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Adaptation to climate change via adjustment in land leasing: Evidence from dryland wheat farms in the U.S. Pacific Northwest

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ABSTRACT

Land leasing is a possible climate adaptation where risk is shared. We investigate how climate affects dryland wheat farmland rental patterns in the U.S. Pacific Northwest. Using farm-level agricultural census data, we study the relationships between climate and leasing arrangements. We find that increases in precipitation reduce leased land and increase the use of cash-rent leases, while increases in precipitation variability reduce the prevalence of cash-rent leases. Using medium and high greenhouse-gas emission-based climate projections we predict that, by 2050, leased acreage will decline by 23% and, respectively 29%.

1. Introduction

Climate change is happening with increases in temperature, precipitation variability and extreme weather event frequency being observed and such trends are expected to continue to evolve (IPCC, 2014). Climate have been found to influence actions and outcomes in the agricultural sector, including livestock production, crop yields, food security, farm profitability, farmland value and land use (as reviewed in IPCC, 2014 and Dell et al., 2014).

Although subsistence farms in developing countries are likely to be most vulnerable to climate change, impacts of climate change on developed countries such as the United States (US) are also important to consider for the world agricultural market. For example, over 20 percent of US agricultural production was exported in 2015–2017, including 46 percent of wheat production.[1] Furthermore, the agricultural sector makes an important contribution to the US economy especially local economies in rural areas with 11 percent of 2015 total US employment occurring in the agricultural and food sectors.[2]

A growing body of literature has examined potential adaptations to climate change through changes in management practices and policies, e.g., planting dates, irrigation technologies, crop insurance, agricultural land use, cropping systems and fallow rotation (Negri et al., 2005; Smith et al., 2007; Ortiz-Bobea and Just, 2013; Smith et al., 2014; Annan and Schlenker, 2015; Olen et al., 2016; McCarl et al., 2016; Antle et al., 2017; Mu et al., 2017; Zhang et al., 2017). A less studied possible adaptation involves use of land leasing (Eskander and Barbier, 2016) which is a means of sharing production risk with landowners. Climate may influence the extent of leasing and the type of lease arrangements. According to the 2012 Census of Agriculture, 78% of dryland wheat farms in the U.S. Pacific Northwest region leased some land, among which 74% had cash rent leases and 69% crop share leases (some farms used a mixture of both). Leasing contracts tradeoff between risk-sharing and incentives (Cheung, 1968; Stiglitz, 1974; Otsuka et al., 1992) and different forms differ in transaction costs and extent of risk transfer (Allen and Lueck, 1992).

Issues in agricultural land leasing markets have been studied with focuses on property right insecurity (Myyrä et al., 2005; Maddison, 2007; Yegbemey et al., 2013), land tenancy (Paulson and Schnitkey, 2013), rental contact choice (Qiu et al., 2011; Bryan et al., 2015), and farmland rental rates (Breustedt and Habermann, 2011; Ciaian and Kancs, 2012; Kirwan and Roberts, 2014). Eskander and Barbier (2016) did a study linking climate influences finding in Bangladesh that

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[1] Data are available at https://www.fas.usda.gov/data/percentage-us-agricultural-products-exported. Accessed on June 14, 2018.
[2] Data are available at https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58282. Accessed on June 14, 2018.

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farmers' reliance on leased land increases as losses from floods and storms rise. However, their study only narrowly treated climate and thus did not reveal how land leasing decisions adjust in response to temperature and precipitation as well as their variability which we address in this analysis.

To do this, we use US Census of Agriculture farm-level land leasing data for Pacific Northwest (PNW) dryland wheat farms. We examine leasing responses to 5-year average growing season precipitation and temperature as well as climate variability including effects on type of lease. We then predict changes in leased acreage by 2050 based on climate projections under two greenhouse-gas emission scenarios.

2. Theoretical framework

The principal-agent model can be used to analyze climate effects on land rental markets and we use it to explore choice of rental market participation and leasing arrangements. In doing this we assume that the principal, i.e., a landowner, and the agent, i.e., a tenant, are both risk-averse. Following Huffman and Just (2004), the tenant's production on a unit land is a stochastic function,

$$y(e) = \mu e + \varepsilon, \tag{1}$$

where y is the yield per unit land, e is tenant effort that is unobservable to landowners, μ is land productivity, and ε is a random shock with a mean of zero and a variance of σ^2 (e.g., weather-related risk). A rise in μ implies an increase in production, while a rise in σ^2 implies an increase in the production uncertainty. Climate can alter both μ and σ^2 influencing average productivity and its variance.

Suppose in the land market a landowner offers a linear incentive contract to a potential tenant (Stiglitz, 1974),

$$w = \alpha p y - \beta, \tag{2}$$

where w is the total payment received by the tenant, α is the share of output received by the tenant ($0 \le \alpha \le 1$), p is the output price, and β is a cash payment. Note that the parameter β is not necessarily positive: if β is negative, then the landowner pays either a cash wage or part of the costs borne by the tenant; alternatively, if β is positive, the tenant pays a cash rent to the landowner. When $\alpha = 1$ and $\beta > 0$, the contract represents a pure fixed cash-rent system; thus, the contract moves toward a pure cash-rent system as α goes up. In contrast, a contract with $\alpha > 0$ and $\beta < 0$ is a crop share where the tenant retains part of the output and the landowner pays part of the costs of production. Other forms of rental contracts are possible.

Following Huffman and Just (2004), suppose the tenant's cost of farming is a quadratic function of effort (e), $0.5ke^2$, with k representing a tenant-specific parameter. Then, the net return received by the tenant (π^T) is,

$$\pi^T(e) = w - 0.5ke^2. \tag{3}$$

Combining Eqs. (1)–(3), the tenant's expected net return is $E[\pi^T(e)] = \alpha\mu p e – \beta – 0.5ke^2$, and the variance of the expected net return is $Var(\pi^T(e)) = \alpha^2 p^2 \sigma^2$. Now we assume tenant has a smooth and twice differentiable utility function (U^T). The tenant's problem is to choose the optimal effort for maximizing expected utility, which can be approximated by a linear mean-variance utility function (Just and Zilberman, 1983),

$$\begin{aligned} &Max_e E[U^T(\pi^T(e))]. \\ &= Max_e E[\pi^T(e)] - 0.5r^T Var(\pi^T(e)) \\ &= Max_e \alpha\mu p e - \beta - 0.5ke^2 - 0.5r^T\alpha^2p^2\sigma^2 \end{aligned} \tag{4}$$

where r^T is the tenant's risk aversion coefficient. The tenant's optimal effort (e^*) is derived from the first-order condition of Eq. (4),

$$e^* = \alpha\mu p/k. \tag{5}$$

Substituting the Eqs. (5) into (4), we obtain the tenant's maximum expected utility,

$$E[U^T(\pi^T(e^*))] = 0.5\alpha^2p^2\left(\frac{\mu^2}{k} - r^T\sigma^2\right) - \beta. \tag{6}$$

The landowner's net return from the contract is,

$$\pi^L(\alpha,\ \beta) = (1-\alpha)py + \beta, \tag{7}$$

Similar to the tenant, assume the landowner has a smooth and twice differentiable utility function (U^T). The landowner maximizes the expected utility function that can be approximated by a mean-variance utility function,

$$\begin{aligned} &Max_{\alpha,\beta} E[U^L(\pi^L)] \\ &= Max_{\alpha,\beta} E[\pi^L] - 0.5r^L Var(\pi^L) \\ &= Max_{\alpha,\beta}(1-\alpha)\mu p e + \beta - 0.5r^L(1-\alpha)^2p^2\sigma^2. \end{aligned} \tag{8}$$

In turn, the tenant will accept the incentive contract offered by the landowner in Eq. (2) if the contract satisfies incentive compatibility and voluntary participation conditions. With incentive compatibility, the landowner is assumed to choose the contract under which the tenant chooses his optimal effort in Eq. (5). With voluntary participation, the expected net return received by the tenant from the contract is at least as large as the tenant's reserved utility (u^R). Assuming that the reservation utility is equal to the maximized expected utility as given by (6), the cash rent paid by the tenant can be expressed as

$$\beta = 0.5\alpha^2p^2\left(\frac{\mu^2}{k} - r^T\sigma^2\right) - u^R. \tag{9}$$

Combining Eq. (8) with the incentive compatibility constraint (5) and voluntary participation constraint (9), the landowner's problem can be rewritten as,

$$Max_\alpha (1-\alpha)\alpha\frac{\mu^2p^2}{k} + 0.5\alpha^2p^2\left(\frac{\mu^2}{k} - r^T\sigma^2\right) - u^R - 0.5r^L(1-\alpha)^2p^2\sigma^2. \tag{10}$$

The optimal share of the output received by the tenant is derived from the first-order condition of Eq. (10),

$$\alpha^* = \frac{\frac{\mu^2}{k} + r^L\sigma^2}{\frac{\mu^2}{k} + (r^T + r^L)\sigma^2}, \tag{11}$$

and substituting Eq. (11) into Eq. (9) obtains the optimal cash payment received by the tenant,

$$\beta^* = 0.5\left[\frac{\frac{\mu^2}{k} + r^L\sigma^2}{\frac{\mu^2}{k} + (r^T + r^L)\sigma^2}\right]^2 p^2\left(\frac{\mu^2}{k} - r^T\sigma^2\right) - u^R \tag{12}$$

For the purpose of this study, we focus on climate impacts on land rental market participation and farmland leasing arrangements through land productivity (μ) and production certainty (σ^2). From Eqs. (11) and (12), we obtain the following relationships:

$$\frac{d\alpha^*}{d\mu} > 0,\ \frac{d\alpha^*}{d\sigma^2} < 0,\ \frac{d\beta^*}{d\mu} > 0,\ \frac{d\beta^*}{d\sigma^2} < 0. \tag{13}$$

Here increases in land productivity (μ) increase the share of crop received by the tenant and results in the contract moving toward a cash rental contract. In contrast, increases in production uncertainty reduces the share of crop received by the tenant and results in the contract moving toward a crop share contract. In terms of rental market

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