zones. Because an increase in education generally implies more outside options, this could mean that a more educated kraal owner devotes less time to cattle management and so increases inefficiency of the farm. Somewhat surprisingly, the influence of calves share contracts was not different from that of owner-input-supply arrangements regardless of zone. This is contrary to other studies that have shown that contract type influences efficiency or productivity (Kassie and Holden, 2007, Laffont and Matoussi, 1995, Shearer, 2004). We interpret this to mean that contracts do not matter for increases in number of calves, since incentives for the kraal owner and cattle owner to increase the number of calves are aligned under calves-sharing arrangements. Thus, we should not expect Marshallian inefficiency here. Similarly, remunerating a herdsman with milk did not influence inefficiency differently from remunerating a herdsman with a heifer.

This study can be viewed as contributing to address the paucity of literature on technical efficiency of extensive livestock production in Tropical Africa and as a first evaluation of efficiency of livestock production in Ghana. When the kraal owner is closer to his kraal, he is better able to supervise and monitor his herdsmen and animals and thereby reduce inefficiency in production. Yet, the more educated a kraal owner is, the stronger is the tendency to move to urban areas where he has more outside options, better infrastructure and social amenities. In this respect governments could provide some infrastructure and social amenities in rural areas, since this will motivate the more educated kraal owners to remain in the rural areas where they can combine available formal jobs with cattle rearing more efficiently. In developing countries, livestock plays significant roles in people's livelihoods including accumulation of capital for emergency expenditure (Moyo and Swanepoel, 2010).

The chapter is organised as follows. In Section 5.2, we give a brief exposition on agro-ecological zones, production systems and methods in Ghana. In Section 5.3, we outline our empirical strategy and in Section 5.4 describe our data. We present our results and discussions in Section 5.5 and conclude in Section 5.6.

5.2 Agro-ecological zones, production systems and methods

In Ghana, cattle production technology generally is the same everywhere although production is prominent across different agro-ecological zones. The production system is largely extensive and agro-pastoral. The breeds of cattle are largely the same and the differences in agro-ecology do not limit knowledge and use of external inputs such as veterinary care inputs and supplementary feed. Thus, production methods are similar across the different zones noted for cattle production.

The production system is extensive because of the reliance on natural pasture (or rangelands) for nutrition and simple housing (Oppong-Anane, 2006). This reliance on pasture means that cattle must be herded into the pasture fields to graze and drink water. Consequently, cattle nutrition and condition are closely related to quality and availability of grassland herbage quality throughout the year, which in turn is associated with rainfall distribution (Fleischer and Abenney-Mickson, 1998). There is minimal use of external inputs such as feed supplements and veterinary drugs and vaccines. Feed supplements include crop residues and by-products such as rice bran and wheat bran from agro-processing. They are used mostly for growing and fattening young bulls for the market. Veterinary care comprises worm control, tick control, vaccinations, and occasional treatment of animals.

The production system is agro pastoral because cattle farmers, especially kraal owners, grow crops in addition to keeping animals. However, some businessmen and other persons who are not crop farmers also acquire and rear cattle. They may entrust their cattle with a kraal owner to keep for them. They can also directly hire herdsmen to take care of the cattle for them. In these cases, there often exist contractual arrangements between kraal owner and herdsman, and between kraal owner and cattle owners who entrust their cattle with the former for care taking. Often, several cattle owners keep their animals with a single kraal owner. Together, the other owners of cattle usually own the majority of the total stock of cattle in a kraal.

The parties involved in cattle production have some contractual arrangements between them. Two sets of contracts can be identified, one between the kraal owner and the herdsman (kraal owner-herdsman contract) and another between the cattle owner and the kraal owner (cattle owner-kraal owner contract). The kraal owner-herdsman contract is characterised by the form of remuneration the kraal owner offers to the herdsman, since the latter's duties are standard. The major duty of a herdsman is to send cattle into grazing lands and herd them as they feed and look for water. Generally, herdsmen are paid (in kind) either with milk or cattle. Regarding milk payments, herdsmen may be allowed to appropriate all the milk harvested from cow. They use this milk as food and sell the surplus for money. Some herdsmen have a fixed-duration contract and at the end of this they are given a heifer. This end-of-contract remuneration is supplemented with food provisions during the contract period. The distribution of kraal owner-herdsman contracts from this perspective is shown in Table 5.1 (for the zones, see Fig 2.1 and below). Detailed description of KH contracts are provided in section 2.5.3. Here, we emphasise heifer payments, with or without milk payment, and non-heifer milk payments, since this dichotomy brings out incentive issues which are elaborated on later under empirical strategy in section 5.3.2.

Table 5.1. Type of herdsman payment by agro-ecological zone (frequency and percentage)

	Agro-ecological zone				
Kraal owner-herdsman contract	Coastal	Guinea	Sudan	Transitional	Total
Milk payment	20	115	56	56	247
	39.22	100.00	98.25	94.92	87.59
Heifer payment	31	0	1	3	35
	60.78	0.00	1.75	5.08	12.41
Total	51	115	57	59	282
	100.00	100.00	100.00	100.00	100.00

Source: Field data, 2014

In Chapter 2, cattle owner-kraal owner contracts were characterised into four types: the fixed-wage contract with or without subsidies (reinterpreted as owner-input-supply), subsidy-only contracts, calves-sharing contracts, and unspecified contracts. Generally, all cattle owners have similar contracts with a kraal owner into whose care they entrust their animals. Fixed-wage payments involve a cattle owner paying a kraal owner cash as his remuneration. Subsidies comprise full or partial compensation of a kraal owner for expenses incurred on a cattle owner's cattle, or provision for anticipated expenditure on inputs for the cattle owner's animals. These inputs could be veterinary care inputs or labour input for herding of cattle. The cattle owner can also share calves from his cows with the kraal owner according to agreed rules. For instance, if there is equal sharing of cattle, then the first calf delivered by a cattle owner's cow goes to the cattle owner while the second calf born to the same cow goes to the kraal owner. Hence, this form of sharing is rotational. In unspecified contracts, the kraal owner's rewards are not specified ex ante. The cattle owner accumulates calves and observes production outcomes over several periods and then rewards the kraal owner based on the outcomes. Waiting for a couple of periods before rewarding the kraal owner has insurance against income risk built into it (see Chapter 3). If the kraal owner were under a rotational sharing contract he could lose his animal when it gets to his turn, and thus lose his income. However, if animals are accumulated over a few periods before a share is given him, income risk is reduced.

The four cattle owner-kraal owner contract types can be condensed into two: share contract and owner-input-supply contract, when we consider the responsibility for material input supply. The distribution of contract types for the sub-sample used in this chapter are presented in Table 5.2. Here we are more interested in material inputs provided by cattle owner or kraal owner than labour input, which is primarily provided by the herdsman. In the fixed-wage contract, the cattle owner supplies all material inputs and appropriates all the output. Also in the subsidy-only contract the cattle owner supplies all or nearly all the material inputs and appropriates all the output. Hence, the fixed-wage (or owner-input-supply contract) and the subsidy-only contract have similar incentive effects for material input supply. Similarly, the rotational calves-sharing contract and the unspecified contract are viewed as share contracts with similar incentive effects for material input supply. The use of material inputs such as feed supplements and veterinary drugs is crucial for the growth and survivability of cattle (see Chapter 4).

Table 5.2. Distribution of cattle owner-kraal owner contract type by agro-ecological zone for sub-sample (frequency and percentage)

	Agro-ecological zone				
Cattle owner-kraal owner contract	Coastal	Guinea	Sudan	Transitional	Total
Share	49	66	48	24	187
	100.00	61.11	78.69	43.64	68.50
Owner-input-supply	0	42	13	31	86
	0.00	38.89	21.31	56.36	31.50
Total	49	108	61	55	273
	100.00	100.00	100.00	100.00	100.00

Source field data, 2014

The cattle kept are mostly indigenous breeds, including the West African Short Horn (WASH), and a cross between the WASH and zebu breeds, which is known as Sanga (Otchere and Okantah, 2001). The Sanga has become an established breed essentially. Attempts by the state to introduce exotic breeds such as the Friesian and Jersey have not been successful due to their ill adaptation to the tropical climatic conditions. A strategy for breed improvement through artificial insemination of local breeds with the semen of the exotic breeds has also yielded little success. The keeping of such cross breeds by farmers is not widespread, since it involves adopting a more intensive system of production which many farmers find difficult to cope with.

There are six agro-ecological zones in Ghana including the Rain Forest, Deciduous Forest, Transitional zone, Coastal savannah, Guinea savannah and the Sudan savanna. Four of these zones are noted for cattle production in the country. These are the Guinea, Sudan and Coastal savannah zones, and the Transitional zone. These zones differ in rainfall amounts and distribution. The Transitional zone has the highest annual rainfall amount (1300mm), followed by the Guinea savannah (1100mm), the Sudan (1000mm) and the Coastal savannah (800mm) (MOFA, 2013). Whereas the Guinea and Sudan savannah zones have unimodal rainfall distribution, the Transitional and the Coastal zones have bimodal rainfall distribution. Accordingly, the Guinea and Sudan savannah have more dry months than the Transitional zone and Coastal savannah. In the Guinea and Sudan savannahs (northern Ghana) rainfall usually starts from April and ends in September. In the areas with bimodal rainfall, the major rains usually occur from April to July and the minor season rains occur from September to October. Thus, agro-ecological zones present different constraints for production in terms of pasture availability and disease burden.

5.3 Theoretical framework and empirical strategy

5.3.1 Production technology and efficiency

Technical efficiency relates to the ability to avoid waste. This can be done first by minimizing input use in the production of a given output vector, or second by producing maximum output from a given vector of inputs (Fried et al., 2008, Kumbhakar and Lovell, 2003). Key to the formulation of measures of technical efficiency is the characterisation of production technology, which allows the transformation of a nonnegative vector of inputs, denoted $x = (x_1, \ldots, x_N) \in R_+^N$, to a nonnegative vector of outputs, denoted $y = (y_1, \ldots, y_M) \in R_+^M$. Production technology can be represented in three alternative ways. First, it can be represented as the set of feasible input output combinations. This can be denoted as $T =$

$\{(y,x): x\ can\ produce\ y\}$. This set is also known as the production possibilities set. Second, production technology can be represented as a set of input vectors that can produce a given output vector y. This set is denoted as $L(y) = \{x: (x,y) \in T\}$. With two inputs x_1 and x_2 this is the area bounded below by the isoquant of y units. Third, production technology can be characterised by a set of output vectors that can be produced with a given input vector x. This set can be represented as $P(x) = \{y: (y,x) \in T\}$. With two outputs y_1 and y_2 this is the area bounded above by a production possibility curve. Technical efficiency is often defined relative to the boundary of the input set $L(y)$ or the output set $P(x)$, which yields an input-oriented or output-oriented measure, respectively.

We consider a single output y produced with multiple inputs. The production frontier is a function $f(x)$ that specifies the maximum output y that can be attained with a given input vector x. Hence, it is defined by $f(x) = max[y: (y,x) \epsilon T]$. To measure technical efficiency, we use an output-oriented indicator $TE(x,y)$ defined as $TE(x,y) = max[\{\mu: \mu y \leq f(x)\}]^{-1}$. This measures the reciprocal of the maximum rate (μ ≥1) at which current output y can be expanded with the same input vector x, hence $TE(x,y) \leq 1$ (Kumbhakar and Lovell, 2003).

5.3.2 Empirical strategy

In practice, efficiency measurements have been done by benchmarking the performance of firms in a group against the best in the group. These measurements have been done using both non-parametric and parametric methods. The main non-parametric method is the Data Envelopment Approach (DEA). The parametric methods include the use of deterministic frontiers or stochastic frontiers. In the deterministic frontier approach, output is bounded upwards by a non-stochastic deterministic quantity, whereas in the stochastic frontier approach, output is bounded upwards by the sum of the deterministic and a symmetric random stochastic element that accounts for statistical noise. The stochastic frontier model is estimated by econometric methods that allow the simultaneous modelling of inefficiency in terms of its determinants. A major critique of the non-parametric methods such as the DEA is that it captures the symmetric random stochastic error term as part of the inefficiency term (Coelli et al., 2005, Fried et al., 2008). Nevertheless, the DEA can be attractive because one does not have to make any distribution assumptions about inefficiency.

We use the Stochastic Frontier Model to estimate technical efficiency. The function $f(\cdot)$ is specified as a Cobb-Douglas production function. Second-order functional forms such as the translog and quadratic functions may be preferred to a first-order flexible functional form such as the Cobb-Douglas form, but the increased flexibility attained with the former comes at a cost as there are more parameters to estimate, which may lead to econometric problems such as multicollinearity (Coelli et al., 2005). We conduct the likelihood ratio test to assess the adequacy of using the Cobb-Douglas to specify the production function. The relation between actual output y_i of kraal owner i and the maximum possible output can be specified as

$$y_i \leq f(x_i\,;\,\beta) exp\{v_i\}$$

where x_i is a vector of inputs, β is a vector of parameters, and v_i is the error term (Fried et al., 2008). The inefficiency term u_i ($u_i \geq 0$) is introduced into the equation such that the weak inequality becomes a strict equality:

$$y_i = f(x_i\,;\,\beta) exp\{v_i - u_i\}.$$

We assume an exponential distribution for the inefficiency term. Technical efficiency (TE_i) follows as the ratio of actual output to the maximum possible output:

$$TE_i(x_i, y_i) = y_i / f(x_i\,;\,\beta) exp\{v_i\} = exp\{-u_i\} \leq 1.$$

Technical efficiency is less than (or equal to) 1 and gives a measure of the shortfall between actual output and the maximum feasible output (Kumbhakar and Lovell, 2003).

Output has been measured in various ways in efficiency analyses of cattle production, including beef (Hadley, 2006), milk (Kumbhakar et al., 1991) and weaned calves or their value (Rakipova et al., 2003, Samarajeewa et al., 2012). In this study, output (y) is measured as the number of calves born in a given year, which is similar to weaned calves. Wean calves take account of pre-weaning calf mortality, but in our case, we do not have reliable data on mortality. Hence, we stick to the number of calves. Most farmers aim to accumulate cattle and then sell them in times of need. As indicated earlier, the precautionary motive for keeping cattle means that the sales of animals are intermittent and unplanned, so it does not reflect accurately output of a farm. Indigenous cattle breeds which are mostly kept are poor milk producers, hence milk is often not the focus of cattle production. Milk output is of concern only to the extent that it is needed to feed calves and as food by herdsmen. Yet, calves form the basis for beef production, a major output of the extensive production system. Consequently, we settle on the number of calves produced in a kraal given the number of cows of breeding age, which is also a basic measure of fertility rate (Mukasa-Mugerwa, 1989), as our measure of performance.

Inputs (x) for calf production consist of cows (female animals of breeding age), veterinary care, and herdsmen. Veterinary care includes routine worm control, tick control, and vaccinations. Because we do not have reliable quantitative data on veterinary care, a dummy variable is used as follows. It takes a value of 0 if at least one of these three veterinary care practices occur on a farm, and a value of 1 if two or more of the practices occur. It is expected that adequate and routine practice of veterinary care will improve health of cows in a herd and lead to more of them calving. Also, it is expected that increases in the number of cows in a herd will lead to a higher number of calves delivered per annum.

Pasture is a major input used in cattle production. However, this is naturally occurring, and cattle owners do not influence pasture availability to cattle beyond employing herdsmen to take cattle for grazing on this pasture. We consider this as an environmental variable which affects inefficiency, so we elaborate on it when we consider factors that influence inefficiency.

Herdsmen influence the effectiveness of herding cattle on the grazing lands. A herd can be split between herdsmen (if there is more than one) so that each of them can herd their group of animals to different areas of the grazing lands. This ensures that cattle are not crowded together and can obtain adequate feed. Alternatively, herdsmen can run shifts in taking cattle for grazing, which can lengthen grazing time and the quantity of grass ingested. Consequently, an increase in the number of herdsmen is expected to be positively correlated with the number calves delivered in a herd per annum.

It may be noted that in some cases, kraal owners used supplementary feed in addition to grazing. However, supplementary feed was mostly used to grow and fatten young bulls for the market, so we do not use it as an explanatory variable in our model.

The estimation of production efficiency often entails the assumption that the production technology used by different individuals is the same. The technology used by different firms could vary, however, in which case separate frontiers must be estimated for groups of firms with similar technology. For instance, separate frontiers have been estimated for microfinance institutions with different ownership (Servin et al., 2012), for different garment firms (Battese et al., 2004) and for crop varieties (Villano et al., 2010). Statistical tests are usually conducted to find out whether the separate group frontiers are significantly different from the single production frontier for all the groups. Some studies have gone a step further by estimating metafrontier production functions for the firms in groups with different technologies. The metafrontier function envelopes the deterministic components of the stochastic production function for the group of firms with different technologies (Battese et al., 2004, O'Donnell et al., 2008). The metafrontier function allows the estimation of comparable technical efficiencies for firms using different production technologies. In addition, this method can be used to estimate technology gaps between firms with different technologies.

The different agro-ecological zones provide different constraints to production in terms of climate and disease burden. Thus, we test the appropriateness of estimates of a pooled frontier compared to separate zonal frontiers. There are four zones, but the sample sizes for individual zones are small. Thus, we combine zones according to their similarity based on rainfall distribution. Thus, we combine the Guinea savannah and Sudan savannah, both with a unimodal rainfall distribution, and the Coastal savannah and Transitional zone, both having a bi-modal rainfall distribution. Nevertheless, we do not estimate metafrontiers since in this chapter we are primarily interested in intra-group comparison of efficiency estimates, not inter-group comparisons.

In order to analyse the sources of technical efficiency in cattle production, we write the inefficiency term u_i in the output equation in terms of a vector of variables (z_i) and associated parameters (γ):

$$u_i = u_i(z_i;\, \gamma).$$

Following Aigner et al. (1977), Meeusen and van den Broeck (1977) and Battese and Coelli (1995), we estimate the stochastic frontier model in one stage:

$$y_i = f(x_i\,;\, \beta) exp\{v_i - u_i(z_i; \gamma\}.$$

Numerous factors can affect inefficiency (u_i). The literature suggests such factors as education, farmer experience, contact with extension agents, access to credit, farm size (Bravo-Ureta and Pinheiro, 1993), proportion of family labour (Cabrera et al., 2010, Samarajeewa et al., 2012), technology type (Cabrera et al., 2010, Kompas and Che, 2006), and intensity of input use such as ratio of purchased feed to number of cows (Cabrera et al., 2010, Kompas and Che, 2006). We include the kraal owner's experience in cattle farming, proxied by age, his education level, contact with extension agents, and livestock density in a region as sources of inefficiency. We also include cattle owner-kraal owner contract type and type of herdsman remuneration. Education level of the kraal owner is defined as the number of years of schooling he has had, and we estimate this duration from the level of schooling he attained. Contact with extension staff is a binary variable that takes a value 1 if the kraal owner has had contact with extension agents in the past year and 0 otherwise. The cattle owner–kraal owner contract variable is also binary where a value of one (1) indicates a share contract and zero (0) an owner-input-supply contract. Herder remuneration takes a value of one (1) if the herdsman receives a heifer as his main remuneration and (zero) 0 if he receives milk as his main remuneration.

Greater experience and education of kraal owners are likely to result in the accumulation of knowledge on best practices in cattle production. Hence, we expect that the more experienced the kraal owner is (thus the older he is) and the higher his education level, the higher will be the efficiency level he attains. Also, contact with extension agents is expected to increase the kraal owner's knowledge of good production practices and thus to increase the efficiency. Further, the higher the livestock density (stocking rate) per square kilometre, the smaller is the grazing area and therefore the feed available to an animal. Thus, an increase of the stocking rate beyond a critical maximum (the carrying capacity) will lead to inadequate nutrition and reduced performance of the animals. Livestock density is highest in the Sudan savannah, yet feed scarcity can be high in the dry season. Hence, the carrying capacity is likely to be exceeded in this zone.

Contract type is expected to influence efficiency in the following way. First, a calves-sharing arrangement between cattle owner and kraal owner is likely to go with more inefficiency relative to owner-operator contracts. Generally, share contracts are thought to generate less efficiency outcomes than fixed-rent contracts and owner-operator arrangements (Ahmed et al., 2002, Helfand and Levine, 2004, Laffont and Matoussi, 1995, Otsuka et al., 1992, Shaban, 1987). Often, the majority of cattle in a kraal are owned by other people than the kraal owner (Chapter 4); thus, the bulk of inputs will be used on other people's cattle. Furthermore, all other cattle owners keeping cattle in a kraal usually have the same contract type. Therefore, the use of inputs in a kraal could be influenced by the prevailing contract type in the kraal. Second, the influence of a herdsman's remuneration, in the form of a heifer compared to entitlement to milk harvest, on inefficiency is likely to be ambiguous. As argued in Chapter 2, entitlement to daily milk production is likely to motivate the herdsman to spend longer time in the fields so that the animals can obtain adequate nutrition and produce more milk. The resultant effect is that the number of cows in a herd that calve could increase and calf mortality could also reduce. However, entitlement to milk could also make him milk the cows excessively so that the calves do not get enough milk, which could lead to increased calf mortality. Hence, we cannot tell *a prori* if the number of calves will be higher when herdsman remuneration is in the form of a heifer than when it is in the form of entitlement to milk harvest.

As mentioned earlier, natural pasture availability influences production efficiency. Herbage yield from natural pasture reflects its availability. In Ghana, it is known to be highly correlated with rainfall availability and distribution (Fleischer and Abenney-Mickson, 1998). Although herbage yield data is available for some cattle production areas such as the Coastal savannah, it is not available for the majority of the production areas including the Guinea savannah, Sudan savannah, and the Transitional zone. Consequently, we use rainfall amount for the regions constituting the respective agro-ecological zones as a proxy for herbage yield. Several factors influence herbage dry matter yield, including soil, climatic factors such as temperature, relative humidity, and rainfall, and management factors such as cutting interval, fertilizer application, stocking rate, grazing intensity, pasture management and plant species (Fleischer and Abenney-Mickson, 1998). However, in semi-humid West Africa, temperature and relative humidity appear insignificant, since they do not vary much in a year. Among climatic factors that influence herbage dry matter yield, rainfall is the most dominant (Doppler, 1980, Fleischer et al., 1996). We compute total rainfall amounts for the wet season and for the dry season, to reflect periods of high rainfall (herbage abundance) and low rainfall (herbage scarcity) in a region. Distinguishing between wet and dry seasons is similar to the practice of Samarajeewa et al. (2012), who differentiate winter feed from summer pasture, and Huang et al. (2016), who differentiate summer pasture from winter pasture, although the former use these factors in the production function rather than the efficiency equation. Rainfall influences cattle nutrition via pasture availability and quality. Furthermore, good and adequate nutrition reduces the calving interval, which is the number of days between consecutive calvings for a cow (Mukasa-Mugerwa, 1989). The shortening of calving interval means that more cows in a kraal can calve each year. Thus, we expect that rainfall will exert a positive influence on the number of calves delivered by a herd of given size.

Incorporating rainfall into the production function then results in the estimation of technical efficiency net of environmental influences (Coelli et al., 1999). If environmental factors are included in the technical-efficiency equation (see below), then the technical-efficiency scores capture environmental influence, which is an approach that Battese and Coelli (1995) take. Coelli et al. (1999) use both approaches in their stochastic frontier analysis and note that, though the choice of approach leads to different efficiency estimates, it does not alter the ranking among producers with respect to their efficiency.

5.4 The data

We obtained data from a survey of kraal owners, cattle owners, and herdsmen from four agro-ecological zones in Ghana (Coastal savannah, Guinea savannah, Sudan savannah and the Transitional zone), where cattle production is most prominent. The survey was conducted in 2014. Furthermore, we selected three districts from the Coastal savannah, three districts from the Guinea savannah, two districts from the Sudan savannah, and three districts from the Transitional zone. Then we sampled cattle farms (kraals) randomly from a list of cattle kraals made by agricultural officers in the respective districts. We interviewed kraal owners and herdsmen associated with each kraal to elicit data on kraal, kraal owner, cattle owner, and herdsman characteristics, on number of other cattle owners keeping cattle in the kraal, herd size and herd structure, and on indicators of productivity including number of calves delivered and mortality in the previous year. Cattle owners provided data on the number of cattle they kept with a kraal owner. We also obtained data on duties and obligations of kraal owners, cattle owners, and herdsmen in order to characterise contract types between a kraal owner and herdsman, and a cattle owner and a kraal owner.

Data was collected from 342 kraals, their associated kraal owners, other cattle owners, and herdsmen. However, there were missing data for some variables and we also had to eliminate cases in which the number of calves and cows appeared to be inaccurate. Chapter 2 provides details of the survey methodology.

Table 5.3 presents summary statistics for the sub-sample used for our analyses. These statistics are presented for the pooled data, combined Coastal and Transitional zone, and the combined Guinea and Sudan zone. The mean number of calves delivered per kraal in a year were nearly the same for the two (combined) zones, while the mean number of cows (stock of breeding animals) in a kraal was slightly higher in the Coastal/Transitional zone than the Guinea/Sudan savannah. As already explained, the dummy variable for veterinary care indicates whether it is low (0) or high (1) in a kraal. The fraction of kraals with high veterinary care is twice as high in the Coastal/Transitional zone. The mean number of herdsmen per kraal in the two zones was between one and two. Kraal owners in the Guinea/Sudan savannah were older. The average number of years of education of the kraal owner in the Coastal/Transitional savannah was more than three times that in the Guinea/Sudan zone. Over 80 percent of kraal owners had contact with extension agents in the past year in both zones.

Total rainfall per annum in the seven wettest months in the Guinea/Sudan was higher on average than in the Coastal/Transitional. Yet, rainfall in the driest five months was much higher in the Coastal/Transitional zone, over four times. These rainfall figures are averages for the period 1980 – 2010 and compiled from Choudhary and D'Alessandro (2015). The rainfall figures were for representative weather stations in each region belonging to the four agro-ecological zones. These stations were Zuarungu (Upper East Region), Babile (Upper West Region), Nyankpala (Northern Region), Afrienya (Greater Accra Region), and Ejura (Brong – Ahafo). The Ejura station, which is located in the Transition zone of the Ashanti Region, is close to the Transition zone of the Brong-Ahafo Region, so we used the figure for Ejura for both the Ashanti and Brong-Ahafo Regions. The Volta Region

Table 5.3. Summary statistics

Variable	Zone	Obs	Mean	Std. Dev.	Min	Max
Number of calves	Pooled	287	14.60	14.88	0	137
	Coastal/Transitional	110	14.49	17.33	0	137
	Guinea/Sudan	177	14.67	13.17	0	70
Number of cows	Pooled	288	32.59	35.76	2	300
	Coastal/Transitional	110	34.85	48.47	2	300
	Guinea/Sudan	178	31.20	24.93	2	150
Veterinary care	Pooled	283	0.57	0.50	0	1
	Coastal/Transitional	109	0.84	0.36	0	1
	Guinea/Sudan	174	0.40	0.49	0	1
Number of herdsmen	Pooled	285	1.72	1.55	1	15
	Coastal/Transitional	109	1.46	1.15	1	9
	Guinea/Sudan	176	1.88	1.74	1	15
Total rainfall in dry season in regions in mm	Pooled	6	87.83	65.04	20	180
	Coastal/Transitional		168.83	12.09	155	180
	Guinea/Sudan		37.78	13.12	20	50
Total rainfall in wet season in regions in mm	Pooled	6	937.32	154.38	635	1120
	Coastal/Transitional	3	896.46	240.85	635	1120
	Guinea/Sudan	3	962.57	35.23	894	981
Contact with extension agents	Pooled	286	0.84	0.36	0	1
	Coastal/Transitional	109	0.84	0.36	0	1
	Guinea/Sudan	177	0.84	0.37	0	1
Age of kraal owner in years	Pooled	288	57.41	16.40	23	95
	Coastal/Transitional	110	53.47	15.36	23	91
	Guinea/Sudan	178	59.84	16.59	30	95
Years of education	Pooled	288	3.54	5.25	0	18
	Coastal/Transitional	110	6.6	5.65	0	18
	Guinea/Sudan	178	1.65	3.96	0	18
Cattle owner – kraal owner contract	Pooled	273	0.68	0.47	0	1
	Coastal/Transitional	104	0.70	0.46	0	1
	Guinea/Sudan	169	0.67	0.47	0	1
Herdsman remuneration	Pooled	282	0.12	0.33	0	1
	Coastal/Transitional	110	0.31	0.46	0	1
	Guinea/Sudan	172	0.01	0.08	0	1
Livestock density – head/km^2 in zone	Pooled	6	12.88	8.46	1.3	24.7
	Coastal/Transitional	3	6.87	7.35	1.3	18.9
	Guinea/Sudan	3	16.59	6.83	6.2	24.7
Number of cattle owners	Pooled	266	3.09	2.82	0	20
	Coastal/Transitional	99	3.64	3.64	0	20
	Guinea/Sudan	167	2.76	2.15	0	11
Cattle owner's herd size	Pooled	214	13.64	11.56	1	95
	Coastal/Transitional	70	13.66	14.20	1	95
	Guinea/Sudan	144	13.64	10.09	1	53
Total number of cattle in kraal	Pooled	279	70.78	71.82	8	600
	Coastal/Transitional	106	79.06	96.98	8	600
	Guinea/Sudan	173	65.70	50.27	8	288

Source: Field data

cuts across four agro-ecological zones, hence we did not use figures for the representative weather station (Akaa) in Choudhary and D'Alessandro (2015). Instead, we used the total rainfall figure for the Coastal Savannah from MOFA (2013) and divided this into amounts for the wet and dry periods, based on the proportion of the wet and dry periods in the Afienya station (which is also in the Coastal Savannah). Most cattle owner-kraal owner contracts (68 percent) were share contracts, and the rest had owner-input-supply arrangements.

In about a third of kraals in the Coastal/Transitional zone, herdsmen received heifers as their main form of remuneration, while the rest received milk. The proportion of herdsmen receiving heifer as their main form of remuneration was just about one percent in the Guinea/Sudan. Average cattle density (heads per kilometre squared) in the Guinea/Sudan was more than twice that in the Coastal/Transitional zone. The cattle density figures for the various administrative regions of Ghana were obtained from the Global Livestock Production and Health Atlas (GLiPHA), (F.A.O, 2016). On average, more other persons owned cattle in a kraal in the Coastal/Transitional zone than in the Guinea/Sudan and in both zones each person had an average of 14 cattle. The average herd size of a kraal was 71 cattle. This implies that on average the outside cattle owners together own about sixty percent of animals in a kraal (42/71) and the kraal owner himself about forty percent. Given the average number of cattle owners, the number of cattle each owner has, and the average number of cattle in a kraal, about 57 percent and 62 percent of kraal owners in the Guinea/Sudan and Coastal/Transitional zone, respectively, own cattle in a kraal.

5.5 Results and discussions

A likelihood ratio test was conducted to test the hypothesis that the Cobb-Douglas function was an appropriate representation of the production function against the alternative hypothesis that the Translog specification was more appropriate. For the pooled data and Coastal/Transitional zone data, the hypothesis could not be rejected. For the Guinea/Sudan data, the hypothesis was rejected only at the 10 percent level. Therefore, we estimated the stochastic production frontier using a Cobb-Douglas specification of the production function. Also, the likelihood ratio test was carried out to test the hypothesis that the pooled frontier was the same as the separate zonal frontiers. This hypothesis was rejected at the 10 percent level. Hence, separate frontiers were estimated for the different zones, Coastal/Transitional and Guinea/Sudan.

Table 5.4 presents results of the maximum likelihood estimation of the stochastic production frontier. In a test of the null hypothesis that there is no technical inefficiency versus the alternative hypothesis that there is inefficiency, the null hypothesis was strongly rejected, regardless of zone, p-value of 0.01. Irrespective of zone, we also rejected the hypothesis that differences in kraal owner's herd size caused the symmetric error term to be heteroskedastic (see Appendix 5.1). Furthermore, we tested whether the production function exhibited constant returns to scale. While this was rejected based on a wald statistic of 3.90 and a p-value of 0.05 for the pooled data, and wald statistic of 4.06 and a p-value of 0.04 for the Coastal/Transitional zone, it could not be rejected for the Guinea/Sudan zone based on wald statistics of 0.77 and p-value of 0.38. The sum of the elasticities (coefficients) of inputs in the production function are 0.866 and 0.802 for the pooled frontier and the Coastal/Transitional frontier respectively, indicating decreasing returns to scale. Constant returns to scale implies that there is no proportional relationship between kraal or farm size and output. Consequently, productivity improvements in farms will not depend on the scale of the farm but on improvements in technology and efficiency (Kompas and Che, 2006).

Table 5.4. Maximum likelihood estimates of a stochastic production frontier for extensive cattle production in Ghana assuming exponential distribution of inefficiency (u)

	Pooled frontier	Separate frontiers	
	(1)	(2)	(3)
	All zones	Coastal/Transitional	Guinea/Sudan
	Dependent variable is number of calves		
Number of cows	0.879***	0.860***	0.884***
	(0.27)	(0.046)	(0.035)
Veterinary care	0.017	-0.090	0.082
	(0.047)	(0.071)	(0.064)
Number of herdsmen	-0.030	0.032	-0.052
	(0.044)	(0.085)	(0.058)
Constant	0.097	0.257**	0.062
	(0.081)	(0.115)	(0.119)
$In\sigma_v^2$	-3.222***	-4.710***	-2.925***
	(0.307)	(1.009)	(0.355)
$In\sigma_u^2$	-1.370***	-1.234***	-1.409***
	(0.185)	(0.267)	(0.251)
N	274	107	167
Log likelihood	-175.981	-57.150	-112.926

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

Among the input variables, only number of cows is significant (1 percent level) irrespective of zone. Since output and input figures are transformed into logarithms, we can interpret the coefficients as output elasticities, which are 0.86 and 0.88 for the Coastal/Transitional and the Guinea/Sudan zone, respectively. This means that a 100 percent increase in the number of cows will lead to at least 86 percent increase in the number of calves in both zones. These percentage increases in number of calves are large; cows rarely twin, so it is not expected that the number of calves delivered will be higher than the number of cows available in any given year. An alternative specification of the production frontier with rainfall in the production function yielded similar results. For instance, output elasticities were 0.87 and 0.81 for the Coastal/Transitional and Guinea/Sudan zone (Appendix 5.2). This positive relationship between livestock output and the number of animals is of course expected, and is also found by Otieno et al. (2014) and Temoso et al. (2015) for beef production systems in Kenya and Botswana, respectively. Veterinary care and number of herdsmen are insignificant in both zones, possibly because their levels do not vary much across kraals. These inputs could be meeting just the minimum requirements, so that variations in the physiological and reproductive performance of cows are too little to be discerned.

Table 5.5 presents technical-efficiency scores for the pooled sample and by agro-ecological zone. The mean technical-efficiency score for the pooled sample is 0.66. This means that on average a kraal owner is about 66 percent as efficient as farmers on the production frontier. The mean technical-efficiency scores for the Coastal/Transitional zone was 0.64 and that for the Guinea/Sudan zone 0.67. Also, these indicate that the typical kraal in each zone was 36 percent and 33 percent short of the performance of best kraal in the Coastal/Transitional zone and Guinea/Sudan zone, respectively. When rainfall was included in the production function, technical efficiency scores were similar (pooled data, 0.66; Coastal/Transitional zone, 0.63; Guinea/Sudan zone, 0.68; see Appendix 5.3.

The range of individual technical-efficiency scores among kraal owners is very wide (Table 5.5). For the pooled and separate zones, the minimum score was less than 0.1, while the maximum score was at least 0.93. The wide range in scores regardless of zone indicates that some farmers need to improve their efficiency levels a great deal to catch up with the most efficient ones. Whereas our mean technical-efficiency estimates of 0.64 - 0.67 are lower than the 0.84 obtained by Huang et al. (2016) for extensive yak production systems in China, our range of technical efficiency is similar to theirs (0.06 – 0.99) when they incorporated a measure of herbage quality and quantity into the production function, and also similar to theirs (0.04 – 0.98) when herbage quality and quantity were not incorporated into the production function. Our mean technical efficiency scores are generally lower than those obtained by Temoso et al. (2015) for extensive beef production in Botswana, which had a narrower range for different regions, irrespective of whether the figures were generated using stochastic frontiers or metafrontiers . Otieno et al. (2014) also obtained an average score of 0.70 and a range of 0.27 – 0.91 for beef production among agropastoralists in Kenya using the meta production frontier model. For beef cow-calf farms in Canada, Samarajeewa et al. (2012) obtained an average technical efficiency score of 0.83.

Table 5.5: Summary statistics of technical efficiency scores

Agro-ecological zone	Observations	Mean	Std. Dev.	Min	Max
All	274	0.66	0.21	0.05	0.94
Coastal/Transitional	107	0.64	0.23	0.13	0.96
Guinea/Sudan	167	0.67	0.20	0.05	0.93

The distribution (kernel density) of the technical-efficiency scores for all zones and the individual zones are also presented in Fig 5.1. Generally, the distributions of efficiency scores for the agro-ecological zones are similar. They have a long lower tail and a mode of technical efficiency close to 0.8 irrespective of zone. However, the pooled zones, and to some extent the Guinea/Sudan zone, show bimodality of technical efficiency scores of about 0.5 and 0.8. As the Guinea/Sudan savannah is the largest cattle production zone, there could be some heterogeneity in the factors accounting for inefficiency even within this zone. Nevertheless, most technical efficiency scores are under 0.8.

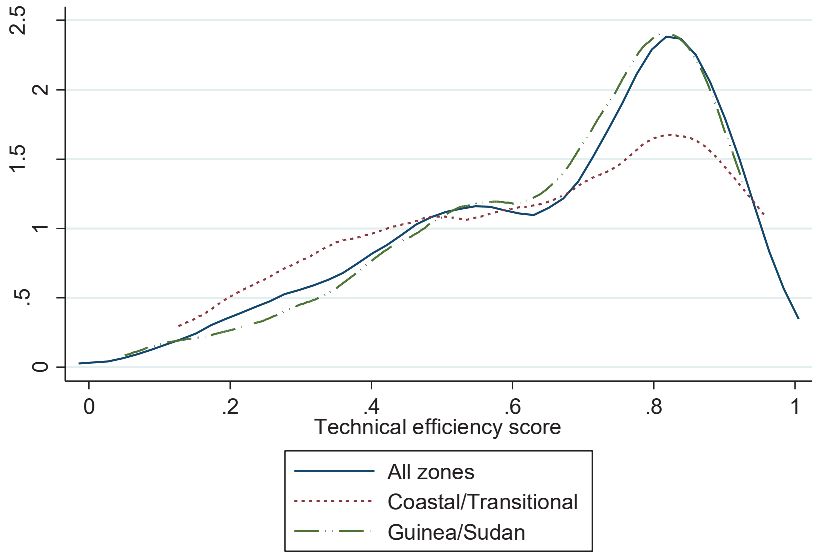

Fig 5.1. Distribution of technical efficiency scores by agro-ecological zones

Table 5.6 shows results of the joint maximum likelihood estimation of the stochastic production frontier and the determinants of inefficiency for all zones (column 1), Coastal/Transitional zone (column 2) and the Guinea/Sudan zone (column 3). The estimation of the Guinea/Sudan frontier model with herdsmen remuneration did not converge, so we removed it. The contract variables, cattle owner – kraal owner contract, and herdsmen remuneration were not significant for any of the zones. As argued in Section 5.3, we expected that for the cattle owner-kraal owner contract, a calves-sharing contract will increase inefficiency consistent with the so called Marshallian-inefficiency hypothesis (Laffont and Matoussi, 1995, Otsuka and Hayami, 1988, Sen, 2011). In Chapter 3, it was shown that the influence of owner-input-supply arrangements on veterinary care inputs was not different from that of calves-sharing contracts. It was also shown that veterinary care inputs influence long-term productivity. Number of calves, which is the dependent variable here, is influenced only in the long term. Thus, if contract type does not influence veterinary care inputs, which is long-term productivity-enhancing, then it is not likely to influence number of calves.

Contact with extension agents and age (a proxy for experience) did not significantly influence inefficiency, contrary to findings by Bravo-Ureta and Pinheiro (1993) that these variables do improve technical efficiency. However, increases in livestock density in the Guinea/Sudan savannah, measured as the number of cattle per squared kilometre, were correlated with increases in inefficiency. Also, increases in wet-season rainfall are associated with decreases in inefficiency in the Guinea/Sudan savannah. As indicated earlier, rainfall is associated with herbage availability, which improves cow nutrition and performance. Besides, this region has a longer dry season than wet season, hence good rains in the wet season could prepare animals for the harsher dry season.

Although the pooled frontier is not our major focus for the interpretation of results, there is an interesting result regarding the relationship between education level and inefficiency: the education of the kraal owner is positively correlated with inefficiency, significant at the 5 percent level. However, there is no significant correlation between education and inefficiency for the separate zones. This could be explained by the decrease in sample size for the separate zones. This leads to a reduction in the power of the test and makes it difficult to pick up the response, if it is present.

The positive correlation of education with inefficiency in the pooled sample is counter intuitive and contrary to findings from other studies such as (Bravo-Ureta and Pinheiro, 1993, Kumbhakar et al., 1991). One way to interpret this positive relationship between kraal owner's education and inefficiency is as follows. An increase in education tends to lead to more outside employment options, which exist especially in urban areas. Combining formal employment and cattle rearing would then result in higher supervision and monitoring cost for the kraal owner, since he cannot always stay close to the kraal. This probably decreases supervision and monitoring of his herdsmen and cattle, causing the noted inefficiency. The results of the joint estimation of the stochastic frontier and determinants of inefficiency with rainfall in the production function was again similar to the specification with rainfall in the inefficiency model (Appendix 5.3)

Table 5.6. Maximum likelihood estimates of a stochastic production frontier for extensive cattle production in Ghana assuming exponential distribution of u

	Pooled frontier	Separate frontiers	
	(1) All zones	(2) Coastal/Transitional	(3) Guinea/Sudan
Dependent variable is number of calves			
Number of cows	0.868*** (0.031)	0.831*** (0.047)	0.806*** (0.048)
Veterinary care	0.028 (0.052)	-0.103 (0.074)	0.115 (0.077)
Number of herdsmen	-0.028 (0.048)	0.095 (0.086)	-0.079 (0.064)
Constant	0.069 (0.093)	0.321** (0.127)	0.179 (0.145)
$In\sigma_v^2$			
_Constant	-2.930*** (0.326)	-4.602*** (0.783)	-2.321*** (0.360)
Inefficiency effects			
Herdsmen's remuneration in the form of heifer	0.123 (0.601)	0.024 (0.591)	
Calves-sharing contract	-0.067 (0.350)	-0.392 (0.608)	0.191 (0.486)
Contact with extension agents	-0.326 (0.441)	0.393 (0.703)	-0.314 (0.597)
Kraal owner experience	-0.003 (0.010)	-0.000 (0.014)	-0.012 (0.016)
Kraal owner education	0.060** (0.031)	0.034 (0.039)	0.057 (0.051)
Livestock density	-0.039 (0.033)	-0.053 (0.052)	0.154** (0.079)
Wet-season rainfall amount	-1.381 (1.119)	-1.828 (1.506)	-29.242** (14.836)
Dry-season rainfall amount	-0.628 (0.382)		
_Constant	11.232 (8.743)	11.112 (10.907)	197.022* (100.566)
N	251	100	157
Log likelihood	-156.258	-51.098	-103.940

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

5.6 Conclusion

We estimate technical efficiency in extensive cattle production in Ghana and analyse sources of technical efficiency. We use stochastic frontier analysis to estimate technical efficiency and analyse the sources of efficiency. For the Coastal/Transitional zone and the Guinea/Sudan zone, we estimate a mean technical efficiency scores of 0.64 and 0.67 respectively. The score for all zones was 0.66. These average efficiency levels and their wide spread we find in them suggest that there is still much room for efficiency improvements in cattle production.

In the Guinea/Sudan zone, we show that the cattle production function exhibits constant returns to scale but not in the Coastal/Transistional zone. This rules out possible improvement in productivity via changes in the scale of production, and thus reinforces the need for improvements in efficiency and technology in the Guinea/Sudan zone.

In both the separate and pooled zones, the effects of contract types and work experience on efficiency are insignificant. The insignificance of some of the variables in the model could be attributed to lack of variation in them. The data on some of the variables had only a few observations, as these were regional data. However, in the Guinea/Sudan, we find that livestock density and wet-season rainfall amounts were significantly correlated with inefficiency, but this was not so in the Coastal/Transistional. Also, an unexpected positive effect of kraal owner's education on inefficiency, found in the results of the pooled data estimation, could be interpreted to mean that, as an increase in education probably leads to more outside options, more education goes with less time for cattle management and so increase in inefficiency.

Our finding that contract types do not significantly influence number of calves suggests that contracts do not matter for performance in calving among kraals. Investing in good health of cows through the use veterinary care makes economic sense even if one receives only a fraction of the calves. Also, by keeping cows healthy, the calving interval is likely to be shortened so that the cattle owner can receive his share of calves sooner than if cows were left in poor health. Thus, the incentives of the kraal owner and cattle owner are well aligned, and we do not find Marshallian inefficiency to play a key role.

We view this study as contributing to knowledge regarding technical efficiency of extensive livestock production in Tropical Africa, and as a first evaluation of efficiency of livestock production in Ghana. We suggest that future research might consider investing in the collection of panel data from farmers to capture changes in key variables over time and within individuals to help isolate the determinants of inefficiency better. The possibility of using remote sensing techniques to estimate herbage yield could also provide more disaggregate data for most part of the country and therefore improve the availability and quality of this data. As indicated earlier, the availability of numerous outside options for the more educated kraal owner takes him further away from rural areas where cattle are reared, probably increasing inefficiencies on the farm. Thus, governments could consider improving infrastructure and social amenities in rural areas so that more educated kraal owners can be motivated to remain in the rural areas where they can combine cattle rearing.

Appendix 5.1

Appendix 5.1
Maximum likelihood estimates of a stochastic production frontier for extensive cattle production in Ghana controlling for heteroscedasticity due to cattle herd size and assuming exponential distribution of u

	Pooled frontier	Separate frontiers	
	(1)	(2)	(3)
	sfa_pooled2hetero	sfa_ct2hetero	sfa_gs2hetero
Dependent variable is number of calves			
lncow_02	0.879***	0.866***	0.888***
	(0.034)	(0.049)	(0.037)
Veterinary care	0.012	-0.089	0.075
	(0.047)	(0.077)	(0.064)
Number of herdsmen	-0.024	0.041	-0.040
	(0.045)	(0.087)	(0.061)
_cons	0.099	0.215*	0.062
	(0.093)	(0.127)	(0.121)
$In\sigma_v^2$			
kherdsize1	0.001	-0.006	0.001
	(0.005)	(0.007)	(0.005)
_cons	-3.282***	-3.989***	-3.036***
	(0.383)	(0.766)	(0.516)
$In\sigma_u^2$			
_cons	-1.403***	-1.380***	-1.366***
	(0.198)	(0.247)	(0.247)
N	265	103	162
Log likelihood	-167.502	-50.843	-110.139

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

Appendix 5.3
Maximum likelihood estimates of a stochastic production frontier for extensive cattle production with rainfall in production function

	Pooled frontier	Separate frontiers	
	(1) All zones	(2) Coastal/Transitional	(3) Guinea/Sudan
Dependent variable is Number of calves			
Number of cows	0.883***	0.873***	0.806***
	(0.027)	(0.037)	(0.051)
Veterinary care	0.025	-0.083	0.113
	(0.050)	(0.057)	(0.070)
Number of herdsmen	-0.029	0.038	-0.030
	(0.045)	(0.066)	(0.062)
Wet season rainfall Amount	0.097	2.498	1.447
	(0.123)	(1.880)	(0.984)
Dry season rainfall Amount	-0.007	-9.150	0.281**
	(0.032)	(7.286)	(0.126)
Constant	-0.550	30.245	-10.678
	(0.891)	(24.622)	(6.929)
$In\sigma_v^2$			
Constant	-3.264***	-5.472***	-2.827***
	(0.324)	(1.299)	(0.345)
$In\sigma_u^2$			
Constant	-1.356***	-1.174***	-1.518***
	(0.187)	(0.245)	(0.266)
N	274	107	167
Ll	-175.597	-55.107	-110.181

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

Appendix 5.3

Summary statistics of technical efficiency scores

Agro-ecological zone	Observations	Mean	Std. Dev.	Min	Max
All	274	0.66	0.22	0.05	0.94
Coastal/Transitional	107	0.63	0.24	0.14	0.97
Guinea/Sudan	167	0.68	0.20	0.06	0.93

Appendix 5.4.

Maximum likelihood estimates of a stochastic production frontier for extensive cattle production in Ghana with rainfall in production frontier and assuming exponential distribution of μ

	Pooled frontier	Separate frontiers	
	(1) All zones	(2) Coastal/Transitional	(3) Guinea/Sudan
Dependent variable is number of calves			
Number of cows	0.865***	0.841***	0.733***
	(0.031)	(0.045)	(0.054)
Veterinary care	0.025	-0.089	0.124
	(0.054)	(0.067)	(0.076)
Number of herdsmen	-0.021	0.094	-0.031
	(0.049)	(0.078)	(0.064)
Wet season rainfall Amount	0.036	2.128	1.722
	(0.152)	(1.937)	(1.117)
Dry season rainfall Amount	0.025	-7.902	0.463***
	(0.041)	(7.543)	(0.141)
Constant	-0.266	26.416	-13.038*
	(1.105)	(25.571)	(7.810)
$In\sigma_v^2$			
Constant	-2.959***	-4.924***	-2.716***
	(0.323)	(0.965)	(0.360)
Inefficiency effects			
Herdsmen's remuneration in the form of heifer	-0.067	0.107	
	(0.457)	(0.577)	
Calves-sharing Contract	0.092	-0.175	0.198
	(0.329)	(0.562)	(0.409)
Contact with extension Agents	-0.192	0.546	-0.399
	(0.423)	(0.671)	(0.558)
Kraal owner Experience	-0.002	0.001	-0.010
	(0.010)	(0.014)	(0.013)
Kraal owner Education	0.047*	0.032	0.046
	(0.028)	(0.039)	(0.046)
Livestock density	0.003	-0.012	-0.017
	(0.020)	(0.042)	(0.033)
Constant	-1.503*	-1.838*	-0.624
	(0.837)	(1.058)	(1.276)
N	251	100	157
Ll	-157.766	-50.955	-102.112

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

CHAPTER 6

General discussion and conclusion

6.1 Introduction

Demand for animal products as food is expected to increase in developing countries because of increasing population and urbanization (Delgado, 1999). One option for meeting these future increases in demand for animal products as food is to improve productivity in the production of poultry and livestock. Cattle has great potential for meeting increases in the demand for meat and milk. In Ghana, cattle contributes the largest proportion of economic value generated by households raising livestock (GSS, 2014). Yet, cattle production in the country, which is extensive and agro-pastoral, can be constrained by several factors including contractual arrangements between parties involved in the production process. In this thesis, we set out to ascertain the nature of contracts in cattle production in Ghana, explain their existence, and analyse the effects of contract type on input use and efficiency. Using mostly primary data and econometric methods, we examined a number of questions, raised in Chapter 1, in Chapters 2 to 5. In this chapter, brief answers to the questions are presented. The findings are then discussed and put in a broader context. Next, a discussion of the limitations of the study and recommendations for policy and future research are presented.

6.2 Brief answers to research questions

A first step towards answering questions posed in this thesis is to identify types of contracts that exist in cattle production in Ghana. Hence the question was asked: What is the nature of contracts in cattle production in Ghana, and what explains the existence of these contracts? We used survey data collected from cattle owners, kraal owners, and herdsmen for the characterisation of contract types. This characterisation is based on the duties a party to a contract has towards another party to the contract, and the remuneration the former receives for performing his duties. Chapter 2 presented the characterisation of contracts and explanations for their occurrence. Two main categories of contracts, the kraal owner-herdsman (KH) contract and the cattle owner-kraal owner (CK) contract, were found. The kraal owner-herdsman contracts were further divided into milk payment contracts and contracts with non-milk fixed payment in kind or cash. The cattle owner-kraal owner contracts were either explicit contracts, with the remuneration received by the kraal owner specified, or implicit contracts with the rewards received by the kraal owner not specified. The specified contracts were fixed-payment contracts (with or without subsidies), share contracts (with or without subsidies), and subsidy-only contracts. Subsidies comprise contributions made to the kraal owner to cover part of the expenses he makes on the animals of cattle owners. These expenses include payment of herdsmen, and veterinary care and drug cost. Contract types were significantly associated with agro-ecological zones. In particular, implicit contracts were widespread and yet concentrated in particular regions, especially the Guinea and Sudan Savanah.

We learned that transaction costs explain the existence of several of the cattle owner-kraal owner contract types, including the subsidy-only, unspecified, and fixed-wage contracts. The dimensions of transaction cost that were relevant in explaining contract type included asset specificity of production assets, environmental uncertainty, opportunism, and monitoring cost. Nonetheless, moral hazard and risk aversion also played a role in explaining calves-sharing contracts. The nature of KH contracts, both milk payment and non-milk fixed-payment contracts, was explained using transaction cost and agency theory, but specifically in terms of the difficulty of measuring performance and the monitoring cost associated with reducing opportunism among herdsmen, and the presence of hidden information regarding the skills of herdsmen.

Having found that implicit CK contracts are widespread, but associated with specific regions with varying levels of production risk or environmental uncertainty, we became interested in verifying this possible association with environmental uncertainty using more robust empirical methods. Hence, we asked the question: What is the role of potential production loss, trust, and risk aversion in the choice of implicit contracts over explicit contracts? In Chapter 3, we analysed the influence of these factors on the choice of contract type. We formulated a model which provided hypotheses concerning the influence of the factors on contract type. Using data from surveys, experiments, and secondary sources, we estimated a series of equations to establish support for the hypotheses. Potential production loss and trust were shown to be positively correlated with the occurrence of implicit contracts. Also, the correlation between the choice of implicit contracts and education, which was our proxy for risk aversion, was negative. This means that risk aversion is positively correlated with the choice of implicit contracts.

A key mechanism through which contract type can impact productivity is its influence on input use. Thus, in Chapter 4 we addressed the question: What is the influence of contract type on input use? We modelled cattle production as a dynamic process to show that inputs can be classified as either short-term or long-term productivity-enhancing and derived hypotheses regarding the influence of contract type on the two kinds of input use. Using survey data, input use was regressed on contract type with agro-ecological zone fixed effects and controls for farm and farmer characteristics in one specification and without these controls in another. It was shown that the correlation between short-term productivity-enhancing input use, such as providing feed supplements for young bulls, was higher under fixed-wage contracts than under calves-sharing contracts. However, the influence of contract type on long-term productivity-enhancing input use including provision of veterinary care, which reduces mortality and therefore positively influences cattle stock was generally insignificant. We also showed that omitted variable bias did not drive the results, in most cases.

The use of external inputs or new technology is not sufficient to achieve desired levels of productivity. It is important that, whatever the inputs that are applied, they are used efficiently so as to attain the maximum output possible. It is also important to know factors that influence efficiency, so that steps can be taken to address any gaps in production efficiency. Consequently, in Chapter 5 we addressed the question: What are the levels and sources of efficiency in extensive cattle production systems? We used survey data and the Stochastic Frontier Model to estimate technical efficiency and analyse factors that influence it. It was found that the mean technical-efficiency score is relatively low across agro-ecological zones and has a wide spread among farms within these zones. While increases in livestock density and decreases in wet-season rainfall were associated with increases in inefficiency in the Guinea/Sudan zone, these variables were not associated with inefficiency in the Coastal/Transitional zone. Also, to some surprise, a positive relationship was found between education and inefficiency when all zones were put together. Furthermore, we learned that extensive cattle production exhibited constant returns to scale in the Guinea/Sudan zone, but not in the Coastal/Transitional zone. However, our data could not show that contract type influences technical efficiency.

Putting all the chapters together, this thesis looked at the spectrum of issues related to contracts, their nature and drivers, and the influence of contract type on input use and efficiency. Chapters 2 and 3 show that the environmental uncertainty inherent in agro-ecological zones and manifested in production risk plays a key role in shaping contracts, especially CK contracts. The results about the impact of contract type established in Chapters 4 and 5 support each other. For instance, in Chapter 4, it was found that whereas contract type influenced short-term productivity-enhancing input use, no significant relationship was found between contract type and long-term productivity-enhancing input use. The latter appears to account for the insignificant relationship we found between contract type and technical efficiency in Chapter 5, because the performance indicator used there for assessing technical efficiency was the number of calves delivered in a kraal in a specific year. This performance indicator is indeed largely influenced in the long term.

6.3 Reflections and discussions

The issues addressed in this thesis relate to scientific debates in several areas, including explanation of agrarian contracts and their incentive effects (Braverman and Stiglitz, 1986, Ghebru and Holden, 2015, Hallagan, 1978, Pender and Fafchamps, 2006, Sen, 2011, Sengupta, 1997, Stiglitz, 1974, Tadesse et al., 2016), implicit contracts and uncertainty (Azariadis, 1975, Baily, 1974, Fafchamps, 2011, Fafchamps and Lund, 2003, Kátay, 2016, Murgai et al., 2002), efficiency of agricultural production (Ahmed et al., 2002, Bravo-Ureta and Pinheiro, 1993, Hadley, 2006, Helfand and Levine, 2004, Huang et al., 2016, Moreira and Bravo-Ureta, 2010, Samarajeewa et al., 2012, Temoso et al., 2015), and institutions (formal and informal) and development (Acemoglu et al., 2000, Beekman and Bulte, 2012, Brunnschweiler and Bulte, 2008, Guiso et al., 2004, Guiso et al., 2008, North, 1991, Tu and Bulte, 2010, Williamson, 2000).

Explanations of agrarian contracts have been provided using largely theoretical analyses (Allen, 1985, Eswaran and Kotwal, 1985, Hallagan, 1978, Muthoo, 1998, Newbery, 1977, Sen, 2011, Stiglitz, 1974). However, a few empirical studies have sought to verify these theoretical predictions. For instance, Allen and Lueck (1993) explain the existence of cost sharing in share cropping in terms of difficulty and cost of measuring and dividing ownership of inputs, while Ackerberg and Botticini (2002) explain the existence of share cropping in terms of both risk aversion and multitasking issues. Chapters 2 and 3 are related to this strand of the literature. While Chapter 2 seeks to explain the observed contract types in terms of transaction cost and agency theory, Chapter 3 goes further to empirically verify the relationship between environmental uncertainty, trust and risk aversion on the one hand and the choice of implicit over explicit contracts on the other. Environmental uncertainty also creates the need for insurance mechanisms to be put in place, so we addressed the relationship between implicit contracts and insurance subsequently. In Chapter 2, we learned that low productive asset specificity allows the aggregation of input demand across cattle owners, thus yielding economies of scale when the kraal owner receives contributions from cattle owners who keep cattle with him and purchases inputs on their behalf, or when he hires a herdsman to take care of their collective herds. This explains the finding of subsidy-only contracts, in which the cattle owner makes only cash or kind contributions to the kraal owner. Also, we learned that environmental uncertainties account for the reason why the kraal owners' remuneration is not specified explicitly in some observed contracts, which we called implicit contracts. The ultimate remuneration depends on production outcomes over several periods. This makes the remuneration that the kraal owner finally obtains compensate for income that he could have lost had he been paid per period. Likewise, virtual absence of fixed-wage contracts in the Coastal savannah could be linked to higher monitoring costs resulting from more outside options for cattle owners. Hence, calves-sharing contracts, which have built-in incentives to reduce moral hazard, were the contract type of choice in the Coastal savannah. In the case of calves-sharing contracts, agency cost theory offers a plausible explanation for their existence.

For the kraal owner–herdsman contract both transaction cost and agency theory provide plausible explanations. Regarding transaction cost, there is difficulty in measuring the performance of herdsmen.

Also, herdsmen can be opportunistic, requiring that they are monitored. A herdsman enables cattle to obtain adequate nutrition through grazing, which boosts reproductive performance and milk output, but his milking activities can lead to over-milking, which is detrimental to calf-survival and future production. When family labour is employed, the kraal owner can use low-incentive, fixed-payment contracts, since moral hazard and therefore monitoring cost is lower. When labour is hired, the kraal owner uses a high-incentive contract by offering the entire milk or a high proportion of the milk harvested to the herdsman, so that he ensures that the cattle are adequately grazed, and the milk produced can be enough for both the herdsman and the calves. The explanation in terms of measurement difficulty is in line with Barzel (1982) and Holmstrom and Milgrom (1991), who show that measurement cost or difficulty can shape the design of contracts. Among herdsmen, some received milk payments while others received non-milk fixed payment. This is explained by the presence of hidden information regarding the herdsman's skills, and the resolution of the problem by the kraal owner's design of a menu of contracts tailored at the herdsman's skill type. A high-skill herdsman chooses a milk payment contract, since he has the ability to take good care of the cattle to produce adequate milk sufficient for his food and income needs and feed for the calves. A low-skill herdsman chooses non-milk payment contracts, because he cannot take good enough care of cattle to produce milk which will be sufficient for his food and income and still leave enough to feed the calves. This thesis has provided further insights into the drivers of cattle production contracts. As far as we are aware, only few studies (Binswanger and McIntire, 1987, Ensminger, 2001, Tadesse et al., 2016) have sought to explain relations in cattle production using contract theory.

Regarding the incentive effects of agrarian contracts, the debate has often centred around the inefficiency of share contracts compared with fixed-rent contracts and owner-cultivation (Jacoby and Mansuri, 2009, Laffont and Matoussi, 1995, Shaban, 1987). Sometimes the property right implications of these contracts have been studied in relation to their effects on investment (Abdulai et al., 2011, Beekman and Bulte, 2012, Deininger and Jin, 2006, Goldstein and Udry, 2008). Chapter 4, which relates to agrarian contracts and their incentive effects, supports the view that contract types have different effects on short-term and long-term productivity-enhancing input use or investments. The different effects on investment can also be attributed to the property rights implications of the contracts. The output of short-term productivity-enhancing investment, fattened bulls or meat, was appropriated entirely by cattle owners. Hence, fixed-wage contracts had greater influence on the use of inputs for growth and fattening bulls than share contracts did. On the other hand, both cattle owners and kraal owners often share calves delivered. Thus, fixed-wage and share contracts do not have significantly different influence in the use of input that influences calf delivery and survivability. Whereas most of the studies relate to property rights and investment with crop production (Abdulai et al., 2011, Beekman and Bulte, 2012), this thesis has used data from cattle production to study the same phenomenon and come to similar conclusion that contract types or the rights of ownership and use that contracts confer on their holders have different effects on short-term and long-term productivity-enhancing expenditure.

The existence of implicit contracts has been explained in terms of the need to insure parties against uncertain production outcomes or income. In a principal agent relationship where the principal is risk neutral and the agent risk averse, the former may insure the latter against income risks (Azariadis, 1975, Baily, 1974, Kátay, 2016). In situations where both parties are risk averse, risk is often pooled, leading to mutual insurance (Fafchamps, 2011, Fafchamps and Lund, 2003, Murgai et al., 2002). Chapter 3 is about implicit contracts and uncertainty. Implicit contracts were found to be associated with increasing potential production loss, suggesting the need for insurance for the parties. Parties to the contracts insure each other leading to a kind of mutual insurance since parties are risk averse. Also, we found that higher levels of trust make the adoption of implicit contracts easier. These findings support the notion that implicit contracts arise in response to uncertainty about some future outcomes (Baily, 1974, Fafchamps, 2011, Fafchamps and Lund, 2003, Kátay, 2016, Murgai et al., 2002).

Production efficiency implies the avoidance of waste in the production process. The quest to keep improving production efficiency has led to numerous studies that have estimated efficiency scores in production systems and determined the sources of efficiency. In developing countries, the focus has often been on efficiency in agricultural production (Ahmed et al., 2002, Bravo-Ureta and Pinheiro, 1993, Helfand and Levine, 2004, Huang et al., 2016, Moreira and Bravo-Ureta, 2010, Otieno et al., 2014, Sadoulet et al., 1994). Chapter 5 relates to efficiency of developing-country agriculture. Our findings support previous findings that obtained relatively low efficiency scores and a wide spread in the scores for extensive livestock production (Huang et al., 2016, Otieno et al., 2014, Temoso et al., 2015). We learn that contract type does not influence inefficiency. This suggests that the incentives of kraal owner and cattle owners are aligned, and Marshallian inefficiency does not come into play. The negative effect of education on efficiency we observed contradicts that of previous findings. The explanation we forwarded was that the higher the education levels of kraal owners, the more their outside options and so the opportunity cost of time and effort for supervision and monitoring their cattle and herdsmen. This decreased ability to monitor and supervise herdsmen and cattle leads to decreased efficiency in their kraals.

In Chapter 3 we relate education to risk aversion, whereas in Chapter 5 we look at education in terms of outside options. On the surface, the two views of education may look different. Yet, they are related. In the first instance, education is linked to risk aversion through its association with potential earnings and therefore wealth. In the second instance, outside options for employment are also associated with earnings and wealth, and the quest for this wealth influences monitoring ability. The common denominator in both discussions of education is wealth, making our view of education in both cases quite similar.

The study of contracts and their implications for production can also be viewed through the lens of institutions. In this regard, property rights conferred on parties by the contracts they engage in relate to the rules of the game, while the governance issues such as monitoring of parties that arise from incompleteness of contracts and the attempt by principals to design contracts that encourage optimal resource allocation relate to the second, third and fourth levels of institutions as defined by (Williamson, 2000). Agrarian contracts, especially in developing countries, can be seen as informal institutions. Helmke and Levitsky (2004) define informal institutions as socially shared rules, usually unwritten, that are created, communicated, and enforced outside of official sanctioning channels. Thus, we view both the implicit and explicit contracts that we study as informal contracts. The influence of institutions, both formal and informal, on economic outcomes is not in doubt. This is because institutions determine transaction and production cost and therefore the profitability of carrying out economic activities (North, 1991). Acemoglu et al. (2000) also showed that in countries where Europeans faced low mortalities, they settled and set up less extractive institutions. These institutions have persisted and promoted higher economic performance. Furthermore, the quality of institutions is also considered important. For instance, Brunnschweiler and Bulte (2008) show that whereas resource abundance influences the quality of institutions (formal), poor institutions are linked with resource dependence, meaning that countries with poor institutions are not likely to develop non-primary production sector that could promote higher growth. The importance of informal institutions is shown in the work of (Beekman and Bulte, 2012), who show that local institutions (tenure security, and social norms) influence soil conservation decisions, and that of Abdulai et al. (2011), who also demonstrate the effect of land tenure systems on land improving measures. To the extent that these informal institutions, cattle production contracts, shape production and investment activities in the cattle sub-sector, they constrain or facilitate growth in agricultural output and economic development. This further illustrates the importance of institutions for development.

A common thread that runs through the thesis is contracts in cattle production. As suggested earlier, these contracts are largely informal. By studying them and their influence on input use and efficiency we have contributed to knowledge on the link between institutions and their influence on development especially of developing countries such as Ghana and other Sub-Saharan African countries.

6.4 Policy recommendations

A few policy recommendations can be made from the findings of this thesis. First, the occurrence of implicit contracts between cattle owner and kraal owner - contracts in which the cattle owner does not specify the kraal owner's remuneration in advance but rewards him based on the production outcome over several periods - was high in some regions including the Guinea and Sudan savannah, where the number of rainy months are fewer than in other zones. Thus, implicit contracts provide insurance to overcome some inherent risk in the production environment. Consequently, there is the need to find out if there are alternative and more effective ways to provide such insurance. The implementation of such insurance schemes could create better incentives for kraal owners and cattle owners to engage in cattle production.

Second, contracts in which the cattle owner supplies the inputs were found to have higher correlation with the use of external inputs than other contract types. The external inputs such as veterinary drugs, vaccines, and feed supplements are inputs purchased on a market and not freely available like naturally growing pasture. Yet, the use of external inputs greatly enhances cattle growth and productivity. Hence, in order to increase beef production for instance, incentives could be created to attract cattle owners who are more likely to provide external inputs and thereby improve productivity. The government could take steps to make land acquisition for cattle production easy, and promote individual or communal pasture cultivation, make it easy for farmers to access loanable funds, and could protect and improve existing natural pastures. Such an enabling environment for investment in cattle production is likely to attract more people to invest in market oriented cattle production in which greater use is made of external inputs or new technology.

Third, having found that a large proportion of kraals have low technical efficiency, steps could be taken to improve this. We found that a kraal owner's education is negatively correlated with technical efficiency. The explanation for this negative relationship seems to be that the more numerous outside options of more educated kraal owners, and the high monitoring and supervision cost they might incur by not staying very close to their kraals, leads them to pay insufficient attention to cattle production. In Ghana, a lot of educated people like to invest in cattle production to supplement their incomes or to secure their pensions during retirement. Yet, most of them prefer to stay and work in urban areas even if similar employment avenues exist in the rural areas. This mainly is because of the lack of basic infrastructure and amenities in most rural areas, such as schools for children, health care facilities, and electricity. If a kraal owner is working in a rural area, the opportunity cost for devoting time and effort to monitoring their herdsmen and investments is likely to be lower. Consequently, the government could create basic infrastructure such as roads, electricity and other amenities in rural areas to attract young and educated people to stay in the rural areas so that they can be closer to their cattle and better monitor their employees and investment. Currently, the sitting government is encouraging bureaucrats including politicians, members of parliament, civil and public servants to venture into agriculture alongside their formal employment. The provision of basic infrastructure and amenities in rural areas could motivate people to invest more in agriculture including cattle production.

6.5 Limitations of the study and recommendations for future research

This study has a few limitations which we discuss below; we then make suggestions for future search.

It was not possible to attribute causality in many of the relationships we estimated, partly because we had access to only cross-sectional data. Additionally, we could not find suitable instruments for contract type to deal with the possible endogeneity of the contract variable, which led us to interpret the relationship between contract type and input use as correlational. Another issue that was dealt with was the lack of quantitative measures for some variables, making one rely more on qualitative changes in variables. The limited variation in some of these qualitative variables could have contributed to the statistical insignificance of some explanatory factors. Nevertheless, care has been taken to ensure that the findings of this thesis are reliable.

Another limitation of this thesis is that we have considered cattle owner and kraal owner contracts separately in the analyses. Typically, three players, a kraal owner, a cattle owner, and a herdsman are involved in the operation and management of a kraal. Thus, it is possible that the cattle owner - kraal owner contract pertaining in one kraal influences the kraal owner-herdsman contract in the same kraal, such that they could be considered together as a system. For instance, though we hardly find any cattle owner receiving milk and not giving milk entitlements to the kraal owner, it is conceivable that if the cattle owner keeps the entitlement to milk to himself, then the kraal owner is not able to give milking rights to the herdsman. In order to make our theory and analyses simple and tractable, we ignored any interaction between the cattle owner and kraal owner contracts.

In order to be conclusive on the causal nature of the relationship between contract type and input use in cattle production, we suggest that steps be taken to collect panel data for the extension of the analyses in this thesis. Panel data will provide information on variations in the dependent variables within subjects and thereby allow a more robust attribution of the effect of explanatory variables on dependent variables. Though we did not find significant correlation between contract type and cattle owner's distance from his home to the kraal in our data set, and hence could not use the cattle owner's distance as an instrument for contract type, this can still be investigated using other data sets. Additionally, the study can be extended to other livestock commodities that could play significant role in meeting the increasing demand for animal products, and how contract types could influence the production of these commodities. We have suggested that conditions in rural areas be made attractive to ensure that educated persons take up employment appointments in rural areas, so that they can be closer to investments they may wish to make in cattle production. Studies could be carried out to investigate factors that might create the necessary enabling environment for potential investors who wish to go into cattle production.

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SUMMARY

Contracts provide incentives for the supply of inputs under various contractual arrangements. Contracts in cattle production are therefore important for the supply of inputs in the production process. Yet, not much is known about the nature and drivers of these contracts. Nor do we know the effects of contracts on input use and efficiency in cattle production. This thesis investigates the nature and drivers of contracts and their influence on input use and efficiency. We use mainly empirical approaches to address the issues raised. In Chapter 1, we outline the specific questions the thesis seeks to answer and provide an overview of the respective methodologies we employ in answering the questions.

Chapter 2 investigates the nature and drivers of contracts in cattle production in Ghana. We conduct a survey to generate data for characterising the contracts based on remunerations that agents receive. We found two main contracts: cattle owner-kraal owner contracts and kraal owner-herdsman contracts. The cattle owner-kraal owner contracts comprise calves-sharing contracts, fixed-wage contracts, subsidy-only contracts, and unspecified contracts. The kraal owner-herdsman contracts comprise broadly milk payment contracts, and fixed payment in kind or cash contracts. We view unspecified contracts as implicit contracts with remuneration not specified beforehand but dependent on future production outcomes, while the other contracts are explicit with remuneration explicitly specified. We learn that variations in both contracts can be explained using the transaction cost and principal agent theories.

We view implicit contracts as serving the purpose of mutual insurance. Thus, in Chapter 3, we investigate factors that influence the choice of implicit versus explicit contracts. To do this, we formulate a model that generates hypotheses regarding the influence of trust, production loss, and risk aversion on implicit-contract choice. We use a combination of experimental and survey data to test the hypotheses. We find support for our theoretical predictions that trust, production loss, and risk aversion are positively correlated with a preference for implicit contracts.

In Chapter 4, we study the influence of contracts on input use. We develop a model which shows that supplementary feed is short-term productivity-enhancing, while veterinary care inputs are long-term productivity-enhancing. We model the cattle owner and kraal owner decisions to use inputs under various contract types as a Stackelberg game. We test the resulting hypotheses that supplementary feed occurs only under fixed-wage contracts and that the use of veterinary care inputs is the same under fixed-wage contracts and calves-sharing contracts. Employing primary data, we show that the hypotheses are generally supported by the data.

In Chapter 5, we investigate the efficiency in extensive cattle production, focusing on the influence of cattle production contracts on efficiency. We use the stochastic frontier analysis and find that on average efficiency scores are low, but have a wide spread. Nevertheless, we learn that contract type does not matter for inefficiency. On the other hand, the kraal owner’s education is positively correlated with inefficiency. We interpret this to mean that, since higher educated kraal owners have more outside options, they are likely to devote less time to monitoring activities in the kraal, thus leading to low efficiency.

Chapter 6 provides brief answers to the research questions. Then the findings are put into broader perspective in terms of current scientific debates. In this regard, the thesis contributes to various strands of the literature. These include the nature of contracts and explanations for them, implicit contracts and uncertainty, incentive effects of contracts, and contracts and inefficiency. Also, the thesis contributes to the literature on institutions and development. We view cattle production contracts as informal institutions which impact productivity in the livestock sub-sector, and therefore the agricultural sector and economy

at large. The policy implications are also discussed. The limitations of the study are identified, and suggestions for future research made.

SAMENVATTING (SUMMARY IN DUTCH)

Contracten bieden prikkels voor de levering van inputs onder uiteenlopende contractuele regelingen. Contracten bij de rundveehouderij zijn daarom belangrijk voor de toevoer van inputs in het productieproces. Toch is er niet veel bekend over de aard en de drijfveren van deze contracten. Evenmin kennen we de effecten van contracten op inputgebruik en efficiëntie bij de rundveehouderij. Dit proefschrift onderzoekt de aard en drijfveren van contracten en hun invloed op inputgebruik en efficiëntie. We gebruiken voornamelijk empirische benaderingen om de opgeworpen problemen aan te pakken. In hoofdstuk 1 schetsen we de specifieke vragen die het proefschrift tracht te beantwoorden en geven we een overzicht van de respectieve methodologieën die we gebruiken bij het beantwoorden van de vragen.

Hoofdstuk 2 onderzoekt de aard en drijfveren van contracten bij de rundveehouderij in Ghana. We voeren een enquête uit om gegevens te genereren voor het karakteriseren van de contracten op basis van de vergoedingen die betrokkenen ontvangen. We hebben twee hoofdcontracten gevonden: contracten tussen vee-eigenaren en kraal-eigenaren en contracten tussen kraal-eigenaren en herders. Eerstgenoemde contracten bestaan uit overeenkomsten voor het verdelen van kalveren, contracten voor een vast loon voor de kraal-eigenaar, contracten met alleen subsidie voor de kraal-eigenaar, en niet-gespecificeerde contracten. De contracten tussen kraal-eigenaar en herder omvatten in ruime mate contracten met betaling in melk en met vaste betalingen in natura of contant. We beschouwen niet-gespecificeerde contracten als impliciete contracten met een vergoeding die niet vooraf is gespecificeerd, maar afhankelijk is van toekomstige productie-uitkomsten, terwijl de andere contracten expliciet zijn met uitdrukkelijk gespecificeerde beloningen. We leren dat variaties in beide contract typen kunnen worden verklaard aan de hand van transactiekosten theorie en principaal-agent theorie.

Wij beschouwen impliciete contracten als contracten die wederzijdse verzekering als doel hebben. In hoofdstuk 3 onderzoeken we daarom factoren die de keuze van impliciete versus expliciete contracten beïnvloeden. Om dit te doen, formuleren we een model dat hypotheses genereert over de invloed van vertrouwen, mogelijk productieverlies en risicoaversie op de keuze voor een impliciet contract. We gebruiken een combinatie van experimentele en enquêtegegevens om de hypothesen te testen. We vinden steun voor onze theoretische voorspellingen dat vertrouwen, productieverlies en risicoaversie positief gecorreleerd zijn met een voorkeur voor impliciete contracten.

In hoofdstuk 4 bestuderen we de invloed van contracten op inputgebruik. We ontwikkelen een model dat laat zien dat aanvullend veevoer op de korte termijn productiviteitsverhogend werkt, terwijl de input van veterinaire zorg op de lange termijn productiviteitsverhogend werkt. We modelleren de beslissingen van de vee-eigenaar en kraal-eigenaar om inputs onder verschillende contracttypen te gebruiken als een Stackelberg-spel. We testen de resulterende hypothesen dat het bijvoeren alleen voorkomt bij vast-loon contracten en dat het gebruik van veterinaire zorg niet verschilt tussen vast-loon contracten en overeenkomsten voor het verdelen van kalveren. Aan de hand van primaire data laten we zien dat de hypothesen over het algemeen worden ondersteund.

In hoofdstuk 5 onderzoeken we de efficiëntie bij extensieve rundveehouderij, met de nadruk op de invloed van veeteeltcontracten op efficiëntie. Met behulp van stochastische grensanalyse vinden we dat de gemiddelde efficiëntie scores laag zijn, maar een grote spreiding hebben. Desondanks leren we dat het type contract niet van belang is voor de mate van inefficiëntie. Wel is de opleiding van de kraal-eigenaar positief gecorreleerd met inefficiëntie. We interpreteren dit als volgt: omdat hoger opgeleide kraal-eigenaren meer werk opties naast hun huidige baan hebben, zullen ze waarschijnlijk minder tijd aan monitoringactiviteiten in de kraal besteden, wat leidt tot een lager rendement.

Hoofdstuk 6 geeft korte antwoorden op de onderzoeksvragen. Vervolgens worden de bevindingen in een breder perspectief geplaatst door deze te relateren aan actuele wetenschappelijke discussies. In dit opzicht draagt het proefschrift bij aan verschillende thema's in de literatuur. Deze omvatten de aard van contracten en verklaringen hiervoor, impliciete contracten en onzekerheid, de effecten van de stimulansen die uitgaan van contracten, en contracten en inefficiëntie. Ook levert het proefschrift een bijdrage aan de literatuur over instituties en ontwikkeling. We beschouwen contracten in de rundveehouderij als informele instituties die van invloed zijn op de productiviteit in de veesector, en dus de landbouwsector en economie als geheel. De beleidsimplicaties worden ook besproken. De beperkingen van het onderzoek zijn geïdentificeerd en suggesties voor toekomstig onderzoek worden gedaan.

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COMPLETED TRAINING AND SUPERVISION PLAN (TSP)

Godwin Yao Ameleke
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Wageningen School of Social Sciences

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
PhD Research Proposal	WUR	2012	6.0
Advanced Econometrics, AEP 60306	WUR	2012	6.0
Theory and Practice of Efficiency and Productivity Analysis-Dynamic Efficiency	WASS	2012	1.5
Central Themes in Development Economics, DEC 30306	WUR	2012	6.0
Behavioural and Experimental Economics, ECH 50306	WUR	2012	6.0
B) General research related competences			
Introduction course	WASS	2012	1.0
From Topic to Thesis Proposal	WASS	2012	4.0
Information Literacy & Endnote	WGS	2012	0.6
C) Career related competences/personal development			
'Does trust correlate with kraal owner-other cattle owner contract types in cattle production in Ghana'	CSIR-Animal Research Institute Seminar Series, Accra, Ghana	2015	1.0
Total			**32.1**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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