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Examining farmers' willingness to grow and allocate land for oilseed crops for biofuel production

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Abstract

The purpose of this paper is to determine farmers' willingness to adopt and allocate land for growing non-food oilseeds as bio-energy crops across the western US. A mail survey was conducted in three regions of the western US from randomly selected wheat farmers. Data was analyzed using Heckman's two stage selection model to correct for selection bias. Under favorable contracts, the study found that 58 percent of sample farmers were willing to adopt oilseeds as bio-energy crops and initially contribute an average of 160 acres of land for production per farm. Concerning farmers' adoption decisions, factors such as experience growing oilseed crops, availability of a nearby crushing facility, use of no till, being a first adopter and having a college degree positively affected adoption, while risk behavior, farm experience and gender negatively affected adoption. With regard to the land allocation decision, factors such as farm income and gender positively affected land allocation decisions, whereas percentage of land rented on a crop share basis, profit ratio (wheat/canola) and livestock ownership negatively affected land allocation decisions.

Keywords: Land use, Bio-jet fuel, oilseed, contract wheat

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1. Introduction

Numerous countries are searching for renewable and secure sources of energy that reduce greenhouse gas emissions caused by fossil fuels. The demand for sustainable and secure sources of renewable energy has risen due to higher transportation costs, environmental issues and national security concerns. Biodiesel and ethanol have become two competing fuel sources that can substitute for petroleum-based fuels (Ardebili et al., 2011). Biofuels have substantially lower greenhouse gas (GHG) emissions during their lifecycles compared to more conventional fossil fuels (IATA, 2009).

Ragen and Kenkel (2007) found that low agricultural commodity prices help spur domestic production of biofuels in the US. While ethanol remains the predominant biofuel produced, there exists potential for increased biodiesel production. Ethanol production increased from 3.4 billion gallons in 2004 to 13.9 billion gallons in 2011, representing an increase of about 300 percent. In the same time period, biodiesel production increased from 28 million gallons to 967 million gallons, an increase of 3,300 percent (Yeboah et al., 2013). A number of initiatives within the airline industry are taking place to enhance the production and use of biofuels. Based on the International Air Transportation Association (IATA, 2010), the global air industry has a goal of becoming carbon neutral by 2020 and to significantly reduce GHG emission levels by 2050.

Examining the potential of alternative sources for biofuels is important to meet the potential demand for biofuel, particularly biodiesel for the airline industry. According to Moser (2010), soybean production is currently the largest source for biodiesel. However, given the current demand for biodiesel globally, this source is not adequate. Other alternative crops need to be considered for biodiesel production. Oilseed crops such as canola, camelina, rapeseed, safflower, mustard, and sunflower can act as feedstocks to fill the potential future demand for biodiesel. Oilseeds have a number of agronomic features such as adaptability to local growing conditions, drought tolerance, low agricultural inputs, a definable growing season, uniform seed maturation rates, fallow land compatibility, adaptability to rotate with conventional commodity crops, and commercial outlets for agricultural byproducts, such as meal. Fuels prepared from biological feedstock's that meet all or most of the above criteria hold the greatest promise as alternatives to petroleum-derived fuels (Moser, 2010).

Oilseed crops such as camelina and canola have good properties for bio-based jet fuel. Canola biodiesel has a higher cetane number (56%) than soybean biodiesel (47%) (Atkinson et al., 2006). A higher cetane number indicates the fuel provides for easier starting and quieter engine operation. Camelina shows excellent promise as a significant source of a "drop-in" alternative to traditional petroleum-derived diesel and jet fuels. Cultivation of camelina as an energy crop in a rotational cycle with wheat that displaces fallow weeds on otherwise unused land suggests this rotation may have minimal land use change impacts, since no food production is displaced by camelina under such a scenario (Yeboah et al., 2013). Winchester et al. (2013) found that to meet aviation biofuel goals in 2020 using oilseeds other than soybean in rotation with wheat (during regular fallow periods) would require a subsidy of $0.35 per gallon of biodiesel compared to $2.69 per gallon when soybean oil is used (not in rotation with wheat).

Considering the specific bio-jet fuel features of oilseed crops and the potential for increased in bio-jet fuel demand, understanding if farmers would grow these oilseed crops is crucial for market development. Studying the technical feasibility of oilseed crops in connection to biofuel production is not enough. Production of bio-jet fuel from oilseeds will not be successful unless farmers are willing to grow them. Therefore, this paper provides an *ex ante* examination of farmers' willingness to grow oilseed crops for bio-jet fuel production on existing farm land in rotation with wheat. This provides information for agencies (government, NGOs, individuals etc.) in general and the airline industry in particular that are targeting use of these specific types of oilseed crops for biofuel production. More specifically, the probability of and factors affecting farmers' willingness to adopt oilseed crops and farmers' potential initial land allocation they would devote to oilseed crop production under contract are assessed.

This paper contributes to the literature on biofuel production in two ways. First, it uses recent data that covers major states of the western United States, while others are limited to more specific geographic locations (Bergtold, et al. 2014, Caldas, et al. 2014; Fewell, et al. 2012, Lynes, et al. 2016). Second, it focuses on the willingness of famers to grow oilseed crops in rotation with wheat for biofuel production, while others focus primarily on cellulosic biofuel feedstock production (Caldas, et al. 2014; Paulrud and Laitila, 2010; Lynes, et al. 2016).

2. Background

Evidence from previous studies about the probability of and factors affecting farmers' willingness to grow alternative bioenergy crops and farmers' potential initial land allocations for bioenergy crop production, provide support for examining the use of oilseeds for bio-jet fuel production. Lynes, et al. (2016) examined the willingness of farmers to grow bioenergy crops, including annual bioenergy crops (e.g. sweet sorghum) and perennial bioenergy crops (e.g. switchgrass) in Kansas. Results indicated that 61 and 44 percent of farmers surveyed would be willing to grow annual and perennial bioenergy crops, respectively. Furthermore, these farmers indicated they would be willing to allocate on average 122 and 97 acres for annual and perennial bioenergy crop production, respectively. Willingness of farmers to grow bioenergy crops though varies by location.

Quals et al. (2012) found that farmers 67 percent of farmers they surveyed were willing to grow switchgrass on 24 percent of their farm land on average. Another study by Wen et al. (2009), identified that about 43 percent of farmers in south Virginia, expressed willingness to grow switchgrass as a bioenergy crop on 66 acres of their farm land on average. Willingness of farmers to produce switchgrass production as bioenergy crop in Tennessee was also studied by Jensen et al. (2007). They found that about 30 percent of the farmers surveyed were willing to allocate about 27 acres of their land for bioenergy crop production.

However, the farmers' willingness to specifically adopt oilseed crops and farmers' potential initial land allocations for oilseed crop production under contract are still unclear. Oilseed crops are increasingly recognized as a good source for biofuel production, involving species such as camelina (Camelina spp.), flaxseed (Linum usitatissimum L.), sunflower (Helianthus annuus L.), safflower (Carthamus tinctorius L.), crambe (Crambe spp.), rapeseed (Brassica spp.), and canola (Brassica napus L. and B. rapa L.) (Putnam et al., 1993). Potentially low-cost feedstocks for biofuel production include oilseed crops grown in rotation with other crops on land that would otherwise be left fallow.

A study by Shonnard et al. (2010); revealed that pennycress and camelina are two promising rotational crops in the US. Pennycress is a winter annual crop that could potentially be produced in the Midwest in rotation with summer corn and spring soybean crops. Traditionally, crop land would remain fallow between the fall corn harvest and before spring soybean planting. Pennycress may be a good option to grow during this time period as it requires a low quantity of inputs such as fertilizer, pesticides, and water. Further, it is compatible with existing farm infrastructure and could potentially be grow on about 40 million acres of land per year.

Guy and Gareau (1998), show that different brassica crops including camelina, canola, yellow mustard, and oriental mustard have potential as biofuel crops. This is not an exhaustive list, but these crops are commonly grown in rotation with winter wheat. When evaluating the potential economic benefit of these crops, it is imperative to include the rotational effect of these crops on winter wheat. For instance, camelina is currently targeted as a dedicated biofuel crop to be grown in rotation with wheat. Evidence from Guy et al. (1995), a study done in Washington, indicated that winter wheat grown after broadleaf crops, such as brassica crops, showed 29 percent greater yield compared to winter wheat following winter wheat with optimum applications of nitrogen fertilizer.

Farmers decide to introduce oilseed crops in their farming systems when they believe that the expected profit from the new crop is higher than the expected profit without the new crop. At the same time, farmers' who are willing to adopt also consider how much land to allocate for the new crop. During adoption and land allocation decisions, different factors affect the farmers' willingness to grow bioenergy crops. From economic theory and literature, factors affecting farmers' willingness to incorporate oilseed crops for biofuel production in their existing cropping system are presented below. We classified these factors in to two: factors that affect willingness of farmers to grow and initial land allocation decision for oilseed crops for bioenergy production.

2.1. Factors that affect willingness of farmers to grow oilseed crops

Factors that impact farmers' willingness to grow oilseed crops are divided into farm and farmer characteristics. The factors in each category are indicated below.

Farm characteristics:

(i) Farm income: Paulrud and Laitila (2010) and Lynes, et al. (2016) indicate that farm income affected farmers' willingness to adopt new bioenergy crops negatively.

(ii) Farm size: Farm size has had a mixed effect on farmers' willingness to adopt bioenergy crops (Jensen et al., 2007; Pulrud and Laitila, 2010; Qualls et al., 2012). Farm size may have a positive effect on the farmers' willingness to adopt new bioenergy crops, as bio-refineries may prefer to deal with large scale producers. Dealing with small scale farmers involves higher transaction costs. Qualls et al. (2012) found that farm size had no effect on farmers' willingness to adopt bioenergy crops. It is hypothesized that the opportunity cost of diversifying farming operations affects bioenergy crop adoption positively (Qualls et. al., 2012).

(iii) Operational Practices: Qualls et al. (2012) and Lynes et al. (2016) showed that owning necessary equipment (inputs) affects the adoption of bioenergy crops positively. Similarly, Jensen et al. (2007) indicated that use of no-till conservation practices affected farmers' willingness to adopt bioenergy crops positively.

(iv) Livestock ownership: Jensen et al. (2007) and Qualls et al. (2012) found that livestock ownership had a negative effect on bioenergy crop adoption. Conversely, Lynes, et al.

(2016) found that livestock ownership had no effect on bioenergy crop production decisions.

(v) Land Tenure: Land leased or rented had a negative effect on farmers' willingness to grow bioenergy crops (Jensen et al., 2007 and Qualls et al., 2012). However, Paulrud and Laitila (2010) reported that leased or rented land had no effect on farmers' willingness to grow bioenergy crops.

Farmer characteristics:

(i) Age: Age may affect the adoption process negatively or may have no effect on the willingness of farmers to grow bioenergy crops. When farmers become older, they may become more risk-averse, potentially reducing adoption of new technologies. It has been shown that age can negatively affect new technology adoption and willingness to grow new crops (Featherstone and Goodwin, 1993; Daberkow and McBride, 1998; Paulrud and Laitila, 2010; Qualls et al., 2012). On the other hand, Jensen et al. (2007) reported that age had no effect on farmers' willingness to grow bioenergy crops.

(ii) Education: Baidu-Forson (1999), Jensen et al. (2007) and Singer et al. (2007) reported that education had a positive effect on farmer's willingness to adopt new technologies and willingness to grow new bioenergy crops.

(iii) Off-farm income: The effect of off-farm income on adoption of energy crops may be mixed. Jensen et al. (2007) found that off-farm income had no significant effect on the willingness of farmers to grow energy crops. However, Gould et al. (1989) reported that off-farm income has a negative effect on new technology adoption. In contrast, Fernandez et al. (2005) and Qualls et al. (2012) found that off-farm income had a positive effect on farmers' willingness to adopt bioenergy crops.

(iv) Risk: Farmers' perception toward financial risk is an important variable that can affect the adoption process. Farmers remain reluctant about adopting new technologies as they may be more averse to what they foresee as significant financial losses and uncertainty. Risk averse farmers are usually late to adopt new technologies. Fernandez et al. (1994);

Daberkow and Mcbride (1998), and Fernandez et al. (2001) found that early adopters are less risk averse than late adopters or to those who are not willing to adopt. Daberkow and McBride (1998) noted that late and unwilling adopters have large production and financial risk perceptions when trying out new technologies.

(v) Farm Experience: Jensen et al. (2007) revealed that farm experience affected bioenergy crop adoption positively. However, Lynes, et al. (2016) found that farm experience had no effect on farmers' willingness to adopt bioenergy crops.

2.2. Factors that affect land allocation decision for oilseed crops

Factors that affect the land allocation decisions for bioenergy crop production are reviewed from previous studies.

Farm characteristics:

(i) Farm size: Evidence suggests that farm size may have a negative (Jensen et al., 2007; Paulrud and Laitila, 2010 and Qualls et al., 2012) or positive effect (Tyndall, Berg and Colletti, 2011; Lynes et al., 2016) on land allocation decisions for bioenergy crops. A negative effect could be possible, as small farms may have a comparative advantage by adopting bioenergy crops on marginal land that requires less input, where larger farms do not. Paulrud and Laitila (2010) found that land planted to a bioenergy crop decreased by 0.1% for each acre farm size increased. Farm size may have positive effect on land allocation decisions, as well. It could be that larger farms may be able to allocate more land to the production of new crops as they may be more diversified across the agricultural landscape compared to smaller size farms, reducing potential adverse impacts from adoption of a new crop. Lynes et al. (2016) found that as farm size increases by 100 acres, land allocated to bioenergy crops would likely increase by 2.4 acres for surveyed farms.

(ii) Farm income: An increase in farm income per hectare can increase the ability of growers to produce new crops (Gould et al., 1989), but higher farm income had a negative effect in some studies on farmers' willingness to covert land to bioenergy production (Jensen et al., 2007). This finding may be associated with the opportunity cost of allocated land for bioenergy crop production, which includes the foregone income from planting the next best possible cash crop in rotation. Opportunity costs may be higher for farms with larger incomes or those that produce more high valued crops (Norris and Batie, 1987). As opportunity costs increase, farmers' willingness to convert land for bioenergy production will likely decrease (Fewell, 2012).

(iii) Livestock production: Livestock ownership was found to have a negative effect on farm land conversion to bioenergy crops, which may indicate higher opportunity costs from potentially losing hay or pastoral land (Kristjanson et al., 2005, and Jensen et al., 2007; Tyndall, Berg and Colletti, 2011; Qualls et al., 2012). Nevertheless, Lynes et al. (2016), found that livestock ownership had no effect on the land allocation decision for annual or perennial bioenergy crops.

(iv) Land tenure: Leased or rented land reduces operational control by farmers over potential land uses on these lands, potentially reducing the amount of land that could be allocated to biofuel production (Lynne, et al., 1988; Nkonya, et al, 1997; Brummer et al., 2000; Jensen et al., 2007). Lynes et al. (2016) found that land tenure had no effect on the land allocation decision for bioenergy crop production.

(v) Operational practices: Use of no-till conservation practices may have a positive effect on land allocation decisions. Jensen et al. (2007) emphasizes that farmers using no-till practices are more likely to be willing to adopt environmentally friendly technologies. In turn, they find that farmers be willing to allocate land for bioenergy crop production, if the crop is perceived as environmentally friendly.

(vi) Crop insurance: Previous literature indicates that crop insurance has no effect on bioenergy crop land allocation decisions, which may be due to the lack of markets for particular biofuel feedstocks (Qualls et al., 2012). However, crop insurance is provided to farmers as a mechanism for risk management (Velandia et al., 2009). If bioenergy crop production does significantly increase in the future, we hypothesize that insurance products would be provided and likely be a driving factor for land allocation decisions.

(vii) Crop rotation: A significant advantage of utilizing oilseeds as bioenergy crops is that they can be grown in rotation with other crops, such as wheat on existing farm land.

Being able to incorporate bioenergy crops into existing crop rotations is likely to have a positive effect on land allocation decisions for bioenergy crops (Calvino and Messing, 2012; Lynes et al., 2016).

Farmer characteristics:

(i) Prior experience: Previous experience of growing oilseed crops can play a critical role in the land allocation decisions, but findings are mixed. Prior experience with bioenergy crops has mixed effects on land allocation decisions. Jensen et al. (2007), and Rossi and Hindrichs (2011), stated that prior experience had a positive effect on willingness to grow and land allocation decisions, while Qualls et al. (2102), indicated that prior experience with bioenergy crops had a negative effect on land allocation decision.

(ii) Education: In a majority of the previous literature on bioenergy crop land allocation decisions, higher education has been shown to have a positive effect on land allocation decisions for bioenergy crop production (Fernandez et al., 2001; Jensen et al., 2007, and Lynes et al., 2016). Qualls et al. (2102), though, found that education had no statistically significant effect on land allocation decisions for bioenergy crop production.

(iii) Off-farm income: The effect of off-farm income on land allocation decision for bioenergy crops is mixed. Off-farm income can have a positive effect on land conversion to bioenergy production (Fernandez et al., 2001; Ransom et al., 2003; Jensen et al., 2007, and Lynes et al., 2016). It is hypothesized that off-farm income increases the ability of farmers to purchase or invest in new technologies and enterprises on-farm. However, Qualls et al. (2102) found that off-farm income had a negative effect on land allocation decisions for bioenergy crops. It could be the case that off-farm job opportunities require significant time (and other resource) commitments, making off-farm income have a negative effect on land allocation decisions.

(iv) Adoption behavior: First adopters of new technology are more likely willing to convert more land for bioenergy technology than late adopters (Fernandez et al., 1994; Fernandez et al., 2001; Qualls et al., 2012).

(v) Age: Effect of age on willingness to allocate land for bioenergy crops is mixed. Younger farmers have been found to be more interested in converting farm land to bioenergy crop production (Rajasekharan and Veeraputhran, 2002; Jensen et al., 2007, and Lynes et al., 2016). However, Qualls et al. (2102) indicated that old farm managers devoted more land for bioenergy crops when compared to young farm managers.

3. Data and Methods

We first present a conceptual two stage model of the adoption-land allocation decision process, followed by an empirical model that is based on the conceptual model that is estimated using primary survey data.

3.1 Conceptual Model

A two stage conceptual model is presented here. The first stage concerns farmers' willingness to adopt a new crop and the second stage concerns farmers' willingness to allocate land for new crop production. That is, there are two decisions which have to be addressed by the farmers. The first decision is about the decision to grow a new oilseed crop or not. Conditional on this first decision, the second decision is about how much land to allocate for the new oilseed crop. Both decisions are assumed to be made sequentially.

3.1.1. Stage one: Farmers' willingness to grow a new oilseed crop

An expected utility maximization framework is used to examine farmers' willingness to grow a new oilseed crop on their existing farm land. Assume that farmers are profit oriented and their expected satisfaction or utility depends on the level of profit earned. Furthermore, assume that utility is monotonically increasing in expected profit. Then, to maximize expected utility, profit oriented farmers would want to maximize expected profit, as well. A higher profit means a higher expected utility for the farmer.

Thus, for the ith farmer:

$$U_i = \mathrm{U}({R^E}_i(\mathrm{C}_i, \mathrm{Z}_i), \mathrm{S}_i) \quad \ldots\ldots\ldots\ldots \quad (1)$$

where “U_i” is expected utility of farmer “i”, “$R^E{}_i$” is expected profit of farmer “i”, “C_i” is the new oilseed crop chosen by farmer “i”, “Z_i” is vector of activities of farmer “i” that directly impact expected profits of oilseed crop production, and “S_i” is a vectors of socio-cultural and other factors shaping the utility received by farmer “i”. The inclusion of S_i is meant to capture socio-cultural and other factors such as attitudes, lifestyle choices, and cultural aspects that play a role in affecting the decision of farmers to adopt a new crop or not (i.e. how the farm is managed and operated).

Following Lynes et al., (2016), a farmer will decide to adopt a new crop, if the expected utility (U_i) which is expressed in terms of expected profit from growing a new crop (C_i) is greater than the expected utility of not growing a new crop ($\mathrm{C}_i{}'$). Notation is simplified so that U_i is simply stated as a function of C_i, leading to the following condition:

$$U_i(\mathrm{C}_i) > U_i(\mathrm{C}_i{}')$$

That is:

$$U_i(\mathrm{C}_i) - U_i(\mathrm{C}_i{}') = \Delta U_i > 0 \quad \text{(2)}$$

3.1.2. Stage two: Initial land allocation decision for a new crop

Initial land allocated to a new crop is dependent on willingness to grow, thus the initial land allocation decision is a second stage of the decision process. Farmers who decide to grow a new oilseed crop will likely perceive it is profitable for their existing operation and then make corresponding land use decisions. Following Parks and and Kramer (1995); Wu and Segerson (1995); and Wu and Li (20013), the land allocation decision is a function of expected profit from land allocated to the new oilseed crop and profit allocated to other activities (e.g. other crop(s), livestock etc.).

The farmer’s decision at stage two is to:

$$\underset{(a_{iC}, a_{iZ})}{Max} \quad \pi_i(\, R_{EiC}\,(a_{iC}, r_{iC}), R_{EiZ}\,(a_{iZ}, r_{iZ}))$$

$$\boldsymbol{s.t.}\ a_{iC} + a_{iZ} \leq \bar{a}_i \quad \text{(3)}$$

where “π_i” is total expected profit for farmer “i”; “R_{EiC}” is expected profit for the new crop for farmer “i”, which is a function of “a_{iC}”, the amount of land allocated to the new crop, and “r_{iC}”, the amount of profit per unit of land of the new crop; "R_{EiZ}" is expected profit of other activities of farmer "i", which is a function of "a_{iZ}", the amount of land applied to other activities, and "r_{iZ}", the amount of profit per unit of land for these other activities; and "$\bar{a}_i$" is the total amount of land available to farmer "i".

The optimal amount of land allocated to growing the new crop in the above problem can be found by solving the KKT conditions for the problem, and can be represented as:

$$a_{iC}{}^{*} = a_C(R_{EiC}\,, R_{EiZ}\,, \bar{a}_i) \quad (4)$$

$$a_{iZ}{}^{*} = a_Z(R_{EiC}\,, R_{EiZ}\,, \bar{a}_i) \quad (5)$$

The land allocation decision for the new crop (a_{iC}) and other activities (a_{iZ}) for the i^{th} farmer is a function of expected profit from the new crop (R_{EiC}), expected profit from other activities (R_{EiZ}) and total acreage ($\bar{\bar{a}}_i$).

3.2 Empirical model

The conceptual model provides the foundation for the equations estimated in the two-stage empirical model presented below. The empirical model arises from the operationalization of equations (2) and (4).

3.2.1. Stage one: Farmers' willingness to adopt oilseed crop

The decision to grow a new oilseed crop is observed as a binary decision. Let $Y_i = 1$, when $\Delta U_i > 0$, and "0" otherwise. That is, $Y_i = 1$, when farmer "i" is willing to grow a new oilseed crop and $Y_i = 0$, otherwise. Factors that can affect the adoption decision are assumed to be linearly related to the farmers' willingness to grow an oilseed crop. Let $\boldsymbol{X_{ai}} = (X_{a1} \ldots, X_{ak})$ be the factors that affecting the adoption decision identified in section 2.1, $\boldsymbol{\alpha_{ai}} = (\alpha_{a1} \ldots, \alpha_{ak})$ be a vector of parameters and ε be a mean zero IID error term. Then, the growing decision can be modeled as:

$$\Delta U_i = \boldsymbol{\alpha_{ai}} \boldsymbol{X_{ai}} + \varepsilon,\ Y_i = \begin{cases} 1 \ if \ \Delta U_i > 0 \\ 0 \ otherwise \end{cases} \quad (6)$$

Assuming ε is standard normally distributed, the probability of adoption ca be estimated using a standard Probit model. The marginal effects of the explanatory variables on the probability of growing a new oilseed crops can be estimated at the means of the explanatory variables and asymptotic standard errors estimated using the delta method (Green, 2008).

3.2.2. Stage two: Initial land allocation decision for oilseed crop(s)

Farmers who decide to grow a new oilseed crop(s) must also decide how much land to allocate for oilseed production. To maximize total expected profit, farmers try to optimize land allocation between oilseed crop(s) and other activities. The optimal land allocation decision for oilseed crop(s) and other activities for the i^{th} farmer is a function of expected profit from oilseed crop(s) (R_{EiC}), expected profit from other activities (R_{EiZ}) and total acreage ($\bar{a}_i$) owned, i.e. $a_{Ci}* = a_{Ci}$ $(R_{EiC}, R_{EiZ}, \bar{a}_i)$

Land demand for oilseed crop(s) (a_{Ci}) is assumed to be linearly dependent on a number of different explanatory factors. Let $\boldsymbol{X_{bi}} = (X_{b1} \ldots, X_{bk})$ be the factors that affect the land allocation decision identified in section 2.2, $\boldsymbol{\beta_{bi}} = (\beta_{b1} \ldots, \beta_{bk})$ a vector of parameters, and u be a mean zero IID error term. The land allocation decision equation can then be empirically modelled as:

$$a_{Ci} = \boldsymbol{\beta_{bi}} \boldsymbol{X_{bi}} + u \sim \mathrm{N}(0, \sigma^2) \quad \ldots\ldots (7)$$

3.2.3. Estimation

In order to avoid self-selection bias, from the survey question asked (see section 3.3) and the two-stage decision process, Heckman's two step selection model is adopted for estimation. In this model, both equations (6) and (7) are estimated simultaneously. Following Heckman (1979), the initial land allocation decision (a_C) only occurs when farmers are willing to adopt a new oilseed crop(s), ($Y_i = 1$). Hence, a_{Ci} depends both on $\boldsymbol{X_{bi}}$ and Y_i, i.e.

$$\mathrm{E}(a_{ci} | X_{bi}, Y_i = 1) = \boldsymbol{\beta_{bi}} \boldsymbol{X_{bi}} + \mathrm{E}(u | X_{bi}, Y_i = 1) \quad \ldots\ldots (8)$$

Heckman's two step model helps to avoid self-selection bias (Puhani, 2000). If the correlation between the standard errors of the two models namely willingness to grow oilseed crops and initial land allocation decision models is not zero, then there will be self-selection bias.

That is:

$$E(u|X_{bi}, Y_i = 1) = \rho\sigma_u \frac{\phi(\alpha_{ai}X_{ai})}{\varphi(\alpha_{ai}X_{ai})}$$

where ρ is the correlation between ε and u, σ is the standard deviation of u, ϕ is the standard normal probability function and φ is the standard normal cumulative density function. According to Gourieroux (2000), when ρ equals zero no self-selection bias is present. Marginal effects for the conditional second stage regression for the explanatory variables are estimated at the means of the explanatory variable and asymptotic standard errors estimated using the delta method (Greene, 2008).

3.3 Data

A project funded by the US Department of Agriculture and Agricultural Research Service through the office of Naval Research was undertaken to conduct research on the development of bio-jet fuel from oilseeds crops. As part of the project, a survey was administered, focusing on farmers' interest and willingness to grow oilseeds in rotation with wheat for biofuel production. The survey was administered by Iowa State University's Survey & Behavioral Research Services (SBRS) unit.

Survey data was collected through a mailed questionnaire to wheat farmers located in 11 states across three US regions: (i) California, Oregon and Washington of the Pacific Northwest Fruitful Rim region, (ii) Colorado, Kansas, Nebraska, Oklahoma and Texas of the Prairie Gateway region; and (iii) Montana, North Dakoda and South Dakoda of the Northern Gateway region in 2013. Regions were selected based on USDA, Economic Research Service and USDA-National Agricultural Statistics Service crop production data for wheat and oilseed production. Farmers who produced at least 50 acres of wheat were randomly selected from predominantly wheat producing counties within the states indicated earlier. Sample sizes for each individual county were set to be proportional to the population of wheat farmers in that county relative to the region being sampled. Farmer lists were obtained from farmermarketid.com. To familiarize farmers with the identified oilseed crops, a fact sheet was developed with oilseed information and full colored pictures of oilseed crops. A cover letter that included a description of the study and survey purpose was provided, as well. A mail survey was used given the large sample of farms selected and geographic area being examined.

The survey sample population comprised 10,089 wheat farmers. The initial questionnaire was mailed on April 2, 2013. Between April 12 and April 24, 2013, postcard reminders were sent to non-responds. A second shortened questionnaire was mailed to non-respondents from April 26 to May 10, 2013. Of the 10,089 sample farmers, 241 (2.4%) were not eligible, 125 (1.2%) were undeliverable, 133 (1.3%) refused to complete, 8,611(85.4%) were non-response, and 971 (9.7%) had completed the full survey. This gave a response rate of about 10 percent. A potential reason for the low response rate (10%) was the timing of the questionnaire, and/or interest in producing oilseeds.

For the dependent variable in the model, farmers were asked about willingness to adopt and allocate land for oilseed crops under two assumptions: (i) the farmers would have a favorable contract and (ii) growing the crops on their existing farm land included leased or rented land". The question asked was (i) "Would you produce oilseeds as bio-energy crops, under a favorable contract? Indicate, yes or no"; and (ii) "If you say "yes", what is the maximum acreage you would be willing to plant to oilseed as a bio-energy crop?"

Other questions were used to identify the independent variables, including farm characteristics and management, perceptions, adoption behaviors and other demographic variables. The independent variables which were hypothesized to affect the dependent variables such as farmers' willingness to adopt and initial land allocation decision for bioenergy crops were selected from literature review and economic theory (see sections 2.1 and 2.2). The farm characteristics and management variables included: fixed effects for Pacific Northwest Fruitful Rim and Prairie Gateway; total acres owned; income from the farm; percentage of leased/rented land; risk behavior; experience with oilseed practices; crop rotation; use of no-till or minimum till conservation practices; off-farm employment; percent of land rented on crop share basis; profit of wheat crop relative to canola crop; livestock ownership; use of irrigation; and farming experience. Perception, adoption behavior and demographic variables included: experience of a cash crop failure; being a first adopter; nearby crushing facility; use of crop insurance; having a college degree; age; and gender.

Table 1 provides a comparison of the 2012 census of Agricultural statistics and survey statistics for farmers found in three regions of the US namely Pacific Northwest Fruitful Rim, Prairie Gateway and Northern Great Plains. The aim of the comparison is to know whether the sample farmers were representative of the survey area or not. Survey respondents exhibit more or less similar average age with the 2012 census average age. The average age of farmers from the survey is around 56 years old while it is 58 years old in the census. Regarding gender, the survey has a slightly lower number of females than the census. The percentage of females in the survey is 7 percent as compared to 18 percent in the 2012 census of agriculture. Average farm size was slightly larger for survey participants as compared to the report from the census. While surveyed farmers operate on average 1318 acres of land, average land area owned by farmers in the Census was 860 acres. The average farm size of the survey as compared to the census is higher likely due to commercial size operations being more likely to respond and prominent in the survey sample.

Table 2 provides descriptive statistics for the variables. On average around 58 percent of the respondents are willing to grow an oilseed crop. Similarly, these farmers who are willing to cultivate oilseed crops are also ready to allocate on average about 160 acres. In this study, farmers were asked to express their willingness to grow bioenergy crops with the assumption of a favorable contract.

The sample farmers were from Pacific Northwest Fruitful Rim, Prairie Gateway and Northern Great Plains. The Pacific Northwest Fruitful Rim, Prairie Gateway region and Northern Great Plains accounted for around 17, 47, and 36 percent of the sample farms, respectively. Land is a main resource in agriculture. On average surveyed farmers' operated 1318 acres of land, and almost half of the land operated by a farmers' was leased or rented. On average, farmers received 87 percent of their income from the farm. This showed that the livelihood of these sample farm households depends more on farming than off-farm employment.

Risk taking behavior of farmers is an important variable especially during adoption of new crops. New crops are characterized by uncertain payoffs. Those farmers who are more risk averse (cautious or extremely risk averse) accounted for 21 percent of the farms surveyed. Around 56 percent of the farmers indicated they have experience with oilseed crops. Having a nearby crushing facility can reduce a farmer's transportation cost for processing oilseeds. Sixteen percent of the sample farmers indicated they have crushing facilities nearby. Crop rotation behavior is considered as a plus to ease farmers' adoption of oilseed crops. Among the main arguments of the present study is to grow oilseed crops in rotation with wheat instead of leaving the land fallow. So, crop rotation is an important variable. Seventy-eight percent of the farmers use crop rotations.

If the land is leased or rented on a crop-share basis, the payment for rent increases with an increase in returns from production. Land leased or rented on crop share basis may provide less incentive for farmers to undertake optimal input use (Marshall, 1890). Survey of data indicates that 43 percent of land leased or rented was on a crop-share basis. It was indicated that about 68 and 72 percent of farmers apply no till and minimum till conservation practices, respectively.

Opportunity costs come into play when farmers decide on land-use options. As canola was the most common oilseed crop tried in the study area, it is taken as a proxy to measure opportunity costs. The profit of wheat relative to canola was estimated from USDA statistics in 2013 (USDA, 2012). On average the profit ratio of wheat to canola is 1.12 to 1.0. That is, for every $1 of additional profit from oilseed production, there will be $1.12 given up in wheat production.

On average, 88 percent of the famers have experienced a cash crop failure. To minimize crop failure risk, farmers may purchase crop insurance, of which 89 percent of the farmers surveyed purchased. In terms of new technology, farmers differ in their timing of adoption. While some adopt early, others adopt late. Thirty-four percent of the farmers indicated that they were early adopters. Farming experience is another independent variable taken in to consideration. It measures how long farmers have been engaged in farming. On average, farmers surveyed had 34 years of farming experience.

Livestock is another dimension in farming. Many farmers own livestock as an additional enterprise to crops. Of the farmers surveyed, 36 percent own livestock. Likewise, about 57 percent of the farmers surveyed use irrigation on their crops. Around 58 percent of the sampled farmers have a college degree.

4. Results and Discussion

We estimated a joint Heckman two-step selection model examining both farmers' willingness to grow and to allocate land for new oilseed crop(s). The Pseudo R^2 for the jointly estimated model was 0.22, providing evidence that the model provides a decent fit to the sample data. Farmers' willingness to grow oilseed crops was estimated using a Probit model and estimation results are provided in Table 3. The selection model in Table 3 represents the second stage initial land allocation decision, and identifies factors that affect the initial land allocation decision for growing oilseed crops for biofuel production. Rho was significant and estimated as -0.349 with a standard error of 0.142, indicating that selection bias was present. Therefore, it was appropriate to use the sample selection model introduced by Heckman (1979). To take account of any potential heteroscedasticity problem in both stages of the model, clustered robust standard errors were applied, as an extension to Heckman's two step model (Rogers, 1993; Bertrand et al., 2004; Wooldridge, 2010, and Cameron and Miller, 2015). If there are no heteroscedasticity problems, then cluster-robust standard error estimates show the traditional standard errors estimates. Hence applying cluster robust standard error gives more robust results even if the model is homoscedastic (Cameron and Miller, 2010).

4.1 Stage one: Farmers' willingness to grow oilseed crop(s) for biofuel production

A number of factors that affect the willingness of farmers to grow oilseed crops for bio-fuel production were found to be statistically significant. These factors include: risk behavior, experience of growing oilseed crops, availability of a nearby crushing facility, use of no-tillage, being a first-adopter, farming experience, having a college degree and gender.

Farm characteristics: Farmers who have a crushing facility nearby their farms were more likely to adopt oilseed crops than those who do not. Based on marginal effect estimates, farmers who have a crushing facility nearby were 18% more likely to adopt oilseed crops than farmers who don't have a nearby crushing facilities. Crushing facilities are a first step in the process to obtain the needed vegetable oil that will be processed into bio-jet fuel. Having a facility nearby will likely reduce the uncertainty farmers face with the establishment of a market for these crops and help to minimize farmers' transportation costs. This is supported by findings in Qualls et al. (2012) and Lynes, et al. (2016) who found that the availability of necessary equipment and facilities had a positive effect on the adoption of bioenergy crops. Farmers who use no-till conservation practices were 9% more likely to adopt oilseed crops. Farmers may consider oilseed crops as a good rotational crop that may enhance fertility of the soil, as oilseed crops can fix nitrogen, reduce fertilizer needs, have a definable growth season, have uniform seed maturation rate, and fallow lands compatible (Moser, 2010). This is further supported by Jensen et al. (2007) who found that no-till practices have a positive influence on farmers' willingness to adopt bioenergy crops.

Farmer characteristics: Farmers who have experience with oilseed production were 21% more likely to adopt oilseed crops than farmers who don't have experience in oilseed production. This may result from circumstances where experienced farmers have already had a positive experience with oilseed crops that makes them more willing to grow these crops for non-food purposes.

Farmers who adopt technology before their neighbors (first-adopters) were more likely to adopt oilseed crops than farmers who are late in new technology adoption by 8.8%. Fernandez et al. (1994); Daberkow and Mcbride (1998); Fernandez et al. (1998), and Qualls et al. (2012), reported that adopters who are less risk averse were found to be early adopters and those that are more risk averse were found to be late adopters for new technology. Growing oilseed crops as a new practice is sensitive to the risks involved. Farmers who were risk averse were 16.5% less likely to adopt oilseed crops when compared to farmers' who were not risk averse. This result agrees with Fernandez et al. (1994); Daberkow and Mcbride (1998), and Fernandez et al. (2001) who reported that risk averse farmers were reluctant to adopt bioenergy crops. Keske et al. (2013) indicated that risk averse farmers were less likely to adopt until they receive a certain guarantee of profit.

Farmers who have a college degree were 6% more likely to adopt oilseed crops as compared to farmers who did not have one. Nkonya et al. (1997); Baidu-Forson (1999); Jensen et al. (2007), and Singer et al. (2007) all reported that a higher level of education had a positive effect on adoption of new technology. Farmers who had more years of farming experience were less likely to grow oilseed crops. For each year of additional experience, there is a 0.34% decrease in the likelihood of growing an oilseed crop. Experienced farmers may have already established a better option or could be resistant to change to adopt new activities, which may make them reluctant to introduce or shift to a new oilseed crop. In this study, experience has a different effect when compared to Jensen et al. (2007) and Lynes et al. (2016). According to Jensen et al. (2007), farmers' experience had a positive effect for bioenergy crop adoption. Female farmers 36% less likely to adopt oilseed crops when compared to their male counterparts.

Factors such as location, farm size, farm income, off-farm income, land leased or rented, crop insurance, crop rotation, land rented on a crop-share basis, experience of failure of a cash crop, livestock ownership, irrigation, and age were found to be statistically insignificant in affecting the adoption process. Though it is insignificant, farm income is positively correlated to the growing decision, which contradicts with results from Paulrud and Laitila (2010), and Lynes et al. (2016). These studies indicated that higher farm income had a negative effect on adoption. Off-farm income had a positive correlation. This is in line with Fernandez et al. (2005), and Qualls et al. (2012), who indicated greater off-farm income had a positive effect on adoption. However, it contradicts with Norris and Batie (1987), and Gould et al. (1989) who reported that off-farm income had a negative effect on the adoption process of new technology and crops.

4.2 Stage two: Initial land allocation decision for oilseed crop(s)

Farmers who were willing to grow oilseed crops were willing to initially allocate 160 acres of land to oilseed production. Lynes et al. (2016) found that farmers in Kansas, USA were willing to allocate an average land of 121 acres and 97 acres for annual and perennial bioenergy crops, respectively. Results seem to suggest there exists a potential supply of non-food oilseeds for bio-jet fuel production. This potential supply would expect to play a role in satisfying the increasing demand for biofuels that may arise within the airline industry. Guy et al. (1995) stated that wheat production rotated with oilseed crops could be increased by up to 29%.

Farmer characteristics: Statistically significant factors that positively affect the initial land allocation decision of farmers for oilseed production were farm income and gender. A 1% increase in the percentage of household income from the farm, increases the amount of land that farmers were willing to use for cultivation of oilseed crops by 1.4 acres. This contradicts with the findings by Jensen et al. (2007), and Lynes et al. (2016) that indicated that farm income had a negative effect on the land allocation decision for bioenergy crops. It may be that oilseed crops represent a more favorable alternative than cellulosic-based bioenergy crops. While female farmers were less likely to adopt an oilseed crop, they were likely to plant more land for oilseed crops than male farmers. Female farmers were willing to grow 3.41 more acres of oilseed crops than their male counterparts.

Farm Characteristics**:** Other variables, such as land rented on a crop-share basis, profit (wheat/canola) ratio and livestock ownership were statistically significant and affected the initial land allocation decision of farmers for oilseed production negatively. There are alternative ways on how farmers may rent or lease land. One pathway is on a crop-share basis. Results indicated that a 1% increase in the percentage of rented land on a crop-share basis decreased the amount of initial land farmers were willing to allocate to oilseed production by 0.82 acres. This matches with Jensen et al. (2007) who reported that leased or rented land had a negative effect on the biofuel crop land allocation decision.

The opportunity cost of switching from wheat to oilseed production was addressed using related returns of canola to wheat as a proxy. Canola is used to address the opportunity cost if farmers would like to switch land use from wheat to oilseed production, as it is a more popular oilseed crop and grown across the Great Plains of the US where sample farms are located. As the profit of wheat to canola ratio increases by one unit, farmers were willing to grow 0.99 less acres of an oilseed crop(s). As the opportunity cost increases, farmers lose more from increasing land conversion for oilseed crops. Livestock ownership affected the land allocation decision for oilseed production as well. Farmers who own livestock were willing to grow 61.7 less acres for oilseed production than farmers who do not own livestock. This matches with Kristjanson et al. (2005) and Jensen et al. (2007) who found that livestock owners were willing to allocate less land than those who do not own livestock.

A contract that minimizes the risk and guarantees profit for farmers' is necessary for the successful adoption of oilseeds as bioenergy crops. Unless farmers obtain favorable contracts that minimize risk and guarantee profit, the success of oilseed production will be highly uncertain. Contracts in terms of net returns above the next best alternative enterprise, contract length, having a bio-refinery harvest option, availability of insurance and having monetary incentives or cost-share are determinants that will impact adoption of alternative biofuel feedstock's (Bergtold et al., 2014). Similarly, successful adoption of oilseed crops requires a net financial return, net energy gain to have environmental benefits be economically competitive, and be producible in large quantities without reducing food supplies (Jensen et al., 2007). A conducive environment (market and institution) that coordinates these actors is important for development of oilseed production as a bioenergy crop.

5. Summary and Conclusion

This study examined the willingness of farmers to adopt and allocate land for oilseed crops for bio-jet fuel production by wheat farmers located in 11 states in three regions of the western US. An expected utility framework was used to determine farmers willing to grow and allocate land for oilseed crops using a Heckman two-stage selection model. The study found, under a favorable contract, 58 percent of the farmers were willing to grow oilseed crops on an initial acreage of 160 acres. This potential supply, which is subject to having a favorable contract, shows potential for market development of these biofuel feedstocks *ex ante*.

Factors such as experience in growing oilseed crops, availability of a nearby crushing facility, use of no-till conservation practices, being a first-adopter and having a college degree had a positive and significant effect on the likelihood of adoption, while risk behavior, farming experience and gender had significant negative effects on farmers' likelihood of adopting. Similarly factors such as percentage of income from farm and gender had positive and significant effects on the initial land allocation decision, while land rented on a crop-share basis, profit ratio (wheat/canola) and livestock ownership had negative and significant effects for farmers' willingness to initially allocate land for oilseed production.

There is some consistency and differences between this and previous studies with regard to the factors that affect the adoption and land allocation decisions for bioenergy crops. This implies that factors that affect farmers' adoption and land allocation decisions are likely feedstock dependent, as well as dependent on location and timing of adoption. Hence, any agent (governmental and non-governmental) that wants to promote the development of oilseeds as a bioenergy crop should consider the above factors during market and policy development and when locating facilities.

To increase the adoption and supply of oilseed crops for biofuel production, results suggest the following policy implications.

- Availability of nearby crushing facilities are important. Nearby availability of crushing facilities increases the chance of market establishment for oilseed crops. Government and industry should help to establish enough crushing facilities in places if adoption is desired.
- Oilseed experienced farmers have a positive influence on the adoption process. This may help to create a conducive environment where oilseed experienced farmers can share their experience with other farmers, especially with farmers who have more years of farming experience to provide mentoring and encouragement to less experienced farmers.
- When assessing adoption, consideration of land tenure arrangements should be considered. Land rented on a crop-share basis was less likely to be allocated to oilseed production. Involve land owners earlier on in the process to get their buy-in.
- Increasing the profit of oilseed varieties (discovering good varieties, price support etc.) could lessen the opportunity costs of switching to oilseed production. Hence more land could be converted for oilseed production as the opportunity cost of growing oilseed is reduced.
- A potential supply for oilseed crops for biofuel and bio-jet fuel production is possible, but barriers to market establishment still need to be overcome.

Further research is needed to conduct similar studies in other areas. It is also recommended to determine what favorable contracts for farmers should consist of. A favorable contract is different for different farmers, as well as between farmers and bio-refineries. In this study, willingness to grow oilseed crops were treated as one activity. But there are different types of oilseed crops which are suited to different locations. Further research is then recommended to identify which oilseeds would be optimal for different locations.

References

Ardebili, M.S., Ghobadian, B., Najafi, G. and Chegeni, A., 2011. Biodiesel production potential from edible oil seeds in Iran. *Renewable and Sustainable Energy Reviews*, *15*(6), pp.3041-3044.

Atkinson, A.D., Rich, B.A., Tungate, K.D., Creamer, K.S., Green, J.T. and Moore, A.D., 2006. *North Carolina Canola Production. North Carolina State University, North Carolina Solar Center & College of Agricultural and Life Sciences*. SJS/KEL-9/06-W07.

Baidu-Forson, J., 1999. Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agricultural Economics*, *20*(3), pp.231-239.

Bergtold, J.S., Fewell, J. and Williams, J., 2014. Farmers' willingness to produce alternative cellulosic biofuel feedstocks under contract in Kansas using stated choice experiments. *BioEnergy Research*, *7*(3), pp.876-884.

Bertrand M., Esther D., Sendhil M. 2004. How much should we trust dierences-in-di erences estimates? Quarterly Journal of Economics 119: 249-275.

Brummer, E.C., Burras, C.L., Duffy, M.D. and Moore, K.J., 2000. Switchgrass production in Iowa: economic analysis, soil suitability, and varietal performance. *Iowa State University, Ames, Iowa*.

Caldas, M.M., Bergtold, J.S., Peterson, J.M., Graves, R.W., Earnhart, D., Gong, S., Lauer, B. and Brown, J.C., 2014. Factors affecting farmers' willingness to grow alternative biofuel feedstocks across Kansas. *biomass and bioenergy*, *66*, pp.223-231.

Calvino, M. and Messing, J., 2012. Sweet sorghum as a model system for bioenergy crops. *Current opinion in biotechnology*, *23*(3), pp.323-329..

Cameron, A.C. and Miller, D.L., 2015. A practitioner's guide to cluster-robust inference. *Journal of Human Resources*, *50*(2), pp.317-372.

Cameron, A.C. and Miller, D.L., 2010. *Robust inference with clustered data* (No. 10, 7). Working Papers, University of California, Department of Economics.

Daberkow, S.G. and McBride, W.D., 1998. Socioeconomic profiles of early adopters of precision agriculture technologies. *Journal of Agribusiness*, *16*, pp.151-168.

Featherstone, A.M. and Goodwin, B.K., 1993. Factors influencing a farmer's decision to invest in long-term conservation improvements. *Land economics*, pp.67-81.

Fewell, J.E., 2012. *Essays on Kansas farmers' willingness to adopt alternative energy crops and conservation practices* (Doctoral dissertation, Kansas State University).

Fernandez-Cornejo, J., Beach, E.D. and Huang, W.Y., 1994. The adoption of IPM techniques by vegetable growers in Florida, Michigan and Texas. *Journal of Agricultural and Applied Economics*, *26*(01), pp.158-172.

Fernandez-Cornejo, J., Daberkow, S. and McBride, W.D., 2001. Decomposing the size effect on the adoption of innovations [computer file].

Fernandez-Cornejo, J., Hendricks, C. and Mishra, A., 2005. Technology adoption and off-farm household income: the case of herbicide-tolerant soybeans. *Journal of Agricultural and Applied Economics*, *37*(03), pp.549-563.

Gould, B.W., Saupe, W.E. and Klemme, R.M., 1989. Conservation tillage: the role of farm and operator characteristics and the perception of soil erosion. *Land economics*, *65*(2), pp.167-182.

Gourieroux C. 2000. Econometrics of Qualitative Dependent Variables. Cambridge: Cambridge University Press. UK.

Greene H. 2008. Econometric Analysis (6th Edition ed.). Upper Saddle River, New Jersey. Pearson Prentice Hall.

Guy, S.O. and Gareau, R.M., 1998. Crop rotation, residue durability, and nitrogen fertilizer effects on winter wheat production. *Journal of production agriculture*, *11*(4), pp.457-461.

Guy, S.O., Gareau, R.M. and Heikkinem, M.K., 1995, Canola, rapeseed, mustard and other crop rotational influence on witner wheat productivity and N fertilizer response. In *Proceedings of the Pacific Northwest Canola Conference Coeur d'Alene, ID* (pp. 5-7).

Heckman J. 1979. Sample Selection Bias as a Specification Error. Econometrica 47(1): 153-161.

IATA, A., 2009. Global Approach to Reducing Aviation Emissions. *First Stop: Carbon Neutral Growth from*, *2020*.

International Air Transport Association (IATA), 2010. Report on alternative fuels. Available at: https://www.iata.org/publications/Documents/IATA%202010%20Report%20on%20Alternative%20Fuels.pdf. (Accessed on March 12, 2014)

Jensen, K., Clark, C.D., Ellis, P., English, B., Menard, J., Walsh, M. and de la Torre Ugarte, D., 2007. Farmer willingness to grow switchgrass for energy production. *Biomass and Bioenergy*, *31*(11), pp.773-781.

Keske, C.M., Hoag, D.L., Brandess, A. and Johnson, J.J., 2013. Is it economically feasible for farmers to grow their own fuel? A study of Camelina sativa produced in the western United States as an on-farm biofuel. *Biomass and bioenergy*, *54*, pp.89-99.

Kristjanson, P., Okike, I., Tarawali, S., Singh, B.B. and Manyong, V.M., 2005. Farmers' perceptions of benefits and factors affecting the adoption of improved dual-purpose cowpea in the dry savannas of Nigeria. *Agricultural Economics*, *32*(2), pp.195-210.

Lynes, M.K., Bergtold, J.S., Williams, J.R. and Fewell, J.E., 2016. Willingness of Kansas farm managers to produce alternative cellulosic biofuel feedstocks: An analysis of adoption and initial acreage allocation. *Energy Economics*, *59*, pp.336-348.

Lynne, G.D., Shonkwiler, J.S. and Rola, L.R., 1988. Attitudes and farmer conservation behavior. *American journal of agricultural economics*, *70*(1), pp.12-19.

Marshall A. 1890. Principles of Economics. 8th edition, London: Macmillan 1956

Moser, B.R., 2010. Camelina (Camelina sativa L.) oil as a biofuels feedstock: Golden opportunity or false hope?. *Lipid technology*, *22*(12), pp.270-273.

Nkonya, E., Schroeder, T. and Norman, D., 1997. Factors affecting adoption of improved maize seed and fertiliser in northern Tanzania. *Journal of Agricultural Economics*, *48*(1-3), pp.1-12.

Norris P. and Batie S. 1987. Virginia farmers’ soil conservation decisions: an application of Tobit analysis. South J Agr Econ. 19:79-90.

Parks P. and Kramer R. 1995. A Policy Simulation of the Wetlands Reserve Program. J. En-viron. Econ. and Manage. 28: 223-40.

Paulrud, S. and Laitila, T., 2010. Farmers’ attitudes about growing energy crops: a choice experiment approach. *Biomass and Bioenergy*, *34*(12), pp.1770-1779.

Puhani A. 2000. The Heckman Correction for Sample Selection and Its Critique. Journal of Economic Surveys 14: 53-68.

Putnam, D.H., Budin, J.T., Field, L.A. and Breene, W.M., 1993. Camelina: a promising low-input oilseed. *New crops. Wiley, New York*, *314*.

Qualls, D.J., Jensen, K.L., Clark, C.D., English, B.C., Larson, J.A. and Yen, S.T., 2012. Analysis of factors affecting willingness to produce switchgrass in the southeastern United States. *biomass and bioenergy*, *39*, pp.159-167.

Ragan, H.R. and Kenkel, P.L., 2007, February. The impact of biofuel production on crop production in the southern plains. In *Southern Agricultural Economics Association Annual Meeting, February 4-7, 2007, Mobile, Alabama*.

Rajasekharan P., Veeraputhran S. 2002. Adoption of intercropping in rubber smallholdings in Kerala, India: a Tobit analysis. Agroforestry Systems; 56:1–11.

Ransom K., Paudyal K., Adhikari K. 2003. Adoption of improved maize varieties in the hills of Nepal. Agricultural Economics; 29:299–305.

Rogers H. 1993. Regression Standard Errors in Clustered Samples. Stata Technical Bulletin 13: 19-23.

Rossi, A.M. and Hinrichs, C.C., 2011. Hope and skepticism: Farmer and local community views on the socio-economic benefits of agricultural bioenergy. *Biomass and Bioenergy*, *35*(4), pp.1418-1428.

Shonnard, D.R., Williams, L. and Kalnes, T.N., 2010. Camelina-derived jet fuel and diesel: Sustainable advanced biofuels. *Environmental Progress & Sustainable Energy*, *29*(3), pp.382-392.

Singer, J.W., Nusser, S.M. and Alf, C.J., 2007. Are cover crops being used in the US corn belt? *Journal of Soil and Water Conservation*, *62*(5), pp.353-358.

Tyndall, J.C., Berg, E.J. and Colletti, J.P., 2011. Corn stover as a biofuel feedstock in Iowa's bio-economy: an Iowa farmer survey. *Biomass and bioenergy*, *35*(4), pp.1485-1495.

US Department of Agriculture (USDA). 2012. Two thousand twelve censes of agriculture. USA. Availableat: http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf. (Accessed on July 18, 2014)

Velandia, M., Rejesus, R.M., Knight, T.O. and Sherrick, B.J., 2009. Factors affecting farmers' utilization of agricultural risk management tools: the case of crop insurance, forward contracting, and spreading sales. *Journal of agricultural and applied economics*, *41*(1), pp.107-123.

Wen, Z., Ignosh, J., Parrish, D., Stowe, J. and Jones, B., 2009. Identifying farmers' interest in growing switchgrass for bioenergy in southern Virginia. *Journal of Extension*, *47*(5), pp.1-10.

Winchester, N., Wollersheim, C., Clewlow, R., Jost, N.C., Paltsev, S., Reilly, J.M. and Waitz, I.A., 2013. The impact of climate policy on US aviation. *Journal of Transport Economics and Policy (JTEP)*, *47*(1), pp.1-15.

Wooldridge, J.M., 2010. *Econometric analysis of cross section and panel data*. MIT press.

Wu, J. and Segerson, K., 1995. The impact of policies and land characteristics on potential groundwater pollution in Wisconsin. *American Journal of Agricultural Economics*, *77*(4), pp.1033-1047.

Wu, J. and Li, M., 2013. Land use change and agricultural intensification: key Research Questions and Innovative Modeling Approaches. *A background paper submitted to the International Food Policy Research Institute. Final Report*.

Yeboah, A., Naanwaab, C., Yeboah, O.A., Owens, J.P. and Bynum, J.S., 2013. Economic feasibility of sustainable high oilseed-based biofuel production: the case for biodiesel in North Carolina. *International Food and Agribusiness Management Review*, *16*(1).

Tables

Table 1: Comparison of farmers' demographics to survey respondents

		2012 Census of Agriculture	**Survey (*N*=957)**
Age (in years)		58.30	55.50
Gender	Percentage Female	18	07
	Percentage Male	82	93
Average farm size (acres)		860	1318
Percentage of land leased or rented		57	51

Source: USDA, 2014

Table 2: Variable definitions and descriptive statistics

Variable	Definition	Mean (N=957)	Standard error
	Dependent variables		
Farmer willingness to grow an oilseed crop	Equal to 1 if farmer is willing to grow and 0 otherwise	0.58	0.49
Initial land allocation	Initial acreage a farmer would be willing to grow an oilseed crop on	159.81	322.48
	Independent variables		
Pacific Northwest	Equal to 1 if farm is located in Pacific Northwest and 0 otherwise	0.17	0.37
Prairie Gateway	Equal to 1 if farm is located in Prairie Gateway and 0, otherwise	0.47	0.50
Farm characteristics			
Farm size	Total farm size measured in acres	1318.40	1295.60
Income from farm	Percentage of total income that comes from farming operation measured (0 – 100)	75.30	29.30
Land from lease or rent	Percentage of land that is leased or rented (0 – 100)	51.40	34.50
Failure of Cash crop	Equal to 1 if farmer has experienced any cash crop failures and 0 otherwise	0.88	0.33
Crop insurance	Equal to 1 if farmer has crop insurance and 0 otherwise	0.89	0.31
First adoption	Equal to 1 if farmer considers themselves a first adopter 0 otherwise	0.34	0.47
Livestock ownership	Equal to 1 if farmer raises any type of livestock and 0 otherwise	0.36	0.48
Irrigation practice	Equal to 1 if farmer irrigates any of their crops and 0 otherwise	0.57	0.50
Crushing facility	Equal to 1 if a crushing facility is located near to the farm and 0 otherwise	0.16	0.37
Crop rotation	Equal to 1 if farmer rotates their crops and 0 otherwise	0.78	0.42
Crop-share	Percentage of land rented on a crop-share basis (0 – 100)	43.28	43.15
Profit(wheat/canola) ratio	Ratio of net returns in dollars per acre of wheat to canola, estimated using state level extension crop budgets.	1.12	0.50
No till conservation	Equal to 1 if farmer uses no-till practices and 0 otherwise	0.68	0.47
Minimum till conservation	Equal to 1 if farmer uses minimum till practices and 0 otherwise	0.72	0.45
Farmer characteristics			
Risk behavior	Equal to 1 if farmer identifies themselves as risk averse and 0 otherwise. A farmer identified as risk averse if they indicated they were an extreme risk avoider, cautious or willing to take risks only after adequate research.	0.21	0.41
Off-farm income	Equal to 1 if farmer receives any off-farm income and 0 otherwise	0.45	0.50
Farm experience	The number of years the farmer has worked on their current farm	33.94	13.12
College degree	Equal to 1 if farmer has a college degree and 0 otherwise	0.54	0.50
Age	Farmer age in years	55.47	19.40
Gender	Equal to 1 if farmer is female and 0, otherwise	0.09	0.28

Table 3: Heckman's two step model estimation results for farmer willingness to grow and initial land allocation decisions related to growing an oilseed bioenergy crop(s)

	Probit Model: Willingness to Grow Oilseed Crop				Linear Regression: Initial land allocation model	
	Parameters estimates		Marginal effects		Parameters estimates	
	Estimates	Std. error	Estimates	Std. error	Estimates	Std. error
Intercept	0.15	0.47			440.51**	189.79
Pacific Northwest	-0.25	0.16	-0.076	0.047	10.24	57.37
Prairie Gateway	-0.01	0.11	-0.0033	0.032	6.76	42.82
Farm characteristics						
Farm size	-0.70-05	0.37-04	-0.21-05	0.11-04	0.02	0.015
Income from farm	0.00080	0.0019	0.00020	0.00060	1.41*	0.75
Land from lease or rent	-0.00040	0.0016	-0.00010	0.00050	0.068	0.61
Crop insurance	-0.10	0.36	-0.03	0.10	-5.75	62.11
Crushing facility	0.63***	0.14	0.18***	0.04	-	-
Crop rotation	0.057	0.12	0.017	0.04	-28.76	47.15
Land rent crop-shares	0.0016	0.0013	0.00050	0.00040	-0.82*	0.47
Profit (wheat/canola) ratio	-0.00050	0.0011	-0.00020	0.00030	-0.99*	0.54
No till conservation	0.31***	0.11	0.09***	0.03	6.48	47.84
Minimum till conserve.	-0.020	0.10	-0.0061	0.029	-18.66	38.87
Failure of Cash crop	0.14	0.34	0.042	0.10	-	-
First adoption	0.29**	0.12	0.10**	0.040	15.87	43.91
Livestock ownership	0.070	0.090	0.020	0.030	-61.71*	36.50
Irrigation practices	-0.020	0.090	-0.0055	0.029	-	-
Farmer characteristics						
Risk behavior	-0.52***	0.11	-0.17***	0.040	40.26	67.74
Experience with oilseed	0.65***	0.10	0.21***	0.030	-94.24	65.066
Off-farm income	0.0075	0.12	0.0022	0.037	-14.93	44.25
Farm experience	-0.011***	0.0040	-0.0034***	0.0012	1.96	2.020
College degree	0.20*	0.11	0.06*	0.033	-50.33	39.00
Age	-0.0058	0.0050	-0.0017	0.0015	-0.229	1.84
Gender	-1.17**	0.50	-0.36***	0.13	3.41*	202.58

Rho					-0.35**	0.14
Fit Statistics						
Log likelihood						-506.93
Pseudo R^2						0.22
Number of observations						957

Note: ***, **, * indicates statistical significance at the 1%, 5%, 10% level respectively.