The roles of risk preferences, selection, and uncertain returns on land contracts

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Using panel data on a statistically representative sample of Iowa farmland parcels from 1997 to 2017, we analyze the factors determining whether land is farmed by the owner or rented out under a cash rent or crop share contract. The landowner's decision to rent or operate the land depends on the distribution of expected net returns to the land, and so estimates of the factors affecting rental terms will be biased if only rental contracts are included in the analysis. Land with higher mean and/or lower variance of expected net returns is most likely to be rented out. Participants in the rental market will include the most risk-averse landowners and the least risk-averse tenants, while the least risk-averse landowners operate their own land. Our empirical results suggest that the rising use of cash rent contracts and declining incidence of owner-operation and crop-share rental contracts is consistent with falling coefficient of variation in expected net returns per acre.

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1. Introduction

This article analyzes the determinants of land contracts for Iowa farmland. The analysis reexamines a question that has been dormant for many years: whether shared risk between landowner and tenant or the costs of contracting drive the contract. Marshall (1890) argues that sharecropping was inefficient at the time due to its weaker incentives compared to cash rents, and suggested that share rental contracts would disappear. However, Cheung (1969) and Stiglitz (1974) state that crop shares could be optimal under uncertain returns as they allow the parties to balance the expenses of carrying risk against the production incentives from carrying more of the risk. As Cheung (1983) emphasizes, farming faces inherent risks from nature that must be absorbed by either or both parties and that can only partially be covered by insurance.

There have been significant changes in farmland tenure in the United States—cash rental contracts have become more common while crop share contracts have decreased in importance (Paulson and Schnitkey, 2013; Bigelow, Allison, and Todd, 2016; Zhang, Plastina, and Sawadgo, 2018). Figure 1 shows the trend of farmland tenure in Iowa from 1982 to 2017. The share of land farmed by the landowner is decreasing. Cash rent contracts are becoming increasingly dominant, representing 82% of rental contracts compared to just 49% in 1982. Perhaps this reflects a movement toward more efficient cash rent contracts as predicted by Marshall. However, the availability of advanced crop insurance systems, farm management companies, enforceable contracts, supportive USDA programs, and university extension programs have lowered production and price risk, reducing the need for shared risk contracts relative to the risk environment in Marshall’s day.

Much of the empirical work on contract type has tried to assess whether measures of output variability affect the use of crop share contracts compared to cash rent contracts. Allen and Lueck (1992a; 1993; 1999) and Prendergast (2002) argue that the real reason for crop share contracts was to minimize transaction costs and not to allocate risk between the landowner and tenant. A series of empirical tests conducted by Allen and Lueck find that greater yield variation decreases the use of crop share contracts, which they viewed as contradicting the principal-agent prediction of greater risk pooling when there is greater uncertainty. On the other hand, Fukunaga and Huffman (2009) find that greater yield variability increases the probability of crop share contracting.

In our reexamination of the question, we argue that past studies relied on data that excluded a critical third option—for landowners to operate the land themselves. If the choice of renting a parcel depends on the parcel's level of production risk, studies of contracts that exclude the option of the owner operating the farm will be subject to potentially important selection bias that could explain the inconsistent findings in past research.

This article uses micro-level data on Iowa land tenure and farm and owner characteristics from 1997 to 2017 to analyze the determinants of land rental contracts. The Iowa Farmland Ownership and Tenure survey is based on an areal sample of randomly selected 40-acre tracts of Iowa farmland. The survey has many advantages for testing land tenancy and rental terms. First, inclusion in the analysis is not dependent on whether the parcel is rented out, and so the analysis is not subject to selection bias by the form of land tenure. Second, because the parcels are statistically representative of the state (Zhang, Plastina, and Sawadgo, 2018), the survey provides consistent information on land ownership, tenure transfer, and the characteristics of the landowner and the land. Third, parcels remain in the sample even if the tenancy changes or if the owner sells the land or passes it on through inheritance, thus findings are not subject to attrition bias due to changes in land tenure. Fourth, detailed information on local soil quality and weather allows us to measure production risk, which we can demonstrate is consistent with measured variance in net returns by the land tenancy. Finally, because the data are longitudinal, we can control for time-invariant unobservable attributes of the land and landowners that could confound tests on contractual terms.

We find that rising expected net returns per acre increase the incentive to rent out land rather than having the land farmed by the landowner. Increases in the second moment of expected net returns reduces the probability of renting the land, a result that would only occur if risk preferences matter for contract choice as predicted by the model. We also find that the share of crop-share contracts among all rental contracts increases as the variance increases, consistent with the incentives to use risk-sharing contracts when the variance of returns rises. These results suggest that the reason for the rising importance of cash rent and the falling incidence of owner-operation in Iowa would be due to rising expected net returns per acre and/or decreasing relative variance of returns on cash rented land.

The remainder of this article proceeds as follows. Section 2 presents and summarizes the previous articles related to this topic. Section 3 discusses the theoretical background. Section 4 introduces the empirical method and data. Section 5 interprets our result. The final section offers some concluding statements.

2. Rental Contract, Risk, and Incentives, and Sharecropping

Empirical tests of the relationship between risk and incentives often find a positive correlation rather than the predicted negative trade-off. The relationship is generally insignificant or positive when evaluated on samples of executives (Aggarwal and Samwick, 1999; Core and Guay, 1999;

Oyer and Shaefer, 2001) or franchisees (Martin, 1988; Lafontaine, 1992) and generally positive in samples of sharecroppers (Rao, 1971; Allen and Lueck, 1992b; 1995). Findings consistent with the theory have been obtained. In contrast, the predicted negative relationship has been found in experimental settings (Corgnet and Hernán-González, 2019; Chowdhurry and Karakostas, 2020). The disagreement between experimental and econometric findings merits a reexamination of the empirical methods.

Our reexamination is in the context of farmland rental contracts. Although sharecropping persisted throughout the twentieth century, Marshall (1890) predicts the disappearance of crop share contracts, as incentives to produce are greater if the landowner operates the land or rents it to a tenant for cash. However, share tenancy could still be the preferred contract in the presence of uncertain output if tenants and landowners are risk-averse (Cheung, 1969; Stiglitz, 1974; Cheung, 1978; Quibria and Rashid, 1984).

We take particular care in our analysis to include both land that is not rented as well as land that is rented. The reason is that, in theory, the landowner's choice of whether to rent or farm the land will depend on the mean and variance of expected net returns on the land. The selection problem could be sufficiently large so as to produce results that are contrary to the predicted effect of uncertainty on rental contracts.

Prendergast (2002) discusses a related selection issue in the context of firms assigning tasks and setting compensation terms for their employees. Greater uncertainty in the production process makes incentive pay riskier as workers see less of a link between their effort and their compensation, and so we should expect less use of incentive pay as production risk rises. However, we frequently observe the opposite. As Prendergast (2002) points out, uncertain production environments are also those in which employers give employees more discretion in decisions. Because employee actions are less predictable, it is difficult for employers to monitor employee effort, and so employers base compensation on more observable output. In more certain production environments, employers routinize employee tasks, and thus monitoring employee effort is relatively easy. Hence, employers base compensation on observable effort and not output. In this case, it is the selection of employee responsibilities—conditional on the uncertain production environment—that leads to the unexpected positive relationship between uncertainty and incentive pay. In our context, landowners will rent out parcels with relatively low production risk, meaning that they will base observed rental contracts and the choice of cash versus share contracts on relatively predictable yields and we will not observe rental terms on the riskiest parcels.

Most of the empirical analysis of land contracts focuses on developing countries. The findings suggest that in countries as diverse as Ecuador, India, Tunisia, and early Renaissance Tuscany (Otsuka and Hayami, 1988; Otsuka, Chuma, and Hayami, 1992; Lanjouw, 1999; Banerjee, Gertler, and Ghatak, 2002; Rao, 1971; Laffont and Matoussi, 1995; Ackerberg and Botticini, 2002), economic uncertainty does affect land contract type, holding constant the wealth of the tenant and the agents' risk-preferences. Bellemare (2012) and Bellemare and Lim (2018) find that in Madagascar, an alternative contract where tenants are hired to farm the land increases tenant income and food security and lowers income variability.

Developing countries lack commonly used private and government insurance programs to reduce production and price risk. This suggests that the factors influencing rental contract types in developing countries may not be informative for contracts in developed countries. Allen and

Lueck (1992b; 1993; 1998; 1999) argue that in the United States, transaction costs are the primary driver of contract choice and not risk-sharing. Allen and Borchers (2016) argue that the prevalence of cash rent does not depend on the risk preferences of the farmer. Huffman and Fukunaga (2008) and Fukunaga and Huffman (2009) find evidence more supportive of risk sharing using data from the 1999 Agricultural Economics and Land Ownership Survey. Since then, descriptive information on U.S. land ownership has documented a tendency toward more use of cash rent contracts (Bigelow, Allison, and Todd, 2016; Burns et al., 2018), but there is little reexamination of whether the determinants or the underlying risk have been changing contract type.

3. Theory

In this section, we examine how the inclusion of the option not to rent the land affects the predictions of how rental contracts change in response to rising uncertainty of returns. We base our theory on a given parcel of land that the landowner or tenant can farm. We use the term ‘operator’ to refer to the person who farms the land. An owner-operator is a landowner who farms the land.

Landowners and operators have an incentive to reach an agreement that makes both parties better off than their other options. For the landowner, the outside option is to farm the land as an owner-operator. For the operator, the outside option is to farm other properties including their own. Our model of tenancy contracts extends the framework developed by Huffman and Just (2004) that relies on a linear incentive scheme. Such contracts have been used widely to optimize incentives in the presence of uncertainty (Hurwicz and Shaprio, 1978; Diamond, 1998; Edmans and Gabaix, 2011; Chassang, 2013; Carroll, 2015; Holmström, 2017).

Our goal is to show how the moments of the returns by contract type affect the choice of contract. Each farm operator *i* can enter contracts with up to *J* potential landowners, such that an operator can farm multiple parcels at time *t*. The production function for the *i*th farm operator on the *j*th parcel at time *t* is

$$y_{ijt}(e_{ijt}) = a_i e_{ijt} + \epsilon_{it} + \delta_j \tag{1}$$

$$\sum_{j=1}^{J} y_{ijt}(e_{ijt}) = y_{it}(e_{ijt}) \tag{2}$$

where y_{ijt} is the output; e_{ijt} is the *i*th operator's effort on the *j*th parcel at time *t*; a_i is an index indicating the *i*th operator's ability or productivity; $\epsilon_{it}$is a zero-mean, operator-specific random shock to production with variance σ_{it}^2; and, δ_j is a parcel-specific fixed productivity effect with zero mean and variance $\sigma_{\delta_j}^2$. The fixed effect reflects naturally occurring climate and soil quality that shapes the potential output on parcel *j*. All shocks are mutually uncorrelated.

We can characterize the range of contracts between the landowner and the operator using a linear incentive scheme defining the operator's return (w_{it})

$$w_{it} = \sum_{j}^{J}(\alpha_{ijt} + \beta_{ijt} y_{ijt}) \tag{3}$$

where α_{ijt} is a fixed payment regardless of operator *i*'s effort on the *j*th parcel at time *t*; and, $\beta_{ijt} \in [0,1]$ is a payment that depends on the output. Holmström and Milgrom (1987), Holmström (1989, 2017), and Dixit (2002) show that these linear incentive contracts elicit the optimal effort from the agent. Cash rent contracts set $\beta_{ijt} = 1$ and $\alpha_{ijt} < 0$ represent the fixed cash rent paid to the landowner. If the owner decides to pay fixed wage or operates by themselves, $\beta_{ijt} = 0$ and $\alpha_{ijt} > 0$. Crop share contracts set $0 < \beta_{ijt} < 1$ and $\alpha_{ijt} = 0$, which suggests that the landowner gets (1-β_{ijt}) of the output.

We can embed the contract into the operator's optimization problem by plugging (1) into (3). As shown in Appendix A1, the expected mean and variance of the compensation of operator is

$$E(w_{it}(e_{ijt})) = \sum_j^J(\alpha_{ijt} + \beta_{ijt}a_i e_{ijt}) \tag{4}$$

$$V(w_{it}(e_{ijt})) = \sum_j^J \beta_{ijt}^2 \omega_{ijt}^2 = \sum_j^J(\beta_{ijt}\left(\sigma_{it}^2 + \sigma_{\delta_j}^2\right)) \tag{5}$$

where $\omega_{ijt}^2 = \sigma_{it}^2 + \sigma_{\delta_j}^2$ is the variance of output.

We assume that the quadratic utility (Just and Zilberman, 1983) characterizes operators' tastes. Then, the expected utility for the operator is

$$E[U_{it}(e_{ijt})] = \sum_j^J(\alpha_{ijt} + \beta_{ijt}a_i e_{ijt} + \delta_j) - \frac{1}{2}\Phi_i \sum_j^J\left(\beta_{ijt}^2(\omega_{ijt}^2)\right) - \frac{1}{2}\kappa_i \sum_j^J e_{ijt}^2 \tag{6}$$

where Φ_i is the local operator-specific absolute risk aversion; and, κ_i represents the operator's cost of effort. Taking the derivative of (6) with respect to operator effort, the first-order condition implies that optimal effort of i^{th} operator on farm j is

$$e_{ijt}^* = \frac{\beta_{ijt}a_i}{\kappa_i} \tag{7}$$

The optimal effort is positively correlated with the incentive rate, β_{ijt}, and on the operator's ability, a_i, but negatively related to the cost of effort, κ_i. The optimal effort will be greatest under the cash rent contract, smallest under the fixed pay contract, and between those extremes under the crop share contract.

We can substitute the optimal effort (7) back into the production (1) and expected utility functions (6) to eliminate the endogenous effort terms. Then, after some further manipulation described in Appendix A1, the optimal output share for the operator is

$$\beta_{ijt}^* = \frac{m_{ijt} + \frac{a_i^2}{\kappa_i} + \Phi^{\mathrm{L}}\omega_{ijt}^2}{\frac{a_i^2}{\kappa_i} + (\Phi_i + \Phi^{\mathrm{L}})\omega_{ijt}^2} \tag{8}$$

where $m_{ijt} \in (0,1)$ is the landowner's monitoring cost per unit of output on parcel j; Φ^{L} is the landowner's absolute risk aversion; and, the other parameters are as defined above. Equation (8) shows that the optimal operator's share, β_{ijt}^*, depends on six terms: the cost of monitoring, m_{ijt}; the operator's ability, a_i; the cost of effort, κ_i; the parcel j output variance, ω_{ijt}^2; and, the operator's and landowner's risk aversion, $\Phi_i, and\ \Phi^L$. Applying comparative static analysis reveals how these parameters influence the operator's share.

Recall that $\beta_{ijt} = 0$ means the landowner operates the parcel, $\beta_{ijt} = 1$ means that the landowner rents the parcel out for cash, and $0 < \beta_{ijt} < 1$ means that the landowner rents the parcel out for a share of the return. A high variance of output decreases the operator share and leads to operation by the landowner ($\frac{\partial \beta_{ijt}^*}{\partial \omega_{ijt}^2} < 0$). As a result, when the outcome of farming is highly variable, landowners tend to operate their farms on their own rather than rent out the land. In other words, both cash rent and crop share contracts decrease in production risk. This result shows why ignoring the option that landowners can farm the land themselves and focusing only on the rental contracts leads to an important selection bias. Studies that focus only on cash rent versus crop share are selecting only the low variance parcels and implicitly selecting on whether the landowner has decided to rent the parcel. As we will see, it is common for parcels to move in and out of the rental market as risk preferences of landowners and operators change or as the variance of output changes.

A second result from equation (8) is that, if $\Phi_i = \Phi^{\mathrm{L}} = 0$, then ω_{ijt}^2 does not affect β_{ijt}^*. That is, if both a landowner and an operator are risk-neutral, the crop share contract only depends on monitoring cost, the ability of the operator, and the cost of effort. A test of whether contracts serve as risk sharing mechanisms (Stiglitz, 1974) as opposed to solely reflecting contracting costs (Allen and Lueck, 1999) is whether $\frac{\partial \beta_{ijt}^*}{\partial \omega_{ijt}^2} = 0$. We will show that ω_{ijt}^2 has a negative and significant coefficient on renting the land, and has the stongest negatiove effect on cash rent contract, consistent with the theory. Note that if either the landowner or tenant are risk-averse, ω_{ijt}^2 will affect contract choice, and so a finding that ω_{ijt}^2 lowers β_{ijt}^* will not tell us whether it is the landowner, the tenant, or both who are averse to risk.

The tenant's share of output is rising in the landowner's risk aversion ($\frac{\partial \beta_{ijt}^*}{\partial \Phi^L} > 0$) and decreasing in the tenants' own risk aversion ($\frac{\partial \beta_{ijt}^*}{\partial \Phi_i} < 0$). However, the signs of the second derivatives ($\frac{\partial^2 \beta_{ijt}^*}{\partial \omega_{ijt}^2 \partial \Phi_i}$, $\frac{\partial^2 \beta_{ijt}^*}{\partial \omega_{ijt}^2 \partial \Phi^L}$) are ambiguous, and so we do not know which agents, the landowners or the tenants, are more sensitive to changes in the variance of net returns. As the number of rental contracts decreases, the remaining agents will include the least risk-averse tenants and the most risk-averse landowners, and so the share of contracts that are cash rent or crop share could rise or fall. This statement becomes even stronger if in (8), the tenant's ability to produce, a_i, decreases in the variance of net returns, or if the cost of monitoring, m_{ijt}, increases in variance.[1] As a result, the value of β in a rental contract will depend on the relative

[1] Landowners are likely to have parcel-specific knowledge that improves their ability to farm on lands with greater variability, while tenants will lack that parcel-specific knowledge. Similarly, it is more difficult to observe effort when the production process is subject to greater variability.

sensitivity of risk-averse landowners, risk-averse tenants, parcel-specific knowledge, and costs of monitoring to increases in ω_{ijt}^2, which is an empirical question that we address next.

4. Empirical Method

4.1 *Data*

This article uses panel data of Iowa Farmland Ownership and Tenure Survey responses from 1997 to 2017 (Zhang, Plastina, and Sawadgo, 2018). The survey is conducted via telephone every five years, as mandated by Iowa code, and includes a panel data of parcels that are statistically representative of all Iowa farmland and landowners. The response rates for these surveys are very high: the 2017 survey, which has the lowest response rate, has 535 usable responses and a 68% response rate. The survey provides representative information on land ownership, tenure, and characteristics of all landowners in Iowa. We also utilize age, education, farm size, and proximity to the farm, which previous studies use as measures of risk preferences or cost of contracting. A unique feature of the data is that it is an areal sample of randomly selected 40-acre land parcels chosen in 1988 following a two-stage sampling design. [2] Because the randomization is over land and not producers, the results will correspond to the universe of farmland for agricultural purposes and their owners in Iowa as opposed to the universe of producers or operators. Because our sample is longitudinal in the parcel and not the owner or operator, we do not lose observations when the parcel changes landowners or tenants.

[2] The first stage assured a geographic dispersal of sample sections in each county in a systematic manner, and the second stage selected a single 40-acre unit at random within each sample section within each county. All landowners within this sample unit were then identified and became potential survey respondents, and then asked about the ownership, leasing and transition of their land owned in the same fashion as in the selected 40-acre tracts.

The surveys conducted in 2007, 2012 and 2017 include acre weights, whose sum preserves the total size of farmland in Iowa and their corresponding crop reporting districts. These weights allow us to make statistical inference regarding the percentage of farmland owned at the state or district level, and thus are used in robustness checks for our regression analysis. Landowner weights are also collected in the two most recent surveys conducted in 2012 and 2017. We only rely on acre weights because the landowner weights are only available for the last two rounds. An appendix of Zhang, Sawadgo, and Plastina (2018) includes the details about the sampling design, the 2017 survey questionnaire, and formulas for the landowner and acre weights.

We supplement the data on contracts with detailed cost data from Ag Decision Maker at Iowa State University that allows us to compute county-level expected moments of the net returns from each tenancy option. Estimated Costs of Crop Production in Iowa provides the estimated costs of crops based on data from several sources and is representative of average costs for farms in Iowa. The availability of both means and variances of the returns to contract type is a novel innovation that offers a clearer test of how risk preferences shape contract choice. We explain a detailed method of calculating returns in the appendix.

Unique to this study, we are able to measure the expected net return and variance for each contract. The annual Iowa Cash Rent Survey reports county-level rental rates by contract type from 1992 to 2017. The Estimated Costs of Crop Production in Iowa 1992–2017 provides the estimated Iowa-average cost for growing corn following soybeans, which is the most common crop rotation in Iowa. We also collect the county-level crop yield data from the United States Department of Agriculture National Agricultural Statistics Service. Appendix A2 presents the equations we use to calculate the net return of each contract per acre.

Figures 2 and 3 show the time paths of the mean and standard deviation of 5-year lagged net returns by contract type in Iowa. In Figure 2, we can see that net returns per acre are trending upward for all land tenures. In Figure 3, we can see that the standard deviation of net returns is relatively stable when comparing the staring and endng values, but that owner-operated and crop share rental contracts have an extended period of much larger deviations in the middle years. Considering that the vertical axis in Figure 3 ranges from 0 to 200, the changes in standard deviation are much smaller than the changes in the mean, and so the coefficient of variation[3] is falling over time. We can guess that the effect of the mean will outweigh the standard deviation in shaping changing contract choice in our context.

We also use weather data from the Iowa Environmental Mesonet Climodat Reports and Data 1992–2017. This data provides daily observations of high and low temperature, precipitation, and modified Growing Degree Days (GDD), which are used to estimate the growth of plants during the growing season. The reported base temperature for corn is 50°F, and the growing season for corn is roughly April through September. Therefore, we use the GDD 50-86, Apr-Sep, which is the sum of GDD from April to September with a base temperature of 50°F and a maximum allowable temperature of 86°F. We also use Corn Suitability Rating 2 (CSR2), which rates the soil's potential to produce row crops for the 40-acre sampled field. CSR2 ranges from 5 (least productive) to 100 (most productive).

Table 1 shows the summary statistics of each variable. The total number of observations in the analysis is 3,708. The average age of landowners is 63.4 years old. We measure education in

[3] The standard deviation divided by the mean is taken as a measure of the risk per dollar of expected return. We can presume that the decreasing coefficient of variation suggests less uncertainty about net returns over the sample period.

five categories: 1 if 11th grade or less; 2 if high school (includes GED); 3 if some post-high school education but no 4-year degree; 4 if a 4-year degree is the highest attained; and 5 if the respondent completed a graduate degree. Of survey respondents, 83.7% live in Iowa, and only 11.8% want to hold their land for the long term. The average landholding for landowners is 5.5 log acres of land, or roughly 245 acres. The past-five-year's average net return of each contract by county (*MEAN*) is $124.4 and the standard deviation of it is 45.8 (*STD*).

Table 1 also provides the summary statistics by contract type. There are 1,667 cash rent cases, 453 crop share cases, and 1,558 owner-operators (not rented). The average age of owner-operators is 57.2, which is younger than the landowners renting out land. Of the landowners who rent their land, 65.3% of those with crop share contracts live in Iowa compared to 81.5% for those who rent for cash. Although the size of the farm (*Acre(log)*) is not significantly different among the three contracts, only 8% of owner-operators want to keep their land for the long term compared to 15.7% of cash renters and 10.4% for crop share landowners. The lowest expected return is for land that is rented for crop share at $91.30 per acre, while land rented out for cash has an expected net return of $123.4 and land operated by the owner averages $134.80. Another large difference comes from the variation in net return (*STD)*—cash rent contracts have the most stable net return, and parcels operated by owners have the greatest variance.

Our model points to the critical importance of measured variances in the return to land. In Table 2, we demonstrate the validity of our measures of expected returns and their variances by contract type. We expect that our measures will correspond to variation across parcels in measures of weather, weather variability, and soil quality. We also include the measures of landowner attributes that we will include in our later analysis. We generate five-year averages and variances for each parcel, and regress the measures on available weather and soil quality measures. The first column in Table 2 presents a regression of *the past-five-year's average net return* (*MEAN*) on soil quality measured by CSR2 and on the means and variances of GDDs and precipitation. We can explain 30% of the variation in mean returns per acre using these measures with higher returns associated with greater average rainfall and better soil quality. In column (2), we repeat the exercise to explain variation in the *past-five-year's standard deviation of GDD 50-86, Apr-Sep.* The model explains 19% of the variation in the standard deviation of returns with greater uncertainty in returns in counties associated with greater variation in heating degree days and rainfall. Therefore, our means and standard deviations of the dollar returns per parcel tie closely to the agroclimatic and soil conditions of the parcel.

This table explains why we do not include common explanatory variables such as weather and soil quality which are used in other land contract papers. However, in order to handle possible endogeneity problems, we later use these variables as instrument variables.

4.2 *Econometric Model*

We use a multinomial probit model to assess how owners and operators choose among the three types of contracts: cash rent, crop share, and owner-operator. Cash rent is a contract in which an operator pays cash and the owner does not participate in the production. Crop share is the most common type of lease, and the landowner and operator divide crop income and expenses. Owner-operators do not lease their farm and instead operate on their own.

We model contract decisions as the outcome of a utility maximization problem. Let $U_{ijt}^{C}, U_{ijt}^{S}, and\ U_{ijt}^{O}$ denote landowner i's expected utility from cash rent, crop share, and not renting a farm j at time t. The observed variable is contract choice and can be explained by the latent variable of U, where

$$Y_{ijt} = \begin{cases} 1 \; if \; U^C_{ijt} > U^S_{ijt} \; \; and \; U^C_{ijt} > U^O_{ijt} \\ 2 \; if \; U^S_{ijt} > U^C_{ijt} \; \; and \; U^S_{ijt} > U^O_{ijt} \\ 3 \; if \; U^O_{ijt} > U^S_{ijt} \; \; and \; U^O_{ijt} > U^C_{ijt} \end{cases}$$

Each individual's expected utility under the alternative contract is assumed to be a function of explanatory variables, x_{it}, y_{jt}, z_{ijt}, and a random disturbance that captures unmodeled effects. Therefore, the probabilities are

$$P(Y_{ijt} = c) = \frac{e^{\gamma_{c1}x_{it}+\gamma_{c2}y_{jt}+\gamma_{c3}z_{ijt}}}{1 + \sum_{k=1}^{2} e^{\gamma_{k1}x_{it}+\gamma_{k2}y_{jt}+\gamma_{k3}z_{ijt}}} \; , where \; c = 1,2,3$$

5. Results

We use multinomial probit to estimate how the moments of expected net returns affect whether each parcel is rented, and if rented, whether the contract is for cash or crop share. We control for attributes of the landowner that are meant to control for monitoring costs (farm size, whether the owner lives in Iowa) or the ability or tastes of the owner (age, education, long-term interests in the farmland). Table 3 presents the marginal effect of each factor on the probability of selecting each rental option. The marginal effects must sum to zero. Column (1) presents the marginal effects for selecting cash rent; column (2) presents the marginal effects for crop share; and column (3) presents the marginal effects for the landowner farming the parcel rather than renting the land. We cluster the standard errors by landowner.

The first row shows that the *MEAN* raises cash and crop share rents and lowers owner-operation. A $10 increase in *MEAN* net returns per acre raises the probability of renting the parcel for cash by 0.003, and it raises the probability of using a crop share contract rises by 0.012The result suggests that more productive land is rented out, while less productive land is

$\frac{\partial \beta_{ijt}^{*}}{\partial\left(\frac{a_i^2}{\kappa_i}\right)}$

farmed by the landowner. This raises the possibility that, if parcel productivity is not carefully controlled, the higher productivity on rented land will be incorrectly attributed to the tenant's incentives and not to the higher productivity of rented land.[4]

The more important test involves the effect of the variance of expected net returns on rental contract. Increases in the variance of net returns lowers the use of both types of rental contracts and increases the probability that the landowner operates the parcel. A $10 increase in the standard deviation of net returns lowers the probability of cash rent contracts by 0.001 and lowers the probability of a crop share contract by 0.004. Meanwhile, the robability that the landowner farms the land rather than renting it rises by 0.005. The finding that, as the variance of net returns rises, the probability of renting the parcel falls is consistent with theory. However, the prediction that the relative probability of crop share contracts would rise relative to cash rent contracts is not supported.

We also find that older landowners are less likely to farm their own land. Their preferred rental arrangement is crop share rather than cash rent. Not surprisingly, landowners who live in Iowa are most likely to operate the farm by themselves. If Iowa residents rent, they are more likely to opt for cash rent rather than crop share.

There are two concerns with our use of the expected mean and variance of net returns by contract type. The first is that the observed returns will reflect the endogenous selection of the

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[4] A higher expected mean net return is consistent with higher values of $\left(\frac{a_i^2}{\kappa_i}\right)$, the ratio of operator productivity relative to the cost of effort. More productive land raises productivity per effort expended. This finding suggests that $\frac{\partial \beta_{ijt}^{*}}{\partial\left(\frac{a_i^2}{\kappa_i}\right)} > 0$ which happens if $\Phi_i \omega_{ijt}^2 > m_{jt}$ in equation (8).

contract type. The second is that the expected net returns will be subject to measurement error. Both problems would bias the coefficients, but both problems can be addressed using instrumental variables. Our results in Table 2 suggest plausible instruments for the expected mean and variance of expected net returns, namely, the parcel's soil quality as measured by the corn suitability rating, and the means and variances of rainfall and growing degree days for the county in which the parcel is located.[5] Table 4 presents the marginal effects of the multinomial probit model using the instrumental equations in Table (2) to identify *MEAN* and *STD*. Bootstrapped standard errors are in parentheses. Compared to Table 3, these results are more consistent with the theoretical predictions from equation (8). A $10 increase in MEAN expected net returns per acre raises the cash rent contracts by 0.02 while lowering owner-occupied parcels by 0.02. The probability of parcels farmed under crop share contracts is not significantly affected. A $10 increase in the standard deviation of expected returns, STD, reduces the probability of cash rent contracts by 0.04 while raising the probability that the land is farmed by the owner by 0.04. However, now the crop share contracts are not significantly affected by the increase in variance, and so the relative probability of crop share versus cash rent contracts rises as the varance of expected net returns rises.. Comparative statics based on equation (8) predicted that increases in the variation of net returns would lower the probability that a parcel is rented out and rental contracts would shift toward greater use of crop share contracts, exactly the outcome suggested by the coefficients on STD.

We can illustrate how sample selection and endogenous net returns affect the coefficients on the moments of expected net returns. The first two columns of Table 5 report the coefficients

[5] The first stage estimation is reported in Appendix A3. We easily pass the weak instruments test.

from our preferred specification that uses the instrumented MEAN and STD in the sample that includes all parcels in Table 4. We get the predicted result that there will be less probability that the land is rented as the variance of net returns rises, but it is more likely that a crop share contract wll be used if the land is rented. We also see that land with greater expected returns is mre likely to be rented out. The second two columns show what happens if the moments are assumed exogenous, as in the results from Table 3. Higher mean returns only raise the probability of cash rent cohtracts, and a higher variance raises the relative probability of a cashrent contract relative to crop share. The final two columns show what happens when only rented land is included in the analysis. We would now incorrectly infer that crop share contracts decrease as expected net returns to the contracts rise, and that the number of crop share contracts increases as the variance increases. Our point is that inference from analysis of land contracts must take into account the endogeneity of expected returns and their variances, and that analysis that excludes the option of not renting the land will be selected on the means and variances of expected net returns to the parcel.

6. Conclusion

Panel data on land tenancy on Iowa farmland 1997-2017 are used to test how the means and variances of contract-specific expected net returns affect contract choice. This data, based on a statistically representative sample of Iowa farmland owners, tracks the contractual arrangements of the same land parcels over time, regardless of land ownership changes. The survey allows us to control for the productive attributes of the land, and the attributes of the landowners.

Our results show a positive and significant effect of the expected contract-specific net return and a negative effect of the associate variance of the expected net return on contract choice. The empirical results show that variance of expected returns matters for contract choice, a result that would only occur if risk preferences of either the landowner or the tenant matter for contract choice. The results are consistent with the risk-sharing theory that predicts that the riskiest parcels will be operated by the landowner, while the least risky parcels will be rented out. We also find that when the sample includes all parcels rather than selecting only the reneted parcels, and when appropriately controlling for possible measurement error and endogeneity of the moments of the expected net returns, relative use of crop share contracts rises as the variance risies. Unlike past studies of land contracts that relied only on samples of rented land or that did not correct for likely endogeneity of expected net returns per acre, all of our findings are consistent with the predictions from optimal linear contracts in the presence of uncertain returns to land.

In Iowa, the variance of net returns on agricultural land was relatively stable while the mean of net returns increased at the same time over our sample period from 1997 to 2017. We have seen in Figure 1 that the share of farmlanded under cash rent contracts rose from 21% to 49%, while owner-operated farmland share decreased from 55% to 41% and the crop-share rental share decreased from 21% to 10%. The rising mean net returns would increase the rental share compared to owoner-operation, while the falling coefficient of variation raises the relative use of cash rent compared to crop share contracts.

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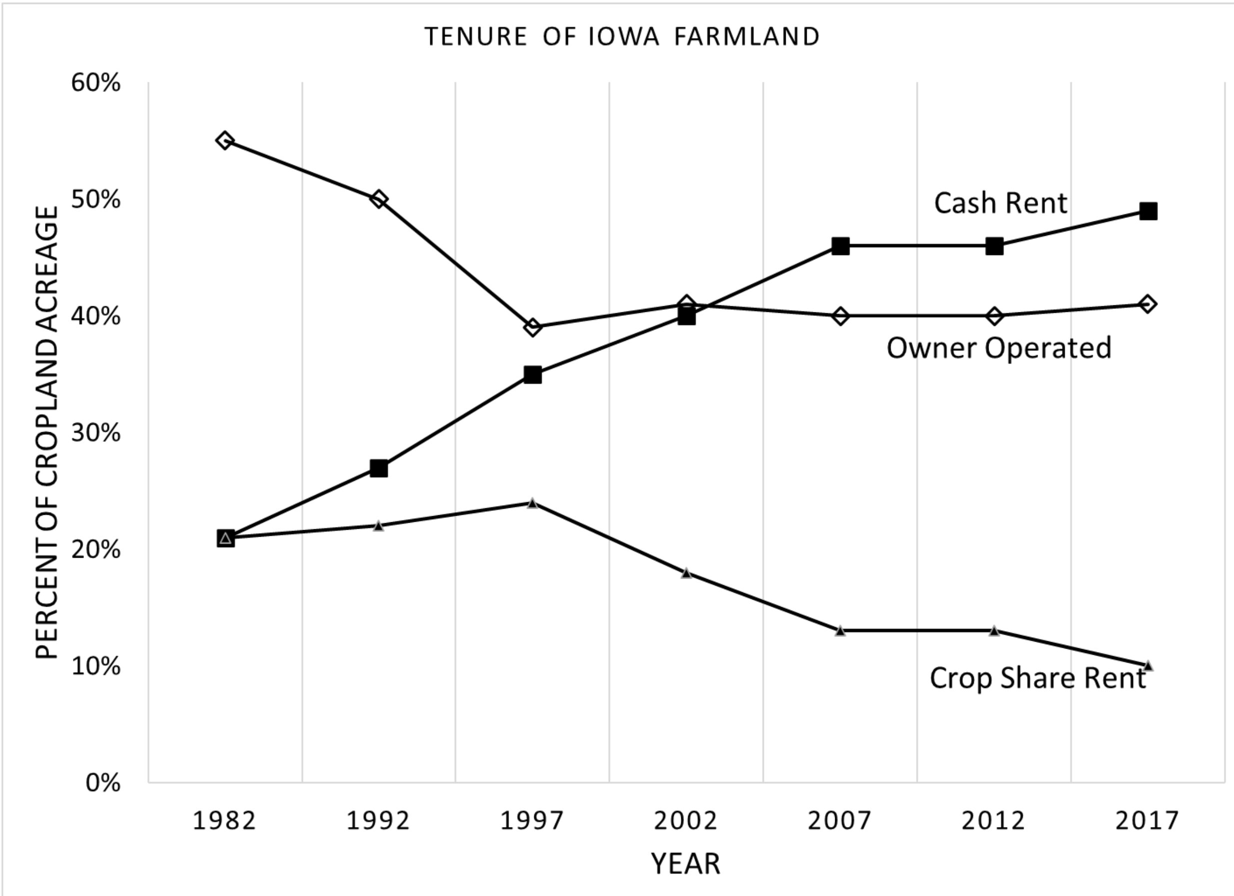
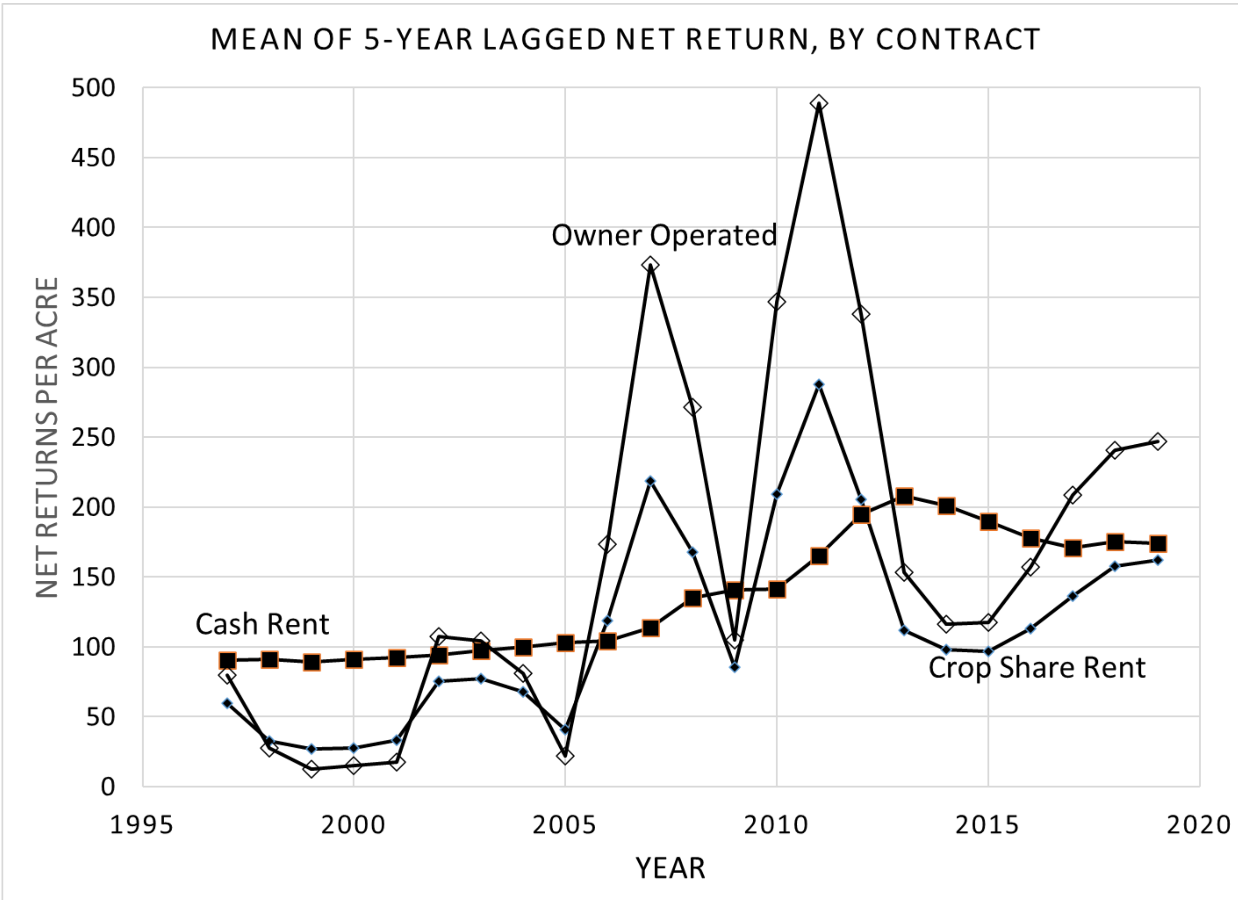
Figure 1. Tenure of Iowa Farmland



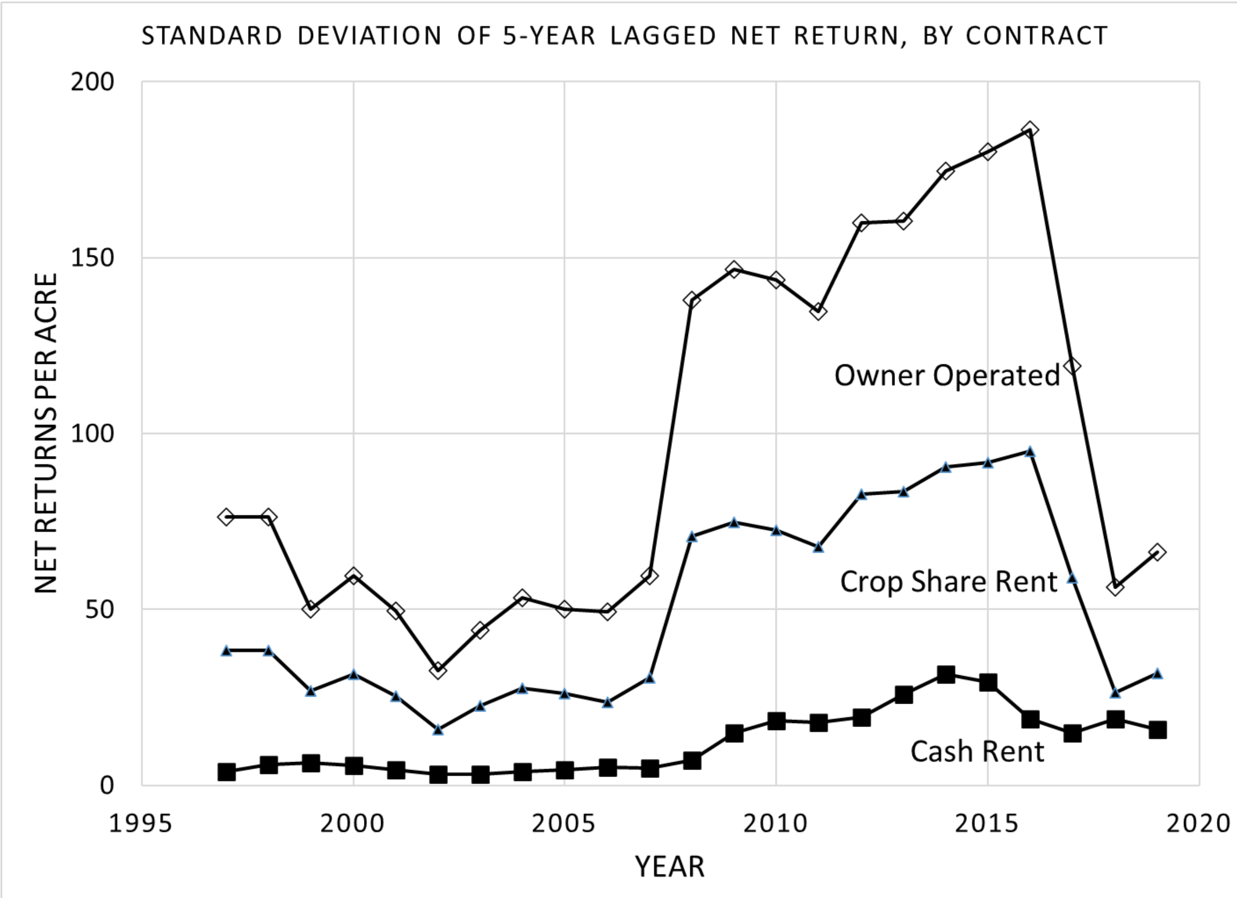
Source: Zhang, Plastina, and Sawadgo (2018)

Figure 2. Mean of 5-year Lagged Net Return, by Contract



Source: based on authors' calculation from the combined landownership 1997-2017 survey.

Figure 3. Standard Deviation of 5-year Lagged Net Return, by Contract



Source: based on authors' calculation from the combined landownership 1997-2017 survey.

Table 1. Summary Statistics

A. All Contracts

VARIABLES	N=3,708 Mean	Number of Landowners 794-861 SD	Min	Max
Age	63.36	14.33	18	98
Education	2.806	1.066	1	5
Live in IA	0.837	0.369	0	1
Longterm	0.118	0.323	0	1
Acre(log)	5.487	1.069	0.693	9.721
MEAN	124.4	82.78	-14.93	418.7
STD	45.80	49.45	0.770	224.3

B. By Contract Type

VARIABLES	Cash rent (N=1667)	Crop share (N=453)	Not rented (N=1588)
Age	67.59	69.46	57.18
Education	2.755	2.892	2.836
Live in IA	0.815	0.653	0.914
Longterm	0.157	0.104	0.0819
Acre(log)	5.480	5.614	5.457
MEAN	123.4	91.26	134.8
STD	9.269	42.37	85.13

Table 2. Relationship Between Mean and Variance of Parcel-specific Net Returns per Acre and Soil Quality, County Weather, and County Weather Variability

VARIABLES	(1) MEAN	(2) STD
Instruments		
CSR2	0.4196***	0.0302
	(0.0827)	(0.0607)
Past 5 years Average GDD 50-86, Apr-Sep	-0.0182**	-0.0028
	(0.0076)	(0.0061)
Past 5 years SD of GDD 50-86, Apr-Sep	0.8332***	0.3400***
	(0.0482)	(0.0281)
Past 5 year Average Total precipitation, Apr-Sep	0.0364	0.0705
	(0.7333)	(0.4551)
Past 5 years SD of Total precipitation, Apr-Sep	2.8130***	2.6713***
	(0.6842)	(0.4202)
Landowner Attributes		
Age	0.1463	-0.7441***
	(0.1049)	(0.0743)
Education	8.3523***	2.1314*
	(1.2524)	(1.1537)
Acre(log)	-4.2229**	-0.2462
	(1.6808)	(1.3271)
Longterm	20.8682***	-3.1324
	(4.5727)	(3.4809)
Live in IA	33.3293***	17.9791***
	(2.8743)	(2.4582)
Constant	-54.5107*	2.0206
	(32.7940)	(23.0873)
R-squared	0.2955	0.1899
Observations	3,708	3,708
Exclusion test for instruments, F(5,3703)	15.2***	63.7***

Standard errors in parentheses are clustered by parcel. *** p<0.01, ** p<0.05, * p<0.1
Exclusion tests easily pass the hurdle for weak instruments (Stock and Yogo, 2005; Sanderson and Windmeijer,2016).

Table 3. Multinomial Probit Model of the Determinants of Land Tenancy and Contract Type

VARIABLES	(1) Cash rent	(2) Crop share	(3) Not Rented
MEAN	0.00027***	0.00120***	-0.00147***
	(0.00004)	(0.00010)	(0.00010)
STD	-0.00095***	-0.00386***	0.00482***
	(0.00014)	(0.00024)	(0.00023)
Age	-0.00002	0.00365***	-0.00363***
	(0.00003)	(0.00035)	(0.00035)
Education	0.00011	0.00378	-0.00389
	(0.00041)	(0.00509)	(0.00506)
Acre(log)	0.00006	0.00230	-0.00236
	(0.00038)	(0.00483)	(0.00479)
Longterm	0.00059	0.01192	-0.01251
	(0.00136)	(0.02072)	(0.02068)
Live in IA	0.00144	-0.14884***	0.14740***
	(0.00158)	(0.01476)	(0.01463)
Observations		3,708	
Log likelihood		-579.70476	

Note: The table reports the marginal effect of variables. Standard errors in parentheses are clustered by parcel. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Multinomial Probit Model of the Determinants of Land Tenancy and Contract Type with Instrumental Variables Identifying the Mean and Variance of Expected Net Returns

VARIABLES	(1) Cash_rent	(2) Sharecropping	(3) Not Rented
MEAN	0.00172***	0.00023	-0.00195***
	(0.00065)	(0.00044)	(0.00064)
STD	-0.00392***	-0.00023	0.00415***
	(0.00150)	(0.00100)	(0.00148)
Age	0.00541***	0.00365***	-0.00906***
	(0.00140)	(0.00094)	(0.00134)
Education	-0.00932	0.00924*	0.00009
	(0.00860)	(0.00533)	(0.00842)
Acre(log)	-0.01410*	0.01069*	0.00341
	(0.00741)	(0.00548)	(0.00760)
Longterm	0.09972***	-0.03033*	-0.06939**
	(0.03064)	(0.01779)	(0.03009)
Live in IA	-0.07298***	-0.16102***	0.23400***
	(0.02489)	(0.01980)	(0.02021)
Observations		3708	
Log likelihood		-3220.9592	

Note: This table reports the marginal effect of variables. Joint estimation of the instrumenting and multinomial probit was conducted using the 2 step method with bootstrapping in Stata. Standard errors in parentheses are clustered by parcel. Exclusion tests of the soil quality and weather variables used in Table 2 yielded F-statistics of 15.2 for MEAN and 63.7 for STD, easily passing the hurdle for weak instruments (Stock and Yogo, 2005; Sanderson and Windmeijer, 2016).

Table 5. Comparison of Multinomial Probit Model of the Determinants of Land Tenancy and Contract Type Including and Excluding Owner-operation as an Option

	Full sample, IV		Full sample, no IV		Selected sample, no IV	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cash rent	Crop share	Cash rent	Crop share	Cash rent	Crop share
MEAN	0.00172***	0.00023	0.00027***	0.00120***	0.00043***	-0.00042***
	(0.00065)	(0.00044)	(0.00004)	(0.00010)	(0.00014)	(0.00014)
STD	-0.00392***	-0.00023	-0.00095***	-0.00386***	-0.00136***	0.00134***
	(0.00150)	(0.00100)	(0.00014)	(0.00024)	(0.00045)	(0.00046)
Observations	3708		3708		2,120	
Log likelihood	-3220.96		-579.7		-3.66	

Note: The table reports the marginal effect of variables. The first four columns are the multinomial probit results from table 3 and 4. The last two columns are the result of a probit model that includes only the rental contracts and excludes the owner-operated option. Standard errors in parentheses are clustered by parcel. *** p<0.01, ** p<0.05, * p<0.1

Appendix A1 Detailed Theoretical Derivation

The production function for the i^{th} farm operator (agent) on the j^{th} parcel at time t is

$$y_{ijt}(e_{ijt}) = a_i e_{ijt} + \epsilon_{it} + \delta_t \tag{1}$$

$$\sum_{j=1}^{J} y_{ijt}(e_{ijt}) = y_{it}(e_{ijt}) \tag{2}$$

where y_{ijt} is the output; e_{ijt} is the i^{th} operator's effort on the j^{th} farm at time t; a_i is an index indicating the i^{th} operator's ability or productivity; $\epsilon_{it}$is a zero-mean, operator-specific random shock to production with variance σ_{it}^2; and, δ_j is a fixed-effect with zero mean and variance $\sigma_{\delta_t}^2$ specific to parcel j that reflects naturally occurring climate and soil quality. All shocks are mutually uncorrelated.

We can characterize the range of contracts between the landowner and the operator using a linear incentive scheme defining the operator's return (w_{it}),

$$w_{it} = \sum_j^J (\alpha_{ijt} + \beta_{ijt} y_{ijt}) \tag{3}$$

where α_{ijt} is a fixed payment regardless of operator i's effort on the j^{th} parcel at time t; and, $\beta_{ijt} \in [0,1]$ is a payment that depends on the output. These linear incentive contracts have been shown to elicit the optimal effort from the agent (Holmström and Milgrom, 1987; Holmström, 1989; Dixit, 2002). Cash rent contracts set $\beta_{ijt} = 1$ and $\alpha_{ijt} < 0$. If the owner decides to farm the land, $\beta_{ijt} = 0$ and $\alpha_{ijt} > 0$. Crop share contracts set $0 < \beta_{ijt} < 1$ and $\alpha_{ijt} = 0$.

We can embed the contract into the operator's optimization problem by plugging (1) into (3),

$$w_{it} = \sum_j^J (\alpha_{ijt} + \beta_{ijt}(a_i e_{ijt} + \epsilon_{it} + \delta_t)) \tag{4}$$

The expected mean and variance of the compensation is

$$E(w_{it}(e_{ijt})) = \sum_j^J(\alpha_{ijt} + \beta_{ijt} a_i e_{ijt}) \tag{5}$$

$$V\left[w_{it}\left(e_{ijt}\right)\right] = \sum_j^J \beta_{ijt}^2 \omega_{ijt}^2 = \sum_j^J (\beta_{ijt}\left(\sigma_{it}^2 + \sigma_{\delta_j}^2\right)) \tag{6}$$

where $\omega_{ijt}^2 = \sigma_{it}^2 + \sigma_{\delta_j}^2$ is the variance of output.

We assume that the quadratic utility characterizes operators' tastes. Then, the expected utility for the operator is

$$E[U_{it}\left(e_{ijt}\right)] = \sum_j^J\left(\alpha_{ijt} + \beta_{ijt} a_i e_{ijt} + \delta_j\right) - \frac{1}{2}\Phi_i \sum_j^J \left(\beta_{ijt}^2\left(\omega_{ijt}^2\right)\right) - \frac{1}{2}\kappa_i \sum_j^J e_{ijt}^2 \tag{7}$$

where Φ_i is the local operator-specific absolute risk aversion; and, κ_i represents an operator-specific cost parameter. Taking the derivative of (7) with respect to operator effort, the first-order condition implies that optimal effort of the i^{th} operator on farm *j* is

$$e_{ijt}^* = \frac{\beta_{ijt} a_i}{\kappa_i} \tag{8}$$

The optimal effort is positively correlated with the incentive rate, β_{ijt}, and on the operator's ability, a_i, but negatively related to the cost of effort, κ_i. The optimal effort will be greatest under the cash rent contract, smallest under the custom contract, and between those extremes under the crop share contract.

We can substitute the optimal effort (8) back into the production (1) and expected utility functions (7) to eliminate the endogenous effort terms:

$$y_{ijt}\left(e_{ijt}\right) = a_i^2 \frac{\beta_{ijt}}{\kappa_i} + \epsilon_{it} + \delta_j \tag{9}$$

$$E\left[U_{it}\left(e_{ijt}^*\right)\right] = \sum_j(\alpha_{ijt} + 0.5\beta_{ijt}^2 \left(\frac{a_i^2}{\kappa_i} - \Phi_i \omega_{ijt}^2\right)) \tag{10}$$

where Φ_i is the local agent-specific absolute risk aversion coefficient ($\Phi_i > 0$).

We assume that each parcel has one operator.[6] The landowner's profit after paying operators is

$$\Pi_{\mathrm{t}} = y_{it}(e_{ijt}) - w_{it}(e_{ijt}) - \sum_j^J m_{ijt} y_{ijt}(e_{ijt}) = \sum_j^J[(1-\beta_{ijt})(a_i e_{ijt} - m_{ijt} + \epsilon_{it} + \delta_j) - \alpha_{ijt}] \quad (11)$$

where $m_{ijt} \in [0,1]$ is a monitoring cost per unit of output for land *j*, operated by operator *i*, at time *t*. We assume that monitoring cost is proportional to the amount of production. Monitoring cost includes the expenses of measuring and other costs that prevent potential moral hazard (Bryan, Deaton, and Weersink, 2015). Substituting in the operator's optimal effort, we can characterize the landowner's choice of contract terms with the embedded operator response. The landowner's expected profit is

$$E(\Pi_{\mathrm{t}}) = \sum_j^J[(1-\beta_{ijt})(\beta_{ijt}\frac{a_i^2}{\kappa_i} - m_{ijt}) - \alpha_{ijt}] \quad (12)$$

and the landowner's variance of profit is:

$$V(\Pi_t) = \sum_j^J(1-\beta_{ijt})^2\sigma_{\delta_j}^2 + \sum_j^J[(1-\beta_{ijt})^2\sigma_{it}^2] = \sum_j^J(1-\beta_{ijt})^2(\omega_{ijt}^2) \quad (13)$$

Using equations (12) and (13), the landowner's certainty equivalent expected quadratic utility is

$$E[U_t(\Phi)] = \sum_j^J[(1-\beta_{ijt})(\beta_{ijt}\frac{a_i^2}{\kappa_i} - \mathrm{m_{ijt}}) - \alpha_{ijt}] - \frac{1}{2}\Phi^{\mathrm{L}}\left[\sum_j^J(1-\beta_{ijt})^2\omega_{ijt}^2\right] \quad (14)$$

[6] This is consistent with the data. According to the Survey of Iowa Leasing Practices, 2017, 73% of acres are owned by a landowner with only one tenant, and another 18% owned by those with two tenants. Because our data involves parcels and not entire farms, it is unlikely that operation on single parcels would be divided between multiple tenants.

where Φ^{L} is the local landowner-specific absolute risk aversion coefficient. The constraints can be each operator's reservation utility which can be represented as:

$$E\left[U_{it}\left(e_{ijt}^{*}\right)\right] = \sum_{j}(\alpha_{ijt} + 0.5\beta_{ijt}^{2}\left(\frac{a_i^2}{\kappa_i} - \Phi_i\omega_{ijt}^2\right)) \geq \mu_i \tag{15}$$

where μ_i is operator *i's* reservation utility.

Solving (15) with strict equality gives

$$\sum_{j}\alpha_{ijt} = \mu_i - \sum_{j} 0.5\beta_{ijt}^{2}\left(\frac{a_i^2}{\kappa_i} - \Phi_i\omega_{ijt}^2\right) \tag{16}$$

Substituting (16) into (14) and maximizing with respect to the contract weight on effort gives

$$\frac{\partial E[U_t(\Pi)]}{\partial \beta_{ijt}} = \left(1 - 2\beta_{ijt}\right)\frac{a_i^2}{\kappa_i} + m_{ijt} + \beta_{ijt}\left(\frac{a_i^2}{\kappa_i} - \Phi_i\omega_{ijt}^2\right) + \Phi^{\mathrm{L}}(1 - \beta_{ijt})\omega_{ijt}^2 = 0 \tag{17}$$

Rearranging, the reduced form solution for the optimal contract weight placed on effort is

$$\beta_{ijt}^{*} = \frac{m_{ijt} + \frac{a_i^2}{\kappa_i} + \Phi^{\mathrm{L}}\omega_{ijt}^2}{\frac{a_i^2}{\kappa_i} + (\Phi_i + \Phi^{\mathrm{L}})\omega_{ijt}^2} \tag{18}$$

This implies that a risk-taking operator tends to share more output than a risk-averse operator.

Differentiating the optimal contract with respect to risk aversion factors and the variance of output gives

$$\frac{\partial \beta_{ijt}^{*}}{\partial \Phi_i} = \frac{-\omega_{ijt}^2(m_{ijt} + \frac{a_i^2}{\kappa_i} + \Phi^{\mathrm{L}}\omega_{ijt}^2)}{\left(\frac{a_i^2}{\kappa_i} + (\Phi_i + \Phi^{\mathrm{L}})\omega_{ijt}^2\right)^2} < 0$$

If $\Phi_i\omega_{ijt}^2 > m_{jt}$, an increase in ability and a decrease in the cost of effort would lead to a higher operator cropshare ($\frac{\partial \beta_{ijt}^{*}}{\partial a_i} > 0,\ \frac{\partial \beta_{ijt}^{*}}{\partial \kappa_i} < 0$). The optimal operator cropshare increases toward 1 as a landowner's risk aversion increases $\left(\frac{\partial \beta_{ijt}^*}{\partial \Phi^L} > 0\right)$. This suggests that the more risk-averse landowners will rent out rather than operate, and the most risk-averse of those will opt for cash rent rather than crop share contracts. As monitoring costs increase, a higher output share of an operator is needed to increase their incentive, which, in the limit, leads to cash rent ($\frac{\partial \beta_{ijt}^*}{\partial m_{ijt}} >$ 0). If $\Phi_i \omega_{ijt}^2 < m_{jt}$, then the opposite is true, but this is a not reasonable where optimal operator cropshare decreases as a landowner's risk aversion increases.

Then we substitute β_{ijt}^* into $\sum_j \alpha_{ijt}$ and assume that $\frac{a_i^2}{\kappa_i} > \Phi_i \omega_{ijt}^2$, then the operator's optimal guarantee is positively related to the variance of output ($\frac{\partial \Sigma \alpha_{ijt}}{\partial \omega_{ijt}^2} > 0$). In other words, in the case of volatile production, we can expect that the contract will be skewed towards cash rent, which lowers output share and gives a high fixed amount. If $\frac{a_i^2}{\kappa_i} < \Phi_i \omega_{ijt}^2$, we cannot tell the sign, but it is less plausible that the operator received lower output share and guarantee at the same time in the volatile situation. If $\frac{a_i^2}{\kappa_i} = \Phi_i \omega_{ijt}^2$, then the optimal guarantee is, again, positively related to the variance of output. This explains the well-known story that people take more certainty and try to rule out uncertainty in volatile circumstances.

$$\frac{\partial \beta_{ijt}^*}{\partial \Phi^L} = \frac{\omega_{ijt}^2 \left(\Phi_i \omega_{ijt}^2 - m_{ijt}\right)}{\left(\frac{a_i^2}{\kappa_i} + (\Phi_i + \Phi^{\mathrm{L}})\omega_{ijt}^2\right)^2} > 0$$

$$\frac{\partial \beta_{ijt}^*}{\partial \omega_{ijt}^2} = \frac{-m_{ijt}(\Phi_i + \Phi^{\mathrm{L}}) - \frac{a_i^2}{\kappa_i}\Phi_i}{\left(\frac{a_i^2}{\kappa_i} + (\Phi_i + \Phi^{\mathrm{L}})\omega_{ijt}^2\right)^2} < 0$$

However, the sign of the second derivatives are ambiguous ($\frac{\partial^2 \beta_{ijt}^*}{\partial \omega_{ijt}^2 \partial \Phi_i}$, $\frac{\partial^2 \beta_{ijt}^*}{\partial \omega_{ijt}^2 \partial \Phi^L}$).

Appendix A2: Calcuating the expected net return for landowner by county

$$Net\ return\ of\ Cashrent = Cashrent * 0.77$$

$$Expense = Cashrent * 0.23$$

$$Net\ return\ of\ Cropshare$$

$$= \frac{1}{2}(Yield * price)$$

$$- \frac{1}{2}(Herbicides + Machinery * 0.3 + Crop\ Insurance$$

$$+ Interest\ on\ preharvest\ variable\ costs + Lime(yearly\ cost)$$

$$+ Misc\ costs + Total\ n, p, k + Seed) - Expense$$

$$Net\ return\ of\ Owner\ operator$$

$$= Yield * price$$

$$- (Herbicides + Machinery + Crop\ Insurance$$

$$+ Interest\ on\ preharvest\ variable\ costs + Lime(yearly\ cost)$$

$$+ Misc\ costs + Total\ n, p, k + Seed) - Labor - Expense$$

We use the county level yield and state-average price data to calculate net returns. Usually, 23% of landowner expenses for cash rental arrangements consist of 10% of property taxes, about 5% for maintenance and building insurance, etc., and 8% of management costs in terms of time for landowners. For $Net\ return\ of\ Cropshare$ we assume that 30% of machinery cost is used for drying. $Total\ n, p, k$ represent the cost of nitrogen, phosphate, and potash.

Appendix A3: Use of Sample Weights

We also confirm our empirical results by using acre weights. As explained earlier in the Data section, the sum of acre weights of all farmlands owned by surveyed landowners is equal to the total acres of farmland in the crop reporting district and Iowa in general (Zhang, Plastina, and Sawadgo, 2018). However, the weights are only available from 2007 to 2017. Therefore, we run a multinomial probit with acre weights over the shorter panel, which allows us to make statistical inference regarding all Iowa farmlands. Appendix Table 3 reports the average marginal effect from multinomial regression with acre weights. The structure of regression used in the analysis is the same as in Table 3. The net return variables are statistically significant, and the directions are the same. The coefficients of *MEAN* are 0.0005, 0.0005, and -0.0009 for cash rent, crop share, and owner-operator, respectively; and those for *STD* are -0.0017, -0.0018, and 0.0035, respectively. *Education* has the only difference from the regression in Table 3—it is significant for the cash rent and not rented cases.

Appendix Table 3: Multinomial Probit Model of the Determinants of Land Tenancy and Contract Type with Acre Weights

VARIABLES	(1) Cash rent	(2) Crop share	(3) Not rented
MEAN	0.00046***	0.00046***	-0.00092***
	(0.00007)	(0.00012)	(0.00012)
STD	-0.00165***	-0.00181***	0.00346***
	(0.00024)	(0.00026)	(0.00027)
Age	-0.00003	0.00348***	-0.00345***
	(0.00006)	(0.00045)	(0.00045)
Education	0.00045	0.01112*	-0.01157*
	(0.00077)	(0.00639)	(0.00633)
Acre(log)	-0.00006	-0.00432	0.00438
	(0.00078)	(0.00596)	(0.00591)
Longterm	0.00190	0.00710	-0.00899
	(0.00248)	(0.01864)	(0.01858)
Live in IA	0.00195	-0.11839***	0.11644***
	(0.00361)	(0.03341)	(0.03300)
Observations		83,541,942	
Log likelihood		-13216328	

Note: The table reports the marginal effect of variables. Standard errors in parentheses are clustered by parcel. *** p<0.01, ** p<0.05, * p<0.1