Three Essays on Groundwater and Tenancy Contracts in Rural Economies

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vorgelegt von

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to my parents

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1 Introduction

From the viewpoint of development economics, missing or imperfect markets represent a crucial step in the understanding of the economic problems of developing countries. These missing or imperfect markets also lie at the heart of informal institutions, which are reactions to the market failures that arise because of legal, informational, or incentive constraints. These failures are often exacerbated by an unequal distribution of income or wealth. Another essential property of imperfect markets is that they are contagious: a market failure in some sector can lead to problems in other markets. For example, an incomplete credit market failing to provide each household facing a rewarding investment opportunity with a loan may lead to a failure in the market for whose infrastructure the investment was going to be made. One of these informal institutions designed to fill the loopholes in imperfect markets are share contracts. Instead of specifying a fixed payment, share contracts make the payment to a production factor dependent on the - mostly uncertain - outcome of the production process in which that production factor is involved. Share contracts in the agricultural sector of developing economies are best known for their use in combining the markets for land and for labour, but there is growing evidence that share contracts are also a common contractual form in the emerging informal markets for groundwater. The dissertation in hand deals with share contracts in both the market for land and the market for groundwater.

It is a daunting undertaking to conduct research in the realm of share contracts in agrarian economies given the fact that the inquiry into the merits and drawbacks of share tenancy contracts compared to fixed-rent leasehold tenancy started as early as in the eighteenth and nineteenth century with Adam Smith (1776) and John Stuart Mill (1848), followed by a steady growing literature investigating the efficiency implications of share contracts and the reasons for their existence. A large part of this literature is summarized in

Singh (1989), Otsuka et al. (1992), and Hayami and Otsuka (1993). But with that matters seem to have not been settled because since then a new strand of literature has emerged, offering new explanations for the choice of sharecropping tenancy contracts.[1] This literature, however, the recent one as well as the older one, considers only land-tenancy and labour-employment contracts which 'are alternative arrangements to combine the two primary factors of production in agrarian economies', as Hayami and Otsuka (1993) put it. This approach leaves out of consideration that there is a third 'primary' factor of production, namely water, which for a long time might have been not especially worth considering in the context of contract theory, since the inter and intra village allocation of this factor of production was governed by collective action rather than by contracts between private parties. But this has changed nowadays, since the use of groundwater for irrigation purposes is steadily replacing the use of surface water from the notoriously ill-maintained and therefore unreliable canal systems. Apart from the canal systems being in bad condition, the fact that more and more farmers are growing more water-intensive crops also leads to an increasing demand for groundwater, since the canal water supply does not meet this demand. The equipment needed to gain access to groundwater is available to farmers who have the necessary liquidity or access to credit. Since the access to groundwater makes those farmers partly independent of the canal system, they face a smaller incentive to engage in the collective maintenance of it. That in turn leads to a further decay of the surface irrigation system, making more farmers dependent on groundwater irrigation. On account of the fact that normally part of the households in a village cannot invest in the necessary equipment due to lack of liquidity and

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[1] To cite a few more recent references: Basu (1992), Sadoulet et. al. (1994), Sengupta (1997), Ray (1999), Ghatak and Pandey (2000), Ackerberg and Botticini (2001), Ray and Singh (2001), Dubois (2002).

credit-constrainedness, water has become a factor of production the access to which is no longer exclusively determined by rules set by the village collective. It is now rather a factor of production which is owned privately by some of the households and the allocation of which therefore requires contracting between private parties. Strictly speaking, there is now a mixed regime of access to water: For one part of their seasonal irrigation needs, farmers still rely on surface water, for the other part, they have to rely on their own wells or on other farmer's wells.

This is where the second and the third chapter of this dissertation set in: The contractual forms under which groundwater is traded between households turn out to be the same as those employed to allocate the two other 'primary' factors of production, land and labour. The two main contractual forms to combine groundwater with land and labour are that the farmer who needs additional irrigation pays the seller either a fixed rate per unit of water he receives or a prespecified share of his output on the field irrigated by the seller's well. The mainly observed contractual forms combining land and labour are, first, a fixed payment in cash or kind from the tenant to the landlord, second, a share of the output produced on the tenancy paid by the tenant to the landlord, or, third, a fixed wage rate paid by the landlord to the hired workers working on his fields. At this place, we will not go into the details under which circumstances what kind of contractual form is chosen in land and labour transactions, the interested reader is referred to the literature cited above. But there is one obvious difference between the principal-agent relationship in land-tenancy and labour-employment contracts and the principal-agent relationship in groundwater contracts. Agency theory[2], on which the treatment of land and labour contracts is based, considers the choice of an optimum contract between a principal (the owner of a resource) and an agent (the user of the resource)

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[2] See, for example, Arrow (1985), Hart and Holmstrom (1987), Levinthal (1988).

and it is assumed that 'an agency problem arises when the agent's action (e.g. work-effort) is not directly observable by the principal and the outcome is influenced not only by the agent's action but also by uncertain factors outside the agent's control' (Hayami and Otsuka, 1993, p. 3). Things are different for groundwater contracts. First, the owner of the resource, the wellowner, is under none of the contractual forms interested in monitoring the user's (the water buyer's) actions, since under a fixed rate contract his payment is in any case independent of the buyer's actions and in the case of a groundwater share contract, as matters stand, the contract is only negotiated when the buyer has already supplied all other inputs, so that the wellowner can observe the condition of the crop before entering the contract and personally applying his resource to the crop. Second, in the case of groundwater transactions it is the wellowner's (the resource owner's) actions which are observable for the buyer but which are not enforceable by the buyer. Thus, there is a reversal of roles between the resource owner and the resource user, the user of the resource having to provide incentives to the owner of the resource. The role of groundwater is therefore, with some reservations, probably best compared to the role of labour in tenancy contracts.

More detailed information on the pattern of contract choice in so-called informal groundwater markets is presented in chapter 2, which contains the results of a field study on groundwater transactions conducted by myself during January and February 2001 in Tamil Nadu, India. The main reason which led me to undertake the study was the perception that the existing empirical literature on informal groundwater transactions, which is cited in the first section of chapter 2, is mostly based on studies which are on a rather aggregated level and therefore fail to provide a satisfactory detailed depiction of the pattern of groundwater transactions and of the associated payment modes at the household level. But since these empirical details are vital for a theoretical investigation of the determinants of contract choice, information on such questions as the following was gathered in the study: At which point in time during the cultivation period the contractual form is chosen? Is there any connection between the remaining number of days in the cultivation season for which a farmer needs water and the contractual form chosen? Is it the wellowner who dictates the contractual form and the terms of the contract, or do the parties bargain over the terms of the contract? Once the contract has been chosen, who then decides how much groundwater will be supplied, and how much of the other inputs such as labour, fertilizer etc. will be employed in the production process? Does a contract with a wellowner assure a supply of groundwater, or is there no way of ensuring that the seller will deliver the amount of water agreed upon in advance? The answers to these question are of particular interest if one wants to shed some light on the fact that fixed rate payments and sharecropping arrangements coexist in some local water markets, but not in others. In addition, chapter 2 presents descriptive statistics for some characteristics of the sample households and for some variables related to their groundwater transactions. The household characteristics include landholdings in the different categories of land, wellownership, and the amount of money invested in irrigation equipment. The variables related to the groundwater transactions are, for example, the number of buyers and sellers transacted with in the season under consideration, the fixed rate or cropshare paid or received for groundwater, and the number of days for which water was bought during the season. Comparisons regarding these characteristics and variables are made between the three household categories sellers, buyers, and non-transactors, and between the two sub-categories of buyers, cash-buyers and share-buyers. These descriptive statistics let one gain some insight into the factors determining whether a household sells water, purchases water, or is inactive in the informal water market.

In chapter 3, I come back to the empirical facts set out in chapter 2 in order to build up a model capable of explaining the choice of different contractual forms in informal groundwater markets. This task is definitely worth undertaking, since on the one hand, the only two existing theoretical papers on the issue, Jacoby et al. (2001) and Kajisa and Sakurai (2000), investigate price discrimination and monopoly power in informal groundwater markets as well as the individual-level determinants of groundwater prices, but they do not address which are the determinants of the choice of the contract form. On the other hand, the literature on tenancy and labour contracts mentioned above offers a variety of explanations why different contract forms coexist in the same market for land and labour, but it is clear that none of the models employed in these contributions can be used to predict contract choice in informal groundwater markets, since the assumptions made in these models are not necessarily compatible with the facts in existing informal groundwater markets.

Among the different approaches taken to explain the existence of sharecropping arrangements in the tenancy market, the model in chapter 3 is most closely related to those contributions which use a bargaining approach to explain the parameter values of individual contracts.[3] In the context of informal groundwater transactions it seems reasonable to assume that the terms of the groundwater trade are the result of bilateral bargaining between the buyer and the seller. Empirical evidence suggests neither that all bargaining power rests with the water seller , which would permit the latter to set the terms of the contract, nor that complete markets for groundwater exist in which all participants take the price as given. According to the empirical observations set out in chapter 2, for example, the bargaining power of each party depends on the amount of water available from the surface irrigation system in the period of the contract, on the expected amount of rainfall, and on the number of other potential buyers or sellers.

Following the pattern suggested by empirical evidence, I model the process of contracting between a risk averse wellowner who faces constant marginal costs for the

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[3] Bell and Zusman (1976), Zusman and Bell (1989), Quiggin and Chambers (2001).

extraction of groundwater and a risk averse farmer who is in need of additional irrigation as a three-stage game. At the first stage, during the growing season, both parties observe the state of the farmer's crop and bargain over the contractual parameters, namely, a cropshare, a fixed payment per unit of water, and an unrestricted transfer payment. In the second stage, nature chooses the amount of rainfall, which is observed by both parties. In the third stage, the wellowner chooses the amount of groundwater he wants to apply to the farmer's crop, where the amount of groundwater the wellowner delivers can be observed by the farmer, but the farmer cannot compel the wellowner to deliver a certain amount of water. Under these assumptions it is shown that the contractual parameters are chosen in such a way that the wellowner always chooses the efficient amount of groundwater and that there is always efficient risk sharing, regardless of incentive considerations. If the utility functions of both the buyer and the seller exhibit constant absolute risk aversion, the optimal cropshare as well as the optimal fixed payment per unit of water are functions of the coefficients of absolute risk aversion of the two parties. For the case where both parties have utility functions of the logarithmic type, I can show how the contractual parameters are influenced by factors such as the buyer's and the seller's incomes from sources other than the contract, the marginal costs of producing the groundwater, and the distribution function of the amount of rainfall in the production period.

In a way, chapter 3 makes also a contribution to the literature on cost-sharing arrangements in the context of sharecropping contracts. Braverman and Stiglitz (1986) show that the resolution for the seeming paradox of the irrelevance of cost-sharing is an asymmetry of information concerning the optimal input use between the landlord and the tenant. Under the assumptions of my model, in contrast, cost-sharing arises because of the risk aversion of the contracting parties combined with the unenforceability of the input in question, whereby cost-sharing is feasible because the supply of the respective input is observable by both parties.

Two central results in chapter 3, the efficient supply of groundwater by the wellowner and the related result of efficient risk sharing between the buyer and the seller, can be only derived because the input supplied by the water seller is assumed to be perfectly observable (observable at low costs) by the water buyer. This assumption is quite realistic, since there is no reason why a farmer should be unable to observe the amount of groundwater supplied by someone else to his one or two field plots. In the case of tenancy and labour contracts, however, it is not so clear whether the work effort of a hired labourer or a share tenant can be costlessly monitored by the landlord. Consequently, there are essentially two types of models dealing with contract choice in land and labour markets. Under the assumption of prohibitively high costs of monitoring the tenant's activities, the so-called 'Marshallian' approach, the theory predicts that the choice of a sharecropping contract will result in an inefficiently low amount of variable inputs applied to the rented land by the tenant, compared to the amount of variable inputs employed on owned land or on plots leased in under a fixed rent contract. If, in contrast, the landlord is able to effectively monitor the tenant's activities, as is assumed under the so-called 'monitoring ' approach, then the efficient amount of variable inputs per unit area can be stipulated in the contract, and there are no incentive problems to be dealt with, so that the cultivation of a plot under a share lease causes no inefficiencies compared with ownership cultivation or cultivation under a fixed rent lease. Since the predictions of the theory concerning such issues as the reasons for the existence of sharecropping arrangements and the efficiency of sharecropping depend crucially on the assumption whether perfect monitoring is possible or not, and since it cannot be settled theoretically which of the two modelling approaches does more justice to the real world, it is essential to take a closer look at the empirical evidence.

In this context, the aim of chapter 4 is to make a contribution to the existing literature in this field in the following respects. First, we reestimate Shaban's (1987) model, using data from a survey of 14 villages in Andhra Pradesh, India. A novel feature of these data is that, for each sharecropping contract, they contain the accompanying cost-sharing rules, so that we do not have to rely on village dummies if we aim to measure the effect of the contractual arrangement on input and output intensities. In an important extension of Shaban's model, we include crop dummies into the analysis. If one wants to compare an owner-sharecropper's performance on his owned and on his sharecropped plots, one has to average over the inputs and the output on all his sharecropped and on all his owned plots, with the side-effect that one also averages over different crop types. But this seems to be undesirable, since it is natural to assume that different crop types are produced with different technologies, as was already mentioned above. This fact would not cause a problem if all types of crops were grown in the same proportions on owned and sharecropped land. But if, as in this dataset, some crops are more extensively grown on sharecropped plots than on owned plots and vice versa, then not controlling for the crop type will lead to a distortion of the estimation results. In the light of this argument, Shaban's technique of using village dummies in order to control for the effect of share tenancy seems to be questionable, since instead of reflecting only the different cost-sharing rules across the villages, these dummies could just as well reflect different distributional pattern of crop types on owned and sharecropped plots between different villages. Indeed, we find that at least part of the differences between input intensities on owned and sharecropped land can be ascribed to different crops grown on these two arrangements.

We then extend our analysis of the differences between input intensities on owned and sharecropped plots to the class of owner-fixed-rent tenants in order to investigate whether there are also differences between input intensities under the latter pair of arrangements, and if there are differences, whether part thereof can be ascribed to the effects of tenancy, or whether the total differences can be explained by plot-specific factors or by different cropping patterns on owned and leased-in land. In this case, too, we find that different cropping patterns are one reason for different input intensities.

There is, however, a fundamental difficulty. If we employ indicator variables in the estimation for whether or not a crop is grown on a particular plot of a particular household, we encounter the problem that this set of crop dummy variables is not exogenously given, but is rather the result of an endogenous choice. If the choice of crops is endogenous and if the factors which determine it enter into the error terms in the estimation of the equations for the input differences (all unobserved household heterogeneity which influences owned and leased-in plots differently), then not controlling for the endogeneity of crop choice will lead to inconsistent estimates for the parameters in the input-difference estimation. This presumption is confirmed by the data at least for the class of owner-sharecroppers: In the model which assumes that the crop variables are exogenous, the estimated coefficients for the crop dummy variables are highly significant, whereas the coefficients for the cost share variable are not significant at all. By contrast, in the model which takes into account the endogeneity of crop choice, the influence of the crop dummy variables becomes less significant, whereas a statistically significant influence of the cost share variables can now be detected.

Chapter 5 summarizes the results and gives a short account of future research.

2 How Informal Water Markets Function: Empirical Evidence from South India

2.1 Introduction

Water is, besides land and labour, one of the essential factors in agricultural production. If there are regular rainfalls during the cultivation season and if, in case that there is a period without rainfall, there are enough perennial streams, ponds, or groundwater resources, the farmers can afford – either because they are wealthy enough or because they have access to credit - to buy and run the necessary irrigation equipment, and if they can insure themselves against crop losses, then these farmers do not face any extraordinary economic situation which would be worth considering. But in a number of developing countries where agriculture is monsoon-dependent, a farmer who wants to avoid crop losses caused by the failure of ill-maintained public irrigation systems, or by the lack of rainfall, is often driven to participate in an informal market for irrigation water, the reasons being missing or incomplete credit markets and the absence of perennial streams or ponds. The term 'market' is somewhat elastically in this context, for what is observed are personalized contracts where both parties often have few or no alternative partners to contract, rather than auction markets in a clearly defined good which is traded at a common price. The good in question is groundwater (the contractual units are either hours of irrigation, area irrigated, or number of irrigations) extracted by farmers who own a well and a pump-set. Describing and explaining the different payment modes associated with these groundwater transactions - especially the coexistence of fixed rate payments and share contracts under which the buyer gives a share of his crop output to the water seller in exchange for the water received – will be one of the main tasks of this chapter.

There are numerous contributions dealing with the phenomenon of informal groundwater 'markets' in developing countries, all but two of them (as far as I can determine)[4]

[4] The exceptions are Jacoby/Murgai/Rehman (2001) and Kajisa/Sakurai (2000).

of a purely empirical nature.[5] Those dealing with India "(a) provide an idea of the magnitude and value of Indian water trading, especially at the national level, (b) outline the technical and institutional environment within which Indian water markets are operating, (c) describe their major economic and institutional features, (d) evaluate their efficiency, equity, and sustainability implications, and (e) suggest the legal and institutional changes needed to make them an efficient institutional option for groundwater management" (Saleth, 1998). In my opinion, however, none of these contributions provides a satisfactory detailed depiction of the pattern of groundwater transactions and of the associated payment modes at the household level. Most of these studies are at a rather aggregated level and therefore fail to provide the information that is necessary to set up a model capable of explaining the choice of different contractual forms.

This was the main reason which led me to undertake the study whose results are presented here. My aim was to gather information on such questions as: At which point in time during the cultivation period the contractual form is chosen? Is it the well owner who dictates the contractual form and the terms of the contract, or do the parties bargain over the terms of the contract? If the contract has been chosen, who then decides how much groundwater will be supplied, and how much of the other inputs such as labour, fertilizer etc. will be employed in the production process? Does a contract with a well owner assure a supply of irrigation water, or is there no way of assuring that the seller will deliver the amount of water agreed upon in advance. The answers to these questions are of particular interest if one wants to shed some light on the fact that fixed rate payments and sharecropping

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[5] See, for example, Saleth (1998), Meinzen-Dick (1998), Satyasai et al. (1997), Janakarajan (1993), Shah (1991). Empirical Studies focusing on groundwater trade in Tamil Nadu's agriculture are Janakarajan (1991a, 1991b, 1994).

arrangements coexist in some local water markets, but not in others. Since the same payment modes can be found in the markets for tenancies, we will also have to investigate the question whether the reasons for the choice of a share contract are the same in both markets. To put it in another way, can the existence of sharecropping arrangements in both cases be attributed to the same form of market incompleteness, such as a missing insurance or credit market, or by the incompleteness of the groundwater market or the tenancy market itself. These are the questions to which the descriptive material in this paper can help provide an answer.

What this chapter cannot do, however, is to calculate the exact price of one unit of water under the various contract forms and then compare them in order to identify risk premiums or monopoly markups. This is done in the studies of Jacoby et al. (2001) and Kajisa and Sakurai (2000). Due to the limitations of the data, no attempt will be made to provide an econometric analysis of contractual choice in informal groundwater markets or to test corresponding models thereof. Such an attempt has been made by Satyasai et al. (1997). Further, we do not assess the extent of the trade in groundwater - the number of buyers and sellers involved and the total monetary value of the water traded – as found in Saleth (1998) and Janakarajan (1993). Nor is there an account of the degree to which groundwater is overexploited and the related lowering of the water table in the study area. Two older studies concerned with these issues are Bhatia (1992) and Moench (1992).

The remainder of the chapter is organized as follows: section 2.2 describes the study area, section 2.3 the sample. Section 2.4 presents some summary statistics of trade in groundwater in the sample villages. In section2.5, we comment on the details of some groundwater transactions in the sample villages. Section 2.6 wraps up the chapter.

2.2 The study area

During January and February 2001, 4 of the 7 villages forming a civil village or village panchayat in Nanguneri Taluk, Tirunelveli District, Tamil Nadu, were studied with special emphasis on informal groundwater transactions. The panchayat is located in a rather drought-prone area, and is surrounded by 7 rain-fed tanks, which provide the surface irrigation water for the so-called *wetland*. These tanks are filled during the monsoon season, and in years of good rainfall, they are a reliable source of irrigation water until the end of February. From the tank, the water reaches the fields through a system of small canals. The second category of cultivable land is the so-called *dryland,* which has no access to tank water, and depends wholly on rainfall and groundwater irrigation. The third category is the *second priority land,* which has access to irrigation water only every second year from a nearby river, and which has no access to tank water and well irrigation. In the alternating year, another village panchayat has the right to take water from the nearby river for irrigation purposes.

In connection with the rotation of rights to water from the river, the farmers told us an interesting story, which reminds one of the state of affairs described by Wade (1979 and 1982). Despite the agreement with the government over the release of water every second year, the farmers complained that they had to bribe the government officials responsible for the distribution of the waters between the two panchayats in order to receive the water they were entitled to. There was strong competition between the villages in the canal system to have the canal outlets opened in their favour. The higher the bribe payments, the higher were the chances that the gate would be opened for the village at the time when the farmers needed the water the most. This competition for the river water gave rise to a well-organized institutional arrangement: Guards who had to take care that the river dams were not broken by farmers of other villages in order to steal water, and the choice of two farmers assigned to collect the money from all other farmers which was needed to pay the bribes and to pay for the services of the guards. For each 0.8 acres of second priority land a farmer cultivated, he had to pay a contribution of 50 rupees. Thus, once again, an inefficient – though 'fair' - distribution system set up by the government has been replaced by an illegal system based on bribes, leading to a more efficient distribution of the water, since the bribes are very likely to reflect the willingness to pay of the groups of farmers. But the revenue from this 'water auction' does not accrue to the government and can be employed in the operation and maintenance of the canal system, instead it remains in the pockets of the government officials. Thus, auctioning off the rights to the river water each day or each week or creating a market for water rights would get the government some revenues and distribute the river water more efficiently.

The 540 acres of wetland belonging to the 4 villages studied depend on 2 of the 7 tanks. The total area of dryland is 600 acres, but cultivable dryland, including the land of second priority, amounts to only 100 acres. These villages comprise 390 households, of which 86 are registered as landowners and 95 are registered as landless agricultural labourers. For some odd reason, there was no information on the remaining households in the VAO's (Village Administrative Officer) records, but he told us that not all landowners or landless labourers might have been registered. Other occupations are, for example, shopkeeper, *beedi* rolling, shepherd, miller, and trading in agricultural products. Of the 86 wells owned by households, 22 are located in the wetland areas and 64 in the dryland. It is not clear, however, how many households are well owners, because often 2,3, or even 4 households share ownership in a single well.

2.3 The sample

Since the main purpose of this field study was to gain a more detailed insight into the exact nature of the single groundwater contract rather than to survey many households[6] in order to obtain a data set with which it would be possible to estimate models of contractual choice in

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[6] This, by the way, would not have been possible with only one interviewer in the space of two months.

the context of informal groundwater markets, we did not employ a special sampling method, but instead tracked down farmers who were available and ready to answer our questions.

Concerning the choice of the village panchayat to be studied, we were looking for villages in which groundwater was sold at a fixed rate as well as under sharecropping arrangements. An interesting general pattern was discovered while travelling through Tirunelveli district in search of a suitable study village: In all of the villages where we stopped to make a short inquiry into the local arrangements, there were active groundwater markets; but in the villages which had access to the Tambraparni Irrigation System (which depends on the perennial Tambraparni river), farmers reported that there existed no sharecropping arrangements at all, and that all groundwater transactions were made in the form of a fixed payment per hour. In the villages which only had access to a rain-fed tank system, however, share contracts were found to be very common. This pattern seems to be related to the fact that a perennial river is a more reliable source of irrigation water than a rain-fed tank system, especially as far as the length of the period for which surface water is available for irrigation is concerned. This implies that in the villages located in the river-fed irrigation system, only a modest volume of groundwater is traded as a substitute for the surface water, whereas in the tank-dependent villages, farmers often have to rely on the informal groundwater markets for one-third of the cultivation season. We will discuss this issue in greater detail in the next section.

Since one of our primary aims was to study sharecropping arrangements in informal groundwater markets, we chose 4 villages in a rather drought-prone area irrigated by a rain-fed tank system, where a large number of such contracts were found. For a household to be selected into the sample, it had to own land, lease in land, or both. On this basis, 49 households were chosen from the total of 390 households. Also, one man was interviewed who worked as an 'irrigator' for a landlord who was selling groundwater from his wells to a number of farmers.

2.4 Irrigation and informal groundwater transactions in Nanguneri Taluk

Traditionally, the irrigation water for these 4 villages comes from 2 rain fed-tanks, and reaches the fields through a system of small channels. The access to canal water of the single field is regulated by outlets. The order and the frequency with which each plot receives water is determined by rules made by the village collective.[7] The farmers reported that in the past, the tanks had been a reliable source of irrigation water from October until March, and that at present, in years of good rainfall it is still possible to receive tank water until March, but that nowadays the tank already dries up at the end of January in years of bad rainfall, as happened in the season in which this study was conducted. The reasons for this development are the following: The first is that the system of canals and the dam of the tank are increasingly ill-maintained, which leads to losses of water through breaches in the dam or because the water seeps away through the unlined channels. The second lies in the fact that many farmers grow more water-intensive crop varieties than hitherto, so that the same amount of water is sufficient only for a shorter period.

The main cropping season in our villages is from mid-October until the end of February or the beginning of March. In this season most of the farmers cultivate paddy (rice), a crop which needs a constant supply of water, and which is very sensitive to the water regime in the field. If the surface water resources in the tanks are used up by the end of January, farmers face the problem of supplying their crops with enough water for another 30 days. The farmers who own wells and pump sets will extract groundwater themselves, whereas the other

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[7] There is an own literature on how the distribution of surface water is regulated in such villages, but we will not address this issue here.

farmers either have to wait for rain – which may or may not come – or gain access to other farmers' groundwater resources through purchases of irrigation water. This kind of access to irrigation is restricted by the fact that another farmer's well must be located not to far away from the farmer's own field, and that this well must have the capacity to serve more than the well-owning farmer's own crops.

In our sample, 39 out of the 50 households are well owners. Of these 39, 28 have one or more wells (max. 4 wells), whereas 11 farmers own only a share of a well (the minimum share is 0.25). For example, owning a share of one-fourth of a well means that the share owner is entitled to one-fourth of the well's capacity and that, on the other hand, he has to bear one-fourth of the operation and maintenance costs. Five of the farmers owning more than one well are also owners of a share of a well. There are 8 farmers who own wells in both the wetland and the dryland areas.

Table 1 ***Pattern of well ownership (number of households)***

	only share of a well	at least one well	total
only in wetland	2	10	12
only in dryland	9	10	19
in wetland and dryland	0	8	8
total	11	28	39

The total number of wells (or, more appropriate, the number of shares of well capacities) owned by the sample households is 48.91 (including share wells), of which 23.25 are located in the wetland, and 25.66 are located in the dryland. Of the 30 households owning wetland plots, 20 are owners of a well or a share of a well located in the wetland; of the 34 sample households owning plots in the dryland, 27 are owners of a well or a share of a well located in the dryland.[8] In the wetland owned by the sample households, there are 0.29 wells per acre, whereas in the dryland, there are 0.25 wells per acre. Thus, although, the dryland has no access to tank irrigation, the number of wells per acre on the different kinds of cultivable land is approximately the same. An interesting fact is that in only a few cases is water from dryland wells traded. The farmers told us that normally only farmers who own a well in the dryland cultivate their dryland plots, because no surface irrigation water other than rainfall is available in the dryland[9], and because the capacity of one well is not sufficient to irrigate more than the holdings of the well owner himself for a whole season. The exclusive dependence on uncertain rainfall and on groundwater irrigation is also the reason why only less water-intensive crops like vegetables, chillies or cotton are normally cultivated in the dryland, but some farmers manage to cultivate paddy or even banana on their dryland plots. It was reported that farmers with adjacent plots sometimes exchange some irrigations (in alternating years or season), but that usually there is no water trade against money. However, in our sample there are at least three farmers who own only a well in the dryland, and are selling groundwater.[10]

There are 7 households in the sample which reported selling water in this season, and 15 households which reported buying water in this season; two households of the latter

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[8] A χ^2-test for equal proportions is not appropriate, since the categories are not mutually exclusive, i.e. farmers may own land in both the wetland and the dryland areas.

[9] The farmers who own dryland plots, but no well in the dryland, cultivate their dryland plots only in years of good rainfall.

[10] Since we do not have detailed information on whether a farmer is selling water from his wetland well or his dryland well, we can conclude that there is water trade in the dryland only in the cases were the seller has a well only in the dryland.

reported selling sometimes water, too, both but not necessarily in the same cropping season (in this season, they were active only on the demand side).

Table 2 ***The terms on which water is traded (number of households)***

	seller	buyer
only fixed rate per hour (cash)	0	6
only share contract	1	6
fixed rate per hour and share contract	6	2
fixed payment in kind	-	1
total	7	15

Six of the seven households selling groundwater have both kind of contracts with different buyers at the same time, whereas only two household buying groundwater have both kind of contracts with different sellers at the same time. We will describe this latter cases among others below in greater detail. The average number of buyers served by each seller is 8.71 (std.dev. 7.91), the minimum is one buyer and the maximum is 20 buyers. The average number of sellers from which a buyer receives water is 1.20 (std.dev. 0.78), the minimum is 1 and the maximum is 4.[11] The fact that sellers have different kinds of contracts with different buyers in the same season indicates that the payment mode is related to the characteristics of

[11] The inconsistency between the fact that each seller in the sample on average has 8-9 clients and the fact that in the sample 49 cultivating households there are only 15 buyers, can be explained by the fact that, according to statements of respondents, we have by far the two biggest water sellers of the whole village panchayat in our sample. Leaving these two aside, the average number of buyers served by each seller is 4.20 (std.dev. 2.17), with the minimum being one buyer and the maximum seven.

each pair of transactors, and that there is no market with a uniform price and a standardized product.

Table 3 and Table 4 show information on the differences in well and land ownership between buyers, sellers, and non-transactors.

Table 3 Well ownership (number of households)

	sellers	buyers	non-transactors	total
owns wells only on wetland	1	6	5	12
owns wells only on dryland	3	6	10	19
owns wells on both wetland and dryland	3	0	5	8
owns no well	0	3	7	10
total	7	15	27	49

Table 4 Land ownership (number of households)

	sellers	buyers	non-transactors	total
owns only wetland	0	5	7	12
owns only dryland	2	3	11	16
owns land in wetland and dryland area	5	7	8	20
owns only second priority land	0	0	1	1
total	9	15	27	49

The strongest differences between sellers and buyers concerning their well ownership are, firstly, that 3 of the buyers do not own a well, whereas, of course, all sellers own a well, and, secondly, that 3 of the sellers own one or more wells in both the wetland and the dryland, whereas this is the case for none of the buyers. Comparing this with the pattern of land ownership it is interesting that 7 of the buyers own both wetland and dryland, but none of them owns wells on both kinds of land. The respective numbers are not so far apart for the sellers where 5 own both kinds of land, but only 3 own wells on both kinds of land. Thus, there is a first indication that there may be gains from the groundwater trade. For the non-transactors, well ownership does not match land ownership in all of the cases, too, in that sense that there are to few wells compared with the respective landholdings. But for some reason to be investigated later in section 2.5, they did not participate in the groundwater market. Since a lot of cells have expected counts less than 5, we used Fisher's exact test to test the hypotheses of equal well and land ownership patterns between the three categories of households. The hypothesis cannot be rejected for both tables.

In the following, we will present some further tables which will underline the differences and similarities between buyers, sellers, and non-transactors concerning their endowments with wells and land.

Table 5 Well ownership (average number of wells per household)

	sellers (n=7)	buyers (n=15)	difference (sellers-buyers)	non-transactors (n=27)
on wetland	0.86 (0.90)	0.55 (0.78)	0.31 (0.82)	0.33 (0.51)
on dryland	1.07 (0.73)	0.31 (0.48)	0.77 (0.57)	0.50 (0.62)
on all land	1.93 (1.37)	0.86 (0.70)	1.07 (0.95)	0.84 (0.81)

Standard deviations are in brackets.

The average number of wells per seller or buyer, broken down by land type, is set out in Table 5. On all land, the average for sellers is more than twice as high as that for buyers.

According to the t-test, the difference is found to be significant at the 5% level[12]. Comparing the average number of wells per household on wetland, the difference is positive but not statistically significant, whereas on dryland, the difference is positive and significant at the 1% level. One would expect that in the market (wetland or dryland) with the stronger difference in the relative endowments, there would be more trade in water than in the other market, but if one believes the statements of the farmers, this is not the case. For the non-transactors, the average number of wells per household on all land equals that of the buyers, whereas the average number of wells per household on wetland and dryland is exactly the reverse to that in the buyers' case.

More convincing in this context may be the average number of wells per unit of land, which is reported in Table 6 for the different categories of land.

Table 6 Well ownership (average number of wells per acre)

	sellers	buyers	difference (sellers-buyers)	non-transactors
wetland	0.15 (0.11) n=5	0.23 (0.26) n=12	-0.07 (0.23)	0.26 (0.23) n=15
dryland	0.33 (0.20) n=7	0.28 (0.40) n=10	0.05 (0.33)	0.26 (0.25) n=19
total own land	0.24 (0.09) n=7	0.35 (0.33) n=14	-0.11 (0.28)	0.28 (0.18) n=23
total land (including leased-in land)	0.22 (0.09) n=7	0.27 (0.27) n=15	-0.05 (0.23)	0.22 (0.19) n=27

Standard deviations are in brackets.

[12] If the variable is not normally distributed, it remains the case that the t-test is robust, but caution is still needed in interpreting the results.

It is interesting that the differences are negative for all land categories except dryland, that is, the buyers seem to own on average more wells in the respective land categories than the sellers. One would expect it to be the other way round. But none of these differences is significantly different from zero at any conventional significance levels using an unpaired t-test[13]. Thus, where the average number of wells to land ratio is concerned, there is no evidence of a difference between the endowments of buyers and sellers. The number of wells to land ratios of the non-transactors are not remarkably different from those of the two other categories. Another feature of well ownership which has a bearing on the availability of irrigation water is the depth of the wells. The deeper the well, the greater is normally the amount of groundwater which can be extracted from it. In Table 7 we report the average well depth and the average well depth per unit of land. Since households may own more than one well, the average depth of these wells is used in the computations.

Table 7 Average well depth and well depth per unit of land (in feet)

	sellers (n=7)	buyers (n=15)	difference (sellers-buyers)	non-transactors (n=27)
average depth	74.89 (57.16)	32.80 (21.71)	42.09 (36.19) [t-value 2.54]	34.18 (23.51)
average depth of the deepest well	87.86 (62.95)	32.20 (21.05)	55.66 (38.71) [t-value 3.14]	35.22 (24.73)
average depth per acre of total land	10.60 (9.11)	10.96 (9.76)	-0.37 (9.57) [t-value –0.08]	12.57 (13.60)

Standard deviations are in brackets.

It can be seen from Table 7 that the average well depth for the sellers in our sample is almost twice the average well depth on the buyers' side. The difference is significant at the 5% level.

[13] Non-parametric tests yield the same results.

The difference is even larger and significant at the 1% level if one compares the means of the deepest wells of sellers and buyers. But if one compares the average well depth per acre of total land of buyers and sellers, one finds a negative difference, though one that is not statistically different from zero using an unpaired t-test. One explanation for the fact that the sellers have on average deeper wells as the buyers, but that the well depth to land ratio is not on average higher for the sellers than for the buyers, is that the capacity of a well may be an increasing function of its depth. This would explain why the sellers have 'surplus' groundwater, which they can sell to other farmers with a similar well depth to land ratio. We do not have data on capacity, nor do we have detailed and complete information on the groundwater extracting devices used by sellers and buyers. But it is clear that a deeper well requires a more powerful extracting device to make efficient use of its capacity. Again, the figures of the non-transacting households are very similar to those of the buyers. Thus, it will have to be explained why this group does not participate in the market by looking at some cases in detail in section 2.5.

Some farmers reported that they leave a fraction of their land uncultivated due to foreseeable shortages of irrigation water. Table 8 shows the ratio of uncultivated land to the number of wells owned by buyers, sellers, and non-transactors. Only the buyers owning a well were used in computations.

Table 8 Uncultivated land (acres) per well

	sellers (n=7)	buyers (n=12)	difference (sellers-buyers)	non-transactors (n=20)
acres of uncultivated land/well	0.18 (0.31)	1.52 (1.08)	-1.34 (0.89) [t-value –3.17]	1.17 (1.42)

Standard deviations are in brackets.

The difference between the sellers' and the buyers' uncultivated land per well is negative and significant at the 1% level. That is, there is strong evidence that the buyers have more difficulties than the sellers to supply their holdings with sufficient irrigation water from their own wells. The non-transactors, on average, leave approximately the same amount of land per well uncultivated as the buyers.

Table 9 gives an overview of the different kinds of landholdings of buyers, sellers, and non-transactors.

Table 9 ***Average landholdings of buyers, sellers and non-transactors (in acres)***

	sellers (n=7)	buyers (n=15)	difference (sellers-buyers)	non-transactors (n=27)
own land	9.57 (6.42)	3.74 (4.12)	5.84 (4.93) [t-value 2.59]	3.26 (3.45)
leased-out land	0.86 (2.27)	0.10 (0.39)	0.76 (1.28) [t-value 1.29]	0.34 (1.02)
leased-in land	0.14 (0.28)	0.42 (1.02)	-0.28 (0.86) [t-value –0.70]	0.92 (2.10)
uncultivated land	0.54 (0.92)	1.38 (1.30)	-0.85 (1.20) [t-value –1.55]	1.43 (2.35)
total land	9.71 (6.31)	4.15 (4.12)	5.56 (4.88) [t-value 2.49]	4.18 (3.49)

Standard deviations are in brackets.

The differences in Table 9 are significant at the 5% level for the categories 'own land' and 'total land': The sellers own on average more land than the buyers, this pattern not being changed by the leasing in of land. If the landholdings of a household can be seen as a proxy for the household's wealth, and wealth in turn can be seen as a proxy for the household's risk aversion, then the buyers in the sample tend to be on average more risk averse than the sellers, and the non-transactors are approximately as risk averse as the buyers. Concerning the leasing in and out of land, there seems to be no difference between sellers and buyers, that is, the tenancy market does not seem to work in favour of a more efficient water allocation. The question arises, why do the farmers with the low capacity wells not lease out their land to farmers with high capacity wells, instead of leaving the land uncultivated? Or, equivalently, why are the farmers with high capacity wells not willing to lease in the land of the farmers with low capacity wells? One explanation could be the availability of other production factors, such as labour. If the sellers with their larger own holdings are short of family labour or face high costs for hired labour, then they will not cultivate additional land, but will rather prefer to supply their surplus water and let the buyer supply the labour. Also, the groundwater deals seem to be less risky for the sellers than potential tenancy contracts: The tenancy contracts are made at the beginning of the cultivation season, which means that the well owner does not know at that moment how much groundwater he will need for his own holdings. The groundwater contracts, in contrast, are more flexible, since in most cases they are made during the season and, as the season proceeds, the well owner gains more information concerning his groundwater needs.

The figures for buyers and non-transactors in Table 9 are again very similar, apart from the fact that the non-transactors, on average, seem to lease in and out slightly more land than the buyers.

Table 10 Average costs of irrigation equipment

	sellers	buyers	difference (sellers-buyers)	non-transactors
operation and maintenance costs (rupees/year)	2625 (3018) (n=7)	1723 (980) (n=12)	903 (1959)	2000 (1753) (n=20)
investment in wells and pumpsets (rupees)	124,286 (185,802) (n=7)	41,455 (55,591) (n=11)	82,831 (121,973)	69,367 (57,374) (n=18)

Standard deviations are in brackets.

In Table 10, the average costs per year for the operation and maintenance of the wells and the pumpsets and the average initial investment in the irrigation equipment are set out. Especially the interpretation of the figures for the investment in irrigation equipment deserves some caution, since some of the farmers inherited their well and therefore could not give an exact number for the well's value. None of the differences in Table 10 is significant at any conventional significance level, but the sign of the differences is positive in both cases as one would expect, indicating again that the sellers are on average wealthier than the buyers. Also, a higher investment in irrigation equipment should enhance the groundwater extracting capacity, so that there is a higher amount of water that can be sold. The non-transactors seem to have invested a higher amount in their irrigation equipment on average than the buyers, which could be one reason why they do not have to participate in the groundwater market (on the demand side).

Having examined the differences between the endowments of buyers and sellers, we now turn to a comparison of the two different categories of buyers. In the following, we will investigate the differences in the endowments of buyers who pay a fixed cash amount per hour of irrigation water and buyers who pay a share of their crop output after the harvest.[14] In the computations, we will take into account only the buyers who exclusively pay in one of the two payment modes to obtain stronger results. Thus, we have six cash buyers and six share buyers (two were doing both and one was paying a fixed payment in kind).

Let us consider first the land holdings of the two categories of buyers in Table 11.

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[14] It does not make sense to do this comparison for the sellers, too, since all except one of the sellers in our sample reported offering both kind of contracts.

Table 11 Average landholdings of the two buyer categories

	fixed payment in cash (n=6)	share (n=6)	difference (cash-share)
total own land	4.61 (6.17)	2.78 (2.05)	1.83 (4.60)
wetland	0.79 (0.84)	2.58 (2.18)	-1.79 (1.65)
dryland	3.9 (6.56)	0.28 (0.43)	3.63 (4.65)

Standard deviations are in brackets.

For total own land, the difference is positive but not statistically different from zero. The difference between the wetland holdings of the cash buyers and the share buyers is negative and just significant at the 10% level. The corresponding difference between the dryland holdings is positive but not significant. Thus, there is at least a hint, even if not significant, that farmers with larger dryland holdings more frequently have fixed-payment groundwater contracts, whereas farmers with larger wetland holdings seem more frequently to have share contracts. A reason for this may be that in most cases, the crops grown on dryland do not need a regular supply of water, whereas mostly water-intensive crops like paddy, which are also very sensitive to water shortages and therefore need a constant water supply ,are grown on wetland. In this case, the farmer with the larger dryland holdings will normally need only a few 'turns'[15] of groundwater, whereas the farmer with the larger wetland holdings will eventually need groundwater for one third of the cultivation season.

Consider, therefore, Table 12, which shows the average number of groundwater 'turns' bought by the different categories of buyers and the average number of sellers from whom they bought water during the season in which this study was conducted.

[15] The farmers reported that one 'turn' is normally the delivery of three hours of groundwater a day produced with a standard pumping device

Table 12 Average number of turns and average number of sellers

	fixed payment in cash (n=6)	share (n=6)	difference (cash-share)
average number of turns	7.5 (3.15)	38.17 (24.92)	-30.67 (17.76)
average number of sellers	1.5 (1.23)	1.00 (0.00)	0.5 (0.87)

Standard deviations are in brackets.

The result is very clear for the average number of turns bought by the two categories of buyers: the difference is negative and significant at the 5% level. That is, buyers and sellers who trade with each other in high volume during the season seem to opt for sharecropping contracts, whereas those who do so on a small scale seem to prefer the fixed payment in cash (which is normally paid per hour of irrigation water received). The reasons given by the buyers and sellers for their respective choices of the payment mode will be listed and discussed in the next section. The other difference, the number of sellers from whom the two categories of buyers bought water, is positive, but not significant. It is interesting that each of the share-buyers purchased from a single seller, whereas the cash-buyers on average bought their groundwater from more than one seller. Especially if a farmer has only a single plot for which he needs additional irrigation, it lies in the nature of a share contract that there can be only one water seller. If, as in the case of the cash-buyers, the payment is not related to the output of the buyer, the only restriction on the number of sellers is the availability of sellers, which in turn is determined by the distance of other farmers' wells from the potential buyer's fields and the groundwater supply of those wells. Also, it is said by some farmers that a sharecropping contract with a seller means an assured supply of water, whereas a farmer who buys water against a fixed rate probably has to deal with several sellers to cover his water needs. Since we do not have adequate data, we are not able to determine whether the contractual form depends on the number of potential sellers available, i.e. whether the contractual form depends on the degree of competition between sellers, or whether it is rather determined by other factors (some of them already mentioned above) and then in turn determines the number of sellers.

In Table 13 the well ownership patterns of cash- and share-buyers are reported.

Table 13 Well ownership of both types of buyers

	fixed payment in cash	share	difference (cash-share)
number of wells per acre	0.42 (0.37) (n=6)	0.11 (0.12) (n=6)	0.32 (0.27)
total well depth per acre (in feet)	17.90 (10.51) (n=6)	6.79 (8.52) (n=6)	11.11 (9.57)
number of wells per acre wetland	0.29 (0.34) (n=4)	0.10 (0.17) (n=6)	0.19 (0.25)
number of wells per acre dryland	0.31 (0.41) (n=5)	0.14 (0.20) (n=2)	0.17 (0.37)

Standard deviations are in brackets.

The first two differences in Table 13, which are statistics based on the total number of wells a farmer owns, are both positive and significant at the 10% level. That is, cash-buyers seem to own on average a larger number of wells per acre than share-buyers, and the sum of the depths of their wells per acre seems to be on average higher than that of the wells of the share-buyers. These findings go with the finding above, that cash-buyers buy a smaller number of groundwater 'turns' than share-buyers, since the number of irrigation devices per unit of land is a factor which determines to what extent a farmer has to rely on the informal groundwater market.

The other two differences, average number of wells per acre of wetland and dryland, respectively, are also positive but not significantly different from zero. At least, the direction of these differences is as expected, the cash-buyers owning on average more wells per acre in both wetland and dryland. The number of observations in these two cases is smaller than in the case in which we take into account all wells, since not all buyers own both wetland and dryland.

It should be mentioned at this point that all the comparisons made for the both categories of buyers are not very meaningful for the sellers, since in our sample all sellers trade groundwater with several buyers using both payment modes.

Another interesting question in comparing the two categories of buyers is to ask which of the contracting parties chose the mode of payment. Table 14 is a frequency table which displays the answers to this question. There seems to be a remarkable difference between the answers of the cash-buyers and that of the share-buyers. Four of the share-buyers reported that it was the seller which dictated the payment mode, whereas only two of the cash-buyers reported to have no say in the choice of the payment mode. Also, one of the share-buyers told that it was the 'system' which dictated the payment mode. This statement rather lets one assume that in this case, too, the seller left the buyer with no choice concerning the terms of the contract. On the other hand, four of the cash-buyers reported that they bargained with the water seller over the terms of contract, i.e. that both had a say in the choice of the payment mode, but none of the share-buyers reported to have bargained with the well owner over how to pay for the groundwater. Of all buyers, only one share-buyer told us that he chose the payment mode himself.

Table 14 Who chose the payment mode (number of households)

	fixed payment in cash buyer	share buyer	total
seller	2	4	6
buyer	0	1	1
bargaining (both)	4	0	4
'system'	0	1	1
total	6	6	12

To see whether these differences find statistical support, we employed Fisher's Exact Test for equal proportions, all cells in Table 14 having expected counts less than 5. The hypothesis of equal proportions between the cash-buyers and the share-buyers is rejected at the 10 % level. Thus, it seems that the buyers who ended up with a contract which specifies a fixed payment per hour had more often a say in the choice of the contractual terms than the buyers did, which ended up with a share contract. This leads one to conclude that the share-buyers in our sample had little or no bargaining power at all, whereas the cash-buyers had at least enough bargaining power so that they were not from the beginning nailed down to a certain payment mode. The situation of the different categories of buyers seems to be reflected in their bargaining power: A farmer who needs 30 days or more of groundwater irrigation is dependent on the groundwater deliveries of his seller, since otherwise he may well lose his entire crop; in contrast, the farmer who needs only some occasional 'turns' during the season is in a better position to bargain with the seller, since he will not lose his entire crop without these purchased turns and therefore might decide to do without purchased groundwater and accept a lower yield instead.

Before we turn to some detailed case studies in the next section, we report some summary statistics for the terms of payment in Table 15.

Table 15 Summary statistics for the terms of payment (by method)

		mean	std dev	min	max
buyers	fixed payment per hour (n=7) (in rupees)	27.86	6.36	20.00	40.00
	share (n=7)	0.50	0	0.50	0.50
sellers	fixed payment per hour (n=7) (in rupees)	27.86	9.94	20.00	50.00
	share (n=8)	0.50	0	0.50	0.50

The average amount per hour of groundwater paid by the buyers paying in cash is exactly the same as the average amount per hour of groundwater received by the sellers selling groundwater against a fixed rate (note that we do not confine the comparison to matching pairs of sellers and buyers), the standard deviation being slightly higher in the latter case. The relatively small standard deviation in both cases and the perfect correspondence of the average prices on both sides of the market can be interpreted as evidence for a well functioning groundwater market with a uniform price, at least in the segment where water is traded in form of a few 'turns' per season and against a fixed cash payment. In the market segment for groundwater share contracts the picture is completely homogeneous: all share-buyers and all share-sellers reported that their share of the crop output was fifty percent[16]. Thus, as often mentioned for tenancy contracts in the literature, the fifty-fifty sharing rule seems to be adopted under a wide variety of circumstances. In our sample, for example, there is no difference between the crop share paid by a buyer who receives groundwater irrigation for thirty days and that by a buyer receiving two months of groundwater irrigation, even though a longer period of additional groundwater irrigation does not mean that the maximum attainable crop output thereby increases. The effect of thirty days more irrigation coverage is only that the crop does not fail as it would without the supplementary irrigation. Considering these facts, one may ask whether sellers subsidize their buyers this way or whether they make profit using the sharing rule. One possibility is that most sellers have a pool of buyers with whom they trade groundwater against a crop share. Some of these buyers then will receive water for only one month, whereas others will receive water for two months. Given that output does not differ too much between the different buyers, the seller will get approximately

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[16] It should be mentioned here that in all cases, no input costs were shared. That is, the only contribution to production by the seller is groundwater.

the same amount of output as if he had demanded different shares from his buyers. Given a mixed pool of buyers, always applying the same sharing rule could be a method for the seller to diversify risk. Also, a common 'rule' saves on transaction's costs and hard feelings about asymmetric treatment.

2.5 Some qualitative features of informal groundwater transactions

In the following, we will use some representative cases in order to illustrate how actual groundwater contracts in our sample villages are entered into and actually function. This will help us to complete the picture we already have gained from looking at the summary statistics above. The section will start with a description of the share-buyers' situation, followed by a description of the terms faced by the cash-buyers, a description of the sellers' situation and a summary of the reasons households gave for not participating in the groundwater trade. At the end of this section, we will address the issue of how groundwater contracts are interlinked with tenancy contracts in the sample villages.

2.5.1 The share-buyers' views

Buyers often have a share contract in one season and in another a fixed payment arrangement, depending on the supply of tank water. In this subsection, we will examine some cases of buyers who had a share contract in the survey period.

One farmer told us that he normally approached a nearby well owner at the beginning of the cultivation season in order to agree with him on eventual groundwater deliveries later in the season. In normal years, he needed ten to fifteen days of groundwater irrigation, and the well owner - on whom he was dependent, since there was no other farmer's well near enough to his fields – offered him only a share contract. But he added that he would not have been able to pay in cash for this amount of water. He claimed that, in general, a well owner who was not a friend, a relative, or the buyer's employer, would have forced the buyer into a share contract, even if the latter expected to need only three or four days of groundwater irrigation.

Another buyer who owns a well himself has to buy water, since the capacity of his well is not always sufficient. He asks the owner of a nearby well for water at the moment he needs it. If this is early in the season, the seller will offer a share contract, but if it is for two turns at the end of the season he will pay in cash. He said that sometimes, when groundwater became very scarce at the end of the season, the water rates rose and that therefore he preferred to have a share contract in the case of a bad water situation. He also claimed, that under a share contract there was an incentive for the seller to deliver the water at the right time. In his opinion, the water situation decided which party had the greater bargaining power in negotiating of the terms of the sale. He once had been forced by the well owner into a share contract, although he had needed water for only three or four days, because the well owner had claimed that the water in his well had been very scarce. Shortly after the contract had been made there had been a heavy rainfall so that there had been no further need for groundwater irrigation, but he still had had to pay the full crop share. This buyer also mentioned that besides the crop share, the well owner demanded services such as field labour in exchange for the groundwater from him.

A further buyer said that she normally approached the well owner only when she needed the water, not before she starts cultivation. It happened in the past that she suffered heavy crop losses because she asked for water too late. This year, she handed the land over to the well owner after 30 days of self-cultivation. For the remaining 60 days of the cultivation season, the well owner was responsible for the irrigation of the land, all other inputs having been applied by her before. She also said that it would be impossible for her to pay in cash for 60 days.

Two other share-buyers gave very similar reasons why in their opinion share contracts are in use. First of all, for most of the buyers, it is not possible, except for a few days, to pay the cash rates charged by the sellers, since they are lacking liquidity. The share contract is a means for farmers to save their money invested in cultivation in seasons in which they need groundwater for a month or more. Without the possibility to enter a share contract, they would either have to leave their land uncultivated or let themselves in for a gamble for rain which they are going to lose with high probability. Also, under a share contract, if the crop failed in spite of the additional groundwater applied or because the well owner did not deliver enough groundwater, one would not lose the cash payments that would have been made already under a contract specifying fixed cash payments per unit of groundwater. On the other hand, sellers choose share contracts because these contracts mean secure earnings from water trade, even if their buyers do not need much water because there is enough rainfall during the remaining time of the season.

Another explanation of how it is decided whether the buyer pays in cash or a share of his output was given by a farmer who was presently receiving groundwater from a well owner. He said that the well owner reserves the right for himself to decide at the end of the season which payment mode to employ. He claimed that the well owner chooses the cash payment if the market price for paddy is low, and the share payment if the market price for paddy is high. This story sounds quite incredible, since it would mean that there is no bargaining power at all on buyer's side, who in this case is not one of the poorest farmers.

2.5.2 The cash-buyers' views

Cash-buyers are often those farmers who own a well themselves but need 3 or 4 additional irrigation turns, either because their well has not enough water or because some of their land is more easily served by the well of another farmer. In the latter, the groundwater is often not traded against money, but the farmers exchange water from their wells, sometimes in the same season, sometimes in consecutive seasons.

One farmer reported that, 30 days before the end of the cultivation season, he was looking for someone who was willing to sell water to him against a cash payment. He thought that he would need only four or five turns of water for three hours until the end of the season, but the well owner he had asked was only willing so far to deliver the water under a share contract. he, however, thought that a share contract would mean that he would pay too much for the little groundwater he would need until the end of the season. It was not clear from his statements from how many potential suppliers he could buy water, but it seemed there was some choice, since he mentioned that he was still looking for someone selling groundwater against cash. He also said that he only looks for groundwater sellers during the season, once he becomes aware that the tank water may not be sufficient. This farmer's account is an indication that the contract chosen might depend on the time during the season at which the potential buyer asks for water. For some farmers, it may be very clear early in the season that they will have to enter into a share contract if they want to avoid losing their crop. But for others it may be worth waiting as long as possible in order to not be forced into a share contract which would mean to pay a too high price for the groundwater.

Another farmer told just the opposite story. She owned a well only in the so called 'dryland' (where, in her opinion, there is no water trade on a large scale), but she also cultivated two separated fields in the so called 'wetland'. For one of these fields, she was buying water for two or three further days against cash. For the other field, she thought that she would still need groundwater for one week or more, and therefore would prefer a share contract. But the well owner did not accept a share contract, since he was in urgent need for cash. She claimed that the crop is always secure under a share contract, because in this case the well owner himself is taking care of the irrigation of the crop. In the case of spot purchases against cash, it may happen that one is refused a water delivery if groundwater is scarce, since the well owner gives priority to his share-buyers.

Another case which deserves attention is a farmer who received his four days of irrigation neither under a share contract nor in exchange for cash payments, but in exchange for the promise to plough the well owner's field in the next season supplying his own bullocks. This buyer said that he always received the amount of water he needed from this seller.

As the numbers from the descriptive statistics in section 2.4 already suggest, most of the cash-buyers purchase water for only a few days. But it seems to happen very often, as in the case illustrated above, that well owners try to force farmers who want to buy some groundwater turns against cash into share contracts. The reason is clear: The less groundwater the buyer needs under a share contract, the higher will be the profit of the seller at the end of the season. If the prospective buyer managed to persuade the well owner to sell him the water against cash, he still faces another problem: In the case of limited groundwater supply, the well owners will give priority to the irrigation of the fields of their share buyers, since they do not want to lose their investment because of crop failure. So it may happen to a cash-buyer that his demand is rejected by the well owner with whom he already has an agreement.

2.5.3 The sellers' views

Since most of the sellers sell water under both payment methods considered here, we do not differentiate between cash-sellers and share-sellers in this section. The accounts of their groundwater sales given by well owners often resemble each other in some major aspects, but they might differ in others.

Consider first a farmer who owned one well in the wetland and reported selling water to up to five farmers. He said that he was normally able to allocate about 50 % of his well's daily capacity to other neighbouring farmers by pumping during the day, having irrigated his own plots during the night. Farmers who might need additional irrigation water during the cultivation season normally contacted him before the start of cultivation in order to be entitled to water later in the season. But the exact terms of the contract were determined only when it was clear how much water the buyer needed, since the method of payment depended on the amount of water demanded by the buyer. He claimed that the decision which payment mode to employ was that of the seller. If farmers had demanded water for half of the cultivation season, then he offered a share contract, whereas if they had demanded only about ten turns, he would have sold the water for 25 rupees per hour. The reasons he gave for this decision rule were the following: If the farmers had had to pay for half the season (i.e. for about 45 days) the rate of 25 rupees per hour, their water costs would have exceeded their returns. Therefore, farmers would rather have left their land uncultivated than paying for 45 days of water in cash. In this case, his water would have remained partially unused, since the pool of farmers to whom he could sell water was limited. Thus, both parties would have been better off in this case if a sharecropping contract had been chosen. Further, the farmer said that in a share contract he was sharing only the output with the buyer and no costs; thus, water was his only contribution to cultivation. He also would have offered share contracts for crops other than paddy, but it was mostly for paddy that farmers needed supplementary irrigation water over such a long period. This farmer was using electric pump-sets to extract the groundwater, and due to some state regulation he was receiving free electricity. Thus, there are mainly only fixed costs for groundwater extraction, except the operating and supervision costs.

Also interesting is the case of the biggest water seller in our sample villages. He reported owning three normal wells and one very deep bore well, and selling water to a minimum of ten and a maximum of twenty buyers. He also received free electricity and sold about one half of his groundwater capacity to other farmers, applying the same rule as the farmer above for the choice of the payment mode: Farmers who needed groundwater irrigation early in the season, shortly after transplanting, received the water against a share of the crop output, whereas farmers who needed water for some days at the end of the season normally paid in cash. He sometimes sold water against labour on his own fields. Especially worth mentioning is that he employs an 'irrigator', a man whose exclusive task is the irrigation of the well owner's and his buyers' plots. This irrigator told us that he received for his services one eighth of the yield of the well owner's fields and that for each of the well owner's share contracts he received one-fourth of the well owner's fifty percent of the buyer's yield, whereas he would have received nothing if the buyers had paid in cash. Since all potential buyers had to negotiate their contracts with him, he had a clear incentive to offer share contracts in most of the cases.

Another seller with a very deep well sells about one fourth of his groundwater to five other farmers. All of these farmers have a share contract with him. Concerning the payment method chosen, he said that there was no choice in the matter, since they would not have been able to pay for the whole amount in cash. On the other hand, he told us that farmers who paid him a 50% share of their paddy crops had often not enough paddy for themselves after having paid him so that they had to buy additional rice in the ration shop. Presumably, they were covering the remainder of their costs out of their 50%. He himself, in contrast, was able to sell paddy on the market. But if the buyers had paid him less than 50 % of their crop outputs, then the corresponding amount would not have been enough to cover his costs of the groundwater extraction. Therefore, the buying of groundwater for half of the season or so was only a temporary solution. He pays only a fixed fee per year for his electricity supply, so that there are also no other variable costs of groundwater extraction than his time and the wear and tear on the equipment. Thus, the statement that the proceeds from a sharecropping contract are just sufficient to cover the costs of the groundwater extraction seems to be questionable. In the case of this seller, the earnings from the groundwater sales may serve also to pay off the loan which he took out for the installation of his bore well. Unfortunately, we do not have information on yields, prices, and input use, so we are not able to verify the claims made in this context by buyers and sellers.

The accounts of their water contracts related by three other sellers also show exactly the same pattern: They sell water both under share contracts and against fixed cash payments, the payment mode depending on the number of days for which the buyer needs groundwater irrigation. The present season was bad where the availability of tank water was concerned; therefore most buyers needed groundwater irrigation for one month or more. The farmers would rather have left their land uncultivated than to pay in cash for so many days of irrigation. Therefore, share contracts were very popular in the season under inquiry, in which mostly paddy was cultivated. The practice is for farmers to inform the sellers before they start cultivation that they may need water later in the season, but the terms of the contract are only negotiated when the farmer requests the first release of groundwater to his fields.

2.5.4 The non-transacting households' view

The reasons mentioned by households for their non-participation in groundwater trade are always the same: They do not sell groundwater either because their well's capacity is not sufficient or because there are technical restrictions on the groundwater transport. They do not purchase groundwater either because they get enough water from their own well or because they cannot buy groundwater due to the same technical restrictions on the groundwater transport. These technical restrictions are in the case of the potential sellers either that the fields of potential buyers are too far away or that the potential seller's fields and wells are situated lower than the potential buyer's fields. For potential buyers, the distance is an obstacle to groundwater trade, too, as well as landholdings that are situated higher than the wells and holdings of a potential seller. Some well owners told us that they would sell water but that they were surrounded by farmers with high capacity irrigation equipments who only would buy water if their pumpsets broke down. So there would be merely an exchange of groundwater in emergencies, and no trading in groundwater. Many of the non-transacting farmers who had landholdings only in the dryland area claimed that they did not buy or sell water because in dryland, everyone was owning a well and therefore there was no need for water trading. But as mentioned earlier, in the sample there is some evidence of water trade in dryland. One farmer reported that he wanted to purchase water but that he could not due to a family argument with the owners of the only well within reach.

2.5.5 Interlinking between groundwater transactions and tenancy contracts

One question that comes to mind when considering the groundwater transactions in the sample villages is, why does the water only go from the well owner to the land owner, as apposed to the land going from the waterless land owner to the well owner for cultivation? When we asked several well owners for an explanation of this phenomenon, the answers we received were always the same: The well owners were not able to lease in land, since they had not even enough time to cultivate all of their own land, and since it was not easy to hire labourers in the local labour market. Therefore, the well owners with surplus water in their wells preferred to apply this water to land which had been already prepared with all necessary inputs, especially labour, instead of renting in this land and cultivating it entirely by themselves.

There are, however, some cases in our sample villages where the trading of groundwater and the leasing in and out of land are at least somehow interlinked.

One well owner who was also selling water to one other farmer under a share contract with a 50 % sharing rule, told us that he was leasing out land together with two wells to another farmer. The contract for this kind of lease was such that the party who provided the land and the wells received one third of the crop output and that the party who provided all other inputs received two thirds of the crop output. He (the well owner) also had to pay for the maintenance costs of the two wells and pump sets. The pump sets were run with free electricity. It is surprising that the well owner receives a higher share of crop output under the contract where he only provides the water than under the contract where he provides both the land and the water. An explanation for this may be that under the groundwater contract the field to be irrigated comes under his supervision which requires some of his time, whereas under the tenancy-cum-water contract none of his time is required for cultivation. Another explanation could lie in the different bargaining positions the well and land owner holds when the two different contracts are negotiated. In the case of the pure groundwater contract he will normally be the owner of the scarce resource, groundwater, because the buyer will normally approach him in the middle of the cultivation season when most farmers are in urgent need of irrigation water. So he will be able to dictate the terms, all more so if he is the only one from whom the buyer can obtain water. The boot will be on the other foot if it is the other party which is the holder of the scarce resources, namely, labour in the tenancy-cum-water contract. This contract is negotiated before the start of the cultivation season and not in an acute scarcity situation. Thus, the prospective tenant will not be totally devoid of bargaining power.

Another farmer was leasing in land together with a well. He paid 50 % of his crop output to the land and well owner. The well, however, is used not only by the tenant, but also by the landlord himself. Also in this case, the tenant has to supply all inputs besides land and water, the well owner being responsible only for the maintenance of the well and the pump set. If the tenant needs money to invest in cultivation, he receives credit from the landlord which he has to repay in kind but without interest.

In yet a further case, a farmer was leasing in land together with a well. He provided all inputs other than land and water, and paid one third of his proceeds to the landowner. The well owner in turn has to look after the well and the pump set and to pay the land revenue. It was said by the farmer in question the choice of contract depended on the amount of tank water available. In this case, the well and land owner left the choice to him, and he preferred a share contract, since tank water was very scarce in that season. He thought that the choice of a fixed payment would have been too risky, since groundwater was of inferior quality to tank water and therefore led to a much lower yield[17].

One household was leasing out its entire holding to a farmer who owned a well. Land is the only contribution of the household. It was stated that as long as this tenant used only tank water in cultivation, he had to pay one-third of his proceeds to the landlord. But as soon as the tenant had to rely on groundwater from his own or from another farmer's well for one day or more, the landlord's crop share would be reduced to one fourth. Thus, there is again evidence that the terms of contracts change according to the scarcity of resources employed in cultivation. In two other cases under similar contracts, the landlord paid the cash rates for the additional groundwater bought by his tenant directly to the water seller because the water from the well leased-in together with the land was not sufficient.

Another household was leasing land in both directions, together with a well. The leased out land was 8 km away from the village. The household only had to look after the pump set, and received one third of the output. Their leased in land is located in the village. The contract for this land is for five years, the rent being an annual payment of 5000 rupees in advance, whether they cultivated or not. They claimed that the leased in land depended entirely on the well leased in together with it, and that they would lose the crop if this well did not have enough water. These seem to be high stakes, but this household also cultivated a lot of its own land in the village, a fact which would suggest that the household is rather wealthy and therefore may be not too risk averse.

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[17] It was told by several farmers that the worse quality of groundwater compared with tank water had a negative effect on crop yields.

One farmer reported that he was leasing in land together with a well, paying one third to the land owner as usual. He also cultivated his own land, but only with tank water. If he wanted to use water from the leased-in well, he would have to pay one half of the output to the well and land owner.

The tenancy contract under which one third of the output goes to the land and well owner is very common in our sample villages. Only very few farmers reported that they were leasing under fixed rent arrangements. When asked for the reasons for the popularity of this contractual pattern, the answer most farmers gave was that due to the often insecure water situation in the villages, the risk of paying a fixed amount is felt by the farmers to be too high. One farmer said that he had switched to a share contract after his entire crop had failed due to water scarcity. Under that arrangement, he had paid a fixed rent of 5000 rupees per year. Several farmers told us that until the year before the study, the share for the land and well owner had been one half, but that in a panchayat-wide, concerted negotiation between landlords and tenants, that had been lowered, since the tenants had not been able to cover their input costs out of their share of the poor yields realised in recent years.

2.6 Conclusion

The aim of this chapter was to empirically explain the functioning of groundwater contracts, using a South-Indian village panchayat as an illustrative example. One important conclusion, which can be drawn from looking at the summary statistics and especially at the case studies, is that water due to its overall scarcity and due to seasonal scarcities in the particular case is often the input according to the availability of which the contractual terms are set, even if it is another input originally contracted on such as land. This can be seen very clearly from the fact that the terms of the tenancy contracts in the villages were changed because the deteriorating water situation in the villages had an adverse effect on the farmers' yields. Concerning the contracts where groundwater is the input contracted on, it is the scarcity situation of the particular buyer which determines his bargaining power vis-à-vis the seller and in that way the terms of the contract, too.

A noticeable characteristic of informal groundwater transactions in our sample villages is that the underlying contracts are in all cases negotiated for only one season, that is, there are no long-term contracts as they are often found in the market for tenancies. This is probably one of the biggest differences between groundwater and tenancy contracts. Also, from the example of groundwater transactions it can be seen in what a flexible manner the different payment methods are used to cope with the incompleteness of different markets at once: On the one hand, the share contract grants the groundwater buying farmer a loan which he would probably not obtain from a bank, whereas at the same time it serves as an insurance for the wellowner that he receives an income even if his groundwater extracting facilities, in which he has invested a lot of money, are not working at full capacity because of unexpected rainfall. In contrast to the choice of payment modes in tenancy contracts, the payment method used in a particular groundwater transaction is strongly related to the number of days which remain till the end of the cultivation season and to the believes of the farmers about the amount of rain to be expected during this period. The contractual terms in tenancy contracts are not handled that flexible; they are set before start of cultivation and are therefore not as perfectly adjusted to the state of nature as those in the groundwater contracts are. However, the risk sharing achieved by the use of sharecropping contracts seems to be a motive for the choice of this contract form in the market for tenancies as well as in the groundwater market. Another aspect common – but slightly different in each case - to share contracts in both markets are the incentives which this contract form provides. But instead of providing incentives for the supply of an input (normally labour) which cannot perfectly be monitored by one of the parties as in tenancy contracts, the share contract in groundwater transactions provides incentives for the supply of an input which can be monitored very easily but which can also be sold alternatively by its owner in spot sales. Of course, the latter argument holds for the tenant's labour in tenancy contracts, too.

These are the conclusions which can be drawn by looking at the case studies in this chapter. However, in order to assess these results on a more general level, one would have to estimate a model of contract choice. The data set appropriate for this task should contain the following information which was not covered by the survey underlying this chapter: First of all it would be important to cover a larger number of households for a completed cultivation season. This would allow to gather data on such questions as: How much water was sold and purchased? How much inputs other than water have been applied to the crop? How much output was produced? What were the costs of extracting the groundwater? Information which is essential if one wants to assess the earnings and costs of farmers involved in groundwater transactions. Also required would be exact information on the area irrigated, on the time in the season when no more tank water was available, and on the time in the season when the farmer first bought groundwater from a wellowner, in order to find out how these facts influence the choice of the contract form. The number of well owners from whom a farmer could possibly buy water will also have a bearing on the contract choice. Further, data would be needed on household characteristics such as household wealth, number of family members working, assets owned, etc., since these characteristics would help to quantify the households attitude towards risk and since they provide information on the households endowment with productive assets. It would also be interesting to identify matching pairs of sellers and buyers, although the choice of a contract partner is more restricted than in the case of a tenancy contract due to the restricted transportability of groundwater. Finally, it would be useful to have a time series of several cultivation seasons and data from different areas to see how differences in rainfall and differences in agro-climatic and groundwater conditions influence contract choice in groundwater transactions.

Appendix: Questionnaire

For well owners:

1. How many wells do you own? What are the respective depths of your wells? Are the wells located in the wetland and/or in the dryland?
2. How many pumpsets do you own?
3. How many acres of land do you own? How many acres in the wetland, how many acres in the dryland?
4. I) Do you lease out land? How many acres? If yes, how does your tenant pay for the leased-in land?

   II) Do you leave some land uncultivated? How many acres? Why?

   III) Do you lease in some additional land? How many acres? How do you pay for the leased-in land?
5. What crop are you cultivating this season?
6. How much money did you invest in your well(s) and in your pumpset(s)?
7. What are the operation and maintenance costs of the well(s) and the pumpset(s) per year?
8. Do you sell water to other farmers?

If yes:

i) Do you agree with them on the water deliveries at the beginning of the crop season, or do they come and ask you for water as they need it?

ii) Do you can always fulfil the water needs of the farmers with which you agreed on water trade?

iii) To how many farmers do you sell water?

iv) What percentage of your pumping capacity do you sell to other farmers (percent of total running hours of the pumpset)?

v) What is the maximum distance from your well to a buyer's field?

vi) How do the farmers pay for the water they receive from you?

<u>If cash:</u>

i) How many rupees per hour?

ii) Who chose the contract form?

<u>If share contract:</u>

i) What is the share?

ii) Do you share only the output, or also costs other than labour costs?

iii) Who decides whether share contract or fixed payment? Why did you enter into a share contract?

iv) Do you receive any other services from your buyers?

v) Do you deliver any other inputs to your buyers?

<u>If not selling water:</u>

i) Why you don't sell water?

9. Do you buy water from other farmers?

<u>If yes:</u>

i) From how many farmers do you buy water?

ii) Do you agree with the well owners at the beginning of the crop season on the water deliveries you will need later in the season, or do you approach them at the time you need the water?

iii) How many irrigation turns you will need during this crop season?

iv) Do you get always the amount of water you need?

v) What is the maximum distance of a seller's well to your field?

vi) How do you pay for the water you receive?

<u>If cash:</u>

i) How many rupees per hour?

ii) Who chose the contract form?

<u>If share contract:</u>

i) What is the share?

ii) Do you share only the output, or also costs other than labour costs?

iii) Who decides which payment mode is chosen? Why did you choose a share contract?

iv) Do you receive any other inputs from the well owner?

v) Do you have to render any other services to the well owner?

<u>For farmers who do not own a well</u>

1. Do you own land?

<u>If yes:</u>

i) How many acres in wetland and in dryland?

ii) Do you lease out land? How many acres?

iii) Do you lease in some additional land? How do you pay for the leased in land?

iv) Do you leave some land uncultivated? Why?

<u>If no:</u>

i) Do you lease in land? How do you pay for the leased in land?

ii) What crop are you cultivating this season?

iii) Do you buy water from other farmers?

<u>If yes:</u>

i) From how many farmers do you buy water?

ii) Do you agree with the well owners at the beginning of the crop season on the water deliveries you will need later in the season, or do you approach them at the time you need the water?

iii) How many irrigation turns you will need during this crop season?

iv) Do you get always the amount of water you need?

v) What is the maximum distance of a seller's well to your field?

vi) How do you pay for the water you receive?

<u>If cash:</u>

i) How many rupees per hour?

ii) Who chose the contract form?

<u>If share contract:</u>

i) What is the share?

ii) Do you share only the output, or also costs other than labour costs?

iii) Who decides which payment mode is chosen? Why did you choose a share contract?

iv) Do you receive any other inputs from the well owner?

v) Do you have to render any other services to the well owner?

<u>If no:</u>

i) Why?

3 Informal Groundwater Markets: The Role of Share Contracts

3.1 Introduction

It is a well-documented fact that informal markets for groundwater are active in a large part of the Indian agricultural sector[18]. These informal groundwater markets are normally found to emerge in situations where the traditional surface water irrigation systems such as tank irrigation fail to cover the water needs of all cultivating farmers. The good traded in these informal markets is groundwater extracted from the soil by farmers owning wells and pump-sets[19], and in exchange for his groundwater the respective wellowner receives either a share of the crop output produced with his water or a fixed payment per hour of irrigation, that is, we have a similar payment structure as it is often observed in the context of land transactions in rural areas.

So far, there is much empirical, but little theoretical work on informal groundwater markets. In many of the empirical papers cited above it is argued that informal groundwater markets may be a suitable institution for supplying small farmers who are not able to invest in an own well with necessary irrigation. This literature, however, also argues that the terms of such water contracts are often exploitative, especially when they take the form of sharecropping arrangements. Turning to the two existing theoretical papers on this issue, Jacoby et al. (2001) investigate price discrimination and monopoly power in informal groundwater markets in Pakistan's southern Punjab, testing whether tubewellowners price-

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[18] See for example Saleth (1998), Meinzen-Dick (1998), Satyasai et al. (1997), Janakarajan (1993), Shah (1991).

[19] There is an open access regime for the groundwater resource, that is, every farmer who owns the necessary extracting facilities can appropriate as much groundwater as he wants. This issue will not be considered in this paper.

discriminate between their own share-tenants and other cultivators, and whether tubewellowners who face only the marginal costs of extraction as their shadow price of groundwater use more groundwater per acre on their own plots than their tenants and their other buyers use on their own plots. Since both price discrimination as well as different groundwater input intensities are found to be prevalent in the data, the authors conclude that there is evidence for monopoly power on the part of the tubewellowner, but they also find that monopoly power in the groundwater market has only limited effects on efficiency and equity. They do not address the issue of different contract forms in the groundwater market. Kajisa and Sakurai (2000) explore theoretically as well as empirically the individual-level determinants of groundwater prices using a bilateral bargaining framework and data from six villages in Madhya Pradesh, India. In their analysis, they take into account the fact that there are different payment modes and investigate whether the contract form has an effect on the price per unit of groundwater. They find that the price per unit of groundwater under a share contract will normally be higher than the unit price under an arrangement including a fixed payment due to a risk premium paid to the water seller for shouldering part of the production risk. They do not, however, address which are the determinants of the choice of the contract form, i.e. they do not answer the question why both contract forms coexist in the same groundwater market.

On the other hand, the theoretical literature on contract choice in the related context of tenancy is extensive. Among the different approaches taken to explain the existence of sharecropping arrangements in the tenancy market, the present paper is most closely related to the contributions which use a bargaining approach to explain the parameter values of individual contracts[20], i.e. the papers by Bell and Zusman (1976), Zusman and Bell (1989) and Quiggin and Chambers (2001), rather than to assume that the terms of contracts are taken by all agents as given price-like parameters, as it is done for example in Bardhan and Srinivasan (1971) or in Newbery (1977), or that there is a principal-agent structure where the principal has all the bargaining power, and is consequently in a position to dictate the terms of the contract, as for example in Eswaran and Kotwal (1985) and Stiglitz (1974). In the context of informal groundwater transactions it seems reasonable to assume that the terms of the groundwater trade are the result of bilateral bargaining between the buyer and the seller. Empirical evidence suggests neither that all bargaining power rests with the water seller, which would permit the latter to set the terms of the contract, nor that complete markets for groundwater exist in which all participants take the price as given. For example, the bargaining power of each party depends on the amount of water available from the surface irrigation system in the period of the contract, on the expected amount of rainfall, and on the number of other potential buyers or sellers. If, moreover, both contracting parties are wellowners, bargaining power also depends on whether the seller of the present period's contract is a potential buyer in the next period. Finally, if two well-owning farmers contract, both of them may simultaneously be a seller and a buyer if each of them owns a field plot which cannot be irrigated with his own well but lies within reach of the other party’s well.

In the context of tenancy, Bell and Zusman (1976) consider risk-neutral landlords and tenants and use the Nash-Bargaining-Solution and the assumption that there are non-tradable production factors to explain the existence of sharecropping, but in their analysis the agents cannot choose between sharecropping and fixed-rent contracts. In a framework of pairwise-

[20] A discussion of bargaining solutions in the context of rural contracts is given in Bell (1989).

bargained agency contracts between risk-averse landlords and tenants, Zusman and Bell (1989) derive in an illustrative example a result for the optimal cropshare, which is similar to that derived by us, under the assumption that there is no moral hazard. Consequently, no incentive problems arise. In another illustrative example, where incentive problems are introduced, the result for the optimal cropshare diverges from ours.

In the present paper, the amount of the crucial input, groundwater, is assumed to be observable but not enforceable. Consequently, an incentive problem arises.[21] Based on the author's own empirical observations in a south Indian village, the present paper addresses the question which factors determine the choice of the terms of trade in informal groundwater transactions between a wellowner and a farmer who is in need of additional water for irrigation. We will particularly be concerned with establishing under what circumstances a share contract is chosen rather than a fixed payment per hour.

We model the process of contracting between a risk averse wellowner who faces constant marginal costs for the extraction of groundwater and a risk averse farmer who is in need of additional irrigation as a three-stage game. At the first stage, during the growing season, both parties observe the state of the farmer's crop and bargain over the contractual parameters, namely, a cropshare, a fixed payment per unit of water, and an unrestricted transfer payment[22]. In the second stage, nature chooses the amount of rainfall, which is observed by both parties. In the third stage, the wellowner chooses the amount of groundwater he wants to apply to the farmer's crop, where the amount of groundwater the wellowner delivers can be observed by the farmer, but the farmer cannot compel the wellowner to deliver

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[21] Stiglitz (1974) considers the trade off between risk sharing and incentives.

[22] Another paper in which contracts with three contractual parameters are considered, is Laffont/Matoussi (1995).

a certain amount of water. We show that the contractual parameters are chosen in such a way that the wellowner always chooses the efficient amount of groundwater and that there is always efficient risk sharing, regardless of incentive considerations. If the utility functions of both the buyer and the seller exhibit constant absolute risk aversion, the optimal cropshare as well as the optimal fixed payment per unit of water are functions of the coefficients of absolute risk aversion of the two parties. For the case where both parties have utility functions of the logarithmic type, we cannot derive an explicit solution, but we can show how the contractual parameters are influenced by factors such as the buyer's and the seller's incomes from sources other than the contract, the marginal costs of producing the groundwater, and the distribution function of the amount of rainfall in the production period.

The present paper makes also a contribution to the literature on cost-sharing arrangements in the context of sharecropping contracts. Braverman and Stiglitz (1986) show that the resolution for the seeming paradox of the irrelevance of cost-sharing is an asymmetry of information concerning the optimal input use between the landlord and the tenant. Under the assumptions of our model, in contrast, cost-sharing arises because of the risk aversion of the contracting parties combined with the unenforceability of the input in question, whereby cost-sharing is feasible because the supply of the respective input is observable by both parties.

The remainder of the paper is organized as follows: In section two we give a detailed description of the structure of informal groundwater transactions, in section three the model and the results are presented, and section 4 concludes the paper.

3.2 The structure of informal groundwater transactions

To motivate the structure of the model to be presented in section 3, we first present some empirical facts on informal groundwater 'markets' on the village level. Most of the information presented here comes from a field study conducted by the author in four villages in Nanguneri District, Tamil Nadu, India during January and February 2001. For a more detailed discussion see Steinmetz (2001).

An important point to be made at the beginning is that it is somewhat misleading to use the term 'market' (as normally defined) in this context, because what is observed in reality are personalized contracts between two parties where often both of them have only few or no alternative partners to contract with, rather than an arrangement for transacting in a clearly defined good which is traded at a common price, and with the possibility for each buyer to contract with each seller in the market and vice versa.

The reason for informal groundwater transactions to arise is the undersupply of irrigation water from common sources such as rivers or rain-fed reservoirs (in south India known as ’tanks’), combined with the fact that not all farmers are owners of a well and a pumpset. In villages where water is rather scarce, it is normally the case that at some moment in time during the crop season the irrigation water available from the rain-fed tank will be used up, so that farmers have to rely on two other irrigation sources to complete their cultivation: rainfall and groundwater. A farmer who does not own groundwater-extracting facilities or whose well does not deliver enough water either has to rely entirely on rainfall, which is random in timing and amount, so that it may happen that the crop fails because of a lack of water, or he has to buy groundwater from another wellowner. In most cases, there will be only a few wellowners, or even only a single wellowner from whom a farmer can buy groundwater because the terrain and the distance between the farmer's field and the well impose technical restrictions on the trading of groundwater.

Empirically, a typical crop and contracting cycle look as follows: At the beginning of the crop season, a farmer starts cultivation, knowing how much water for irrigation purposes he will get from the common tank, but not knowing if there will be rainfall again later in the season to complete cultivation without buying additional water. As the season proceeds, the farmer waits for rain as long as it is possible without incurring the risk of a crop loss before he approaches a wellowner and attempts to bargain over the terms of the water sale. If they agree on a cropsharing arrangement, the area to be irrigated comes entirely under the control of the wellowner, who now decides how much water will be applied to the crop; if, however, a fixed rate per hour of irrigation is chosen, the field remains under the management of the farmer himself, who has to turn to the wellowner for every additional irrigation. An important point to note in this context is that in the case of a share contract, the wellowner always gets his share of the crop, even if he chooses not to apply a drop of water (because of sufficient rainfall) after the contract was agreed on. If, on the other hand, the contract is based on a fixed payment per hour of irrigation, the wellowner is paid only if he delivers the water. The situation is normally such that the farmer can observe the amount of water the wellowner delivers to his field, but that he cannot force the wellowner to deliver a certain amount of water because the wellowner may need the water for his own crop, he may have another higher yielding alternative use, or simply because his pumpset breaks down.

Turning to the question which factors empirically determine the choice of the payment mode, we find evidence (see chapter 2) that the point in the cropping season at which the farmer approaches the wellowner offer of a contract plays an important role: If the contract is chosen early in the season, then, in most cases, both parties agree on a sharecropping arrangement, whereas if the farmer contacts the wellowner late in the season, asking only for a few irrigations, an agreement on a fixed payment per hour of irrigation is more likely to be the outcome of the bargaining. There are two immediate explanations for this. First, the farmer is liquidity-constrained and cannot afford to pay in cash for the obligations resulting from 60 days of groundwater irrigation. Secondly, he is risk averse: if the provision of groundwater irrigation has the effect that output becomes less random or even non-random, then a risk averse farmer is likely to prefer a share contract if he needs groundwater irrigation for a long period, because in the case of a share contract, the payments he has to make do not vary much across the states of nature, whereas in the case of a fixed payment per hour, he has to pay much more if there is low rainfall than when there is high rainfall. That is to say, if a farmer pays a share of his output instead of a fixed rate, he can avoid severe income shocks in a situation where he has to buy groundwater for a long period. With this intuition in mind, we proceed in the next section with the exposition of the model.

3.3 The Model

In this section, we first set up a general model which enables us to derive some results which hold for a wide variety of cases. We then proceed by specifying the utility functions of the buyer and the seller, and the distribution of the amount of rainfall in order to make some statements concerning the factors influencing the contractual parameters. In the third subsection we briefly examine the case of only two contractual parameters.

3.3.1 The General Model

To model the process of contracting between a cultivating farmer and a wellowner described above, we assume that an output, q, is produced with only one input, namely water, where the total amount of water, W, is the sum of the amount of rainfall, R, in the period under consideration and the amount of groundwater, G, bought from the wellowner. In effect, we implicitly assume that all other inputs necessary in production, such as land, labour, canal water, and fertilizer, have already been chosen by the farmer at the moment when he has to decide whether to enter a contract with a wellowner or not. This implies, in particular, that we do not model the farmer's decision of how much land to cultivate, although this decision will certainly be influenced by the effects it will have on the terms of the groundwater contract. We also assume, for simplicity, that neither the farmer nor the wellowner has other parties to contract with. This is not an unrealistic assumption, since there are technical restrictions on trade in groundwater in form of the impossibility of transporting water over large distances. It also excludes the possibility that either the seller or the buyer derive their bargaining power from the number of alternative contract partners they face. The bargaining positions in this case will depend only on the expected amount of rainfall. Let the production function $f(W)$ be everywhere increasing, twice differentiable, concave, and satisfy the lower and upper Inada-conditions. Thus, we assume that there is never too much rainfall, so ruling out corner solutions for the quantity of groundwater applied by the wellowner. This rather restrictive assumption seems to be justifiable if one considers drought-prone areas such as the Nanguneri District in southern Tamil Nadu, where flood-like conditions and crop damaging rainfalls outside the monsoon period are a very unlikely event. Concerning the distribution of rainfall in the production period under consideration, we assume that there is a continuous distribution of rainfall on the interval $[0,\overline{R}]$, with a differentiable distribution function $H(R)$ and density function $h(R)$. Turning to the wellowner, we assume that the costs of extracting one unit of groundwater are constant and equal to *c*, and that there are no costs for transporting the groundwater from the well to the farmer's field. We will also neglect any problems caused by overexploitation of groundwater, although in reality this is an important cost factor which the farmers should take into account to guarantee an intertemporally efficient allocation of groundwater.

Let both the buyer and the seller be risk averse with twice differentiable, concave utility functions defined over income, $v(Y^B)$ and $u(Y^S)$ respectively. We assume further that both the buyer and the seller have a perfectly certain source of income, yielding say $\overline{Y}^B$ and $\overline{Y}^S$, the level of which is such that both parties can always fulfil their obligations arising from a contract; for the farmer, $\overline{Y}^B$ is the non-negative income that he has from somewhere else and that is always sufficient to cover both non-water inputs and the payments for water that must be made before the harvest is in. This assumption could be problematic since in real world scenarios the wealth (credit)-constraints that a farmer faces seem to have a significant influence on the choice of the contract form as mentioned above.

We model the process of contracting between the cultivating farmer and the wellowner as a three-stage game, assuming that the farmer can observe the amount of groundwater the wellowner delivers to his field, but that he cannot compel the wellowner to provide a certain amount of water, that is, the amount of groundwater to be applied to the crop cannot be stipulated in the contract. Since we do not model the case where the wellowner has an uncertain alternative use for his groundwater, we have to establish the unenforceability of the input by assumption. In the first stage both the farmer and the wellowner observe the state of the crop before they bargain over the contractual parameters, i.e. the wellowner's share of the crop output α with $\alpha \in [0,1]$, a fixed payment per unit of groundwater β paid by the farmer (with $\beta > 0$), and an unrestricted transfer payment γ. There is no such explicit transfer payment observed in reality, but we use γ as an instrument to isolate the effects which only result from the necessity to transfer wealth. In real world contracts there are sometimes implicit transfer payments, for example, labour services done by the farmer on the wellowner's fields.[23] In the second stage, after the farmer and the wellowner agreed on a

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[23] Braverman and Stiglitz (1986) also discuss whether or not to include an unrestricted transfer payment in the theoretical analysis (p. 648): "There is some debate about whether this case ($\gamma = 0$), or the case described in the next subsection, where γ is set optimally, is the more relevant. Observed contractual relationships seldom seem to involve fixed transfers between the landlord and the tenant. On the other hand, there are several contractual provisions which may serve as a substitute; for instance, if the landlord provides a certain minimal level of the input, *x*, it is equivalent to $\gamma < 0$; or if the tenant is required to purchase

contract form, nature chooses the amount of rainfall. In the third stage the wellowner observes the amount of rainfall, and then decides how much groundwater he wants to apply to the crop, that is, the wellowner chooses the amount of his input under certainty.

We solve the game described above by backward induction, employing the Nash Bargaining Solution to model the bargaining process in the first stage. We begin with the third stage where the wellowner chooses the amount of groundwater he wishes to apply, that is, he maximizes his income $Y^S = \alpha f\left(R+G\right)+\left(\beta-c\right)G+\gamma+\overline{Y}^S$ with respect to the amount of groundwater supplied:

$$\max_G \alpha f\left(R+G\right)+(\beta-c)G+\gamma+\overline{Y}^S \tag{1}$$

which yields the first-order condition

$$\alpha f'+\beta-c\leq 0, \qquad G\geq 0. \tag{2}$$

Since we have ruled out by assumption above that there will be ever too much water in production, there will be no corner solution for the amount of groundwater applied by the wellowner, even if $R=\overline{R}$, and therefore equation (2) will hold with equality. From this first-order condition it is then immediately clear that the optimal groundwater contract has to be always such that $\beta<c$ since otherwise there will be unlimited demand for *G*.

Define $G^o\left(R\right)\equiv\arg\max_G Y^S$ as the amount of groundwater which maximizes the wellowner's income in each state of nature $R\in\left[0,\overline{R}\right]$. Then, from (2), we have $W^o\left(\alpha,\beta;R\right)=G^o\left(\alpha,\beta;0\right)=R+G^R\left(\alpha,\beta;R\right)$, that is, the wellowner chooses the amount of

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certain inputs from the landlord at above market prices, it may be equivalent to a contract with $\gamma>0$."

groundwater such that in each state of nature the same amount of water is applied to the crop, given a set of contractual parameters (α,β). From this it follows immediately that $f\left(W^o\right)=f\left(R+G^o\right)$, which means that the potential output uncertainty caused by stochastic rainfall is in fact eliminated by the wellowner's choice. This result is a consequence of the assumption that the costs of producing one unit of groundwater are constant and not random.

It is interesting to note that the variability of the total amount of water the crop receives depends crucially on the behaviour of the marginal cost function given a certain distribution of rainfall. Consider the case where, in contrast to our model, the wellowner faces increasing marginal costs in extracting the groundwater, i.e. $c'\left(G^0\right)>0$ and $c''\left(G^0\right)>0$. Then we can derive from the resulting first-order condition for an optimal amount of groundwater the comparative static result: $\frac{\partial G^0}{\partial R}=-\frac{f''}{f''-c''}<0$. In our case with constant marginal extraction costs, the above expression becomes $\frac{\partial G^0}{\partial R}=-1<0$. It is apparent that $\frac{f''}{f''-c''}<1$ for all $c''>0$. Thus, in the case of constant marginal extraction costs, a change in the state of nature is completely offset by the change in the amount of groundwater chosen by the wellowner, whereas in the case of increasing marginal extraction costs, a change in the amount of rainfall is compensated for by the wellowner by less than the full amount. That is, in the case of constant marginal extraction costs, the variance of the total amount of water applied to the crop is zero, whereas in the extreme case of infinitely increasing marginal extraction costs, the variance of the total amount of water is the same as the variance of the rainfall distribution, since $\lim_{c''\to\infty}\frac{\partial G^0}{\partial R}=0$. The less convex are the extraction costs, the closer to one is $\left|\frac{\partial G^0}{\partial R}\right|$, and the smaller is the variance of the resulting distribution of the total amount of water the crop receives. Since in the following we consider only the case of constant marginal costs, we cannot draw further conclusions from this result, but there is an obvious link to the empirical observations: In areas where the wellowners face stronger increasing marginal extraction costs because the groundwater table in their wells decreases more rapidly during the season, cropsharing contracts are found to be very common. If the ex-ante total amount of water is more risky, and therefore the ex-ante crop output is also more risky, then a risk averse farmer will rather prefer a payment mode which transfers part of the production risk to the wellowner.

The corner solution where the wellowner applies no groundwater at all and the extreme case of crop failure because of too much rain are ruled out by the assumptions given above, so that in the following we will deal with interior solutions only.

Standard comparative static analysis yields

$$\frac{\partial W^o}{\partial \alpha} = -\frac{f'}{\alpha f''} > 0\,, \quad \frac{\partial W^o}{\partial \beta} = -\frac{1}{\alpha f''} > 0 \tag{3}$$

Now consider the bargaining process at the second stage. If the farmer and the wellowner come to an agreement, the farmer's state-dependent income is $Y^B = (1-\alpha) f\left(R + G^R\right) - \beta G^R - \gamma + \overline{Y}^B$; if there is no agreement, and the farmer has to depend entirely on rainfall, his expected disagreement payoff is $E\left[v\left(f(R) + \overline{Y}^B\right)\right]$. For the wellowner, we assume that in each state of nature he only earns his certain income $\overline{Y}^S$ if there is no contract with the farmer, that is his expected disagreement payoff in utility terms is $u\left(\overline{Y}^S\right)$.

The outcome of the bargaining process is modelled by choosing (α, β, γ) to maximize the product of the gains from cooperation, expressed in terms of expected utility:

$$\max_{\alpha,\beta,\gamma} \Delta\widetilde{V}\left(Y^B\right)\Delta\widetilde{U}\left(Y^S\right) \tag{4}$$

$$\text{s.t.} \qquad \alpha \in [0,1], \qquad \beta \geq 0,$$

where

$$\Delta\tilde{V}\left(Y^B\right) = E\left[v\left((1-\alpha)f\left(W^o\right) - \beta G^o\left(\alpha,\beta;R\right) - \gamma + \bar{Y}^B\right)\right] - E\left[v\left(f\left(R\right) + \bar{Y}^B\right)\right] \quad (5)$$

and

$$\Delta\tilde{U}\left(Y^S\right) = E\left[u\left(\alpha f\left(W^o\right) + (\beta - c)G^o\left(\alpha,\beta;R\right) + \gamma + \bar{Y}^S\right)\right] - u\left(\bar{Y}^S\right) \quad (6)$$

To simplify notation, in the following we will write G^o instead of $G^o\left(\alpha,\beta;R\right)$. It is important to note that the total amount of water applied to the crop in the optimum, W^o, is not random, only the optimal amount of groundwater chosen by the wellowner, G^o, is random. Thus, in the following expectations are taken with respect to G^o. This non-randomness of W^o enables us to draw some terms, especially the comparative static expressions $\frac{\partial W^o}{\partial \alpha}$ and $\frac{\partial W^o}{\partial \beta}$, out of the expectations operator, as it is done for the following first-order conditions.

The first-order conditions for the maximization problem are:

$$\left(-f + \frac{\partial W^o}{\partial \alpha}\left((1-\alpha)f' - \beta\right)\right)E\left[v'\right]\Delta\tilde{U}\left(Y^S\right) + fE\left[u'\right]\Delta\tilde{V}\left(Y^B\right) \leq 0, \qquad \alpha \geq 0 \quad (7)$$

$$\left(\frac{\partial W^o}{\partial \beta}\left((1-\alpha)f' - \beta\right)E\left[v'\right] - E\left[v'G^o\right]\right)\Delta\tilde{U}\left(Y^S\right) + E\left[u'G^o\right]\Delta\tilde{V}\left(Y^B\right) \leq 0, \qquad \beta \geq 0 \quad (8)$$

$$-E\left[v'\right]\Delta\tilde{U}\left(Y^S\right) + E\left[u'\right]\Delta\tilde{V}\left(Y^B\right) = 0 \quad (9)$$

We now identify the contract form which is chosen in the bargaining process by investigating the Kuhn-Tucker conditions. Assume first that the contract contains only a fixed payment per unit of groundwater and no positive output share for the wellowner, that is $\alpha = 0$ and $\beta > 0$. Then from (7) and (9) we have $f' - \beta \leq 0$, and from (8) and (9) we have $\frac{\partial W^o}{\partial \beta}(f' - \beta) = \frac{E[v'G^o]}{E[v']} - \frac{E[u'G^o]}{E[u']}$. But this is not possible if there is no output sharing between the buyer and the seller. For if $\alpha = 0$ we get from the first-order condition of the seller that $\beta = c$, which in turn implies that the second term on the right hand side of the above condition becomes $E[G^o]$, whereas for the first term on the right hand side we have $\frac{E[v'G^o]}{E[v']} > E[G^o]$ because $v'(f - \beta G^o - \gamma)$ and G^o are positively correlated.[24] From this it follows that the right hand side is strictly positive, whereas the left hand side will never be positive, which is a contradiction. So we must have $\alpha > 0$. Put it in another way, inspection of (1) reveals that from $\alpha = 0$ and $\beta = c$ it follows that $Y^S = \gamma + \overline{Y}^S$, which is constant, the requirement that $\beta = c$ arising from the need to ensure that the seller will sell any amount of water, since in this case there are no incentives for the seller arising from an output share. But since the buyer is also risk averse, it cannot be optimal that he bears all the risk alone.

Next consider the case where $\alpha > 0$ and $\beta = 0$. Then from (7) and (9) we have $(1-\alpha)f' = 0$, and from (8) and (9) $\frac{E[v'G^o]}{E[v']} \geq \frac{E[u'G^o]}{E[u']}$. That is, we have $\alpha = 1$; but this together with the said weak inequality yields a contradiction, because in this case the left hand

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[24] $E\left[(v' - E[v'])(G^o - E[G^o])\right] = E[v'G^o] - E[v']E[G^o] > 0$.

side of the inequality is equal to $E\left[G^o\right]$ whereas for the right hand side we have $\frac{E\left[u'G^o\right]}{E\left[u'\right]} > E\left[G^o\right]$ because $u'\left(f - cG^o + \gamma\right)$ and G^o are positively correlated. This yields the following proposition:[25]

<u>Proposition 1.</u> *If both the buyer and the seller are risk averse, the amount of groundwater delivered by the seller is observable, but not enforceable, and there are constant marginal costs of groundwater extraction, then the optimal contract is such that* $0 < \alpha^o < 1$ *and* $\beta^o > 0$.

What else can be said about the optimal contract? Consider again the conditions which must hold in the optimum:

$$(1-\alpha^o)f' - \beta^o = 0 \tag{10}$$

$$\frac{E\left[v'G^o\right]}{E\left[v'\right]} = \frac{E\left[u'G^o\right]}{E\left[u'\right]} \tag{11}$$

together with (9) and the first order condition for the wellowner, $\alpha^o f' + \beta^o - c = 0$, given the assumption that there will be never too much water in production. (10) combined with the first order condition for the seller yields the efficiency condition $f' = c$ which means that as a consequence of the optimal contract the amount of groundwater is chosen by the wellowner in a way that the marginal product equals the marginal cost. This result follows from the fact that for the optimal contract we have $1 - \alpha^o = \frac{\beta^o}{c}$, or $(1-\alpha^o)c = \beta^o$: Inserting this result in the

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[25] Notice that $\alpha = 1$ only if $\beta = 0$ because $(1-\alpha)f' - \beta = 0$ for $\alpha > 0$.

state-dependent income equations for the buyer and the seller, we obtain $Y_R^B = \left(1-\alpha^o\right)\left\{f - cG^o\right\} - \gamma^o + \overline{Y}^B$ and $Y_R^B = \alpha^o\left\{f - cG^o\right\} + \gamma^o + \overline{Y}^S$, that is, the output produced with the groundwater delivered by the wellowner is shared between the buyer and the seller in the same proportion as the costs incurred by the wellowner in producing the groundwater. This result in turn is caused by the fact that the input in question, namely groundwater, is observable, and can be paid by means of a fixed payment per unit. Also, there is an instrument besides α and β, namely γ, which serves to transfer utility from one party to the other, so this task has not to be shouldered by α and β. Thus, in the theoretical examination of groundwater contracts that contract form turns out to be the optimal one, which is often empirically observed for tenancy contracts, but which in the related theoretical literature is explained by information asymmetries between the landlord and the tenant.[26] In our model, cost-sharing is possible because the input is observable, and it is used to achieve an efficient input supply by the wellowner.

Equation (11) states how the risk is shared between the two parties. One can think of $\frac{E\left[v'G^o\right]}{E\left[v'\right]} - E\left[G^o\right]$ and $\frac{E\left[u'G^o\right]}{E\left[u'\right]} - E\left[G^o\right]$ as the buyer's and the seller's risk premiums, respectively, since if both of them were risk neutral, $\frac{E\left[v'G^o\right]}{E\left[v'\right]}$ and $\frac{E\left[u'G^o\right]}{E\left[u'\right]}$ would reduce to $E\left[G^o\right]$. Thus, the condition states that the contract should yield the same risk premium for the two parties. But this in turn implies that the risky income generated under the contract is optimally (efficiently) shared between the two parties. To see why, consider, for example, a

[26] See Braverman and Stiglitz (1986).

contractual arrangement under which $\frac{E\left[v'G^o\right]}{E\left[v'\right]} < \frac{E\left[u'G^o\right]}{E\left[u'\right]}$. This constellation means that an additional marginal unit of risky income will 'cost' the buyer less than the seller, which cannot be optimal. Therefore, it would increase efficiency to transfer risky income from the buyer to the seller until $\frac{E\left[v'G^o\right]}{E\left[v'\right]} = \frac{E\left[u'G^o\right]}{E\left[u'\right]}$. Optimal risk sharing is achieved in this case, because the necessity to transfer risk is unaffected by incentive effects.

Proposition 2. *Under the optimal contract, the output produced with the groundwater is shared among the buyer and the seller in the same proportion as the costs of groundwater extraction. The seller chooses the amount of groundwater such that* $f'\left(R + G(\alpha^o, \beta^o)\right) = c$. *Finally, risk is optimally shared between the two parties.*

From (9) and (11) it is clear that the particular values of α, β, and γ depend on the parties' degrees of risk aversion. But since nothing more can be said about the characteristics of the solution in general, we now proceed to analyze particular utility functions.

3.3.2 Exponential utility

Assume that both the buyer and the seller have a utility function of the CARA (constant absolute risk aversion) form, $v\left(Y^B\right) = -e^{-aY^B}$ and $u\left(Y^S\right) = -e^{-aY^S}$ respectively, where a is the coefficient of absolute risk aversion which for the beginning is assumed to be the same for both parties. Now, from (10), (11) and the first order condition of the seller, we can derive

$$\frac{\int_0^{\bar{R}} \exp\left[-a\beta R\right] R h(R)\, dR}{\int_0^{\bar{R}} \exp\left[-a\beta R\right] h(R)\, dR} = \frac{\int_0^{\bar{R}} \exp\left[a(\beta - c) R\right] R h(R)\, dR}{\int_0^{\bar{R}} \exp\left[a(\beta - c) R\right] h(R)\, dR}. \tag{12}$$

From (12), proposition 3 follows immediately, on condition that the solution to (12) is unique.[27]

<u>Proposition 3.</u> *If the buyer and the seller have identical utility functions satisfying CARA, the optimal contract is such that*

$$\alpha^o = \frac{1}{2}, \qquad \beta^o = \frac{c}{2}.$$

Notice, that this result is independent of the distribution of the amount of rainfall. Since there are no wealth effects by virtue of CARA, the parameters which determine how the risk is shared under the optimal contract are independent of the risky income (and its determinants) realized under the contract. However, not independent of the rainfall distribution is the unrestricted transfer payment. Using (9) and the results from proposition 3, we can derive

<u>Proposition 3a.</u> *If the buyer and the seller have identical utility functions satisfying CARA, the optimal unrestricted transfer payment is*

$$\gamma^o = \frac{1}{2a}\ln\left(\int_0^{\bar{R}} \exp\left[-af(R)\right]h(R)\,dR\right),$$

where $\int_0^{\bar{R}} \exp\left[-af(R)\right]h(R)\,dR$ *is the risky part of the buyer's expected disagreement payoff.*

Notice, that the optimal unrestricted transfer payment is not chosen to equalize the gains from cooperation, i.e. to achieve $\Delta\tilde{V}\left(Y^B\right) = \Delta\tilde{U}\left(Y^S\right)$, but it is chosen to equalize the gains from cooperation weighted by the marginal expected utilities, i.e.

[27] Conditions for the solution to (11) to be unique are stated in the appendix.

$E[v']\Delta\tilde{U}(Y^S)=E[u']\Delta\tilde{V}(Y^B)$, since both parties are risk averse. Thus, the first-best outcome where $\Delta\tilde{V}(Y^B)=\Delta\tilde{U}(Y^S)$ is not achieved by the contract due to the risk aversion of the parties.

Using the results from propositions 3 and 3a, the state-dependent incomes of the buyer and the seller under the optimal contract are:

$$Y_R^B=\frac{1}{2}\left[f-cG^o\right]-\frac{1}{2a}\ln\left[\int_0^{\bar{R}}\exp\left[-af(R)\right]h(R)dR\right]+\bar{Y}^B$$

$$Y_R^S=\frac{1}{2}\left[f-cG^o\right]+\frac{1}{2a}\ln\left[\int_0^{\bar{R}}\exp\left[-af(R)\right]h(R)dR\right]+\bar{Y}^S.$$

That is, in the case of identical CARA utility functions, the output and the costs for the input in question are shared equally between the buyer and the seller, and as a consequence the seller delivers the efficient amount of groundwater. Now consider the expression for the optimal transfer payment, which can be positive or negative, and depends on the degree of risk aversion and on the risky part of the disagreement payoff of the buyer. The sign of this transfer payment will depend on whether $\int_0^{\bar{R}}\exp\left[-af(R)\right]h(R)dR=\int_0^{\bar{R}}\left|-\exp\left[-af(R)\right]\right|h(R)dR \gtreqless 1$. The bigger the absolute value of this expression, the smaller is the buyer's expected utility in the alternative case where he has no contract with the seller. That is, the smaller the buyer's alternative expected utility, the higher is the transfer payment he has to make to the seller, or the smaller is the transfer payment he receives from the seller, depending on whether the absolute value of his alternative expected utility is bigger or smaller than one. If this alternative expected utility is equal to one, there will be no transfer payment. Considering the effect of change of the degree of risk aversion *a* on the transfer payment, thereby neglecting the indirect effect which is caused by changes in the expected disagreement payoff of the buyer, we find that the absolute values of the transfer payments are the smaller the higher the degrees of risk aversion of the contracting parties. This can be interpreted as a risk premium which each party is willing to pay in order to avoid to bear all risk alone. The said risk premium is increasing in the degree of risk aversion.

To see how particular parameters influence the transfer payment, consider some comparative static results:

$$\frac{\partial \gamma^o}{\partial a} = -\frac{1}{2a^2}\ln\left[\int_0^{\bar{R}} \exp\left[-af\left(R\right)\right]h\left(R\right)dR\right] - \frac{1}{2a}\frac{\int_0^{\bar{R}} f\left(R\right)\exp\left[-af\left(R\right)\right]h\left(R\right)dR}{\int_0^{\bar{R}} \exp\left[-af\left(R\right)\right]h\left(R\right)dR}$$

The second term in this expression is always bigger than zero, whereas the sign of the first term again depends on whether the buyer's alternative expected utility is smaller or bigger than one in absolute terms. The smaller the buyer's alternative expected utility is, the more likely is the first term to be negative, and therefore the more likely is γ^o to be decreasing in *a*. The first term is the direct 'risk premium' effect of *a* on γ^o and the second term is the indirect effect which arises, because the degree of absolute risk aversion has a positive influence on the buyer's alternative expected utility.

To investigate the effect of a change in the rainfall distribution, assume, for example, that the amount of rainfall is uniformly distributed on the interval $\left[0, \bar{R}\right]$ which implies that the density function is $h\left(R\right) = \frac{1}{\bar{R}}$. Differentiating γ^o with respect to $\bar{R}$ we have

$$\frac{\partial \gamma^o}{\partial \bar{R}} = \frac{1}{2a}\frac{1}{\bar{R}}\left\{-1+\frac{\exp\left[-af\left(\bar{R}\right)\right]}{\int_0^{\bar{R}}\exp\left[-af\left(R\right)\right]\frac{1}{\bar{R}}dR}\right\} > 0,$$ since

$$\exp\left[-af\left(\bar{R}\right)\right]-\int_0^{\bar{R}}\exp\left[-af\left(R\right)\right]\frac{1}{\bar{R}}dR > 0.$$

Thus, for a rainfall distribution with higher mean and higher variance which first-order stochastically dominates the other, the buyer has to make a higher transfer payment to the seller, or receives a smaller transfer payment from the latter, depending on whether γ^o is positive or negative. That is, a change in the distribution which makes the buyer better off in the case of no contract, results in a higher transfer payment from the buyer to the seller under the contract. This somewhat puzzling result is a consequence of the maximization of the product of the gains from cooperation.

Now consider the more realistic case in which the utility functions still exhibit CARA, but the buyer and the seller have different coefficients of absolute risk aversion. Let the utility functions be $v\left(Y^B\right) = -e^{-aY^B}$ and $u\left(Y^S\right) = -e^{-bY^S}$, respectively, where a and b are the coefficients of absolute risk aversion. Then, again, from (9), (10), (11), and the first order condition for the seller we can derive the following result:

<u>Proposition 4.</u> *For CARA and different degrees of absolute risk aversion the optimal contract is such that*

$$\alpha^o = \frac{a}{a+b}, \qquad \beta^o = \frac{b}{a+b}c.$$

The intuition behind proposition 4, as well as behind propositions 3 and 3a, is, that the optimal contract requires production efficiency, that is $f'\left(W^o\right) = c$, and that, taking into account the risk aversion of the two parties, α and β must be chosen accordingly. Therefore, from proposition 4 and (2), we have $\frac{a}{a+b}f'+\frac{bc}{a+b}=c$, as required.

Notice that in this little more complicated setting an explicit solution for γ cannot be derived. However, the expressions for α and β in the case of different degrees of risk aversion give a more detailed insight in the nature of the optimal contract than in the case of identical degrees of risk aversion. Consider first the expression for the optimal output share: The higher the degree of risk aversion of the buyer and the smaller the degree of risk aversion of the seller, the higher is the output share which the seller receives. At the same time, the fixed payment per unit of groundwater paid by the buyer is decreasing in the degree of risk aversion of the buyer and increasing in the degree of risk aversion of the seller. In general, the optimal contract is such that the less risk averse party bears a larger proportion of the costs of the ex ante random groundwater production while, ex post, the output is made certain by the wellowner's choice in the third stage. If the wellowner is risk neutral and the farmer is risk averse, the wellowner receives the entire crop output, carries all the costs of producing the groundwater, and there is a fixed payment between the wellowner and the farmer which serves as an instrument to transfer utility. In this case the transfer payment γ must have a negative sign because otherwise the contract would not be attractive for the buyer. If on the other hand the farmer is risk neutral, and the wellowner is risk averse, the farmer receives the entire crop output and carries all the costs of producing the groundwater. Again utility is transferred through the fixed payment which now must have a positive sign.

Given the optimal contractual parameters in the setting with CARA and different degrees of absolute risk aversion, the state-dependent incomes for the buyer and the seller are:

$$Y_R^B=\frac{b}{a+b}\left(f-cG^o\right)-\gamma^o+\overline{Y}^B$$

and

$$Y_R^S = \frac{a}{a+b}\left(f - cG^o\right) + \gamma^o + \overline{Y}^S .$$

That is, in each state of nature the risky surplus is shared between the wellowner and the farmer in a proportion which reflects their respective degrees of absolute risk aversion: if the seller is less risk averse than the buyer, the seller receives a larger share of the risky surplus than the buyer and vice versa. Reallocations of utility resulting from the risk-sharing arrangement are dealt with by the unrestricted transfer payment.

3.3.3 Logarithmic utility

As we have shown above, in the case of CARA the cropshare depends only on the degrees of risk aversion of the contracting parties. Now consider the case of a utility function which exhibits constant relative risk aversion (CRRA) for both the seller and the buyer. More specifically, we assume that $v\left(Y^B\right) = \ln Y^B$ and $u\left(Y^S\right) = \ln Y^S$. In this setting too, propositions 1 and 2 remain valid and we only have to reconsider expression (11), which states how the risk is shared between the contracting parties. Again assuming a uniform distribution of *R* on $\left[0, \overline{R}\right]$, we can rewrite (11) as

$$\frac{\int_0^{\overline{R}} v'\left(Y^B\right) G^o \frac{1}{\overline{R}} dR}{\int_0^{\overline{R}} v'\left(Y^B\right) \frac{1}{\overline{R}} dR} = \frac{\int_0^{\overline{R}} u'\left(Y^S\right) G^o \frac{1}{\overline{R}} dR}{\int_0^{\overline{R}} u'\left(Y^S\right) \frac{1}{\overline{R}} dR},$$

which can be simplified to

$$\frac{\int_0^{\overline{R}} v'\left(Y^B\right) R dR}{\int_0^{\overline{R}} v'\left(Y^B\right) dR} = \frac{\int_0^{\overline{R}} u'\left(Y^S\right) R dR}{\int_0^{\overline{R}} u'\left(Y^S\right) dR}.$$

Using logarithmic utility, integrating, and rearranging terms gives

$$\frac{\beta\left(\alpha f+\gamma+\overline{Y}^S\right)+\left(\beta-c\right)\left((1-\alpha)f-\gamma+\overline{Y}^B\right)}{\left(\beta-c\right)\beta}=$$

$$\overline{R}\frac{\ln\left(\dfrac{\alpha f+(\beta-c)G^0+\gamma+\overline{Y}^S}{\alpha f+(\beta-c)(G^0-\overline{R})+\gamma+\overline{Y}^S}\dfrac{(1-\alpha)f-\beta(G^0-\overline{R})-\gamma+\overline{Y}^B}{(1-\alpha)f-\beta G^0-\gamma+\overline{Y}^B}\right)}{\ln\left(\dfrac{\alpha f+(\beta-c)G^0+\gamma+\overline{Y}^S}{\alpha f+(\beta-c)(G^0-\overline{R})+\gamma+\overline{Y}^S}\right)\ln\left(\dfrac{(1-\alpha)f-\beta(G^0-\overline{R})-\gamma+\overline{Y}^B}{(1-\alpha)f-\beta G^0-\gamma+\overline{Y}^B}\right)}\,. \quad (13)$$

One solution of (13) is characterized by the following condition:

$$\left(\beta-(1-\alpha)c\right)f+\gamma c+\beta\overline{Y}^S+(\beta-c)\overline{Y}^B=0 \quad (14)$$

because, if equation (14) holds, the numerators of both the left hand side and the right hand side of equation (13) vanish. Since, in the optimal contract, we have $\beta^o=(1-\alpha^o)c$, from (14) we can derive $\gamma^o=\alpha^o\overline{Y}^B-(1-\alpha^o)\overline{Y}^S$. This together with the state-dependent incomes for the buyer and the seller leads to

Proposition 5. *If the buyer and the seller have identical logarithmic utility functions and the amount of rainfall is uniformly distributed on* $\left[0,\overline{R}\right]$*, the optimal contract is such that both the buyer and the seller receive a prespecified share of the total income which is generated under the terms of the contract in each state of nature, that is,* $Y^{Bo}=(1-\alpha^o)Y^o$ *and* $Y^{So}=\alpha^oY^o$*, where* $Y^o=f-c\left(G^o-R\right)+\overline{Y}^B+\overline{Y}^S$.

This result is in contrast to the findings of Propositions 3 and 4 where the optimal values of the cropshare and of the fixed payment per unit groundwater were determined independently of the transfer payment. The cropshare and the costshare depended only on the degrees of risk aversion; all other factors which play a role in the bargaining over the contract terms were captured by the transfer payment. In the special case considered in this section, in contrast, the cropshare and the costshare cannot be determined independently of the transfer payment, from which it follows that, in this setting, we will be able to explain how the cropshare depends on the certain incomes and the distribution of the rainfall. Since we consider only linear contracts, the contractual parameters α , β, and γ are not allowed to vary with the state-dependent incomes of the buyer and the seller, which is the reason why both risk averse parties receive fixed shares of the random cake.

Since $Y^o = Y^{Bo} + Y^{So}$ and since, in equilibrium, the coefficients of absolute risk aversion of the buyer and the seller are in this special case $RA^B\left(Y^{B^o}\right)=\frac{1}{Y^{B^o}}$ and $RA^S\left(Y^{S^o}\right)=\frac{1}{Y^{S^o}}$, respectively, we can write $\alpha^o = \frac{RA^B\left(Y^{Bo}\right)}{RA^B\left(Y^{Bo}\right)+RA^S\left(Y^{So}\right)}$. Strictly speaking, this is a tautology, stating for example that, if the cropshare is close to unity, the state-dependent income of the buyer is very small, which in turn implies that his coefficient of absolute risk aversion is very high whereas the state-dependent income of the seller is relatively high, and his coefficient of absolute risk aversion is rather small, from which it follows that the right hand side of the expression is also near to 1. One can see from the above expression that also in the case of logarithmic utility functions the seller's optimal cropshare depends on the degrees of absolute risk aversion of the contracting parties, but since in this case risk aversion varies with income, the cropshare is not independent of factors which determine the conditions under which the contract is made.

To characterize the solution for α, we substitute the results of proposition 5 for the state-dependent incomes of the buyer and the seller into the first-order condition for γ to obtain

$$\frac{\alpha^o}{1-\alpha^o}=\frac{\ln\left(1-\alpha^o\right)+\int_0^{\overline{R}}\ln Y^o\frac{1}{\overline{R}}dR-\int_0^{\overline{R}}\ln\left(f(R)+\overline{Y}^B\right)\frac{1}{\overline{R}}dR}{\ln\alpha^o+\int_0^{\overline{R}}\ln Y^o\frac{1}{\overline{R}}dR-\ln\overline{Y}^S} \tag{15}$$

Since there is no explicit solution for α^o, we use comparative statics to identify the factors on which the optimal value of α depends. Notice, first, that it is obvious from equation (15) that - in spite of the fact that we have assumed identical utility functions for the buyer and the seller - α is not equal to one half unless both parties' disagreement payoffs are equal, which is not surprising, since γ is no longer a pure transfer instrument. Now denote the disagreement payoffs to the buyer and the seller by $D^B = \int_0^{\overline{R}} \ln\left(f(R) + \overline{Y}^B\right)\frac{1}{\overline{R}}dR$ and $D^S = \ln \overline{Y}^S$, respectively, and the expected contract income at the optimum by $E\left[Y^o\right] = \int_0^{\overline{R}} \ln Y^o \frac{1}{\overline{R}} dR$. Then (15) can be rewritten as

$$\alpha^o \overline{R} \ln \alpha^o - (1-\alpha^o)\overline{R} \ln(1-\alpha^o) + (2\alpha^o - 1)E\left[Y^o\right] + (1-\alpha^o)D^B - \alpha^o D^S = 0 \qquad (16)$$

and the following comparative static results with respect to c, $\overline{R}$, $\overline{Y}^B$, and $\overline{Y}^S$ obtained:

$$\frac{\partial \alpha}{\partial c} = \frac{-(2\alpha - 1)\dfrac{\partial E\left[Y^o\right]}{\partial c}}{\det} \lesseqgtr 0 \quad \Leftrightarrow \quad \frac{1}{2} \lesseqgtr \alpha \qquad (17)$$

$$\frac{\partial \alpha}{\partial \overline{R}} = \frac{-(2\alpha - 1)\dfrac{\partial E\left[Y^o\right]}{\partial \overline{R}} - (1-\alpha)\dfrac{\partial D^B}{\partial \overline{R}} - \alpha \ln \alpha + (1-\alpha)\ln(1-\alpha)}{\det} \qquad (18)$$

$$\frac{\partial \alpha}{\partial \overline{Y}^B} = \frac{-(2\alpha - 1)\dfrac{\partial E\left[Y^o\right]}{\partial \overline{Y}^B} - (1-\alpha)\dfrac{\partial D^B}{\partial \overline{Y}^B}}{\det} \qquad (19)$$

$$\frac{\partial \alpha}{\partial \overline{Y}^S} = \frac{-(2\alpha - 1)\dfrac{\partial E\left[Y^o\right]}{\partial \overline{Y}^S} + \alpha\dfrac{\partial D^S}{\partial \overline{Y}^S}}{\det} \qquad (20)$$

where $\det = 2\overline{R} + \ln \alpha + \ln(1-\alpha) + 2E\left[Y^o\right] - D^B - D^S$ is the determinant of the Hessian of the related optimization problem. For the solution to be a maximum, the Hessian has to be negative semi-definite, that is, we have $\det < 0$. We further know that

$$\frac{\partial E\left[Y^o\right]}{\partial c} = -\int_0^{\overline{R}} \frac{1}{Y^o}\left(G^0 - R\right)\frac{1}{\overline{R}}dR < 0,$$

$$\frac{\partial E\left[Y^o\right]}{\partial \overline{R}} = \frac{1}{\overline{R}}\left\{\ln Y^o(\overline{R}) - \int_0^{\overline{R}} \ln Y^o(R)\frac{1}{\overline{R}}dR\right\} > 0,$$

$$\frac{\partial D^B}{\partial \overline{R}} = \frac{1}{\overline{R}}\left\{\ln\left(f(\overline{R}) + \overline{Y}^B\right) - \int_0^{\overline{R}} \ln\left(f(R) + \overline{Y}^B\right)\frac{1}{\overline{R}}dR\right\} > 0,$$

$$\frac{\partial E\left[Y^o\right]}{\partial \overline{Y}^B} = \frac{\partial E\left[Y^o\right]}{\partial \overline{Y}^S} = \int_0^{\overline{R}} \frac{1}{Y^o\overline{R}}dR > 0,$$

$$\frac{\partial D^B}{\partial \overline{Y}^B} = \int_0^{\overline{R}} \frac{1}{\left(f(R) + \overline{Y}^B\right)\overline{R}}dR > 0 \text{ and}$$

$$\frac{\partial D^S}{\partial \overline{Y}^S} = \frac{1}{\overline{Y}^S} > 0.$$

At first glance, we can only say that (17), (18), (19), and (20) may have either sign depending on the optimal value of α. An interesting value of α at which to evaluate the above derivatives is $\alpha = \frac{1}{2}$. It was said above, that this is an unlikely optimal value for α since this will hold only if both parties have the same disagreement payoff. But since $\alpha = \frac{1}{2}$ is the value of the seller's cropshare which is the most frequently observed in real world contracts, we think that one can gain some further insights into the nature of groundwater contracts by using this evaluation point. Then we have:

$$\left.\frac{\partial \alpha}{\partial c}\right|_{\alpha=0.5} = 0,$$

$$\left.\frac{\partial \alpha}{\partial \overline{R}}\right|_{\alpha=0.5} = \frac{-\frac{1}{2}\frac{\partial D^B}{\partial \overline{R}}}{\det} > 0,$$

$$\left.\frac{\partial \alpha}{\partial \overline{Y}^{B}}\right|_{\alpha=0.5} = \frac{-\frac{1}{2}\frac{\partial D^{B}}{\partial \overline{Y}^{B}}}{\det} > 0 \text{ and}$$

$$\left.\frac{\partial \alpha}{\partial \overline{Y}^{S}}\right|_{\alpha=0.5} = \frac{\frac{1}{2}\frac{\partial D^{S}}{\partial \overline{Y}^{S}}}{\det} < 0 .$$

Further, since $\beta^{o} = (1-\alpha^{o})c$, we have

$$\left.\frac{\partial \beta}{\partial c}\right|_{\alpha=0.5} = \frac{1}{2} > 0 ,$$

$$\left.\frac{\partial \beta}{\partial \overline{R}}\right|_{\alpha=0.5} < 0 ,$$

$$\left.\frac{\partial \beta}{\partial \overline{Y}^{B}}\right|_{\alpha=0.5} < 0 \text{ and}$$

$$\left.\frac{\partial \beta}{\partial \overline{Y}^{S}}\right|_{\alpha=0.5} > 0 .$$

We can summarize these results in the following proposition.

Proposition 6. *Consider a situation in which the output is shared equally between the buyer and the seller, and in which the rainfall is uniformly distributed on the interval* $\left[0, \overline{R}\right]$. *Then the seller's optimal cropshare is*

(i) increasing in the buyer's certain income,

(ii) decreasing in the seller's certain income,

(iii) increasing in the upper bound of the rainfall distribution,

and the optimal fixed payment per unit groundwater is

(i) decreasing in the buyer's certain income,

(ii) increasing in the seller's certain income,

(iii) decreasing in the upper bound of the rainfall distribution.

As far as $\frac{\partial \alpha}{\partial \overline{R}}$ and $\frac{\partial \alpha}{\partial \overline{Y}^B}$ are concerned, the above results hold for all cropshares where $\frac{1}{2} \leq \alpha < 1$. For $0 < \alpha < \frac{1}{2}$, the sign is not clear. For $\frac{\partial \alpha}{\partial \overline{Y}^S}$ the above results hold for all cropshares for which $0 < \alpha \leq \frac{1}{2}$, whereas for $\frac{1}{2} < \alpha < 1$ the sign depends on whether the effect on the contractual income or the effect on the disagreement payoff is more pronounced.

How do these results compare to empirical observation? Concerning the amount of rainfall, in areas with a relatively high annual amount of rainfall, sharecropping contracts for groundwater transactions are rare, or non-existent, while the selling of groundwater against a fixed rate per unit is very common. On the other hand, in areas with relatively little rainfall over the year, farmers frequently rely on the use of share contracts as a mode of payment for groundwater transactions. In these areas, fixed rate payments are used only in a few cases, especially if the buyer is in need of only a small number of irrigations. As it was mentioned in section 3.2, it seems that this pattern can be explained empirically by the risk aversion and/or the wealth-constrainedness of the farmers.

In the model considered in this section, however, at least for some optimal values of the cropshare, the results are just the opposite: For example, a 'better' distribution of the amount of rainfall leads to a higher cropshare for the seller (starting from a point where the cropshare is equal to one half). How can this be explained? The reasoning for the optimal cropshare of the seller to rise as $\overline{R}$ increases goes as follows: a 'better' (first-order stochastically dominating) distribution of R raises the total income from the optimal contract and the bargaining power of the buyer by raising his disagreement payoff (or his non-contractual income) while the bargaining power (the non-contractual income) of the seller remains unchanged. But that means that the seller's gains from cooperation will rise, whereas the buyer's gains from cooperation will rise less than the seller's, remain constant, or may even fall. But at the same time, the optimality condition $E[v']\Delta\tilde{U}\left(Y^S\right)=E[u']\Delta\tilde{V}\left(Y^B\right)$ must hold. Therefore, the expected marginal utilities of both parties must be adjusted accordingly, which in this case requires Y^{B^o} to rise and Y^{S^o} to fall. Under the contract, this is achieved by lowering α and increasing β. But since in this case, other than in the case of constant absolute risk aversion, the transfer of wealth cannot be separated from the sharing of risk, the adjustment of α cannot be done without taking into account another condition: The optimality condition in (11) states that for a contract to be optimal, there has to be efficient risk sharing, which means that the 'utility discount rates' of both parties must be equalized. Since in the case of a logarithmic utility function absolute risk aversion is not constant but rather varies with the level of income, the adjustment of α required above leads to an imbalance between the two risk premiums: $\frac{E\left[u'G^o\right]}{E[u']}<\frac{E\left[v'G^o\right]}{E[v']}$. To dissolve this imbalance, the seller's cropshare has to rise again. In the case that we consider here, where the starting point is $\alpha^o=\frac{1}{2}$, this rise is overcompensating the previous fall, resulting in $\left.\frac{\partial\alpha}{\partial\bar{R}}\right|_{\alpha=0.5}>0$ The same argument holds for an increasing certain income of the buyer; for an increasing certain income of the seller, the argument goes the opposite way. In the case of CARA examined further above, the optimal cropshare is affected neither by certain incomes nor the distribution function for the amount of rainfall; for in that case, the coefficient of absolute risk aversion is income-independent.

To summarize, we find that, in a model with two risk averse parties, an observable but not enforceable input and constant marginal costs for this input, the outcome implies an efficient supply of groundwater to the farmer's field. This is a consequence of the observability of the crucial input, namely groundwater, because in the case of a perfectly observable input there are three instruments which can be used in a linear contract: an output share, a fixed payment per each unit of the input, and an unrestricted transfer payment. The combination of an output share and a fixed payment per unit of the input allows the choice of a contract in which the costs of extracting groundwater are shared in the same proportion as the output produced with this groundwater. As a consequence, the wellowner chooses the efficient amount of groundwater. Since, by assumption, we ruled out corner solutions for the amount of groundwater due to too much rainfall, all natural uncertainty is resolved by the time the decision to supply groundwater must be made. In this sense, there is never any 'regret' about G^o, only about (α, β, γ).

3.3.4 The case of only two contractual parameters

An unrestricted transfer payment is not observed in real world contracts, at least not in an explicit monetary form. It is possible that such transfers are made in a different way, for example, by one party delivering services such as field labour or draught power to the other[28]; but transactions of this kind are rather seldom reported. As mentioned above, the existence of a transfer payment is crucial for the result that the optimal parameter values of α and β depend on only the degrees of risk aversion of the seller and the buyer and do not contain any terms which are related to the provision of incentives or the need to transfer utility. Since, in reality, we observe no pure transfer payments, it is of some interest to characterize the solution for the model given if the set of contractual parameters chosen in the bargaining process is limited to a cropshare and a fixed payment per unit.

[28] This services can be lump-sum transfers. It could be negotiated at the beginning of the season, for example, that one party may use the bullock pair of the other party for ten days.

Setting γ equal to zero in the income equations for the buyer and the seller, we can employ the model developed above without other modifications. Again the product of the utility differences is maximised, but this time only with respect to α and β:

$$\max_{\alpha,\beta} \Delta\widetilde{V}\left(Y^B\right)\Delta\widetilde{U}\left(Y^S\right) \tag{21}$$

$$\text{s.t.} \qquad \alpha \in [0,1], \qquad \beta \geq 0,$$

which yields the first-order conditions

$$E[v']\left(-f + \frac{\partial G}{\partial \alpha}\left((1-\alpha)f_W - \beta\right)\right)\Delta\widetilde{U}\left(Y^S\right) + E[u']f\Delta\widetilde{V}\left(Y^B\right) \leq 0, \quad \alpha \geq 0 \tag{22}$$

$$\left\{E[v']\frac{\partial G}{\partial \beta}\left((1-\alpha)f_W - \beta\right) - E[v'G]\right\}\Delta\widetilde{U}\left(Y^S\right) + E[u'G]\Delta\widetilde{V}\left(Y^B\right) \leq 0, \quad \beta \geq 0 \tag{23}$$

Consider first the case where $\alpha = 0$ and $\beta > 0$. From the seller's first-order condition we then have $\beta = c$, which in turn implies that $\Delta\widetilde{U}\left(Y^s\right) = 0$. This cannot be optimal because every contract which splits the entire surplus in a way that both parties gain would yield a higher value of the product of the utility differences. Now assume that $\alpha > 0$ and $\beta = 0$. Then from (22) and (23) we have

$$\frac{\left(\frac{\partial G}{\partial \beta}(1-\alpha)f_W - E[G]\right)f}{\frac{\partial G}{\partial \alpha}(1-\alpha)f_W - f} \geq \frac{E[u'G]}{E[u']}.$$

Since, in this case, u' and G are positive correlated, the inequality $\frac{E[u'G]}{E[u']} > E[G]$ holds[29].

Now consider the condition

$$\frac{\left(\frac{\partial G}{\partial \beta}(1-\alpha)f_W - E[G]\right)f}{\frac{\partial G}{\partial \alpha}(1-\alpha)f_W - f} \geq E[G],$$

which would characterize the solution for a risk neutral seller. Substituting $\frac{\partial G}{\partial \alpha}$ and $\frac{\partial G}{\partial \beta}$ from above, we get, after some manipulation, $f_W \geq \frac{f}{E[G]}$, which is a contradiction because of the concavity of the production function. Moreover, if we have a contradiction for a risk neutral seller, we also have a contradiction for a risk averse seller because $\frac{E[u'G]}{E[u']} > E[G]$. It follows that the optimal contract contains a positive cropshare and a fixed payment per unit. In this case, from (22) and (23) we have

$$\frac{E[v']\frac{\partial G}{\partial \beta}\left((1-\alpha)f_W - \beta\right) - E[v'G]}{E[v']\frac{\partial G}{\partial \alpha}\left((1-\alpha)f_W - \beta\right) - E[v']f} = \frac{E[u'G]}{E[u']f}. \tag{24}$$

Equation (24) shows that in the absence of a fixed transfer payment, the other two contractual parameters depend on the terms reflecting the incentive effects of the parameters if an efficient use of water cannot be guaranteed.[30] If, on the other hand, incentive problems are not to taken into account, i.e. if an efficient choice of the amount of groundwater by the

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[29] $E\left[(u' - E[u'])(G - E[G])\right] = E[u'G] - E[u']E[G] > 0$.

[30] Efficiency would imply that $(1-\alpha)f_W - \beta = 0$.

wellowner could be enforced, equation (24) reduces to $\frac{E[v'G]}{E[v']}=\frac{E[u'G]}{E[u']}$, which is the same optimality condition as in the model with a fixed transfer payment. In general, however, the equation $(1-\alpha)f_W-\beta=0$ does not hold in the case of only two contractual parameters, from which it follows that the solution for the cropshare and for the fixed payment per unit in this case will deviate from the solution in the case of three contractual parameters.[31]

3.4 Conclusion

The aim of this paper was to find an explanation for the fact that in some of the informal groundwater transactions observed in south-Indian villages the wellowner receives a share of the crop output in exchange for the groundwater delivered by him, whereas in other transactions the farmer keeps the entire crop output, and pays a fixed amount for each unit of groundwater the wellowner delivers. In a bargaining framework we showed that – depending on the shape of the utility functions of the buyer and the seller - important determinants of the choice of the contract form are the degrees of absolute risk aversion of the contracting parties in the case of exponential utility and factors that influence the contract-dependent as well as the contract-independent income of the parties, such as the distribution of the amount of rainfall, the marginal costs of groundwater extraction and the certain incomes of the buyer and the seller. Our results underline the fact that sharecropping arrangements in the context of informal groundwater markets, which in the empirical literature dealing with this phenomenon are often condemned as exploitative, are a powerful instrument to overcome inefficiencies which arise in a risky environment when there are incomplete or missing markets for the allocation of a scarce resource and for the allocation of risk, an imperfect

[31] This is the usual story in the literature on tenancy contracts when a full division of the not perfectly observable labour among instruments cannot be attained.

water market, or a missing insurance market on the village level. Our results also show, that under certain conditions even productive efficiency can be achieved by the use of groundwater share contracts.

The analysis of this paper is an important first step in understanding the choice of contracts in an agricultural economy where water is scarce and opens an entire research agenda in the field of agricultural contracts. Future research has to address questions such as how the allocation of groundwater is related to the allocation of land. How does the availability of irrigation water influence a farmer's decision to rent in or rent out land? What are the effects of an increasing density of wells in a village on the contract form chosen? How can the possibility of an overexploitation of the local groundwater resources be taken into account? What are the effects of wealth or credit constraints on the side of the water buyer? Most closely related to the research of this paper is the question how the timing of the farmer's decision on when to approach a wellowner for additional irrigation water can be endogenized and how this matters for the contract choice and for the efficiency achieved by the contract. The farmer's decision how long to wait before entering a contract potentially depends on his beliefs about the quantity of rainfall during the remainder of the growing season. If he decides to wait for future rainfall without entering a contract he has to take into account that the condition of his crop may worsen in the meantime because of a lack of water, which may negatively influence his future bargaining power. This timing consideration plays no role in the context of tenancy contracts, and addressing it may help to deepen the general understanding of how and under which circumstances share contracts can balance risk sharing considerations and incentive problems when markets are incomplete or missing.

Appendix

Conditions for a unique solution to (11):

Using the condition which must hold in the optimum, $\left(1-\alpha\right)=\frac{\beta}{c}$, we can write the state-dependent incomes of the buyer and the seller under the optimal contract as

$$Y^B=\beta\left(\frac{f}{c}-G^o\right)-\gamma+\bar{Y}^B \quad \text{and} \tag{25}$$

$$Y^S=\left(\beta-c\right)\left(-\frac{f}{c}+G^o\right)+\gamma+\bar{Y}^S. \tag{26}$$

Employing the envelope theorem, the derivatives of Y^B and Y^S with respect to β are

$$\frac{\partial Y^B}{\partial\beta}=\frac{f}{c}-G^o \gtreqless 0 \quad \Leftrightarrow \begin{cases} DRS \\ CRS \\ IRS \end{cases} \quad \text{and} \tag{27}$$

$$\frac{\partial Y^S}{\partial\beta}=-\frac{f}{c}+G^o \gtreqless 0 \quad \Leftrightarrow \begin{cases} IRS \\ CRS \\ DRS \end{cases}. \tag{28}$$

In the case of CARA, (11) can be shown to depend only on β. The solution for β will be unique, if the left-hand side of (11) is strictly increasing in β and the right-hand side is strictly decreasing in β, or vice versa.

$$\frac{\partial}{\partial\beta}\left(\frac{E\left[v'G^o\right]}{E\left[v'\right]}\right) \gtreqless 0 \quad \Leftrightarrow E\left[v'\right]E\left[v''\frac{\partial Y^B}{\partial\beta}G^o\right]-E\left[v'G^o\right]E\left[v''\frac{\partial Y^B}{\partial\beta}\right]+E\left[v'\right]^2\frac{\partial W^o}{\partial\beta} \gtreqless 0 \tag{29}$$

If we assume that the indirect effect, $E[v']^2 \frac{\partial W^o}{\partial \beta} > 0$, which arises because a change in β influences the seller's groundwater decision, can be neglected, then the sign of (29) depends on whether $E[v']E\left[v''\frac{\partial Y^B}{\partial \beta}G^o\right] - E[v'G]E\left[v''\frac{\partial Y^B}{\partial \beta}\right] \gtreqless 0$. This can be rewritten using (27) as

$$\frac{f}{c}\left(E[v']E\left[v''G^o\right] - E\left[v'G^o\right]E[v'']\right) + E\left[v'G^o\right]E\left[v''G^o\right] - E[v']E\left[v''\left(G^o\right)^2\right] \gtreqless 0 \qquad (30)$$

The first term of (30) is equal to zero, because for CARA $\frac{E\left[v'G^o\right]}{E[v']} = \frac{E\left[v''G^o\right]}{E[v'']}$. Therefore,

$$\frac{\partial}{\partial \beta}\left(\frac{E\left[v'G^o\right]}{E[v']}\right) \gtreqless 0 \quad \Leftrightarrow \quad \frac{E\left[v'G^o\right]}{E[v']} \lesseqgtr \frac{E\left[v''\left(G^o\right)^2\right]}{E\left[v''G^o\right]}. \qquad (31)$$

Since except for CRS, (27) and (28) will always have the opposite sign, for the risk premium of the seller we have

$$\frac{\partial}{\partial \beta}\left(\frac{E\left[u'G^o\right]}{E[u']}\right) \lesseqgtr 0 \quad \Leftrightarrow \quad \frac{E\left[u'G^o\right]}{E[u']} \lesseqgtr \frac{E\left[u''\left(G^o\right)^2\right]}{E\left[u''G^o\right]}. \qquad (32)$$

Thus, if $\frac{E\left[v'G^o\right]}{E[v']} < \frac{E\left[v''\left(G^o\right)^2\right]}{E\left[v''G^o\right]}$ $\forall Y^B$ and $\frac{E\left[u'G^o\right]}{E[u']} < \frac{E\left[u''\left(G^o\right)^2\right]}{E\left[u''G^o\right]}$ $\forall Y^S$, or if $\frac{E\left[v'G^o\right]}{E[v']} > \frac{E\left[v''\left(G^o\right)^2\right]}{E\left[v''G^o\right]}$ $\forall Y^B$ and $\frac{E\left[u'G^o\right]}{E[u']} > \frac{E\left[u''\left(G^o\right)^2\right]}{E\left[u''G^o\right]}$ $\forall Y^S$, then the solution to (11) in the case of CARA is unique.

4 Different input intensities on owned and sharecropped plots: The consequences of imperfect monitoring, cost sharing, and endogenous crop choice

4.1 Introduction

One of the crucial assumptions in most of the models dealing with the choice of contractual form in the market for tenancies in developing countries is whether the landlord can perfectly (costlessly) monitor the actions taken by his tenant. Under the assumption of prohibitively high costs of monitoring the tenant's activities, the so called 'Marshallian' approach, the theory predicts that the choice of a sharecropping contract will result in an inefficiently low amount of variable inputs applied to the rented land by the tenant, compared to the amount of variable inputs employed on owned land or on plots leased in under a fixed rent contract. If, in contrast, the landlord is able to effectively monitor the tenant's activities, as is assumed under the so called 'monitoring' approach, then the efficient amount of variable inputs per unit area can be stipulated in the contract, and there are no incentive problems to be dealt with, so that the cultivation of a plot under a share lease causes no inefficiencies compared with ownership cultivation or cultivation under a fixed rent lease. Since the predictions of the theory concerning such issues as the reasons for the existence of sharecropping arrangements and the efficiency of sharecropping depend crucially on the assumption whether perfect monitoring is possible or not (as well as on the assumptions describing the agents' risk taking behavior), and since it cannot be settled theoretically which of the two modelling approaches does more justice to the real world, it is essential to take a closer look at the empirical evidence.

This is far from being the first paper to investigate this question. An overview of the older existing literature is given by Hayami and Otsuka (1993), among the older contributions Shaban (1987) deserves special attention, and more recent work on the topic includes Raha (1991), Bell, Raha and Srinivasan (1995), and Acharya and Ekelund (1998).

In comparing the rates of difference in output per hectare of sharecropping from that of owner farming of 32 studies on the productive inefficiency of share contracts, Hayami and Otsuka (1993) find that the mean rate of difference for the studies where the comparisons are made in terms of single-crop output is not significantly different from zero, whereas if the comparisons are based on total output per hectare, the mean of the rates of differences is significantly different from zero in a direction which supports the Marshallian hypothesis. They state that in the latter case the distribution of the rates of differences is highly irregular, the irregularity stemming from differences in the production function due to differences in crop mix between sharecropping and owner-farming areas. They conclude that '...the significantly lower average output value per hectare for share-cropping than for owner-farming areas seems to reflect more of a difference in production functions than the existence of Marshallian inefficiency which refers to suboptimal labour input per hectare for the same production function'. The same argument holds for the comparisons of inputs.

To test whether the monitoring or the Marshallian hypothesis is valid, Shaban (1987) compares a family's average input and output intensities on owned and sharecropped land[32], an approach which controls for family-specific characteristics, such as management ability, access to non-traded inputs, risk aversion and prices of traded inputs and outputs. He regresses the differences of average input intensities on owned and sharecropped plots on plot-specific characteristics such as plot value, soil quality, and irrigation status, and on dummy variables for different villages. Using the plot-specific variables in the regression, he can test whether part of the differences in input and output intensities are attributable to these factors rather than the outcome of different incentives under owner cultivation and under share lease cultivation. The village dummies serve to proxy the variation in the cost-sharing rules across the villages, and thus have the function of capturing the effect on input and output differences which is caused by the contractual arrangement. Estimating a system of seemingly

[32] This comparison was first proposed by Bell (1977).

unrelated regression equations, Shaban finds empirical support for the Marshallian thesis.[33] Acharaya and Ekelund (1998) employ the same method as Shaban for a different data set, additonally controlling for crop variety and plot size, and also find evidence against the monitoring hypothesis.

A different approach is taken by Bell et al. (1995). They investigate whether the differences in resource allocation under share leases and self-cultivation are systematically related to the characteristics of the contracting parties. Their findings also favor the Marshallian hypothesis: In their study area, input intensities, yields and value added per hectare were all much lower on sharecropped than on owner-operated holdings, after controlling for sample selectivity in the choice of a contracting partner and differences in endowments, and even after ridding the data of fixed effects. But they also find that what they call 'matching' (finding a suitable partner to contract with) had the effect of alleviating the agency problems connected with a share lease, and that households made use of such matching to achieve an improvement in contractual performance.

Analyzing a household survey of rice-cultivating farmers from the Philippines, Sadoulet, de Janvry and Fukui (1997) find evidence that supports their hypothesis that sharecroppers who have a kinship relationship with their landlord behave efficiently in applying the socially optimum level of inputs and effort on their land, despite the disincentive effects caused by the sharing of output. But since the results of this study are not based on comparisons of the input and output intensities of households which cultivate both owned and

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[33] Hayami and Otsuka (1993) suggest that the studies of Bell (1977) and Shaban (1987) represent strong evidence for the inefficiency of share tenancy under institutional constraints on tenancy choice rather than evidence for the inefficiency of share tenancy in general. See Hayami and Otsuka (1993), pp.101-102 for details.

sharecropped plots, the authors are not able to control for unobserved household characteristics. Also, the authors did not investigate the question why some of the sharecroppers had a kinship relationship to their landlord, and why some of them did not. This could cause a sample selection problem.

The aim of the present paper is to make a contribution to the existing literature in the following respects. First, we reestimate Shaban's model, using data from a survey of 14 villages in Andhra Pradesh, India. A novel feature of these data is that, for each sharecropping contract, they contain the accompanying cost-sharing rules, so that we do not have to rely on village dummies if we aim to measure the effect of the contractual arrangement on input and output intensities. In an important extension of Shaban's model, we include crop dummies into the analysis. If one wants to compare an owner-sharecropper's performance on his owned and on his sharecropped plots, one has to average over the inputs and the output on all his sharecropped and on all his owned plots, with the side-effect that one also averages over different crop types. But this seems to be undesirable, since it is natural to assume that different crop types are produced with different technologies, as was already mentioned above. This fact would not cause a problem if all types of crops were grown in the same proportions on owned and sharecropped land. But if, as in this dataset, some crops are more extensively grown on sharecropped plots than on owned plots and vice versa, then not controlling for the crop type will lead to a distortion of the estimation results. In the light of this argument, Shaban's technique of using village dummies in order to control for the effect of share tenancy seems to be questionable, since instead of reflecting only the different cost-sharing rules across the villages, these dummies could just as well reflect different distributional pattern of crop types on owned and sharecropped plots between different villages. Indeed, we find that at least part of the differences between input intensities on owned and sharecropped land can be ascribed to different crops grown on these two arrangements.

We then extend our analysis of the differences between input intensities on owned and sharecropped plots to the class of owner-fixed-rent tenants in order to investigate whether there are also differences between input intensities under the latter pair of arrangements, and if there are differences, whether part thereof can be ascribed to the effects of tenancy, or whether the total differences can be explained by plot-specific factors or by different cropping patterns on owned and leased-in land. In this case, too, we find that different cropping patterns are one reason for different input intensities.

There is, however, a fundamental difficulty. If we employ indicator variables in the estimation for whether or not a crop is grown on a particular plot of a particular household, we encounter the problem that this set of crop dummy variables is not exogenously given, but is rather the result of an endogenous choice. If the choice of crops is endogenous and if the factors which determine it enter into the error terms in the estimation of the equations for the input differences (all unobserved household heterogeneity which influences owned and leased-in plots differently[34]), then not controlling for the endogeneity of crop choice will lead to inconsistent estimates for the parameters in the input-difference estimation. This presumption is confirmed by the data at least for the class of owner-sharecroppers: In the model which assumes that the crop variables are exogenous, the estimated coefficients for the

[34] Two papers which deal with the influence of the tenant's and the landlord's characteristics on the choice of the crop type grown and on the choice of the contract form are Bandiera (2000) and Ackerberg and Botticini (2002). The latter find out that different landlords and tenants match on different crop types, since different crops show different degrees of riskiness.

crop dummy variables are highly significant, whereas the coefficients for the cost share variable are not significant at all. By contrast, in the model which takes into account the endogeneity of crop choice, the influence of the crop dummy variables becomes less significant, whereas a statistically significant influence of the cost share variables can now be detected.

The remainder of the paper is organized as follows: section two describes the data and contains some descriptive statistics; in section three we lay out some known theoretical results on costsharing in sharecropping contracts and present an extension to them; section four describes the estimation methods and discusses the results; and section five concludes the paper.

4.2 Description of the data

The data we use come from a survey which was canvassed between November 1980 and May 1982 in Andhra Pradesh, India, covering two kharif seasons and one rabi season.[35] First, five districts were selected purposively. Then from these districts altogether 14 villages were selected, again purposively. Two villages are located in West Godavari district, four in Nalgonda district, two in Mahbubnagar district, two in Kurnool district, and four in Chittoor district. Further, "a census of all households in each village was carried out at the start of the survey period. Data were collected on each household's demographic and social characteristics, its primary and secondary occupations, its endowments of land, livestock and machinery, and the amount of land it was leasing in or out.

[35] The next three paragraphs describing the sampling process draw heavily on Bell, Raha and Srinivasan (1995), who use data for the Punjab from the same survey.

At the third stage of the sampling process, the census was used to assign all households to one of ten socio-economic categories, from which a total of forty households was drawn from each village. Owner-cultivators, owner-tenants and pure tenants were first ranked in order of their operational landholdings, and each category was then divided into three, three and two subgroups of equal size, respectively. One landlord and two owner-cultivators, two owner-tenants and two pure tenants were then drawn from each subgroup, all with probability proportional to the size of the landholding. The first household selected from each subgroup was assigned to a group of households whose activities in cultivation were followed in detail throughout the rabi season." (see Bell et al., pp. 3-4). This sub-sample comprises 213 households.

"The farm management questionnaire canvassed information on the crops grown, the inputs used and the resulting outputs, the unit of observation being the individual plot, as perceived and described by the respondent. The inputs fell into the following categories: seed, fertilizers and pesticides, family labor, hired labor, and draft power services (animals and tractors), each further subdivided by operation where appropriate. Inputs were valued at their transaction value if they were purchased. If they were supplied by the household itself and if the household had a closely related market transaction, the household's transaction unit value was used to make the imputation. Failing such a closely related transaction, the imputation was made on the basis of the prevailing rate in the village. The former imputation applied mostly to family labor; the latter to draftpower services – though the markets for these were very thin. The same method of valuation was also applied to the resulting output." (Bell et al., p. 5)

Next we present some summary statistics concerning the tenancy status and the operational landholdings of the households in the crop production schedule. There are 111 pure owner-cultivators, 39 owner-sharecroppers, 55 owner-tenants (farmers cultivating own land and having a fixed rent lease), 7 pure tenants, and only 1 pure sharecropper. Table 1 shows the average operational landholdings of households under different tenancy regimes. There are two things which attract attention: first, the own holdings of the owner-sharecroppers are smaller on average than their leased holdings, whereas for the owner-tenants this relation is the other way round. However, this difference is statistically significant only for the holdings of the owner-tenants (the p-value for the paired t-test is 0.0021 for the owner-tenants and 0.1862 for the owner-sharecroppers)[36]. Comparing the own holdings of owner-sharecroppers with the own holdings of owner-tenants one observes that the latter are bigger than the former, the difference being significant at the 5 percent level (p-value 0.0416). The comparison of the leased-in holdings of owner-sharecroppers and owner-tenants yields the opposite picture: owner sharecroppers seemed to lease in on average larger amounts of land than owner-tenants, but the difference is not significant at conventional levels (p-value 0.1444). The second striking feature is the similar 'farm size', i.e. the total operational landholdings, across the three different categories pure owners, owner-sharecroppers, and owner-tenants (the three respective hypotheses of equal farm sizes cannot be rejected). By leasing in and out land the households in the crop production schedule on average manage to reach an operational holding size between 4 and 4.5 acres which indicates that this amount of land represents something like an optimal farm size for a wide variety of circumstances. Of course, the exact individual farm size will depend on the particular household characteristics such as family labour, draught power, irrigation facilities, and risk taking behaviour. One may ask, why on average farmers with smaller own holdings end up with sharecropping contracts leasing in a larger amount of land than they own, whereas farmers with larger own holdings

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[36]For all the following t-tests, non-parametric tests (Wilcoxon signed rank, Wilcoxon rank sums) yield the same results.

end up with fixed rent contracts, leasing in a smaller amount of land than they own by themselves. One explanation for this pattern may be, that if tenants with larger own landholdings are also generally wealthier than tenants with smaller landholdings, and wealth can be seen as a proxy for the tenant's risk aversion[37], then theory predicts that more risk averse tenants will choose share contracts because these contracts serve as a risk sharing device, whereas less risk averse or risk neutral tenants will end up with fixed rent contracts because they provide superior incentives from the landlord's point of view. Another explanation could be that sharecropping contracts are predominant in some districts, and leasing under fixed rent in others. If these districts show different climatical or environmental conditions, these conditions could be the reason for the different amounts of land owned and leased-in. In our sample, fixed rent contracts are predominant in the two mechanized villages which are fully irrigated by a canal system and in which almost solely paddy is grown. In the less mechanized and less irrigated villages sharecropping is the most frequent contract form. But is it hard to find an explanation why in a better irrigated environment households should lease in less land than in a sparsely irrigated environment.

The irrigation status of a plot will play a crucial role in the decision which crop should be grown on this particular plot, and therefore will have an influence on the amount of inputs applied. It will also influence the amount of output produced if the crop is sensitive to water scarcity. Table 2 gives an overview of the irrigation status of the plots of the three subgroups pure owners, owner-sharecroppers, and owner-tenants. For all plots in the sample, the percentages for irrigated and unirrigated plots are not too far from one half, but the hypothesis that there are equal proportions of irrigated and unirrigated plots is rejected at the 1-percent level. Likewise, this hypothesis is rejected for all other categories at the 1-percent level,

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[37] See Ackerberg and Botticini (2002).

except for the category of shared plots of the owner-sharecroppers, where it can be rejected only at the 5-percent level. For the plots of the owner-sharecroppers, a slightly higher percentage of the shared than of the owned plots is irrigated, in both categories the unirrigated plots being in the majority. In contrast, the principal share of the plots in both categories for the owner-tenants is irrigated, but also a higher percentage of the leased than of the owned plots being irrigated. After having leased in some plots, the irrigation situation on the total landholdings of the owner-sharecroppers is more equalized than before leasing in, whereas for the total landholdings of the owner-tenants the proportion of irrigated to unirrigated plots is driven apart in favor of the irrigated plots. If a landlord wants his share-tenant to grow a water-intensive crop like paddy, which is often the case, than he must provide the tenant with a plot with a reliable source of irrigation, especially if sharecropping contracts are normally used in areas where not all land is irrigated by a canal system.

Table 2a describes the irrigation situation in the sample based on areas. Comparing the average irrigated and unirrigated farm areas for the different categories, we find a slightly different picture than for the plot-based comparisons. For all categories except the owner-fixed-rent categories the results do not change much. For the plot-based comparisons, the hypothesis of equal proportions could be rejected at the 1% level for all three owner-fixed-rent categories, whereas for the area-based comparisons, the hypothesis of equal irrigated and unirrigated farm areas cannot be rejected for any of these three categories. Further, on average 19 % of the area of the own holdings of owner-sharecroppers are irrigated, whereas on average 32 % of their sharecropped holdings are irrigated. Using a paired t-test, the hypothesis that these percentages are equal can be rejected only at the 10% level. For the owner-fixed-renters, on average 48 % of their own holdings and 56 % of their leased-in holdings are irrigated. The hypothesis that these percentages are equal cannot be rejected.

Table 3 and Table 4 list the main crops cultivated by owner-sharecroppers and owner-tenants, respectively, and reports the frequency with which the different crops are grown on owned and leased-in plots. Employing a chi-square-test to test whether there is a difference between owned and leased plots with respect to cropping patterns, we find that for the subgroup of owner-sharecroppers the null hypothesis of equal cropping patterns on owned and shared plots is rejected at the 5-percent level (p-value 0.0498), whereas for the owner-tenants the null hypothesis can not be rejected even at the 10-percent level (p-value 0.6196). There are also some other crops grown by both owner-sharecroppers and owner-tenants , for example, tomatoes and sugarcane, but we excluded all crops from the tables which showed frequencies less than 5 for both owned and leased-in land. Table 4a shows for each subgroup of land the percentages of land cultivated under different crops. From both the plot-based table and the area-based table it is clear that paddy and groundnut are the crop types which are the main reason for the different cropping patterns on owned and sharecropped plots: 27 % of the owned plots and 10 % of the owned land area is cultivated under paddy, whereas 43 % of the sharecropped plots and 26 % of the sharecropped area is under paddy cultivation. On the other hand, on 18 % of the owned plots and on 25 % of the owned area groundnuts are grown, whereas only on 10 % of the sharecropped plots and on 12 % of the sharecropped land groundnuts are grown. For cotton there is no remarkable difference for the plot-based comparison, but for the area-based comparison the difference is quite clear: 16 % of the sharecropped area is cultivated with cotton, but only 5 % of the owned area. For the owner-fixed-renters, the area-based table shows the same picture as the plot-based table: for none of the crop types there is a remarkable difference between owned and leased-in plots.

The preceding results are for each subgroup of plots as a whole. But for the individual farm, there may well be differences between the cropping patterns on owned and leased-in plots of the owner-fixed-rent tenants. Concerning the cropping patterns on owned and leased plots of the owner-tenants, one could argue that, apart from the physical characteristics of the plots, there is no reason why they should choose different cropping patterns on their owned and leased plots, for the landlord is not involved in the production process. Most of the fixed rents in this sample are paid in kind, however, so that the landlord should indeed have an interest in what kind of crop is cultivated on his leased-out plots. Since the owner-tenants have the best relation of irrigated to unirrigated plots for both leased and owned land, it seems to be natural that the main crop is paddy, whereas other less water-intensive crops are grown less frequently. In general, the cropping patterns on owned and leased-in plots for both types of tenants will depend on the endowment with production factors of both the landlord and the tenant.

Different cropping patterns on owned and shared plots will have an impact on the difference of average input intensities on owned and leased-in plots only if the technologies with which these crops are grown are different. To see whether this is the case or not, consider Table 5, where the mean input intensities for the most frequently grown crops in the crop production schedule are reported. At a first glance, one observes that it seems to be an untenable hypothesis that the different crops are produced with the same techniques. In order to support this observation statistically, we first conducted F-tests for all six input categories which in all cases led to a rejection at the 1-percent level of the hypothesis that the mean input intensities are equal for all crops. The next step was to use a Sidak (or Bonferroni)-test to make multiple pairwise mean comparisons for the different crops. The results, which also reject the hypothesis of identical production techniques for the crops in question, are presented in Table 6. We will elaborate later on these differences of mean input intensities when we take up the regression analysis.

We conclude this section by emphasizing again that there are statistically significant differences between the cropping patterns on owned and shared land as well as between the mean input intensities employed in producing different crops. Ignoring this fact can lead to the omission of relevant variables (i.e. crop dummies) from a regression analysis whose aim is to explain the differences in average input intensities on owned and sharecropped plots of the same household.[38]

4.3 The cost sharing argument

It is widely observed that besides the output in a share contract, the costs of at least one of the inputs, typically fertilizer, are shared between the landlord and the tenant. In our sample, too, most of the share contracts involved some cost-sharing. One question which is crucial for our analysis is whether there is an effect of cost-sharing on the intensity with which the inputs in question are applied to the crop, and how this effect works. A brief account of the relevant theory will help to clarify this point.[39]

It was long believed that, under certainty, a cost-sharing arrangement by which input costs are shared between the landlord and the tenant at the same rate as output would result in the optimum resource allocation, since the share tenant's disincentive to apply inputs under output sharing would be exactly offset by the subsidy to the input costs under the equal output and cost-sharing rule. But Braverman and Stiglitz (1986) make the point that if cost sharing is feasible, then it must be possible for the landlord to observe the level of inputs, and, if the level of inputs is observable, it is at least feasible that the contract specify the level of inputs. Given this, they show that with a linear sharecropping contract (comprising an output share, a

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[38] Shaban (1987) is aware of this potential problem. To assess its importance, he conducts a regression analysis for those households which cultivated Sorghum only. He finds that there is still an effect of tenancy.

[39] Surveys of the theoretical literature on cost-sharing are provided by Singh (1989) and Hayami and Otsuka (1993).

cost share, and a fixed payment), there is no reason for the landlord to opt for cost-sharing, since he does no worse and no better by specifying the input level than he does by using a cost-sharing contract, even if the tenant is risk averse. So why, then, do cost-sharing arrangements exist? Braverman and Stiglitz come up with a resolution to this paradox: asymmetric information between the landlord and the tenant. Since the optimal level of input changes in response to variations in weather and geographically, according to the nature of the soil and other local conditions, the tenant will often be in a better position to make decisions concerning the level of inputs. If these changes and differences in circumstances are observable to the tenant but not to the landlord, then a contract which induces the tenant to adjust the input to the altered circumstances will be preferred by the landlord. In this sense, a cost-sharing contract is a more flexible contract than a fixed-quantity contract. A further explanation for the existence of cost-sharing arrangements is provided by Bardhan and Singh (1987), using a related argument. They show that if the landlord cannot monitor the tenant's actions, and if the tenant is able to resell the input which is cost-shared with the landlord at a price lower than the landlord's opportunity costs for this input, then there is indirect cost sharing at the margin. Relating these results to the task of empirically settling the question of whether the Marshallian or the monitoring approach is the correct one, one can conclude that if the above theories are valid under the actually prevailing conditions, then the existence of cost-sharing in the data is an indicator that there are monitoring problems.[40]

Knowing now why there is cost-sharing, the next question is, how exactly does the presence of cost-sharing influence the tenant's decisions concerning input use. Using the

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[40] Hayami and Otsuka propose another explanation for cost sharing which has not yet been formalized and which makes use of the argument that the inputs supplied under cost sharing can be regarded as de facto production loans.

Braverman-Stiglitz framework, we assume that there is asymmetric information between the landlord and the tenant concerning some aspect of the technology which varies with the state of nature and which affects the productivity of an input such as fertilizer. Consider a risk averse tenant with a twice differentiable concave utility function defined on income, $u(y)$. The tenant is assumed to control an input *x*, the amount of which can be observed by the landlord; but the costs of writing a contract specifying the level of input corresponding to each state of nature are assumed to be prohibitive. Braverman-Stiglitz show that under these assumptions, in general, the optimal contract will entail some degree of cost sharing. Since Braverman-Stiglitz do not investigate how a change in the cost sharing arrangement influences the tenant's input decision, we proceed by modelling the tenant's input choice.

The tenant maximizes his expected utility under the optimal contract by choosing the optimal level of input x^o given his output share, α, his cost share, β, and the price per unit of input, *c*. The level of output is made uncertain by introducing the non-negative, multiplicative scalar θ, which is distributed according to $h(\theta)$ with mean $E[\theta]=1$. Hence, the tenant's maximization problem is:

$$\max_{x} E\{u(\alpha\theta f(x)-\beta cx)\} \tag{33}$$

where the output price is normalized to unity and the production function is assumed to be strictly concave in *x*. For the production function, we assume the lower and upper inada conditions to hold. The necessary and sufficient condition for an optimal *x* is then:

$$\alpha f' E[u'\theta]-\beta cE[u']=0 \tag{34}$$

Dividing (34) by α and defining $\delta \equiv \dfrac{\beta}{\alpha}$, we can rewrite (34) as

$$f' E[u'\theta]-\delta cE[u']=0 \tag{35}$$

For an optimally chosen *x* we can write the value function dependent on δ as:

$$V(\delta) = E\{u(\alpha(\delta)\theta f(x^o) - \alpha(\delta)\delta c x^o)\} \tag{36}$$

For the tenant's expected utility at the optimum not to change with a change in δ we must have

$$\frac{\partial V}{\partial \delta} = E\{u'(\alpha'(\delta)\theta f(x^o) - \alpha'(\delta)\delta c x^o - \alpha(\delta) c x^o)\} = 0 \tag{37}$$

from which it follows that

$$\alpha'(\delta) = \frac{\alpha}{\frac{E[u'\theta]}{E[u']}\frac{f(x^o)}{cx^o} - \delta} > 0, \tag{38}$$

where $\frac{E[u'\theta]}{E[u']} < 1$ by virtue of the fact that *u* is strictly concave. The denominator of the right-hand side of (38) is positive, because we know from (35) that $\delta = \frac{E[u'\theta]}{E[u']}\frac{f'}{c}$ and because for a concave production function we always have $f' < \frac{f}{x}$.

Differentiating the first-order condition in (35) with respect to δ we obtain the comparative static expression which denotes the change of *x* in δ:

$$\frac{\partial x^o}{\partial \delta} = \{cE[u'] + (\alpha'(\delta)\delta + \alpha(\delta))cxE[u''(\theta f' - \delta c)] - \alpha'(\delta) f E[u''\theta(\theta f' - \delta c)]\} / \Delta \tag{39}$$

where $\Delta = f'' E[u'\theta] + \alpha(\delta) E[u''(\theta f' - \delta c)^2] < 0$. The first term in the numerator of the right-hand side of (39) is the direct effect of a change in δ on x, which is positive, because an increase in δ raises the marginal cost of the input. The other two terms represent the indirect effects which arise because the tenant is risk averse (if the tenant is risk neutral, the last two terms are equal to zero). The second term also vanishes if the tenant's utility function shows constant absolute risk aversion. To see this, consider the expression $E[u''(\theta f' - \delta c)]$. For this expression to be equal to zero, we must have $\frac{E[u''\theta]}{E[u'']} = \frac{\delta c}{f'}$. Using the first-order condition in

(35) we can rewrite this expression as $\frac{E[u''\theta]}{E[u'']} = \frac{E[u'\theta]}{E[u']}$. For constant absolute risk aversion the left hand side equals the right hand side, which can easily be seen by inserting the utility function $u(y) = -e^{-ay(\theta)}$ where a denotes the coefficient of absolute risk aversion. The sign of the third term in the case of CARA utility functions (as well as for all other utility functions) depends on whether $\frac{E[u''\theta^2]}{E[u''\theta]} \lesseqgtr \frac{E[u'\theta]}{E[u']}$. We can state the following proposition:

<u>Proposition1.</u> *If the tenant's utility function satisfies CARA, and if θ is uniformly distributed on the interval $[0, \bar{\theta}]$, then the optimal amount of input chosen by the tenant decreases with increasing δ:*

$$\frac{\partial x^o}{\partial \delta} = \{cE[u'] - \alpha'(\delta) f E[u''\theta(\theta f' - \delta c)]\} / \Delta < 0 \text{. } \textit{(Proof see appendix)}$$

That is, given CARA and a uniformly distributed θ, the change in the optimal amount of input caused by a change in the ratio of costshare to outputshare is stronger for a risk averse tenant than for a risk neutral tenant. The second term in (39) is the effect which arises because the change in the costshare changes the tenant's income. For CARA this term is zero, since in this case the tenant's risk aversion does not change with changing income. The third term in (39) is the effect which arises because, for example, the outputshare has to rise to compensate the tenant for a higher costshare, and therefore the risk averse tenant receives a bigger share of the risky output. If then the tenant is sufficiently risk averse, he will employ less of the input to make his stakes at risk smaller.

For utility functions other than CARA utility functions the second term will be usually different from zero, the sign depending on whether $\frac{E[u''\theta]}{E[u'']} \lesseqgtr \frac{E[u'\theta]}{E[u']}$. That is,

$E[u''(\theta f' - \delta c)] \gtreqless 0 \iff \frac{E[u''\theta]}{E[u'']} \lesseqgtr \frac{E[u'\theta]}{E[u']}$ and $E[u''\theta(\theta f' - \delta c)] \gtreqless 0 \iff \frac{E[u''\theta^2]}{E[u''\theta]} \lesseqgtr \frac{E[u'\theta]}{E[u']}$. If $u''' > 0$, which is the case for utility functions showing CARA or DARA, then $\frac{E[u''\theta]}{E[u'']} < 1$ and $\frac{E[u''\theta^2]}{E[u''\theta]} < 1$. For DARA we can say that the stronger absolute risk aversion is decreasing with increasing income, the smaller are these last two expressions. If the indirect effects are small in magnitude compared with the direct effect, then the optimal input amount chosen by the tenant will fall with a raising δ, that is $\frac{\partial x^o}{\partial \delta} < 0$.

Since on a real world farm not only one input will be used in production, but several inputs are used simultaneously in the production of a crop, the question arises whether a change in the costshare-outputshare relation for one input (say fertilizer) has an effect on the amount of another input (say labour) applied by the tenant to his sharecropped plots. Therefore we extend in the following our model to the case of two different inputs, x_1 and x_2. It is assumed that the tenant's costshares for the two inputs are β_1 and β_2, respectively. Further we assume that the production function, $f(x_1, x_2)$, is strictly concave and that the lower and upper inada-conditions hold for both inputs. Then the tenant's maximization problem is:

$$\max_x E\{u(\alpha\theta f(x_1, x_2) - \beta_1 c_1 x_1 - \beta_2 c_2 x_2)\}.$$

Again define $\delta_1 \equiv \frac{\beta_1}{\alpha}$ and $\delta_2 \equiv \frac{\beta_2}{\alpha}$, such that the necessary and sufficient conditions can be written as

$$f_1 E[u'\theta] - \delta_1 c_1 E[u'] = 0, \tag{40}$$

$$f_2 E[u'\theta] - \delta_2 c_2 E[u'] = 0. \tag{41}$$

For optimally chosen x_1 and x_2 the value function dependent on δ_1 and δ_2 is

$$V(\delta_1,\delta_2) = E\{u(\alpha(\delta_1,\delta_2)\theta f(x_1^o,x_2^o) - \alpha(\delta_1,\delta_2)\delta_1 c_1 x_1^o - \alpha(\delta_1,\delta_2)\delta_2 c_2 x_2^o)\}. \qquad (42)$$

To save space, we will derive the following results only for the costshare-outputshare relation of input x_1, but the results can be easily extended to the costshare-outputshare relation of input x_2. Differentiating (42) with respect to δ_1, setting the result equal to zero, and using (40) and (41), we can derive

$$\frac{\partial \alpha}{\partial \delta_1} = \frac{\alpha(\delta_1,\delta_2)}{\frac{1}{c_1}\frac{E[u'\theta]}{E[u']}\left(\frac{f(x_1^o,x_2^o)}{x_1^o} - f_1(x_1^o,x_2^o) - f_2(x_1^o,x_2^o)\frac{x_2^o}{x_1^o}\right)}. \qquad (43)$$

The sign of (43) hinges on the sign of the term in parentheses in the denominator. Employing Euler's Formula we can state that

$$\frac{f(x_1^o,x_2^o)}{x_1^o} - f_1(x_1^o,x_2^o) - f_2(x_1^o,x_2^o)\frac{x_2^o}{x_1^o} \gtreqless 0 \qquad \Leftrightarrow \qquad \begin{cases} DRS \\ CRS \\ IRS \end{cases}.$$

Therefore $\frac{\partial \alpha}{\partial \delta_1} \gtrless 0 \;\Leftrightarrow\; \begin{cases} DRS \\ IRS \end{cases}$. For constant returns to scale, (43) is not defined. Totally differentiating (40) and (41) with respect to δ_1 we obtain

$$\frac{\partial x_1^o}{\partial \delta_1} = \frac{c_1 E[u']\{f_{22}E[u'\theta] + \alpha E[u''(\theta f_2 - \delta_2 c_2)^2]\} - D_1 B_2 + D_2 B_1}{\Delta} \qquad (44)$$

and

$$\frac{\partial x_2^o}{\partial \delta_1} = \frac{-c_1 E[u']\{f_{21}E[u'\theta] + \alpha E[u''(\theta f_1 - \delta_1 c_1)(\theta f_2 - \delta_2 c_2)]\} - D_2 A_1 + D_1 A_2}{\Delta}, \qquad (45)$$

with $\Delta = A_1 B_2 - A_2 B_1 > 0$ since the maximization problem of the tenant is strictly concave. (For $A_1, A_2, B_1, B_2, D_1, D_2$ see appendix). The first term in the numerator of (44) is negative since $B_2 < 0$. If the other terms in the numerator, the indirect effects, are small in magnitude or cancel out, then again the amount of the input chosen in the optimum by the tenant will decrease with an increase in its own costshare-outputshare relation, that is $\frac{\partial x_1^o}{\partial \delta_1} < 0$. For equation (45) the sign is not clear, even if we assume that the indirect effects are small in magnitude or cancel out. The first term in the numerator of (45) consists of two parts, the first of which is negative if the cross product of the two inputs is positive, whereas the second part is positive, since $\theta f_1 - \delta_1 c_1$ and $\theta f_2 - \delta_2 c_2$ will have the same sign in each state of nature. To see this, consider (40) and (41), from which it follows that $\frac{\delta_1 c_1}{f_1} = \frac{\delta_2 c_2}{f_2} = \frac{E[u'\theta]}{E[u']} < 1$. Thus, an increase in the costshare-outputshare relation of another input has a negative effect on the amount of the input in question because of the positive cross product, but it has also a positive effect, since the tenant will substitute this input for the input which becomes relatively more costly and the use of which becomes relatively riskier. Therefore, the sign of (45) will depend on whether the cross product effect or the substitution effect is stronger.

These findings represent testable hypotheses which we will test in the next section. If the results are right, then a tenant whose cost share raises relative to his output share will use a lower amount of the respective input on his sharecropped plot, whereas he will not change his input on his owned plots, so the difference of average input intensities between owned and sharecropped plots will become larger. If there is a monitoring problem, then a raising cost share relative to the output share will have a positive effect on the difference of average input intensities. This argumentation assumes that the tenant cannot divert resources from his tenancy to his owned plots and the other way round, i.e. the production on his leased-in plots is strictly separated from the production on his owned plots. But this may not be the case on real world farms. Bell et al. (1995) identify what they call the 'dilution effect', an effect which arises because some resources are imperfectly tradable, and the tenant therefore must divert such resources, in part, from his own holdings to his tenancy. This effect also extends to tradable resources which are (net) Hicksian complements with non-tradable resources. In our case the presence of this effect would mean that the tenant diverts the non-tradable resource the costshare-outputshare relation of which rises from his tenancy back to his own land, since it becomes relatively more costly to use the respective input on the tenancy. This in turn would imply that in this case the difference between average input intensities on owned and sharecropped plots would even become larger than in the case were no dilution effect is at work.

4.4 Estimation methods and empirical results

In this section we turn to the question of whether there are differences in the amount of inputs supplied per unit of land on owned field plots and plots cultivated under a tenancy, examining both share and fixed rent tenancies. This is done in subsection 4.4.1. If there are differences, we investigate in subsection 4.4.2 whether these differences can be explained by factors which are different on owned and leased-in plots, such as irrigation status or the crop grown, or whether the difference or part of the difference can be attributed to incentive problems which are caused by the form of the tenancy contract. Since a potential problem arises in controlling for the crop type grown on plots of different tenancy status because the crop grown on a particular plot by a particular household may be the outcome of an endogenous choice process rather than exogenously given, we present in subsection 4.4.3 an econometric model which enables us to deal with this problem of endogeneity.

4.4.1 Comparison of average input intensities on owned and leased-in plots

Since each household in the subsample of owner-tenants has several owned and leased-in plots, we will make the comparison on the basis of the weighted averages of input intensities over the different plots, using the plot areas as weights.[41] There were two cultivation seasons in which a household could be observed to grow crops on his owned and leased-in plots, but not all households cultivated in both seasons. A household which cultivated in both seasons was dealt with as two separate observations, that is, we assume that the fixed effects for each household are independent of the season. It seems not too unrealistic to assume that, for example, the households risk aversion and its managerial ability do not change from one cultivating season to the other. Thus, in this and the following sections we have 43 observations for households cultivating both owned and sharecropped plots, and 75 observations for households cultivating both owned plots and plots leased in against a fixed rent payment.

For the owner-sharecroppers we examine the differences in average input intensities for six input categories: seedlings, fertilizer and pesticides, farm yard manure, preharvest labour, harvesting labour, and bullock-pair days. In the case of owner-fixed-renters, there is the additional category 'tractor hours', since in contrast to sharecropping contracts, fixed-rent contracts are common in the two villages where tractors are used frequently instead of draught animals. The differences in average output intensities are also examined for both types of owner-tenants.

In order to take into account the possibility that the covariance between the differences in average input intensities for a given household is not necessarily equal to zero, we use the method of seemingly unrelated regression equations to regress the differences in average input intensities on owned and leased-in land on an intercept. The estimated covariance

[41] As long as we follow exactly Shaban's method of transforming the relevant variables, we will not give a detailed description of the computations. The interested reader is referred to Shaban (1987).

matrix is then used to carry out a Wald test, the null hypothesis being that the differences in average input intensities are jointly equal to zero. The differences in average input and output intensities and the results of the t-tests are reported in table 7. For the owner-sharecroppers, the differences for seed, fertilizer and pesticides, farm yard manure, and harvesting labour are positive but not significantly different from zero, whereas the differences for preharvest labour and bullock pair days are negative but also not statistically different from zero. The mean difference in average output intensities is negative and not significant. Thus, looking at the mean differences for the particular inputs there is no evidence that these inputs are systematically undersupplied on sharecropped plots compared with owned plots. Following the predictions of the Marshallian theory there should be a positive sign for the mean difference in average output intensities, but there is a negative sign, leading one to the conclusion that if there are any negative incentive effects at work, then they are more than offset by other effects. Using the Wald test mentioned above, the hypothesis that all mean input differences are jointly equal to zero is rejected at the 1%-level ($\chi^2_{(6)} = 21.23$), indicating that there are effects which we should control for, determining systematically the mean input differences.

For the owned and leased-in plots of fixed-rent tenants the picture is much clearer. For all but one input the mean differences are negative, statistically significant so for fertilizer and pesticides, harvesting labour, and tractor hours[42] at the 1%-level, for bullock-pair days at the 5%-percent level, and for seeds at the 10%-level. The mean difference for preharvest labour is negative but not significant, and for farm yard manure it is positive but also insignificant. The mean output difference is negative as well, and significant at the 10% level. The mean input

[42] In the case of tractor hours an interaction dummy was used to account for the fact that tractors are used only in two out of the fourteen villages.

differences are found to be jointly significantly different from zero at the 1%-level ($\chi^2_{(7)} = 67.13$). Since there is no theory which predicts that the input intensity on plots under a fixed-rent contract should be systematically higher than on owner cultivated plots, we will have to find out empirically by which factors this phenomenon can be explained.

4.4.2 Explaining the differences in average input and output intensities

In the preceding section we found the mean input differences for the owner-sharecroppers not to be individually different from zero, but the hypothesis that they are jointly equal to zero could be rejected at a high confidence level. This leads one to assume that there may be different effects, correlated for a particular household over the different inputs and working against each other, in determining the amount of a particular input applied to the household's own land and to its tenancy. On the other hand for the owner-fixed-renters the mean input differences are in most cases individually different from zero, which is unexpected, and has to be explained as well as the sign of the difference .

The aim of the following analysis is to identify the factors which systematically influence the differences in input intensities, and eventually to isolate the effects which can be ascribed to the contractual form under which a plot is cultivated. In his attempt to settle the question whether the actions of the tenant are perfectly monitorable or not, Shaban (1987) regresses the differences in average input and output intensities on plot-specific variables such as dummies for the soil type and the irrigation status of the plot, and on a set of village dummies which he such claims to be the only household-specific attributes that are expected to have a differential impact on input intensities on owned and sharecropped plots. He argues that the village dummy variables will partially reflect the variation in the cost sharing rules across the villages. But these village dummies may as well capture the variation in cropping patterns on owned and sharecropped plots across the villages. Instead of using village dummies, therefore, we employ as regressors the relation of the tenant's cost share to his output share and a dummy for whether the application of the respective input is supervised by the tenant alone or by both the landlord and the tenant. These two regressors will measure the pure effect of tenancy, since if one or both of these variables have an effect on the input differences, this means that the form of the particular contract influences the tenant's decision of how much of the respective input to supply. Additionally, we control for different cropping patterns on owned and sharecropped plots, using dummies for several crops which are frequently cultivated.

In this specification of the econometric model there remains a problem with the error term which captures the household's particular and unobserved characteristics that lead to differential behavior on its owned and sharecropped land and that are not captured by the variables controlling for tenancy. These unobserved characteristics include the risk aversion of the tenant and the risk aversion of his contractual partner(s) as well as the other characteristics of the landlord (observed or unobserved) which are not included in the model. This will cause a problem if the crop choice is endogenous, i.e. if the crop chosen under a particular contract depends on these unobserved characteristics of the tenant and the landlord. Since in this case the crop type will be correlated with the error term, naive OLS (SUR) estimation will yield biased estimators. This problem will be dealt with in the next subsection.

Using Shaban's (1987) notation, the equations to be estimated are derived as follows: Consider an owner-sharecropper cultivating K owned and L sharecropped plots with n variable inputs. The input intensities (per unit area) for each input category i on the owned and sharecropped plots are determined by the following equations:

$$x_{ik}^{o} = \alpha_i^{\,o} + g_i(Z) + \delta_i I_k + \sum_{m=1}^{M} \beta_{mi} C_{mk} + \gamma_{1i} S_i + \gamma_{2i} share_i + \varepsilon_i, \quad k = 1,....,K\,, \tag{46}$$

$$x_{il}^{s} = \alpha_i^{\,s} + g_i(Z) + \delta_i I_l + \sum_{m=1}^{M} \beta_{mi} C_{ml} + \gamma'_{1i} S_i + \gamma'_{2i} share_i + \eta_i, \quad l = 1,....,L\,. \tag{47}$$

Shaban defines the term $g_i(Z)$ as 'a function of deterministic and stochastic variables that have identical effects on the choice of intensity of input *i* on owned and sharecropped plots'. As examples of these variables he mentions family-specific shadow values of all inputs and outputs, its managerial ability, and a family's endowment of production resources, human capital, and labor resources. I_k and I_l are dummy variables which stand for whether the plot is irrigated or not, and the C_{mk} and C_{ml} are dummy variables for the *M* different crops which take on the value of one if a crop is cultivated on the respective plot, and are equal to zero otherwise. S_i is a household specific 'average' dummy variable the value of which is between zero and one, and is the closer to one the more closely the plots under tenancy are supervised by both the landlord and the tenant with respect to the input in question, that is $S_i = \frac{\sum_l s_{li} t_l}{\sum_l t_l}$, where the plot areas t_l are used as weights, and the s_{li} are the plot- and input-specific dummy variables which are equal to one if the supply of input *i* on plot *l* is supervised by both the landlord and the tenant, and zero otherwise. The variable $share_i$ is a household- (or contract-) specific variable which is defined as $share_i = \frac{\sum_l cs_{li} t_l}{\sum_l t_l}$. The cs_{li} are the plot- and input-specific costshare to outputshare relations, that is, the cs_{li} are the empirical counterparts to $\delta = \frac{\beta}{\alpha}$ in our theoretical analysis in section *3*. The error terms ε_i and η_i are, as Shaban puts it, 'the missing variables that affect owned and sharecropped plots differentially'. As already mentioned above, especially the characteristics of the tenant's landlord will be captured by these error terms. Under this specification, the error terms are assumed to be identical across different plots of the same tenure status for each household. It is assumed that the error terms have zero means and finite variances, but it is not assumed that there is zero correlation between the error terms of different input categories.

Because each household normally cultivates several owned and sharecropped plots, and because the comparison of input intensities cannot be done on the plot level (since it is not possible to assign a certain owned plot to a certain sharecropped plot), one has to somehow average over the different plots of the same tenure status of a given household. This averaging is done, again following Shaban, by using the plot areas as weights. Thus define:

$$\Delta x_i \equiv \frac{\sum_k x_{ki}^o t_k}{\sum_k t_k} - \frac{\sum_l x_{li}^s t_l}{\sum_l t_l}, \qquad I^o \equiv \frac{\sum_k I_k t_k}{\sum_k t_k}, \quad I^s \equiv \frac{\sum_l I_l t_l}{\sum_l t_l}, \quad C_m^o \equiv \frac{\sum_k C_{mk} t_k}{\sum_k t_k},$$

$$C_m^s \equiv \frac{\sum_l C_{ml} t_l}{\sum_l t_l}, \qquad \alpha_i \equiv \alpha_i^o - \alpha_i^s, \ \theta_{1i} \equiv \gamma_{1i} - \gamma'_{1i}, \ \theta_{2i} \equiv \gamma_{2i} - \gamma'_{2i}, \text{ and } \upsilon_i \equiv \varepsilon_i - \eta_i .$$

Then we can write the differences in average input intensities on owned and sharecropped plots for each household as

$$\Delta x_i = \alpha_i + \delta_i \left(I^o - I^s\right) + \sum_{m=1}^{M} \beta_{mi} \left(C_m^o - C_m^s\right) + \theta_{1i} S_i + \theta_{2i} share_i + \upsilon_i, \quad i = 1,....,n . \qquad (48)$$

The equation for the differences in average output intensities is similar to equation (48) apart from the fact that instead of the supervision dummy, a dummy variable is used which is equal to one if the landlord decides on the cropping pattern on the respective plot, and which is equal to zero if the tenant decides on the cropping pattern. For this dummy variable, too, we take the average over all plots of the same tenancy status.

In the estimation equation for the differences in average input intensities on the owned and leased-in plots of fixed-rent tenants we drop the supervision dummy and the costshare variable since in all cases the input supply is supervised only by the fixed-rent tenants themselves, and the cost share to output share relation is always equal to one. Instead of these variables we include a dummy variable which is equal to one if the landlord is a friend or a relative of the tenant, and which is zero otherwise.[43] We included also a dummy variable to control for whether the rent is paid in kind after the harvest or not, but this variable was not significant in any of the input equations. Since, in contrast to sharecropping contracts, fixed-rent contracts are present in the two sample villages in which tractors are frequently used, we have an additional equation for the input category 'tractor hours'. In this equation we multiply each regressor with an interaction dummy which is equal to one if the observation is from the two villages where tractors are used, and zero otherwise. In this way, we take into consideration that the input 'tractor hours' is used only in these two villages. Further we include an intercept village dummy in the equation for 'bullock-pair days'.

The *n* equations in (48) are estimated by seemingly unrelated regression (SUR), since it is reasonable to assume that the error terms of the same household are correlated with each other over the different input categories. This assumed correlation can be understood by the above argument that the error terms capture the unobserved characteristics of the household which influence owned and sharecropped plots differently. The equation for the differences in average output intensities is estimated separately by OLS. Unlike in Shaban's work, the regressors are not the same in all equations (because not the same crop dummies are used in the different equations), which results in the fact that the use of the SUR method not only has an effect on the test results but also on the estimates for the coefficients, which in this case are different from the OLS estimates.

Tables 8 and 9 contain the estimation results for the SUR estimation for the six input categories for the cultivators of owned and sharecropped land and for the cultivators of owned

[43] This relationship dummy was also employed in the estimation of equation (48), but in no case was it significant.

and leased-in land, respectively. The OLS estimates for the two output equations are reported in the respective tables as well.

First we estimated equations (48) without the costshare variables. Table 8 reports the results. For the six input categories all estimated intercepts are positive, for farm yard manure and harvest labour they are significantly different from zero at the 5% level, for preharvest labour and fertilizer and pesticides they are significant at the 10% level, and for seeds and bullock pair days they are not significantly different from zero. The intercept for the output equation is negative but not significant. Using a Wald test, the hypothesis that all six intercept parameters in the input equations are jointly equal to zero is again rejected at the 1% level ($\chi^2_{(6)} = 18.13$). This is a different picture from that obtained by regressing the differences only on an intercept. In this latter case, no intercept was significantly different from zero, and two of the intercepts had even negative signs. Controlling for other factors which may potentially influence the amount of inputs supplied, however, we find for four of the six inputs a systematically higher input supply on the owned plots. The intercept for the output equation is now positive, but still insignificant.

All coefficients for the irrigation dummy variable are positive, and for all inputs except harvesting labour they are significant at the 1% level. According to the Wald test, the hypothesis that all irrigation coefficients are jointly equal to zero is rejected at the 1% level ($\chi^2_{(6)} = 71.73$). Since there is a strong positive correlation between irrigated plots and plots cultivated with paddy[44], we can draw the conclusion that if, on average, more of the farmer's owned plots than of his sharecropped plots are devoted to irrigated paddy, then the difference between the average input intensities on owned and sharecropped plots will increase for all

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[44] Pearson's correlation coefficient is $\rho = 0.8725$.

inputs and for output. Because of this correlation, we did not include an extra dummy for paddy, so that now unirrigated paddy forms part of the omitted category.[45]

For the crop dummies for grams, groundnut, and castor seed, the parameter estimates in most cases have negative signs, except for groundnut in the equations for seed and fertilizer, and for castor seed in the equation for bullock labour. One of these crop dummies is significant at the 10% level, two are significant at the 5% level, and four at the 1% level. Testing the hypothesis that the coefficients for all crop dummies in all input equations are jointly equal to zero, the null hypothesis is rejected at the 1% level ($\chi^2_{(13)} = 152.67$). Additional Wald tests to test the hypothesis whether the coefficients for all crop dummies in the same input equation are jointly equal to zero show the following results: for the input categories seed, farm yard manure, preharvest labour, and bullock pair days this hypothesis is rejected at the 1% level, for harvest labour it is rejected at the 5% level, and for the category fertilizer and pesticides it cannot be rejected. All this provides strong evidence that the crop mixture grown on different plots of the same tenancy status has in fact a non negligible effect on the differences in average input intensities. We included crop dummies in the output equation, too, but none was found to be significant. This suggests that only irrigated paddy has a significant influence on the difference between average output intensities.

Turning to the estimated coefficients for the supervision dummies we find that they have a negative sign, except for the input category harvest labour. For the category fertilizer

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[45] The other crops belonging to the omitted category are cereals, cotton, and chilies. These crops had no significant influence in any of the seven equations. The dummies for grams, groundnut, and castor seed were not included in all equations; the choice was made on the basis of table 5: if a certain crop was expected from table 5 to have a strong influence on the size of the input category in question, it was included in the equation.

and pesticides, the corresponding parameter is significant at the 5% level, and the positive coefficient in the harvest labour equation is significant at the 10% level. The hypothesis that all coefficients are jointly equal to zero cannot be rejected in this case ($\chi^2_{(6)} = 9.43$). In most cases, the coefficients have the sign that one would expect: If the supply of an input is supervised by both the landlord and the tenant rather than by the tenant alone, then the difference in average input intensities on owned and sharecropped plots decreases. The significantly positive parameter in the harvest labour equation is certainly unexpected. These findings hardly allow one to draw the conclusion that joint supervision by the landlord and the tenant leads to an improved input supply on the sharecropped plots. In the output equation, the coefficient for the cropping pattern decision dummy is negative and not significant. Note that for the output equation we have a relatively high adjusted R-square (0.78), despite the fact that there are only the intercept and two explanatory variables. A very large proportion of the difference in average output intensities seems to be explained by the irrigation status of the plots.

If we include the cost-share variables in the estimation equations we get the results reported in table 8a. Consider first the estimates for the variable *cost share* itself: The coefficients have a negative sign for seed, farm yard manure, preharvest labour, and bullock pair days, and a positive sign for fertilizer and for harvest labour, but only the coefficients for seed and fertilizer are significant at conventional significance levels. The hypothesis that all coefficients are jointly equal to zero can be rejected at the 5% level ($\chi^2_{(6)} = 13.04$). Following our theoretical considerations in section 3, one should expect the signs of the coefficients for the cost share variables to be positive, since a higher cost share to output share relation for the tenant will induce the latter to supply less of the respective input according to the predictions of the theory. But there is only one positive coefficient which is significant at the 5% level, though. Thus there is only weak evidence that this particular contractual characteristic, the cost-sharing arrangement, has an influence on the farmer's input decisions.[46] The effect of including the cost-share variable on the estimated coefficients for the irrigation, crop and supervision dummies is negligible; no sign is reversed, and only for farm yard manure the irrigation coefficient moves from the 1% significance level to the 5% level, and for fertilizer the supervision dummy moves from the 5% to the 10% significance level. The effect on the intercepts is stronger: all coefficients except that one for fertilizer retain their positive sign, but the coefficients for fertilizer, preharvest labour, harvest labour, and bullock-pair days become insignificant, and the hypothesis that all intercept coefficients are jointly equal to zero can now be rejected only at the 5% level instead at the 1% level as before. This is interesting, since the coefficients for the cost-share variables are not found to be individually significantly different from zero (except one), but they seem to explain nevertheless part of the difference in average input intensities which was before captured by the intercept. One reason for this may be that the data are not very rich (only 43 observations in the case of owner-sharecroppers). Another possible reason is that the crop dummies as well as the dummies for supervision and the cost-share variables are not exogenous variables, but are endogenously determined by the characteristics of the tenant and the landlord, which are captured by the error terms in this setting. We will control for such endogeneity in the next section.

According to our theoretical considerations, we should include the cost-shares of the other inputs as regressors in the estimation equation for a certain input, but here we meet with the problem of multicollinearity, since in nearly all cases the cost-shares for different inputs

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[46] The six cost-share variables were also included in the output equation, but none was found to be significant.

are the same in a contract. Thus, it is not possible to test the hypotheses of positive cross-effects.

Another point on which we should remark is the relation between the supervision dummies and the cost share variables: One would expect cost-sharing to be highly correlated with supervision in order to avoid cheating by the tenant; that is, one would expect the supervision to be the closer, the higher the cost share of the landlord. We computed Pearson's correlation coefficient for the six cost-sharing variables and the five supervision dummies, which all had a negative sign as expected, but the correlation was significant only in four cases, twice at the 5% level (the bullock-pair days cost share with the supervision of bullock-pair days and seeds) and twice at the 10% level (the bullock-pair days cost share with the supervision of fertilizers and preharvest labour).

From these findings the answer to the initial question whether there is evidence in favor of the Marshallian hypothesis is not quite clear. The two variables which stand for two characteristics of the respective contract, the supervision dummy and the cost-share variable, are either not jointly significantly different from zero, as in the case of the supervision dummies, or they are not individually different from zero and have the wrong sign, as in the case of the cost-share variable. This implies that the tenant's decision of how intensely to supply inputs on his sharecropped plots is not, in general, influenced by the contractual arrangements concerning the supervision of the inputs, and is only weakly influenced by the contractual arrangements concerning the costs of the inputs. But this means that the predictions of the theory under the assumption of imperfect monitoring are only weakly supported by the evidence of the present data set. There remains the fact that most of the intercepts are positive, and that they are jointly significantly different from zero at the 5% level. But since the data are lacking, we are not able to control for soil quality and plot value[47], two factors which can be different on owned and sharecropped plots, and which are likely to influence the input supply on both types of plots in the same way, we cannot interpret the positive intercept as the effect of tenancy alone without reservation. In the present data set, the differences in average input intensities seem to be explained mostly by different cropping patterns and by the different extent of irrigation on owned and sharecropped plots.

In table 9 the results for the owner-fixed-rent tenants are reported. Comparing the estimated intercepts in table 9 with the mean differences in table 7, one finds that four out of seven intercepts are now positive; before only one intercept had a positive sign. Also, among the mean differences, three were significantly different from zero at the 1% level, one at the 5% level, and one at the 10% level, all of them being negative. Among the intercepts in table 9 only two are significantly different from zero at the 1% level and at the 5% level, the intercept for farm yard manure which is positive and the intercept for tractor hours which is negative, respectively. The intercept for farm yard manure was insignificant before. Thus, as in the case of sharecropping tenancy, including additional explanatory variables leads to some significant changes in the mean differences in average input intensities. But the hypothesis that all intercept coefficients are jointly equal to zero is still rejected at the 1% significance level ($\chi^2_{(7)} = 25.13$). The intercept in the output equation is still negative and insignificant.

The coefficient of the irrigation dummy is positive and significant for four out of the seven inputs, for fertilizer and farm yard manure at the 1% level, and for preharvest labour and tractor hours at the 5% level. It is positive and insignificant for output. Again the hypothesis that all irrigation coefficients in the seven input equations are jointly equal to zero

[47] Shaban controls for these variables and finds a significant influence on the differences in average input intensities.

can be rejected at the 1% level ($\chi^2_{(7)} = 38.69$). Because of the correlation between irrigated plots and plots cultivated under paddy, which is also in this case strongly positive[48], the irrigation dummy variable stands for irrigated paddy; that is, also for the plots of owner-fixed-rent tenants the significantly positive coefficients for the irrigation dummy variable can be interpreted to the effect that the higher the proportion of owned plots cultivated under irrigated paddy compared with the proportion of leased-in plots cultivated under irrigated paddy, the larger is the difference between average input intensities on owned and leased-in plots for the respective input. Among the other crop categories included in the regression, cereals, groundnut, and cotton had a significant influence on the differences in average input intensities. Another crop which is not cultivated by owner-sharecroppers, but which is found to have a strong significant effect on the input category seed and on output, is sugarcane. Testing some joint hypotheses on the coefficients of the crop dummies, we find the following: the cross-equations restriction that all crop coefficients are jointly equal to zero is rejected at the 1% level ($\chi^2_{(14)} = 198.75$), and the hypothesis that for each input category the coefficients of the included crop dummies are jointly equal to zero is rejected at the 1% level for seed, bullock labour, and harvest labour ($\chi^2_{(3)} = 49.63$, $\chi^2_{(3)} = 105.60$, and $\chi^2_{(2)} = 50.35$, respectively), at the 5% level for fertilizer ($\chi^2_{(2)} = 7.75$), and it cannot be rejected for preharvest labour ($\chi^2_{(3)} = 4.68$). In the output equation, the crop dummy for sugarcane and the irrigation dummy are highly significant. That is, the differences in average input intensities of cultivators of owned plots and plots leased in under a fixed-rent contract can also be explained partly by the differences in cropping pattern on owned and leased-in plots.

[48] Pearson's correlation coefficient is $\rho = 0.9331$, which is even higher than in the case of owner-sharecroppers.

Noteworthy is the fact that the relationship dummy variable is negative for all seven input equations, and significantly so for seed at the 5% level, and for preharvest labour and for harvest labour at the 10% level. The hypothesis that the coefficients for the relationship variables in all seven input equations are jointly equal to zero is rejected at the 5% level ($\chi^2_{(7)} = 14.81$). Thus we can draw the conclusion that when the landlord is a friend or a relative of the tenant, this works to increase the latter's input supply on his leased-in plots compared to his owned plots. This result is a surprising one from a theoretical point of view, since theory predicts that in the case of a fixed-rent contract, the efficient input supply on the leased-in plots does not depend on the contracting parties' characteristics (the relationship to the landlord is a contract characteristic in a broader sense). Contract theory predicts that a contract which includes a fixed rent payment from the tenant and no cost sharing has no negative incentive effects. But if one assumes that the input supply on the owned plots is efficient, then the negative coefficients of the relationship dummies imply that there is an inefficient input supply on the leased-in plots which is less inefficient if the landlord is a friend or a relative of the tenant.

There is a theoretical argument by which a different input supply on the owned and leased-in plots of a fixed-rent tenant can be explained: If the contractual arrangement is such that the tenant has to make the fixed rent payment in kind after the harvest (which can be seen as a de facto production loan), then for a risk averse tenant who in the case of a crop failure will not be able to pay the rent there is a 'leverage' effect. This leverage effect is caused by the fact that in the case of a good harvest the tenant gets the whole surplus, whereas in the case of a crop failure his loss is limited to his input costs. This effect can lead to a higher input supply on the leased-in plots. We included a dummy variable in all seven input equations and in the output equation to control for whether the rent is paid in kind after the harvest or in cash before, but the coefficients were not significant for any input category and not for output.

In all input equations except in the equation for tractor hours a village dummy is included which is equal to one if the observation is from the two villages where tractors are used, and is zero otherwise. In these two villages, almost all plots are irrigated and cultivated under paddy, a fact which, together with the higher level of mechanization, could have an influence on the input differences. The village dummy coefficient is significant at the 5% level for seed having a negative sign, and at the 10% level for bullock pair days having a positive sign. For the other input categories the coefficients are not significant, but the hypothesis that all six village dummy coefficients are jointly equal to zero can be rejected a the 1% level ($\chi^2_{(6)} = 17.58$). Thus, the fact that an observation is from the two mechanized villages has a statistically measurable influence on the input differences, but the direction of this influence is not clear.

We conclude from these results that also for the owned and leased-in plots of fixed-rent tenants there are differences in the average input intensities which cannot be ascribed to different plot characteristics or to different cropping patterns on owned and leased-in plots. There are factors such as the relationship between the landlord and the tenant which are linked with the tenancy contract and which determine the amount of inputs supplied to the plots cultivated under this contract.

4.4.3 Endogenous crop choice

In the preceding section we examined how the differences in average input intensities can be explained by plot-specific factors, by the cropping pattern, and by the characteristics of the individual contract. To this end, we have assumed so far that the cropping pattern and the characteristics of the individual contract were exogenously given. But this is not a very realistic assumption, since the decision of which crop to cultivate as well as the fixing of the contractual parameters such as the cost-share will probably be endogenously determined by the observed and unobserved characteristics of the tenant, and – where the plots under tenancy are concerned – by the observed and unobserved characteristics of the respective landlord. As was already mentioned, the error terms in equations (48) capture all unobserved heterogeneity among households which influences the average input intensity on owned and sharecropped or on owned and leased-in plots differently. Examples of this unobserved heterogeneity are the risk aversion of the tenant and the risk aversion of the related landlord, and all other characteristics of the landlord, since the characteristics of the landlord will almost certainly influence the tenant's input decision on his sharecropped-in or leased-in plots on the one hand and on his owned plots on the other hand differently. The problem which now arises is that the crop choice of the tenant and the agreement between the tenant and the landlord on the contractual parameters may be determined among other things by exactly these unobserved characteristics of the tenant and the landlord. Then the crop variables as well as the variables standing for the contract characteristics are correlated with the error term, with the consequence that the estimates for the related coefficients will be inconsistent. In the following, we will focus only on the endogeneity of the crop variables. Concerning the possible endogeneity of contract characteristics such as the cost share, who supervises the production process, and the relationship between the landlord and the tenant, one can argue based on evidence from the data set that the cost share used for a certain crop and a certain input is determined by its common use in the respective village rather than lying within the discretion of the landlord and the tenant. For the other two variables, the supervision and the relationship dummy, it is hard to find an argument against their endogeneity, but we will neglect it in order to not overload the following empirical analysis, which already suffers from data constraints.

The econometric model which takes into account the endogeneity of crop choice can be formulated as follows. The system of equations explaining the differences in average input intensities on owned and leased-in land of the two groups of tenants is still represented by the n equations in (48):

$$\Delta x_i = \alpha_i + \delta_i \left(I^o - I^s\right) + \sum_{m=1}^{M} \beta_{mi} \left(C_m^o - C_m^s\right) + \theta_{1i} S_i + \theta_{2i} share_i + \upsilon_i, \quad i = 1,....,n . \tag{48}$$

Now, however, the crop dummies for the crops cultivated on owned and leased-in land, C_{mk} and C_{ml}, respectively, are no longer assumed to be exogenously given, but rather to be the outcome of some kind of agreement between the landlord and the tenant if the respective plot is cultivated under a tenancy, or to depend on the observed and unobserved characteristics of the tenant alone if the plot is under owner cultivation. Let the total number of plots an owner-sharecropper or an owner-fixed-rent-tenant cultivates be $Q = K + L$, $q = 1,...,Q$. Then C_{qhm} is a dummy variable which is equal to one if crop m is cultivated on plot q of household h ($h = 1,...,H$), and which is equal to zero otherwise. Now define the latent variable underlying the crop choice process, V_{qhm}, as the net benefit from growing crop m on plot q of household h. That is, the individual plot of a certain household cultivating both owned land and leased-in land will be the unit of observation in our crop choice model. Assume that the net benefit is given by

$$V_{qhm} = \beta_a' a_m + \beta_p' p_{qh} + \gamma_T' x_h + \gamma_L' J_{qh} y_{qh} + \delta J_{qh} + u_{qhm} , \tag{49}$$

where a_m is the vector of characteristics of crop m, p_{qh} is the vector of characteristics of plot q of household h, x_h is the vector of characteristics of household h, J_{qh} is a dummy variable which is equal to one if plot q of household h is cultivated under a tenancy, and is equal to zero otherwise, y_{qh} is the vector of characteristics of the landlord belonging to plot q of household h if the plot is cultivated under a tenancy, and u_{qhm} refers to the effects of unobserved heterogeneity. Then the choice of crop m on plot q by household h can be described as follows:

$$C_{qhm} = 1 \qquad \text{if } V_{qhm} \geq V_{qhn} \quad \forall n \neq m\,,$$

$$C_{qhm} = 0 \qquad \text{otherwise.} \tag{50}$$

Equations (49) and (50) describe a multinomial logit model which will be estimated separately for owner-sharecroppers and for owner-fixed-renters, using all owned and leased-in plots of the households we used in the estimations of equations (48) in section 4.4.2. Employing the characteristics of the landlords belonging to a particular plot cultivated under a tenancy in the estimation, we meet with two problems. First, we do not know the characteristics of all landlords, since some of the landlords are not resident in the sample villages and therefore are not recorded in the census. Second, it is reasonable to assume that a particular tenant matches with a particular landlord dependent on their observed and unobserved characteristics[49]. Thus, the landlord's characteristics would then be endogenously determined variables which are potentially correlated with the error term. We deal with these problems by first using only the subset of tenants and landlords for which we know the characteristics of the landlords, regressing each particular landlord characteristic on all tenant characteristics[50]. Then we employ the estimated parameters from this regression to predict the characteristics of all landlords in the total sample of owner-tenants. That is, we take the tenant's characteristics as exogenously given and uncorrelated with the error term, using them

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[49] See Bell, Raha, and Srinivasan (1995).

[50] Again the SUR method is used to estimate the system of equations which link the landlord characteristics with the tenant characteristics, since it is reasonable to assume that for each landlord the error terms are correlated over the different characteristic equations.

as instruments to instrumentalize the endogenous landlord characteristics which we wish to use in the crop choice regression. At the same time, we obtain predicted values for the missing landlord characteristics. The question may arise whether the fact that the landlord is resident or not has a bearing on the choice of contract, for non-resident landlords may find it hard to supervise, and will therefore probably prefer to offer a fixed-rent contract. In table 10a the frequencies of absent landlords are reported for all tenants in the core transaction schedule. There is no evidence that the landlords of fixed-rent tenants are more often absent than the landlords of the sharecroppers: 27 % of the share tenants' landlords and 28 % of the fixed-rent tenants' landlords were absent. The hypothesis of equal proportions cannot be rejected ($\chi^2_{(1)} = 0.008$).

Putting these things together, the econometric model to be estimated is given by the following simultaneous-equations model:

$$\Delta x_i = \alpha_i + \delta_i\left(I^o - I^s\right) + \sum_{m=1}^{M} \beta_{mi}\left(C_m^o - C_m^s\right) + \theta_{1i} S_i + \theta_{2i} share_i + \upsilon_i, \quad i = 1,....,n \tag{48}$$

$$V_{qhm} = \beta_a' a_m + \beta_p' p_{qh} + \gamma_T' x_h + \gamma_L' J_{qh} y_{qh} + \delta J_{qh} + u_{qhm}, \tag{49}$$

$$C_{qhm} = 1 \qquad \text{if } V_{qhm} \geq V_{qhn} \quad \forall n \neq m,$$

$$C_{qhm} = 0 \qquad \text{otherwise,} \tag{50}$$

where V_{qhm} is the latent variable underlying the average crop dummy variables C_m^o and C_m^s, and where the error terms υ_i and u_{qhm} are correlated. Maddala (1983, pp.120-121) proposes a two-stage estimation method to estimate this kind of model: First estimate equation (49) (in our case by a multinomial logit model), get the estimates of all parameters in (49), and derive the predicted probabilities for the crop choices. Then equation (48) can be estimated by SUR after substituting the predicted probabilities for the C_{qhm} underlying the C_m^o and C_m^s in (48).

Table 10 contains the estimation results for the multinomial logit estimation of the crop choices of owner-sharecroppers and owner-fixed-renters. There are seven crop categories for the owner-sharecroppers (paddy, cereals, grams, groundnut, cotton, castor seed, and others, including vegetables and chilies), and eight crop categories for the owner-fixed-renters (paddy, cereals, grams , groundnut, cotton, chilies, sugarcane, and others, including vegetables, castor seed, coconut, tobacco). The category 'others' contains in both cases the crops which were grown in only a few cases by the respective group of owner-tenants. We will not comment on each of the estimated coefficients, but some results are worth mentioning. First, there are not many landlord characteristics which have a statistically measurable influence on the crop choice. We included all landlord characteristics in both estimations which turned out to be at least significant at the 10% level for a particular crop in one of the estimations.[51] We also included a set of dummy variables for whether a particular plot is cultivated under a tenancy or not, but none of these coefficients was found to be significant at any conventional significance level in both estimations. An explanation for this could be that all the effects of tenancy are captured by the characteristics of the landlord and by the match between the landlord and the tenant. The coefficients for *famsizl.paddy* are positive and significant at the 10% level in both estimations, that is, for both owner-sharecroppers and owner-fixed-renters the size of the landlord's family has a positive influence on the probability that paddy is grown on a leased-in plot. This is what one would expect since paddy is the main food crop, and a larger family needs more of it. Also, a larger landlord family means that there are more persons who can monitor the tenants actions, an important task when paddy is concerned. The coefficients for *famlabml.paddy* are negative in

[51] Due to the not very large number of observations, it will not produce very convincing results if we include all possible regressors in the estimation.

both estimations, but only the coefficient in the owner-fixed-renters estimation is significant at the 5% level, whereas the coefficient for the owner-sharecroppers is just not significant at the 10% level. Thus, we find evidence at least for the owner-fixed-renters that the number of adult male workers in the landlord's family reduces the probability that paddy is grown on a leased-in plot. If a landlord has in his own family more workers to produce the relatively labour intensive crop paddy, he will be less interested in receiving his fixed rent payment in the form of paddy.[52] For the tenants the results for these paddy related coefficients are more puzzling. The number of adult male workers in an owner-sharecropper's family has a negative effect (significant at the 1% level) on the probability that paddy is cultivated on a plot (owned or sharecropped-in), and for the owner-fixed-rent tenants the respective coefficient is positive, but not significant at conventional significance levels. The total number of family members in an owner-sharecropper's family has a negative but not significant influence on the choice probability for paddy, whereas the respective coefficient is negative and highly significant for the owner-fixed-rent tenants. It is hard to find a convincing explanation for why the number of family members should induce a farmer to grow less of the main food crop on his owned and leased-in plots. Other variables of interest are the total asset values of the tenant and the landlord. These variables are potential proxy variables for the unobserved risk aversion of the tenant and the landlord. The coefficients of the asset variable for paddy, cereals, and grams are all (except the coefficient for *assett.cereals*) significant at least at the 10% level for both groups of tenants, indicating that the wealth of a tenant has an influence on his crop choice. In contrast, among the estimated *assetl.* coefficients for both groups of tenants only the coefficient for *assetl.grams* is significant at the 10% level. That is, there is only weak evidence that the landlord's wealth influences the cropping pattern on the plots under tenancy.

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[52] In most cases the fixed rent is paid in kind, if paddy is grown under tenancy.

Summarizing, one can say that besides the tenant's characteristics, the landlord characteristics seem to have a non-negligible influence on the crop chosen on a particular plot cultivated under a tenancy.

The next step is to use the predicted probabilities for the crop choices in the SUR estimation of equations (48). The estimated parameters for the SUR estimation using the predicted probabilities are set out in tables 12 and 14 for owner-sharecroppers and owner-fixed-renters, respectively. In section 4.4.2 we used only the crop dummies in the regressions which we expected from tables 3-6 to have a noticeable influence on the differences in average input intensities, since we wanted to save degrees of freedom in order to obtain more precise estimates for the coefficients of interest. In this section, we use in the SUR regressions crop dummies for all the crop categories which were present in the multinomial logit estimation in order to maintain the consistency of the argument. Equations (48) were also reestimated using the actual values for the crop dummies for all crop categories in the multinomial logit model. This provides us with the benchmark with which we can compare the results from the estimations with the predicted crop dummies. The results of these estimations are set out in tables 11 and 13 for the owner-sharecroppers and the owner-fixed-renters, respectively. In the case of owner-sharecroppers we could not use the crop dummies for the categories 'castor seed' and 'others', since they turned out to be collinear with other crop dummies when using the predicted probabilities instead of the actual values.

Before turning to the testing of some hypotheses, something should be said about statistical inference in two-stage methods. It is incorrect to use the standard errors from the second stage of the two-stage procedure in judging whether or not the coefficients are significant, since this procedure ignores the fact that some of the explanatory variables are estimated.[53] For two-stage estimation of reduced-form equations, however, the standard errors for the second stage are normally not far off from the correct standard errors (see Maddala, 1983, p.238). In the following, we will use the standard errors from the second stage.

Comparing the two tables for the owner-sharecroppers, one can see that the parameter estimates for the irrigation dummies and for the supervision dummies do not change their signs, and that, in most cases, these estimates are as precise as those arising from the use of the actual crop dummies. There is, however, a change in the result of the test of one of the joint hypotheses. For the joint hypotheses that all coefficients for the irrigation dummies are jointly equal to zero there is no difference between the actual values and the predicted values estimation: In both cases the null hypothesis is rejected at the 1% level ($\chi^2_{(6)} = 41.21$ and $\chi^2_{(6)} = 38.13$, respectively). Testing the joint null hypotheses for the coefficients of the supervision dummies, one finds that the hypothesis cannot be rejected for the actual-values estimation ($\chi^2_{(6)} = 8.44$), whereas it is rejected at the 5% level ($\chi^2_{(6)} = 15.04$) for the predicted-values estimation. That is, controlling for the endogeneity of the crop choice, we can now reject the hypothesis that there is no influence of the supervision arrangement on the differences in average input intensities. For the intercepts there are some changes in the signs and in the significance levels, but the joint null hypotheses are rejected at the 5% level for both the actual-values and the predicted-values estimation ($\chi^2_{(6)} = 13.05$ and $\chi^2_{(6)} = 15.65$, respectively).

However, there are quite a lot of changes in the signs as well as in the levels of significance of the parameter estimates for the crop dummies and for the cost-share variables. The coefficient for the cost-share variable for the input category 'seed' changes its sign from

[53] See Pagan (1984) for a detailed discussion of this problem.

negative to positive and becomes significant at the 5% level; the cost-share coefficient for the category 'fertilizer and pesticides' keeps its positive sign, but becomes significant at the 1% level instead of at the 5% level. For these two coefficients we now obtain the result that we would expect if we followed the predictions of the theory: a cost share which is larger than the tenant's crop share has a positive influence on the difference between average input intensities on owned and sharecropped plots. Somewhat puzzling is the negative sign of the cost-share coefficient for the category 'farm yard manure', which is now significant at the 5% level. The other three cost share coefficients have a negative sign, but are not significantly different from zero.

Again carrying out some joint hypotheses tests, we find that for the estimation which uses the predicted crop dummies the hypothesis that all cost-share coefficients are jointly equal to zero can now be rejected at the 1% level ($\chi^2_{(6)} = 23.57$), whereas for the estimation using the actual crop dummies it could only be rejected at the 10% level ($\chi^2_{(6)} = 12.31$). Controlling for the endogeneity of the crop choice has the consequence that now the effects of the contractual arrangement on the differences in average input intensities can be identified more clearly. The direction of this influence, however, is not clear. Testing for each of the input equations whether all crop dummy coefficients are jointly equal to zero, this hypothesis is rejected only for the categories 'seed' ($\chi^2_{(4)} = 14.73$) and 'fertilizer' ($\chi^2_{(4)} = 10.37$) for the estimation using the predicted values, whereas it is rejected for the categories 'seed', 'farm yard manure', 'preharvest labour', and 'bullock labour' at different significance levels ($\chi^2_{(4)} = 50.90$, $\chi^2_{(4)} = 7.87$, $\chi^2_{(4)} = 18.87$, and $\chi^2_{(4)} = 12.08$, respectively) for the estimation using the actual values. These results indicate that failing to take into account the endogeneity of the crop choice leads to an overestimation (with no implication for the direction of the overestimation) of the influence of the crop types cultivated on owned and sharecropped plots on the difference in average input intensities (except for the input category 'fertilizer and pesticides'), and to an underestimation (no implication for the direction of the underestimation as well) of the influence of the contractual arrangements related with the tenancy.

Table 15 shows the results for the OLS estimation of the output difference equation, using both the actual and the predicted crop dummies. There are some changes in the signs and in the significance levels of the coefficients for the crop dummies, but the most important change is, that in the estimation which uses the predicted values the intercept is positive and significant at the 5% level, whereas in the estimation using the actual values the intercept is not significantly different from zero. Thus, for output, too, a positive difference between the average output intensities on owned and sharecropped land which cannot be ascribed to different irrigation or cropping pattern can be detected if one controls for the endogeneity of crop choice. That is, for output we find evidence for the Marshallian hypothesis. We also included all cost-share variables in the output difference estimation, but none of them was significant at any conventional significance level.

The joint hypothesis tests we have carried out so far test only whether a certain set of parameters is jointly significantly different from zero. Therefore, we could not say anything about the direction of the joint influence (if any) of the respective variables. But since for the variables connected with the contractual arrangement we are interested in the direction of their joint significance, we now proceed to test some inequality restrictions on sets of parameters. To test nonlinear cross-equations restrictions for a system of equations, Gallant and Jorgenson (1979) propose a test which is an analog of the likelihood ratio test, and which is based on the change in the least-squares criterion function. The test procedure is as follows: First estimate the unrestricted model (in our case by SUR), then estimate the restricted model (by SUR) using the same estimated variance-covariance matrix for the error terms as in the unrestricted model. Then the suggested test statistic is[54]

$$T^0 = n\left(\tilde{\tilde{S}} - \tilde{S}\right)$$

where $\tilde{\tilde{S}}$ is the value of the objective function of the restricted model, $\tilde{S}$ is the value of the objective function of the unrestricted model, an n is the number of observations used in the estimations. When the sample is in accord with the null hypothesis, T^0 will be near zero, and when it is not, T^0 will be large. It can be shown, that T^0 is distributed asymptotically as a chi-square with m degrees of freedom when the null hypothesis is true, where m is the number of parameter restrictions.

We now test several joint hypotheses using this method, testing each hypothesis twice, once using the actual crop dummies and once using the predicted crop dummies in the estimation. Testing whether all intercepts are jointly smaller than or equal to zero, we find that the hypothesis cannot be rejected for the actual values (p-value 0.1093) and that it is rejected for the predicted values at the 10% level (p-value 0.0889). That is, only for the estimation using the predicted values we find evidence that the vector of mean differences in average input intensities on owned and sharecropped plots is positive in all its elements, even after controlling for other factors. That is, there is a generally lower input supply on the sharecropped plots than on the owned plots. The hypothesis that all supervision dummy coefficients are jointly bigger than or equal to zero cannot be rejected for the actual values (p-value 0.4989) and for the predicted values (p-value 0.3545). Therefore we cannot conclude that the supervision of input use by both the tenant and the landlord in general reduces the differences in average input intensities in either of the two models. The hypothesis that all

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[54] See Gallant and Jorgenson (1979, p.279).

cost-share coefficients are jointly smaller than or equal to zero cannot be rejected for the actual values (p-value 0.5405), but it is rejected at the 1% level for the predicted values (p-value 0.0044). Thus, in the model which takes into account the endogeneity of the crop choice there is strong evidence that a cost-share-output-share relation of the tenant which is bigger than one has in general a positive influence on the differences in average input intensities on owned and sharecropped plots. That is, if the cost-share of a tenant rises relative to his output-share, he will reduce the intensity of the respective input on his sharecropped plots by more than on his owned plots. In the model which assumes that the crop type cultivated on a particular plot is exogenously given, no influence of the cost-sharing rule on the differences in average input intensities can be identified.

Turning to the comparison of the results of the two models for the owner-fixed-renters, it is noticeable that for all variables and for all input categories there are some changes in the signs and in the significance of the coefficients.[55] The most dramatic changes are in the category 'seed': The intercept moves from positive significance to negative insignificance, some crop dummies change their sign and their level of significance, and the relationship dummy and the village dummy becomes insignificant. Also, in the estimation using the actual crop dummies, the hypothesis that the coefficients of all variables are jointly equal to zero for the respective input category could be rejected at the 1% level for all seven input categories. However, for the model which uses the predicted crop dummies, this hypothesis cannot be rejected for the category 'harvest labour' and can only be rejected at the 10% level for the category 'bullock labour'. That is, there is less explanatory power in the model which uses the predicted values. A reason for this could be that one loses variation in the explanatory

[55] For the category 'tractor hours' there is only a crop dummy for 'chilies', since in the two villages where tractors are used, only paddy and chilies are cultivated.

variables if one uses the predicted values, so that the parameters cannot be estimated with much precision.

We find that the hypothesis that all intercept parameters are jointly equal to zero is rejected at the 1% level ($\chi^2_{(7)} = 28.05$ for the actual values and $\chi^2_{(7)} = 23.54$ for the predicted values) for both models. It is not, however, possible to establish a general direction of the mean difference in average input intensities in either of the two models: Using the test method of Gallant and Jorgenson, the hypothesis that all intercepts are jointly smaller than or equal to zero cannot be rejected for either the model using the actual values (p-value 0.1570) or the model using the predicted values (p-value 0.2871). This is not surprising, since some of the intercepts are positive and significant, and some of them are negative and significant. Thus, for the owner-fixed-renters there seems to be no evidence for a generally lower input supply on the leased-in plots. The hypothesis that all relationship dummy coefficients are jointly equal to zero is rejected at the 5% level ($\chi^2_{(7)} = 17.67$) for the model using the actual values, but it cannot be rejected ($\chi^2_{(7)} = 5.97$) for the model which uses the predicted values. Again employing the Gallant-Jorgenson test method, the hypothesis that all relationship dummy coefficients are jointly bigger than or equal to zero is rejected at the 5% level (p-value 0.0426) for the model using the actual values, whereas for the model using the predicted values it cannot be rejected (p-value 0.5430). Thus, for the owner-fixed-renters there is exactly the opposite effect of the model which takes into account endogenous crop choice as in the case of owner-sharecroppers: The coefficients for the variable which captures an aspect of the tenancy contract are jointly significant in the model which takes the crop choice as exogenously given, and become jointly insignificant if the crop choice is considered endogenous.

Table 16 shows the results for the OLS estimation of the output difference equation. Worth mentioning is, that for both the actual and the predicted values estimation the intercepts are not significantly different from zero and that the coefficients for the relationship dummy are negative but not significant in both cases. Thus, there is no evidence that tenancy has any effect on the differences in average output intensities in the case of the owner-fixed-rent tenants.

4.5 Conclusion

Making predictions on the efficiency of risk sharing and on productive efficiency under different tenancy contracts often depends crucially on the assumption whether the actions taken by the tenant can be perfectly (costlessly) monitored by the landlord or not. If the landlord is capable to stipulate the amounts of all inputs to be applied to the tenancy in the contract because he can control the tenant's actions at reasonable costs, then there is no reason why there should be different input intensities between owned plots, sharecropped plots, and plots cultivated under a fixed-rent contract. But if this control over the tenant's action is not possible for whatever reason, one would expect lower input intensities on sharecropped plots compared with owned plots and plots leased-in under a fixed-rent contract according to the predictions of the theory: Why should a rational farmer devote the same effort to the cultivation of a crop from the output of which he receives only one half as to the cultivation of a crop the surplus of which accrues wholly to him?

To assess empirically whether the Marshallian or the monitoring approach is valid, we used the method proposed by Shaban (1987), extending his analysis by introducing variables controlling for the crop types grown and for different aspects of the tenancy contract, such as the cost-sharing arrangement, the rules concerning the supervision of the production process, and the relationship between the landlord and the tenant. We studied both owner-sharecroppers and owner-fixed-rent tenants in order to clarify whether lower input intensities are the consequence of the sharecropping contract, or whether this is a phenomenon which can be ascribed to the effects of tenancy itself. Our main findings in the econometric model which takes the crop indicator variables as exogenously given are: (i) the hypothesis that all intercepts are jointly equal to zero is rejected for the owner-sharecroppers at the 5% level; but the hypothesis that these intercepts are jointly smaller than or equal to zero cannot be rejected, (ii) for the owner-fixed-renters, the hypothesis that all intercepts are jointly equal to zero can also be rejected at the 1% level, but no general direction for the differences can be established, (iii) for the owner-sharecroppers, the hypothesis that all cost share coefficients are jointly equal to zero is rejected at the 10% level and the hypothesis that all supervision dummy coefficients are jointly equal to zero cannot be rejected, (iv) for the owner-fixed-renters the hypothesis that all relationship dummy coefficients are jointly equal to zero can be rejected at the 5% level, but again no general direction of the influence can be established, (v) for the output difference estimation the intercept is significantly different from zero neither for the owner-sharecroppers nor for the owner-fixed-rent tenants.

We further estimated a model which takes into account the possibility that the crops grown on plots of different tenancy status are the outcome of an endogenous choice which is influenced amongst other things by the observed and unobserved characteristics of the tenant, and, as far as the crops cultivated under a tenancy are concerned, by the observed and unobserved characteristics of the landlord, too. In this case our main findings are: (i) the hypothesis that all intercepts are jointly equal to zero is rejected for the owner-sharecroppers at the 5% level; moreover, the hypothesis that these intercepts are jointly smaller than or equal to zero can be rejected at the 10% level, (ii) for the owner-fixed-renters, the hypothesis that all intercepts are jointly equal to zero can also be rejected at the 1% level, but no general direction for the differences can be established, (iii) for the owner-sharecroppers, the hypothesis that all cost share coefficients are jointly equal to zero can now be rejected at the

1% level and the hypothesis that all supervision dummy coefficients are jointly equal to zero can now be rejected at the 5% level; for the supervision dummies we cannot say in which direction the influence runs, whereas for the cost-share variables the hypothesis that they are jointly smaller than or equal to zero is rejected at the 1% level, (iv) for the owner-fixed-renters the hypothesis that all relationship dummy coefficients are jointly equal to zero cannot be rejected, (v) in the output difference estimation the intercept is significantly positive at the 5% level for the owner-sharecroppers, whereas it is not significant for the owner-fixed-rent tenants.

That is, in the model which uses the predicted values for the class of owner-sharecroppers the mean differences (the intercepts) between average input intensities on owned and sharecropped plots are positive for all inputs even after controlling for other factors, a finding which can be interpreted as evidence for the Marshallian approach. Controlling for the endogeneity of crop choice, we find also evidence for a positive difference between average output intensities on owned and sharecropped plots, again a finding which is in favor of the Marshallian hypothesis. For the tenants cultivating owned plots and plots leased-in under a fixed-rent contract the mean differences are also jointly different from zero, but they have no uniform direction concerning their sign. Thus, we cannot conclude from either of the two models for this group of tenants that inputs are systematically undersupplied on their leased-in plots. Concerning the differences in average output intensities, we find in the case of the owner-fixed-rent tenants no evidence for a systematically lower output intensity on the leased-in plots. However, for the model which does not account for endogenous crop choice we find evidence that a kinship relation between the landlord and the tenant leads to higher input intensities on the leased-in plots of the owner-fixed-rent tenants, indicating that also fixed rent contracts may not be perfectly efficient. For both groups of tenants, different cropping patterns on owned and leased-in plots explain part of the differences between average input intensities on owned and leased-in plots. But for the owner-sharecroppers, in the model which takes into account the endogeneity of crop choice the influence of the cropping patterns on the input differences becomes less clear, whereas instead of this there is strong evidence that a higher cost-share relative to the output-share of the tenant has a stronger negative influence on the input intensities on the sharecropped-in plots than on the input intensities on his owned plots. This is in accordance with our theoretical predictions and has again the implication that the tenant's actions can be only imperfectly monitored. Otherwise, the characteristics of the contract would not have an influence on the difference in average input intensities.

Appendix

Proof of proposition 1:

We know that for CARA $E[u''(\theta f' - \delta c)] = 0$ and $E[u''\theta(\theta f' - \delta c)] \gtrless 0 \Leftrightarrow \frac{E[u''\theta^2]}{E[u''\theta]} \lessgtr \frac{E[u'\theta]}{E[u']}$.

Making use of the fact that θ is uniformly distributed on $[0, \bar{\theta}]$, we can write

$$\frac{E[u''\theta^2]}{E[u''\theta]} \lessgtr \frac{E[u'\theta]}{E[u']} \Leftrightarrow \frac{\int_0^{\bar{\theta}} \exp[-a(\alpha\theta f - \beta cx)]\theta^2 d\theta}{\int_0^{\bar{\theta}} \exp[-a(\alpha\theta f - \beta cx)]\theta d\theta} \lessgtr \frac{\int_0^{\bar{\theta}} \exp[-a(\alpha\theta f - \beta cx)]\theta d\theta}{\int_0^{\bar{\theta}} \exp[-a(\alpha\theta f - \beta cx)]d\theta}$$

$\Leftrightarrow$

$$2\left(1 - \exp\left[-a\alpha\bar{\theta}f\right]\right)^2 - a\alpha\bar{\theta}f \exp\left[-a\alpha\bar{\theta}f\right]\left(2 + a\alpha\bar{\theta}f\right)\left(1 - \exp\left[-a\alpha\bar{\theta}f\right]\right) \lessgtr$$
$$\left(\left(1 - \exp\left[-a\alpha\bar{\theta}f\right]\right) - a\alpha\bar{\theta}f \exp\left[-a\alpha\bar{\theta}f\right]\right)^2$$

$\Leftrightarrow$

$1 - \exp\left[-a\alpha\bar{\theta}f\right]\left(1 + \left(a\alpha\bar{\theta}f\right)^2\right) \lessgtr 0 \Leftrightarrow a\alpha\bar{\theta}f \lessgtr \ln\left[1 + \left(a\alpha\bar{\theta}f\right)^2\right]$. Define $z \equiv a\alpha\bar{\theta}f$. Since $z \geq 0$, and since $g(z) = \ln\left[1 + z^2\right]$ is strictly convex on the interval $[0,1)$, strictly concave on the interval $(1, +\infty)$, and touches the function $g(z) = z$ at 0 and 1, it follows that $a\alpha\bar{\theta}f \geq \ln\left[1 + \left(a\alpha\bar{\theta}f\right)^2\right]$. Therefore in this case $E[u''\theta(\theta f' - \delta c)] \leq 0$.

Explanations to equations (44) and (45):

$A_1 = f_{11}E[u'\theta] + \alpha E\left[u''(\theta f_1 - \delta_1 c_1)^2\right] < 0$,

$A_2 = f_{21}E[u'\theta] + \alpha E[u''(\theta f_1 - \delta_1 c_1)(\theta f_2 - \delta_2 c_2)]$,

$B_1 = f_{12}E[u'\theta] + \alpha E[u''(\theta f_1 - \delta_1 c_1)(\theta f_2 - \delta_2 c_2)]$,

$B_2 = f_{22}E[u'\theta] + \alpha E\left[u''(\theta f_2 - \delta_2 c_2)^2\right] < 0$,

$$D_1 = -\left\{ \frac{\partial \alpha}{\partial \delta_1} \delta_1 c_1 x_1 + \frac{\partial \alpha}{\partial \delta_1} \delta_2 c_2 x_2 + \alpha c_1 x_1 \right\} E\left[u''\left(\theta f_1 - \delta_1 c_1\right)\right] + \frac{\partial \alpha}{\partial \delta_1} f E\left[u'' \theta\left(\theta f_1 - \delta_1 c_1\right)\right],$$

$$D_2 = -\left\{ \frac{\partial \alpha}{\partial \delta_1} \delta_1 c_1 x_1 + \frac{\partial \alpha}{\partial \delta_1} \delta_2 c_2 x_2 + \alpha c_1 x_1 \right\} E\left[u''\left(\theta f_2 - \delta_2 c_2\right)\right] + \frac{\partial \alpha}{\partial \delta_1} f E\left[u'' \theta\left(\theta f_2 - \delta_2 c_2\right)\right].$$

Table 1: Total operational landholdings of households by tenancy status (in acres)

	mean	std.dev.	min	max	Number of households
pure owners	4.062973	6.57121 (p<0.0001)	0.20	40.61	111
owner/sharecropper owned plots	1.812308	1.65025 (p<0.0001)	0.20	7.86	39
owner/sharecropper shared plots	2.402051	2.97836 (p<0.0001)	0.11	14.82	39
owner/sharecropper total holdings	4.308462	3.97277 (p<0.0001)	0.53	19.03	39
owner/fixed-rent owned plots	2.665091	2.35017 (p<0.0001)	0.24	11.44	55
owner/fixed-rent leased plots	1.617818	1.70932 (p<0.0001)	0.18	10.01	55
owner/fixed-rent total holdings	4.468364	3.36182 (p<0.0001)	0.63	16.30	55

Table 2: Irrigation of plots by tenancy status

	irrigation status	frequency	percent	chi-square test for eq. prop.
all plots	irrigated	274	44.55	7.2992
	unirrigated	341	55.45	(p=0.0069)
pure owners	irrigated	85	33.20	28.8906
	unirrigated	171	66.80	(p<0.0001)
owner/sharecr.	irrigated	23	27.71	16.4940
owned plots	unirrigated	60	72.29	(p<0.0001)
owner/sharecr.	irrigated	21	35.00	5.4
shared plots	unirrigated	39	65.00	(p=0.0201)
owner/sharecr.	irrigated	44	30.77	21.1538
all plots	unirrigated	99	69.23	(p<0.0001)
owner/fixed-r.	irrigated	85	62.04	7.9489
owned plots	unirrigated	52	37.96	(p=0.0048)
owner/fixed-r.	irrigated	48	71.64	12.5522
leased plots	unirrigated	19	28.36	(p=0.0004)
owner/fixed-r.	irrigated	132	65.02	18.3300
all plots	unirrigated	71	34.98	(p<0.0001)

Table 2a: Area irrigated under different tenancy contracts (in acres)

	irrigation status	average farm area	total area	paired t-test (equal irr. and unirr. farm area
all plots	irrigated	0.49	97.73	-3.67
	unirrigated	1.40	281.84	(p=0.0003)
pure owners	irrigated	0.28	28.12	-2.77
	unirrigated	1.42	142.88	(p=0.0067)
owner/sharecr.	irrigated	0.07	2.77	-4.24
owned plots	unirrigated	0.65	25.17	(p=0.0001)
owner/sharecr.	irrigated	0.36	13.41	-1.75
shared plots	unirrigated	1.04	38.41	(p=0.0889)
owner/sharecr.	irrigated	0.42	16.18	-3.26
all plots	unirrigated	1.63	63.58	(p=0.0024)
owner/fixed-r.	irrigated	0.61	31.64	-0.88
owned plots	unirrigated	0.90	46.54	(p=0.3823)
owner/fixed-r.	irrigated	0.43	20.43	0.51
leased plots	unirrigated	0.35	16.80	(p=0.6110)
owner/fixed-r.	irrigated	0.94	51.79	-0.53
all plots	unirrigated	1.15	63.34	(p=0.5994)

Table 3: Frequency table of crops by tenancy status (owner/sharecropper)

	owner/sharecropper owned plots	owner/sharecropper shared plots	total
paddy	50 46.73 26.60	57 53.27 42.54	107 33.23
cereals	38 61.29 20.21	24 38.71 17.91	62 19.25
grams	46 63.01 24.47	27 36.99 20.15	73 22.67
groundnut	34 72.34 18.09	13 27.66 9.70	47 14.60
castor seed	13 65.00 6.91	7 35.00 5.22	20 6.21
cotton	7 53.85 3.72	6 46.15 4.48	13 4.04
total	188 58.39	134 41.61	322 100.00

The order of the cell entries form top to bottom is: frequency, row percent, and column percent. The overall chisquare is $\chi^2_{(5)} = 11.08$.

Table 4: Frequency table of crops by tenancy status (owner/fixed-rent)

	owner/fixed-rent owned plots	owner/fixed-rent leased plots	total
paddy	221 69.28 69.94	98 30.72 65.33	319 68.45
cereals	36 65.45 11.39	19 34.55 12.67	55 11.80
grams	23 62.16 7.28	14 37.84 9.33	37 7.94
groundnut	19 67.86 6.01	9 32.14 6.00	28 6.01
chilies	10 76.92 3.16	3 23.08 2.00	13 2.79
others	7 50.00 2.22	7 50.00 4.67	14 3.00
total	316 67.81	150 32.19	466 100.00

The order of the cell entries form top to bottom is: frequency, row percent, and column percent. The overall chisquare is $\chi^2_{(5)} = 3.53$.

Table 4a: Proportions of land grown under different crops

	pure owners	*owner-sharec. owned plots*	*owner-sharec. sharec. plots*	*owner-fix owned plots*	*owner-fix leased plots*
paddy	0.20	0.10	0.26	0.50	0.49
cereals	0.24	0.32	0.25	0.15	0.17
grams	0.06	0.11	0.11	0.03	0.05
groundnut	0.21	0.25	0.12	0.10	0.16
castor seed	0.09	0.14	0.10	0.07	0.04
cotton	0.11	0.05	0.16	0.09	0.04
chilies	0.02	0.03	0.00	0.04	0.01
sugarcane	0.02	0.00	0.00	0.002	0.004
others	0.05	0.003	0.00	0.007	0.03
total area	431.26	80.80	104.37	171.84	100.90

Total area is measured in acres. Total areas differ from total areas in table 2a, since in this table we use observations from both seasons, whereas in table 2a each plot appears only once in the computations.

Table 5: Mean input intensities for different crops (all plots in crop production schedule)

	preharvest labour	harvest labour	bullock-pair days	seedlings	farm yard manure	fertilizer/ pesticides	number of plots
paddy	479.43 (341.52) p<0.0001	114.70 (96.19) p<0.0001	116.81 (158.22) p<0.0001	2177.19 (2064.36) p<0.0001	598.09 (897.60) p<0.0001	1546.57 (2248.33) p<0.0001	284
cereals	32.53 (56.47) p<0.0001	37.82 (68.39) p<0.0001	20.62 (29.63) p<0.0001	34.64 (64.64) p<0.0001	50.62 (148.22) p<0.0001	18.04 (64.29) p<0.0001	270
grams	3.63 (7.83) p<0.0001	55.68 (68.69) p<0.0001	2.90 (5.99) p<0.0001	152.80 (136.41) p<0.0001	6.02 (27.55) p=0.0009	7.24 (44.82) p=0.0132	239
groundnut	60.58 (36.17) p<0.0001	38.23 (28.79) p<0.0001	16.84 (8.68) p<0.0001	592.90 (333.70) p<0.0001	100.85 (156.03) p<0.0001	172.21 (259.71) p<0.0001	204
castor seed	17.05 (7.31) p<0.0001	27.42 (21.57) p<0.0001	15.58 (6.29) p<0.0001	41.24 (24.91) p<0.0001	29.59 (60.33) p=0.0001	7.81 (23.13) p=0.0065	69
cotton	27.93 (23.51) p<0.0001	15.37 (9.60) p<0.0001	11.34 (4.85) p<0.0001	29.30 (4.57) p<0.0001	15.29 (51.40) p=0.0640	40.92 (92.70) p=0.0073	41
chilies	303.34 (230.77) p<0.0001	109.47 (67.84) p<0.0001	39.61 (39.49) p<0.0001	245.49 (217.52) p<0.0001	590.25 (784.10) p=0.0001	668.33 (698.87) p<0.0001	34
sugarcane	235.43 (308.28) p<0.0001	135.11 (292.81) p=0.0052	24.60 (33.13) p<0.0001	1155.68 (1588.07) p<0.0001	151.79 (301.71) p=0.0025	735.28 (522.60) p<0.0001	41

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs are in rupees per acre. Standard deviations are in parentheses and p represents the p-value for the t-statistic.

Table 6: Results of the Sidak-test

	paddy	cereals	grams	groundn.	castor s.	cotton	chillies	sugarc.
paddy		se,fp,fy, pl,hl,bp	se,fp,fy, pl,hl,bp	se,fp,fy, pl,hl,bp	se,fp,fy, pl,hl,bp	se,fp,fy, pl,hl,bp	se,fp,pl, bp	se,fp,fy, pl,bp
cereal				se			fy,pl,hl	se,fp,pl, hl
grams				se			fy,pl	se,fp,pl, hl
groundn.					se		fy,pl,hl	pl,hl
castor s.							fy,pl,hl	se,pl,hl
cotton							fy,pl,hl	se,pl,hl
chillies								se,fy
sugarc.								

The same table results if a Bonferroni-test is employed. Pl stands for preharvest labour, hl for harvest labour, bp for bullock-pair days, se for seedlings, fy for farm yard manure, fp for fertilizer and pesticides. In the table, all inputs are listed for which the respective pair of crops shows a statistically significant difference at the 1-percent level for the mean input intensities.

Table 7: Mean differences in average input and output intensities

	owner-sharecropper		*owner-fixed-rent*	
	mean differences in average input intensities (std. error)	t-value (p-value)	mean differences in average input intensities (std. error)	t-value (p-value)
seedlings	33.65	1.14	-86.25	-1.83
	(29.59)	(0.2619)	(47.02)	(0.0707)
fertilizer/	3.64	0.21	-107.72	-3.17
pesticides	(17.72)	(0.8381)	(33.97)	(0.0022)
farm yard	8.99	0.43	11.34	1.36
manure	(21.10)	(0.6723)	(8.31)	(0.1765)
preharvest labour	-10.01	-1.13	-8.89	-1.56
	(8.83)	(0.2631)	(5.69)	(0.1223)
harvesting labour	7.06	1.67	-12.76	-2.90
	(4.24)	(0.1032)	(4.40)	(0.0049)
bullock pair days	-2.94	-0.83	-7.55	-2.28
	(3.53)	(0.4100)	(3.31)	(0.0253)
tractor hours	-	-	-52.98	-6.37
			(8.31)	(<0.0001)
output	-301.28	-1.04	-857.80	-1.78
	(289.65)	(0.3045)	(481.52)	(0.0797)
χ^2 -value		21.23		67.13

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs and output are in rupees per acre.

Table 8: Differences on owned and sharecropped land of owner-sharecroppers, without controlling for the cost share (n=43)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*bullock pair days*	*output*
intercept	21.41 (21.43) [0.3240]	29.14 (14.91) [0.0580]	47.87 (19.58) [0.0192]	9.90 (5.55) [0.0823]	10.05 (4.17) [0.0208]	3.30 (2.98) [0.2753]	182.33 (147.61) [0.2243]
irrigation	189.15 (40.02) [<0.0001]	134.55 (28.19) [<0.0001]	93.31 (34.19) [0.0096]	68.04 (10.31) [<0.0001]	12.71 (7.79) [0.1107]	19.29 (5.62) [0.0015]	3062.39 (269.35) [<0.0001]
grams	-353.35 (583.70) [0.5485]	-471.35 (412.90) [0.2608]	-	-254.72 (125.90) [0.0502]	-171.65 (105.70) [0.1127]	-127.78 (81.07) [0.1235]	-
groundnut	360.06 (52.64) [<0.0001]	38.30 (37.24) [0.3102]	-150.28 (47.09) [0.0028]	-52.97 (13.79) [0.0005]	-14.65 (10.35) [0.1650]	-17.17 (7.40) [0.0259]	-
castor seed	-	-	-81.69 (36.67) [0.0319]	-	-	16.30 (4.88) [0.0019]	-
super-vision	-42.92 (67.93) [0.5313]	-125.49 (59.41) [0.0413]	-31.66 (79.84) [0.6939]	-20.83 (19.14) [0.2832]	29.17 (16.57) [0.0863]	-11.96 (8.31) [0.1586]	-
decision cropping pattern	-	-	-	-	-	-	-867.40 (617.07) [0.1679]
adjusted R-square	0.60	0.44	0.32	0.68	0.27	0.43	0.78
χ^2-value	71.07 [<0.0001]	38.34 [<0.0001]	27.16 [<0.0001]	102.25 [<0.0001]	21.41 [0.0007]	47.30 [<0.0001]	-
F-value	-	-	-	-	-	-	68.17 [<0.0001]

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs and output are in rupees per acre. Standard errors are in parentheses, p-values are in brackets.

Table 8a: Differences on owned and sharecropped land of owner-sharecroppers, controlling for the cost share (n=43)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*bullock pair days*	*output*
intercept	144.12 (62.23) [0.0262]	-77.47 (47.25) [0.1095]	115.44 (59.87) [0.0615]	12.50 (13.25) [0.3518]	11.98 (12.91) [0.3595]	9.73 (8.02) [0.2334]	182.33 (147.61) [0.2243]
irrigation	163.03 (40.92) [0.0003]	157.46 (28.91) [<0.0001]	80.82 (35.30) [0.0278]	67.89 (10.63) [<0.0001]	12.51 (8.21) [0.1361]	19.16 (5.60) [0.0016]	3062.39 (269.35) [<0.0001]
grams	-470.57 (572.60) [0.4165]	-364.01 (403.40) [0.3727]	-	-244.13 (128.10) [0.0644]	-167.24 (107.50) [0.1281]	-125.46 (81.13) [0.1308]	-
groundnut	410.98 (56.79) [<0.0001]	-7.02 (40.70) [0.8639]	-122.98 (51.64) [0.0225]	-52.37 (14.55) [0.0009]	-14.13 (11.23) [0.2158]	-16.75 (7.38) [0.0293]	-
castor seed	-	-	-76.64 (37.00) [0.0453]	-	-	15.39 (5.09) [0.0046]	-
cost share	-100.61 (48.39) [0.0446]	88.04 (37.12) [0.0230]	-55.79 (46.60) [0.2388]	-2.02 (9.57) [0.8340]	-1.52 (9.55) [0.8754]	-3.76 (4.39) [0.3972]	-
super-vision	-46.75 (65.77) [0.4817]	-109.09 (57.47) [0.0655]	-41.95 (79.99) [0.6032]	-21.67 (19.59) [0.2758]	29.15 (17.02) [0.0952]	-14.52 (8.78) [0.1068]	-
decision cropping pattern	-	-	-	-	-	-	-867.40 (617.07) [0.1679]
adjusted R-square	0.62	0.48	0.33	0.67	0.22	0.43	0.78
χ^2-value	80.33 [<0.0001]	47.45 [<0.0001]	29.05 [0.0001]	100.53 [<0.0001]	20.79 [0.0019]	47.26 [<0.0001]	-
F-value	-	-	-	-	-	-	68.17 [<0.0001]

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs and output are in rupees per acre. Standard errors are in parentheses, p-values are in brackets.

Table 9: Differences on owned and leased-in land of owner-fixed-rent tenants, (n=75)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*tractor hours*	*bullock pair days*	*output*
intercept	94.09 (57.23) [0.1048]	17.80 (39.58) [0.6543]	36.38 (12.06) [0.0036]	6.97 (7.42) [0.3503]	-2.62 (5.81) [0.6527]	-30.09 (13.25) [0.0262]	-3.12 (3.12) [0.3201]	-25.13 (256.53) [0.9223]
irrigation	65.79 (68.17) [0.3379]	254.26 (59.44) [<.0001]	51.28 (14.07) [0.0005]	31.33 (11.88) [0.0103]	-3.45 (7.81) [0.6594]	42.96 (17.04) [0.0139]	3.18 (3.64) [0.3854]	4356.95 (818.95) [<.0001]
cereals	-177.71 (124.10) [0.1566]	-180.55 (83.00) [0.0330]	-	-31.67 (17.93) [0.0818]	-	-	-	-
grams	-	-	-	-	-	-	-187.79 (28.84) [<.0001]	-
groundnut	400.43 (178.00) [0.0277]	-	-60.64 (31.73) [0.0601]	-41.60 (22.49) [0.0687]	-105.99 (15.47) [<.0001]	-	-35.56 (8.20) [<.0001]	-
cotton	-	-317.35 (142.00) [0.0287]	-	-39.94 (27.44) [0.1502]	-46.24 (15.57) [0.0041]	-	-	-
chilies	-	-	-	-	-	-	-35.84 (14.12) [0.0134]	-
sugarcane	1857.07 (285.00) [<.0001]	-	-	-	-	-	-	19061.00 (1930.84) [<.0001]
relation-ship	-214.31 (88.39) [0.0180]	-66.20 (63.25) [0.2989]	-23.43 (18.56) [0.2110]	-20.22 (11.83) [0.0918]	-17.72 (9.08) [0.0551]	-19.02 (18.02) [0.2946]	-7.94 (4.83) [0.1049]	-
village	-166.06 (76.58) [0.0336]	-59.46 (56.08) [0.2927]	-8.04 (15.93) [0.6153]	4.52 (10.77) [0.6760]	-0.42 (7.97) [0.9587]	-	7.65 (4.12) [0.0677]	-

Table 9 continued

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*tractor hours*	*bullock pair days*	*output*
adjusted R-square	0.37	0.40	0.17	0.22	0.37	0.21	0.47	0.75
χ^2-value	68.35 [<.0001]	80.01 [<.0001]	21.07 [0.0008]	36.51 [<.0001]	67.64 [<.0001]	37.58 [<.0001]	117.40 [<.0001]	-
F-value	-	-	-	-	-	-	-	91.14 [<.0001]

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs and output are in rupees per acre, and tractor hours are in hours per acre. Standard errors are in parentheses, p-values are in brackets.

Table 10: Multinomial logit estimates for the crop choice equations

	owner-sharecropper	*owner-fixed-rent*
irrigation.paddy	34.20 (13.60)	13.81 (2.59)
	[0.0119]	[<0.0001]
irrigation.cereals	-1.17 (0.80)	-16.17 (1331)
	[0.1423]	[0.9903]
irrigation.sugarcane	-	24.71 (7.86)
		[0.0017]
irrigation.others	30.68 (13.83)	0.78 (0.55)
	[0.0266]	[0.1503]
famlabmt.paddy	-1.44 (0.48)	0.16 (0.36)
	[0.0028]	[0.6523]
famlabmt.groundnut	-0.52 (0.23)	-0.16 (0.20)
	[0.0232]	[0.4212]
famlabft.chillies	-	-0.56 (0.35)
		[0.1102]
famlabml.paddy	-3.34 (2.04)	-4.67 (2.02)
	[0.1012]	[0.0206]
famsizt.paddy	-0.36 (0.24)	-0.59 (0.13)
	[0.1323]	[<0.0001]
famsizt.cereals	0.04 (0.06)	-0.002 (0.08)
	[0.5126]	[0.9781]
famsizl.paddy	1.08 (0.59)	1.01 (0.57)
	[0.0659]	[0.0749]
draughtt.paddy	0.80 (0.42)	1.03 (0.44)
	[0.0582]	[0.0196]
draughtt.cotton	0.40 (0.29)	0.27 (0.17)
	[0.1588]	[0.1023]
machint.paddy	2.80 (1.63)	-3.09 (0.62)
	[0.0864]	[<0.0001]
machint.grams	-1.25 (0.78)	-1.37 (0.46)
	[0.1101]	[0.0030]
wellt.cotton	-15.89 (1217)	-2.88 (0.82)
	[0.9896]	[0.0004]
landownt.paddy	0.12 (0.29)	-0.64 (0.20)
	[0.6665]	[0.0015]
landownt.cereals	0.11 (0.11)	0.06 (0.07)
	[0.3148]	[0.4178]

Standard errors are in parentheses, p-values are in brackets.

table 10 continued

	owner-sharecropper	*owner-fixed-rent*
aget.groundnut	0.002 (0.02) [0.9226]	-0.02 (0.02) [0.1988]
aget.chillies	-	0.05 (0.03) [0.0656]
aget.sugarcane	-	-0.12 (0.08) [0.1057]
assett.paddy	2.34 (1.17) [0.0449]	1.97 (0.61) [0.0011]
assett.cereals	-0.66 (0.92) [0.4714]	-1.36 (0.73) [0.0618]
assett.grams	1.64 (0.55) [0.0029]	0.95 (0.51) [0.0600]
assett.chillies	-	0.48 (0.54) [0.3779]
assetl.paddy	0.86 (0.96) [0.3685]	0.63 (0.65) [0.3330]
assetl.cereals	-0.02 (0.48) [0.9601]	0.61 (0.39) [0.1228]
assetl.grams	-0.91 (0.55) [0.0990]	0.59 (0.37) [0.1103]
labourcosts	-0.41 (0.18) [0.0215]	-0.03 (0.02) [0.0851]
othercosts	0.03 (0.01) [0.0119]	-0.009 (0.006) [0.1103]
number of observations	282	431
log likelihood	-336.11	-329.67

Standard errors are in parentheses, p-values are in brackets.

Table 10a: Residence status of landlords

	resident landlord	non-resident landlord	total
sharecroppers	53 72.60 33.97	20 27.40 33.33	73 33.80
fixed-rent tenants	103 72.03 66.03	40 27.97 66.67	143 66.20
total	60 27.78	156 72.22	216 100.00

The order of the cell entries form top to bottom is: frequency, row percent, and column percent. The overall chisquare is $\chi^2_{(1)} = 0.008$.

List of variables in the multinomial logit model

Variable	*Description*
irrigation.	dummy variable (=1 if the plot is irrigated, =0 otherwise)
famlabmt.	number of adult male workers in the tenant's family
famlabft.	number of adult female workers in the tenant's family
famlabml.	number of adult male workers in the landlord's family
famsizt.	number of individuals in the tenant's family
famsizl.	number of individuals in the landlord's family
draughtt.	number of the tenant's draught animals
machint.	number of agricultural machines owned by the tenant
wellt.	number of wells owned by the tenant
landownt.	total land owned by the tenant (in acres)
aget.	age of the tenant
assett.	total asset value of the tenant (in 100,000 rupees)
assetl.	total asset value of the landlord (in 100,000 rupees)
labourcosts	average amount of working hours used in the cultivation of a particular crop (in hours)
othercosts	total average costs of other inputs (fertilizer, pesticides, farm yard manure) used in the cultivation of a particular crop (in rupees)

Table 11: Differences on owned and sharecropped land of owner-sharecroppers, actual crop dummies (n=43)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*bullock pair days*
intercept	141.86	-77.71	132.93	12.31	12.94	10.35
	(65.44)	(51.30)	(63.30)	(13.50)	(13.41)	(8.04)
	[0.0371]	[0.1388]	[0.0430]	[0.3684]	[0.3412]	[0.2065]
irrigation	165.41	156.15	108.23	66.35	10.26	10.69
	(54.82)	(39.03)	(50.54)	(14.43)	(11.06)	(7.63)
	[0.0047]	[0.0003]	[0.0393]	[<.0001]	[0.3597]	[0.1699]
cereals	-13.03	-10.46	70.95	1.87	-1.90	-14.63
	(51.71)	(36.72)	(47.76)	(13.95)	(10.55)	(7.47)
	[0.8025]	[0.7775]	[0.1464]	[0.8944]	[0.8580]	[0.0581]
grams	-23.95	-30.51	4.32	-37.78	-22.69	-21.17
	(107.90)	(71.90)	(93.81)	(27.82)	(20.94)	(15.66)
	[0.8257]	[0.6739]	[0.9636]	[0.1831]	[0.2858]	[0.1850]
groundnut	390.17	-24.50	-87.28	-63.38	-22.01	-28.56
	(60.62)	(42.84)	(55.46)	(15.76)	(11.99)	(8.40)
	[<.0001]	[0.5710]	[0.1245]	[0.0003]	[0.0748]	[0.0017]
cotton	9.63	13.27	-63.44	11.77	-17.56	-8.39
	(150.10)	(107.00)	(138.90)	(39.76)	(29.97)	(21.36)
	[0.9492]	[0.9020]	[0.6507]	[0.7690]	[0.5617]	[0.6967]
super-vision	-45.45	-111.32	-69.35	-25.32	25.71	-12.60
	(72.38)	(60.09)	(79.03)	(20.12)	(17.46)	(9.68)
	[0.5341]	[0.0724]	[0.3862]	[0.2166]	[0.1497]	[0.2019]
cost share	-97.86	89.22	-70.20	-0.86	-1.82	-3.92
	(51.15)	(40.73)	(49.98)	(9.80)	(9.97)	(4.37)
	[0.0640]	[0.0352]	[0.1689]	[0.9305]	[0.8559]	[0.3759]
adjusted R-square	0.60	0.44	0.33	0.65	0.18	0.37
χ^2-value	74.26	43.19	28.47	95.20	18.53	35.52

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs are in rupees per acre. Standard errors are in parentheses, p-values are in brackets.

Table 12: Differences on owned and sharecropped land of owner-sharecroppers, predicted crop dummies (n=43)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*bullock pair days*
intercept	-117.24	-98.41	220.28	18.12	21.31	17.06
	(94.59)	(48.05)	(75.51)	(16.49)	(14.53)	(9.87)
	[0.2234]	[0.0481]	[0.0061]	[0.2792]	[0.1513]	[0.0927]
irrigation	122.63	146.07	171.31	83.33	19.22	13.55
	(79.73)	(41.84)	(70.08)	(19.57)	(13.29)	(10.57)
	[0.1330]	[0.0013]	[0.0197]	[0.0001]	[0.1571]	[0.2085]
cereals	576.56	234.14	-129.92	76.23	-74.78	-24.24
	(380.10)	(199.80)	(332.40)	(90.97)	(63.68)	(47.46)
	[0.1383]	[0.2493]	[0.6983]	[0.4077]	[0.2482]	[0.6127]
grams	-484.77	-279.89	45.57	-9.88	19.68	-35.92
	(216.80)	(112.80)	(190.00)	(54.00)	(36.92)	(29.51)
	[0.0318]	[0.0181]	[0.8119]	[0.8559]	[0.5974]	[0.2317]
groundnut	-102.45	-232.72	31.35	-169.54	11.65	-17.23
	(352.60)	(189.40)	(315.40)	(85.37)	(60.55)	(44.11)
	[0.7731]	[0.2275]	[0.9214]	[0.0549]	[0.8486]	[0.6985]
cotton	-1866.50	326.08	2094.80	287.44	288.12	156.13
	(1308.50)	(689.00)	(1157.10)	(327.30)	(224.60)	(176.50)
	[0.1626]	[0.6390]	[0.0788]	[0.3858]	[0.2079]	[0.3824]
super-vision	-83.46	-96.02	-92.99	-7.74	27.26	-13.42
	(88.85)	(58.06)	(96.96)	(22.44)	(18.49)	(10.08)
	[0.3540]	[0.1071]	[0.3441]	[0.7322]	[0.1493]	[0.1916]
cost share	147.62	121.31	-126.95	-7.78	-8.31	-6.57
	(67.31)	(34.06)	(52.87)	(10.55)	(9.86)	(5.27)
	[0.0350]	[0.0011]	[0.0218]	[0.4658]	[0.4053]	[0.2210]
adjusted R-square	0.37	0.56	0.30	0.56	0.17	0.22
χ^2-value	31.64	65.29	24.45	68.59	17.13	23.11

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs are in rupees per acre. Standard errors are in parentheses, p-values are in brackets.

Table 13: Differences on owned and leased-in land of owner-fixed-rent tenants, actual crop dummies (n=75)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*tractor hours*	*bullock pair days*
intercept	98.66	18.74	36.54	6.61	-2.97	-27.55	-5.16
	(58.81)	(42.14)	(12.44)	(7.78)	(6.02)	(13.36)	(3.58)
	[0.0983]	[0.6580]	[0.0046]	[0.3987]	[0.6235]	[0.0429]	[0.1541]
irrigation	-57.56	293.98	17.49	27.71	7.93	49.59	0.78
	(102.00)	(75.41)	(21.23)	(14.13)	(10.62)	(17.91)	(6.10)
	[0.5744]	[0.0002]	[0.4130]	[0.0542]	[0.4581]	[0.0072]	[0.8984]
cereals	-453.76	-72.27	-85.65	-42.26	39.30	-	12.31
	(211.30)	(152.50)	(44.53)	(28.23)	(21.70)		(12.81)
	[0.0355]	[0.6371]	[0.0589]	[0.1393]	[0.0748]		[0.3401]
grams	549.63	12.80	51.93	-38.40	-0.13	-	-144.69
	(849.80)	(607.00)	(180.00)	(111.80)	(86.77)		(51.78)
	[0.5201]	[0.9832]	[0.7739]	[0.7324]	[0.9988]		[0.0069]
groundnut	151.51	31.67	-129.50	-50.56	-82.19	-	-28.63
	(227.70)	(163.90)	(48.06)	(30.31)	(23.35)		(13.82)
	[0.5082]	[0.8474]	[0.0090]	[0.1002]	[0.0008]		[0.0423]
cotton	-343.40	-236.61	-91.72	-52.07	-23.69	-	-10.49
	(243.90)	(177.50)	(51.21)	(32.99)	(25.17)		(14.72)
	[0.1641]	[0.1872]	[0.0780]	[0.1194]	[0.3501]		[0.4788]
chilies	-58.41	255.17	-59.77	10.23	34.59	91.99	-64.54
	(363.20)	(259.90)	(76.84)	(47.93)	(37.13)	(238.80)	(22.10)
	[0.8727]	[0.3300]	[0.4394]	[0.8317]	[0.3550]	[0.7012]	[0.0048]
sugarcane	1812.59	-105.96	-22.08	-10.30	-11.60	-	-24.23
	(336.00)	(240.00)	(71.15)	(44.20)	(34.30)		(20.47)
	[<.0001]	[0.6603]	[0.7573]	[0.8164]	[0.7363]		[0.2409]
others	-214.40	155.63	-85.96	-14.24	33.21	-	-2.54
	(202.10)	(145.20)	(42.70)	(26.81)	(20.70)		(12.28)
	[0.2928]	[0.2877]	[0.0483]	[0.5972]	[0.1136]		[0.8367]
relation-ship	-212.68	-73.05	-21.79	-20.76	-18.72	-22.08	-3.56
	(90.03)	(65.88)	(18.85)	(12.28)	(9.32)	(18.19)	(5.41)
	[0.0212]	[0.2717]	[0.2519]	[0.0958]	[0.0488]	[0.2289]	[0.5131]
village	-204.57	-46.49	-18.20	3.97	3.51	-	7.25
	(82.15)	(60.40)	(17.16)	(11.29)	(8.53)		(4.93)
	[0.0154]	[0.4443]	[0.2928]	[0.7261]	[0.6824]		[0.1462]

table 13 continued

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*tractor hours*	*bullock pair days*
adjusted R-square	0.35	0.36	0.16	0.19	0.34	0.20	0.34
χ^2-value	60.81 [<.0001]	77.43 [<.0001]	26.71 [0.0051]	36.04 [0.0002]	67.45 [<.0001]	38.78 [<.0001]	52.01 [<.0001]

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs are in rupees per acre, and tractor hours are in hours per acre. Standard errors are in parentheses, p-values are in brackets.

Table 14: Differences on owned and leased-in land of owner-fixed-rent tenants, predicted crop dummies (n=75)

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*tractor hours*	*bullock pair days*
intercept	-11.15	22.82	37.24	3.17	-11.61	-34.46	-3.43
	(63.75)	(45.05)	(13.26)	(7.69)	(7.94)	(13.68)	(4.44)
	[0.8618]	[0.6142]	[0.0066]	[0.6812]	[0.1483]	[0.0140]	[0.4435]
irrigation	49.44	319.84	44.73	25.36	2.77	44.61	-0.34
	(99.14)	(72.27)	(20.39)	(12.67)	(12.43)	(18.01)	(6.83)
	[0.6197]	[<.0001]	[0.0319]	[0.0496]	[0.8247]	[0.0156]	[0.9603]
cereals	510.21	-364.92	27.84	-119.74	-13.58	-	-73.41
	(515.90)	(365.50)	(107.20)	(62.51)	(64.26)		(35.91)
	[0.3264]	[0.3218]	[0.7960]	[0.0599]	[0.8333]		[0.0450]
grams	-2116.09	676.69	-154.89	83.58	5.49	-	184.35
	(912.20)	(645.70)	(189.70)	(110.30)	(113.60)		(63.52)
	[0.0236]	[0.2986]	[0.4171]	[0.4516]	[0.9616]		[0.0051]
groundnut	532.30	3851.44	723.13	-140.14	-467.02	-	-54.57
	(2970.3)	(2095.3)	(618.30)	(356.90)	(369.60)		(207.10)
	[0.8583]	[0.0707]	[0.2465]	[0.6959]	[0.2110]		[0.7930]
cotton	971.08	-693.16	-459.04	-110.48	115.41	-	-108.53
	(1231.9)	(869.90)	(256.30)	(148.30)	(153.30)		(85.86)
	[0.4334]	[0.4285]	[0.0781]	[0.4591]	[0.4544]		[0.2108]
chillis	3714.11	-7.10	204.09	-173.17	19.05	-217.53	-33.42
	(1527.3)	(1108.6)	(314.60)	(193.70)	(191.30)	(265.00)	(105.30)
	[0.0178]	[0.9949]	[0.5189]	[0.3746]	[0.9210]	[0.4145]	[0.7521]
sugarcane	2902.78	1604.02	311.02	-94.91	-23.51	-	-110.50
	(1442.1)	(1017.3)	(300.20)	(173.30)	(179.40)		(100.50)
	[0.0483]	[0.1198]	[0.3041]	[0.5858]	[0.8962]		[0.2759]
others	-4400.59	-3235.99	-406.20	178.68	223.02	-	66.62
	(2506.1)	(1780.6)	(520.30)	(305.30)	(312.40)		(174.30)
	[0.0839]	[0.0738]	[0.4379]	[0.5605]	[0.4778]		[0.7035]
relation-ship	-93.41	-76.81	-14.82	-15.73	-11.73	-13.34	-7.74
	(94.88)	(68.49)	(19.59)	(11.91)	(11.87)	(19.01)	(6.56)
	[0.3286]	[0.2662]	[0.4520]	[0.1912]	[0.3269]	[0.4850]	[0.2426]
village	-128.81	-25.84	-16.43	4.47	8.13	-	9.92
	(86.40)	(62.72)	(17.80)	(10.96)	(10.82)		(5.96)
	[0.1409]	[0.6817]	[0.3595]	[0.6845]	[0.4554]		[0.1008]

table 14 continued

Variable	*seed*	*fertilizer and pesticides*	*farm yard manure*	*preharv. labour*	*harvest labour*	*tractor hours*	*bullock pair days*
adjusted R-square	0.20	0.32	0.17	0.22	-0.05	0.21	0.06
χ^2-value	36.98 [0.0001]	68.53 [<.0001]	26.47 [0.0055]	43.20 [<.0001]	15.29 [0.1695]	38.86 [<.0001]	18.28 [0.0753]

Preharvest labour, harvest labour, and bullock-pair days are measured in days per acre, the other inputs are in rupees per acre, and tractor hours are in hours per acre. Standard errors are in parentheses, p-values are in brackets.

Table 15: Output differences (owner-sharecroppers)

	output (actual values)	*output (predicted values)*
intercept	58.86 (149.12)	499.12 (190.22)
	[0.6957]	[0.0132]
irrigation	1531.34 (864.65)	-7840.22 (2649.82)
	[0.0861]	[0.0058]
cereals	-2396.46 (1181.33)	-1040.51 (4439.96)
	[0.0509]	[0.8162]
grams	-3687.41 (1327.07)	-13856.00 (3310.88)
	[0.0091]	[0.0002]
groundnut	-125.72 (836.61)	-12661.00 (6575.38)
	[0.8815]	[0.0631]
cotton	-2518.49 (1489.44)	-234.44 (12528.00)
	[0.1006]	[0.9852]
castor seed	-2079.57 (1227.99)	-27169.00 (20533.00)
	[0.1001]	[0.1952]
others	-2937.08 (1476.26)	49896.00 (13611.00)
	[0.0552]	[0.0009]
decision cropping pattern	-534.50 (564.59)	-789.21 (579.43)
	[0.3509]	[0.1827]
adjusted R-square	0.83	0.83
F-value	25.90	25.89

Output is measured in rupees per acre. Standard errors are in parentheses, p-values are in brackets.

Table 16: Output differences (owner-fixed-rent tenants)

	output (actual values)	*output (predicted values)*
intercept	264.70 (345.10)	-480.44 (610.12)
	[0.4466]	[0.4347]
irrigation	5656.17 (1920.38)	9530.50 (10247.00)
	[0.0049]	[0.3567]
cereals	2437.02 (1958.85)	4217.55 (16317.00)
	[0.2191]	[0.7971]
grams	784.90 (5261.73)	-12290.00 (12958)
	[0.8820]	[0.3474]
groundnut	3969.36 (1804.31)	57643.00 (50998.00)
	[0.0324]	[0.2636]
cotton	-67.19 (2049.55)	23832.00 (12758.00)
	[0.9740]	[0.0675]
chilies	3096.61 (1891.23)	75341.00 (29732.00)
	[0.1077]	[0.0144]
sugarcane	21517.00 (1889.76)	18302.00 (21179.00)
	[<0.0001]	[0.3915]
others	2503.94 (1237.83)	-115717.00 (42310.00)
	[0.0483]	[0.0086]
relationship	-844.83 (505.26)	-405.00 (853.29)
	[0.1006]	[0.6371]
village	-101.69 (446.43)	391.71 (732.96)
	[0.8207]	[0.5954]
adjusted R-square	0.82	0.51
F-value	28.79	7.34

Output is measured in rupees per acre. Standard errors are in parentheses, p-values are in brackets.

5 Conclusion

The aim of this dissertation was to make a contribution to the literature on contract choice in rural economies. Above all, the hitherto theoretically rather neglected field of informal groundwater markets has been paid special attention. In addition, one of the fundamental questions in the theory of contract choice in agrarian economies, whether the assumption that the tenant's actions are costlessly monitorable and can be enforced by the landlord is valid or not, has been readdressed.

In chapter 2, I presented the results from of a field study on groundwater transactions conducted by myself during January and February 2001 in Tamil Nadu, India. The main purpose of this study had been to fill the gaps left by the existing empirical literature on informal groundwater markets, especially as far as details of the process of choosing the contractual form were concerned. The insights gained by looking at this empirical evidence were very useful in setting up the model presented in chapter 3. Therefore, this study has been an important first step on the way to a better understanding of the functioning of informal groundwater markets.

In order to assess the claims made in chapter 2 on a more general level, however, one would have to estimate a model of contract choice. The data set appropriate for this task should contain the following information which was not covered by the survey underlying this chapter: First of all, it would be important to cover a larger number of households for a completed cultivation season. This would allow to gather data on such questions as: How much water was sold and purchased? What amount of inputs other than water has been applied to the crop? How much output was produced? What were the costs of extracting the groundwater? Information which is essential if one wants to assess the earnings and costs of farmers involved in groundwater transactions. Also required would be exact information on the area irrigated, on the time in the season when no more tank water was available, and on the time in the season when the farmer first bought groundwater from a wellowner, in order to find out how these facts influence the choice of the contract form. The number of wellowners from whom a farmer could possibly buy water will also have a bearing on the contract choice. Further, data would be needed on household characteristics such as household wealth, number of family members working, assets owned, etc., since these characteristics would help to quantify the households attitude towards risk and since they provide information on the households endowment with productive assets. It would also be interesting to identify matching pairs of sellers and buyers, although the choice of a contract partner is more restricted than in the case of a tenancy contract due to the restricted transportability of groundwater. Finally, it would be useful to have a time series of several cultivation seasons and data from different areas to see how differences in rainfall and differences in agro-climatic and groundwater conditions influence contract choice in groundwater transactions.

In chapter 3, I developed a model of contractual choice in informal groundwater markets. In a bargaining framework I showed that – depending on the shape of the utility functions of the buyer and the seller - important determinants of the choice of the contract form are the degrees of absolute risk aversion of the contracting parties in the case of exponential utility and factors that influence the contract-dependent as well as the contract-independent income of the parties, such as the distribution of the amount of rainfall, the marginal costs of groundwater extraction and the certain incomes of the buyer and the seller. My results underline the fact that sharecropping arrangements in the context of informal groundwater markets, which in the empirical literature dealing with this phenomenon are often condemned as exploitative, are a powerful instrument to overcome inefficiencies which arise in a risky environment when there are incomplete or missing markets for the allocation of a scarce resource and for the allocation of risk, an imperfect water market, or a missing insurance market on the village level. My results also show, that under certain conditions even productive efficiency can be achieved by the use of groundwater share contracts.

The analysis of chapter 3 is an important first step in understanding the choice of contracts in an agricultural economy where water is scarce and opens an entire research agenda in the field of agricultural contracts. Future research has to address questions such as how the allocation of groundwater is related to the allocation of land. How does the availability of irrigation water influence a farmer's decision to rent in or rent out land? What are the effects of an increasing density of wells in a village on the contract form chosen? How can the possibility of an overexploitation of the local groundwater resources be taken into account? What are the effects of wealth or credit constraints on the side of the water buyer? Most closely related to the research of this chapter is the question how the timing of the farmer's decision on when to approach a wellowner for additional irrigation water can be endogenized and how this matters for the contract choice and for the efficiency achieved by the contract. The farmer's decision how long to wait before entering a contract potentially depends on his beliefs about the quantity of rainfall during the remainder of the growing season. If he decides to wait for future rainfall without entering a contract he has to take into account that the condition of his crop may worsen in the meantime because of a lack of water, which may negatively influence his future bargaining power. This timing consideration plays no role in the context of tenancy contracts, and addressing it may help to deepen the general understanding of how and under which circumstances share contracts can balance risk sharing considerations and incentive problems when markets are incomplete or missing.

In chapter 4, I reconsidered the issue whether the monitoring or the Marshallian approach is more supported by empirical evidence. Estimating a model which takes the cropping pattern as given as well as a model which assumes that the crops grown on plots of different tenancy status are the outcome of an endogenous choice, I found that in the case of owner-sharecroppers the Marshallian approach is supported by both models. In the case of owner-fixed-rent tenants there is no evidence for the Marshallian approach in the endogenous crop choice model, whereas in the model that takes cropping patterns as exogenously given there is an indication that fixed rent contracts may be as well not perfectly efficient.

Since the econometric analysis of these models suffers from certain data constraints, it would definitely be rewarding to reestimate both models using a richer data set. This would also allow to reestimate the endogenous crop choice model using the full information maximum likelihood method instead of the two-stage estimation method employed here, the former providing more efficient parameter estimates. Finally, although controlling for endogenous crop choice may partially make allowances for the fact that certain tenants match with certain landlords (as far as the preferences for certain crops are concerned), the estimation of a model which explicitly allows for endogenous matching between landlords and tenants based on their characteristics will depict the real world more closely and may lead to results different from those obtained in chapter 4.

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