# Search Theory Risk Preference and Farmland Preservation

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This paper uses search theory to examine the role that risk preference (RP) plays in farmland preservation. Assuming that the distribution of the offer price is fixed, the analysis indicates that risk-averse agents have lower reservation prices than risk-neutral agents, and that agricultural land held by the former exits farming at a faster rate. The results also show that farmland preservation policies which increase reservation prices have a greater capitalization effect if agents are risk-loving, and that such policies, while effectively protecting the interest of land speculators, may be less effective in serving the needs of farming and farm-held open space.

Farmland preservation policies can be found in all fifty states, yet the role that the risk preferences of farmers and other agents play in preserving farmland has received very little attention in the literature. Understanding that role is essential to evaluating the effectiveness of such policies and may provide a basis for informed land-use decisions by policy makers. These decisions are generally motivated by the need to provide open space (Rose), environmental amenities (Kline and Wichelns), and public goods (Nelson), and considerations regarding the production of specialty crops (Berry; Sinclair). The motivations are supported in part by the belief that the free market will not socially optimize the allocation of land between open space and environmental amenities and other uses, such as maintaining sufficient land for a viable agriculture (Gardner). Hence some type of government action is generally proposed to preserve farmland.

The instruments of farmland preservation generally used by government range from property tax relief policies to agricultural zoning and the acquisition of development rights (see Forkenbrock and Fisher; Berry and Plaut; Furuseth; and Nelson 1986 for further discussion of the effectiveness of these policies in preserving farmland). In all cases, the policy instrument has a preservation effect by keeping land in agriculture longer. It has also been argued that in some cases the benefits of the policies are capitalized into farmland prices. Thus, these prices become higher than they would be without government intervention. This increase can be considered the capitalization effect of the policy (see Fischel for a review of the capitalization effects of zoning).

The magnitude of the two effects and the implication they hold for farmland preservation policy is not clear when risk preferences are considered. Past research on uncertainty and land prices provides little guidance because the focus as tended to be on the importance of these elements in land price formation. White and Zimmer illustrate the importance of risk as a determinant of farm real estate prices. Harris and Nehring develop a theoretical model in which they demonstrate the relative importance of the degree of risk aversion in determining bid-price differentials among farm size classes. Brown and Brown examine the effect of heterogeneous expectations on farmland prices and conclude that the speculative component built into a seller's reservation price is partly responsible for the rise in farmland prices.

Though the previous studies identify the effectiveness of certain policy instruments in preserving farmland and the importance of risk and uncertainty in land price formation, the existing literature provides no theoretical framework that integrates farmland preservation and risk preferences. This study attempts to construct a theoretical approach by extending the framework developed by Tavernier and Li (1995). We borrow the search-theoretic approach from labor economics to examine the capitalization and preservation effects of farmland preservation policies when risk prefer-

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ences are considered. The approach is more than a novel method for examining farmland preservation when risk preference is present. The results show that risk preference affects current farmland pricing decisions and holds important implications for future farmland preservation policy. For example, in the case of farmers who are more risk-averse than are other agents, the results of our search model suggest that comparatively more land will end up in the hands of other agents. Under the same ordering of preferences, the results, which are consistent with empirical observations in land market studies, also show that farmers appear to benefit less than other agents from government policies that increase current farm income, making the land they hold more vulnerable to conversion to other uses.

## Basic Model

The basic model has already been developed by Tavernier and Li (1995). It is useful to present the framework again, however, to focus on the underlying relationships that are relevant to this study. The approach uses search theory, which has been shown to be useful in analyzing the market for heterogeneous goods (see Lippman and McCall; Kiyotaki and Wright).

According to "job search theory," an unemployed individual looks for a job offer each period, where the job offer consists of a stated wage rate. The individual knows the distribution of wage rates, and each offer is an independent draw from that distribution. The idea here is that the individual may know the general features of the wage distribution in a location but does not know which firm or unit of the firm offers which wage (Devine and Kiefer). For landowners, the assumption is that an offer to purchase land is made by buyers in the land market. The number or type of buyers in the land market or how much buyers would be willing to pay for the land is not known. Hence the distribution of the offer price for the land market in general is not known, although specific features of the offer distribution, such as soil type, infrastructure, range of previous offers, and so on may be known for a particular location. Common to both the land seller and the job seeker are a degree of uncertainty characterized by imperfect information in both markets and a commitment of time and resources devoted to the search process.

The application of search theory to analyze an unemployed worker's optimal search strategy in a nonsequential framework has already been examined (Stigler; McCall). To the best of our knowledge, however, search theory has not been applied to the farmland market where sellers engage in a sequential search process. Following Sargent, we develop a simple supply-side model to illustrate the formation of the seller's reservation price (or reservation wage in the case of job search theory), which we later use to analyze the impact of risk preference on farmland preservation.

Suppose a farmer owns a parcel of land $L$, where $L = 1$, the normalized unit of land. The farmer obtains income, $I_t$, from the land at time $t$. Hence a risk neutral farmer will maximize the present discounted expected income,

$$v(q) = E\left[\sum_{t=0}^{\infty} \beta^t I_t\right] \tag{1}$$

where $v(q)$ is the expected value of $[\sum_{t=0}^{\infty} \beta^t I_t]$ for a farmer who has offer price $q$ in hand. $E$ is the expectation operator, and $\beta = 1/(1 + r)$ is the discount factor with discount rate $r$. Suppose further that the farmer has the potential to sell the land and gets an offer price, $q$, from the buyer. This means that she can obtain income $I_t$ from one of two sources, farming or the sale of land. If she sells the land at time $t$, she gets price, $q$, a one-time income, and stops the search process (e.g., $I_t = q$ at time $t$ and 0 thereafter). If she keeps farming, she receives farm income, $z$, for this period (i.e., $I_t$ at time $t$) and searches for another offer in the next period $t + 1$. The variable $z$ is assumed to be exogenous even though in reality it might be affected by government agricultural policies and local property tax policies, among others. The decision problem to sell or not to sell can be thought of as weighing the opportunity costs associated with keeping the land in its current farming use as opposed to the expected gain from selling for development. If the farmer decides to search for a new offer price $p$, then she implicitly believes that the present value of the land sold at a future date is more than the present value of the land sold today.

Define the future offer price of land as a nonnegative random variable, $p$, with a cumulative probability price distribution $F(P)$, by $F(P) = \text{Prob}\{p \leq P\}$. We assume $F(0) = 0$ and $F(\infty) = 1$, where $F$ is a nondecreasing function and continuous function from the right. We assume further that $F$ is bounded from above (i.e., there is an upper bound $B < \infty$, such that $F(B) = 1$). The farmer does not observe all $p$, but the distribution $F(P)$ from which the future offer price $p$ at time $t$ is randomly drawn. The farmer knows the distribution of the offer price for land in an area or region but does not know the specific price for any tract of land. So the relevant distribution may be specific to tract characteristics, such as amenity benefits and developmental potential, which is captured in $F$ and might itself be the result of a search effort. For now, we assume that the distribution, $F(P)$, for a particular parcel of land is given.[1]

The sequential nature of the search process makes dynamic programming a convenient method to model the decision-making process. Without recall, Bellman's functional equation can be expressed as

$$(2) \qquad v(q) = \max\left\{q, z + \beta \int_0^\infty v(p)dF(p)\right\}$$

where the maximization is over the two actions, (1) accept the offer $q$ this period, or (2) reject the offer $q$ and receive $z$ this period and draw a new offer price $p$ from distribution of $F(P)$ next period. The value function $v(q)$ is of the following form,

$$(3) \qquad v(q) = \begin{cases} q & \text{if } q \geq r \\ z + \beta \int_0^\infty v(p)dF(p) & \text{if } q \leq r \end{cases}$$

where $r$ is the reservation price or the minimum offer that the farmer would accept for the land. Equation (3) says that if the offer price $q$ is greater than or equal to the reservation price $r$, the farmer will accept the offer $q$; otherwise she receives $z$ and continues to search another offer. Here it is assumed that the probability of getting an offer next period is one (see Sargent for the search model in which this probability is not one). This equation can be converted into an ordinary equation that enables us to solve for the optimal reservation price. At this price there is no difference between accepting the offer, $q$, and searching for a $p$ in the next period.

More formally, evaluating $v(r)$ and using equation (3), we have

$$(4) \qquad r = z + \beta \int_0^\infty v(p)dF(p) = z + \beta \int_0^r r dF(p) + \beta \int_r^\infty p dF(p)$$

which is equivalent to

$$(5) \qquad r - z = \beta Ep + \beta \int_0^r F(p)dp.$$

The solution to equation (5) is unique.[2] The left-hand side of the equation can be considered as the marginal cost of searching one more period when an offer $q$ is made. The right-hand side represents the expected benefit from searching, in terms of the expected present value associated with drawing $p > r$. Equation (5) enables the farmer to set the reservation price such that the cost of searching in one more period equals the marginal benefit from waiting and could be considered the optimal decision rule of farmers in the farmland market. Equation (5) is also an implicit function of the reservation price.

To facilitate the analysis, let

$$(6) \qquad h(r) = \int_0^r F(p)dp.$$

Then equation (5) becomes

$$(7) \qquad r - z = \beta Ep + \beta h(r).$$

Note that $h(0) = 0$, $h'(r) = F(r) > 0$, and $h''(r) = F'(r) > 0$.

## Farmland Market and Preservation Policy

In this section the search model is used to provide insights into the underlying relationships between the farmland market and preservation policy.

Recall that the mix of policies generally used to preserve farmland includes property tax relief, right-to-farm laws, acquisition of development rights, and agricultural zoning. Of these policies, property tax relief is perhaps the most controversial, for some argue that it encourages speculation over preservation (Nelson 1990). The policy reduces the taxes farmers pay because their land is assessed at its agricultural use instead of its market value or development potential. This practice indirectly increases farm income and has implications for the farmland market and farmland preservation.

To see this we apply the implicit function theorem to equation (7) and get

$$(8) \qquad \frac{dr}{dz} = \frac{1}{1 - \beta F(r)} > 0.$$

According to equation (8), increases in farm income lead to increases in the reservation price. This increase in the reservation price is in part related to the effect of the property tax relief policy, which increases farm income, leading to a capitalization of the policy in land values. This finding is supported by Anderson and Bunch.

[1] In another paper, Tavernier and Li (1994) examine the formation of $F(P)$ in a game theoretic framework.

[2] For proof that the above problem satisfies Blackwell's sufficient condition for a contract mapping, see Sargent.

The variable $z$ may also be seen as an opportunity cost of farming (not selling) if it is negative. Increases in the opportunity cost or decreases in farm income decrease the reservation price. This decrease may not necessarily result in the immediate conversion of farmland, because the reservation price is also a function of the subjective belief about the distribution of the future offer price; but, according to our model, a reservation price lower than the offer price increases the chances that farmland will be sold at the current offer price, and conversely a reservation price higher than the offer price decreases the chances that farmland will be sold. In our model, it is assumed that farmers and other agents have the same wealth and the same subjective distribution of offer prices. Further note that the reservation price itself is a function of the subjective belief about the distribution of the offer and should be considered in farmland conversion issues. The case in which farmers and other agents have different subjective distributions of the offer price can be analyzed by the inclusion of the theory of asymmetric information in our framework (Akerlof). However, we are solely interested in the difference between the risk preferences of farmers and other agents for a given level of risk.

The decision to accept or not to accept the current offer price is based on the farmer's reservation price and influences the length of time land remains in farming. Following our definition of $F(\cdot)$, let $F(r)$ be the probability of offer prices lower than reservation prices, i.e., $F(r) = \text{Prob}\{q \leq r\}$. The search model suggests that the farmer rejects such offer prices with probability $F(r)$ and searches for another offer price in the next period.[3] Thus, the probability that the farmer accepts an offer in period $n$ is $(1-F(r))(F(r))^{n-1}$, which follows a geometric distribution from which the preservation effect

$$(9) \qquad T = \frac{1}{1 - F(r)}$$

can be calculated. The variable $T$ equals the amount of time that land remains in farming before it is sold and is the reciprocal of the probability of accepting the offer on a single trial. Equation (9) suggests that any increase in $r$ increases $T$ and delays the sale of farmland and that for a given $F$, the mean waiting period before land is sold, is a monotonically increasing function of the reservation price, $r$. This value can be used as a measure of the impact of public policies on farmland preservation. Notice, however, that increases in $z$ also increase $T$.

Using equations (8) and (9), we have

$$(10) \qquad \frac{dT}{dz} = \frac{dT}{dr} \cdot \frac{dr}{dz} = \frac{f(r)}{(1 - F(r))^2} \frac{dr}{dz} > 0,$$

where $f(r)$ is the probability density function of $F(r)$. It is clear from equation (10) that any policy that increases $z$ directly (e.g., direct production subsidies) or indirectly (property tax-relief) also increases $T$ and has a preservation effect.

The above results are consistent with cases where farmers operate their farms at a loss ($z < 0$) within the relevant range instead of selling below their reservation price.[4] The preservation effect from farming still remains positive, $T > 0$. However, the magnitude of the final preservation effect is not quite clear because of the influence of $F(r)$ in equation (10). This theoretical finding may help explain why empirical analyses of the effectiveness of property tax relief policies in preserving farmland appear insignificant (see Ferguson) and could be due to the omission of a variable or variables measuring the impact of government intervention on the demand side of the farmland market.

The results derived above are based on the assumption that the distribution of offer prices does not change in response to government intervention in the farmland market. This assumption is questionable, for if farmers are rational agents, we would expect them to incorporate all relevant information affecting land transactions into their decision making processes. Hence, considering that property tax relief policies increase reservation prices, farmers may be inclined to set higher reservation prices, which would increase the capitalization effect of property tax relief policies.

## Uncertainty and Risk Aversion

In the previous section we showed that farmland preservation policy and, in particular, property tax relief policies had two possible effects on agricultural land. First, we showed that the policy in-

[3] Note that the probability that a seller will find a buyer for his land in a given period is the probability of receiving an acceptable offer. This probability equals the product of (a) the offer probability, and (b) the probability that a random offer drawn from the distribution of the offer price will be above the seller's reservation price. In the simple framework used here, these factors are constant, so that the probability of selling land is itself constant. Hence the probability that land will remain in farming for one period, two periods, etc., can be calculated from the geometric distribution. See Devine and Kiefer for the argument from the point of view of an unemployed worker.

[4] Such behavior can be considered rational if farmers anticipate higher future offers.

duced an increase in the reservation price, which we called a capitalization effect. Second, we demonstrated that increases in the reservation price delay the sale of land and lead to a preservation effect. We now examine the effect of uncertainty and risk on the capitalization and preservation of farmland.

It is a commonly held position that individuals are not indifferent to uncertainty and will not, in general, value assets with uncertain returns at their expected values (see Arrow and Lind for a greater exposition of this argument). In what follows, uncertainty is modeled as the distribution of the offer price, because farmers do not observe the true offer price. For simplicity we continue with the risk neutrality assumption before demonstrating the impact of different risk attitudes on farmland preservation.

Recent theoretical studies show that land-use control programs may cause an increase in the demand for land because they reduce uncertainty (Titman; Shilling, Sirmans and Guidry). Beaton and Henneberry and Barrows have also established that government land preservation policies affect the degree of uncertainty in the farmland market. Hence, past studies suggest that uncertainty plays a role in land price formation, and risk preference affects land allocation decisions. Therefore, the capitalization and preservation effects of farmland preservation implied by the search model suggest that land price formation under different risk preferences would affect land conversion and subsequent preservation efforts differently.

We have already established that if farmers do not sell their land in the current period, then they wait to draw another $p$ from the distribution of $F(P)$ in the next period, having observed only the distribution of the offer price and not the true offer price. Rothschild and Stiglitz show that an increase in $h(r)$ (in equation [7]) without a corresponding increase in $Ep$ results in a mean-preserving increase in spread. To understand the implication for the reservation price, we formulate the following proposition.

PROPOSITION 1: *An increase in the mean of the offer price and mean-preserving spread results in an increase in the reservation price.*

PROOF: Recall that $h(0) = 0$, $h'(r) = F(r) > 0$, and $h''(r) = F'(r) > 0$, which implies that $h(r)$ is a convex function. Thus, holding all other parameters in equation (7) constant and increasing the mean of the offer price, $Ep$, will shift the curve $(Ep + h(r))$ upward for all $r$. The intersection of the curves, $(r - z)/\beta$ and $(Ep + h(r))$, will result in higher $r$. This graphical sketch of equation (7) proves Proposition 1. This proposition suggests that increases in the reservation price could be the result of increased volatility in the buyer's market or an increase in the mean of the offer price, an observation consistent with the findings of Titman and of Ellson and Roberts. The implication for farmland preservation and the capitalization of farmland has already been noted.

We have up to this point shown how uncertainty affects the reservation price of land owners. Earlier we illustrated the capitalization effects and the delay in the sale of land when farm income was increased. These insights were based on the assumption that farmers were risk-neutral. Though this assumption simplifies the model, it does not explain the risk-averse behavior of many agents in the economic world, a serious omission of farmland preservation studies (Brown and Brown). We now examine the implication for farmland preservation policy when risk aversion is incorporated into the analysis.

Assume that farmers behave as expected utility maximizers following the axioms of rationality established by von Neumann and Morgenstern. Further, assume that their expected utility function, $u$, is $C^2$. Then equation (5) becomes

$$u(r) - u(z) = \beta E[u(p)] + \beta \int_0^r F(p)d[u(p)]. \tag{11}$$

To examine how the farmer's attitude toward risk affects the reservation price and the subsequent implication of risk preferences for farmland preservation, we develop the following proposition.[5]

PROPOSITION 2: *A risk-averse (loving) farmer has a lower (higher) reservation price than a risk-neutral farmer.*

PROOF: Suppose the farmer is risk-averse; then $u$ is a concave function. Because $u$ is $C^2$, $u^{-1}(\ )$ will be a convex function. Using the definition of convexity and concavity and the Jensen inequality, we have

$$r^a = u^{-1}\left[u(z) + \beta E[u(p)] + \beta \int_0^r F(p)d[u(p)]\right]$$

$$\leq u^{-1}(u(z)) + u^{-1}(\beta E[u(p)])$$

[5] Because farm income plays an important role in reservation price increase, we assume that the farm income of farmers and speculators is the same in order to simplify the analysis. This assumption does not dramatically change the result because some farmers may themselves be speculators. Moreover, in the case of property tax relief policies, certain minimum income standards have to be met to qualify for the program, which could be used as the benchmark for farm income.

$$+ u^{-1}(\beta \int_0^r F(p)d[u(p)])$$

$$\leq z + u^{-1}(u(\beta Ep))$$

$$+ u^{-1} (u(\beta \int_0^r F(p)dp))$$

$$\leq z + \beta Ep + \beta \int_0^r F(p)dp = r^n$$

where $r^a$ and $r^n$ are reservation prices under risk-averse and risk-neutral assumptions, respectively. The risk-loving case can be proven in a similar manner.

Even without imposing additional structure, the model provides important insights about the ability of risk preferences to influence land-use decisions. Recall that the reservation price is a major factor in determining whether land is converted to other uses. Increases in the reservation price help to delay the sale of farmland.[6] Hence in the absence of farmland preservation policy, a crucial implication of Proposition 2 is that at the same level of risk, land held by a risk-averse farmer exits farming faster than land held by a risk-neutral farmer because of the lower reservation price. Put another way, the degree of risk aversion is important in determining the extent to which land is preserved and capitalized, because of the impact of risk preferences on the reservation price. Therefore if we assume that real estate speculators are less risk-averse than farmers, then Proposition 2 suggests that because the reservation price of farmers is lower than that of speculators, more land will increasingly be held by speculators, a condition observed by Brown and Brown.

Earlier we showed that increases in farm income increase the reservation price, a capitalization effect, and that increases in the reservation price delay the sale of land, a preservation effect. Suppose that the increase in farm income is the result of government farmland preservation policy. Proposition 3 posits the impact of such a policy on reservation prices when risk preferences are considered.

PROPOSITION 3: *When faced with the same government policy, which increases current farm income, the reservation price increases less (more) if the farmer is risk-averse (loving) than if he is risk-neutral.*

PROOF: Using the implicit relationship derived from equation (8) (i.e., $dr/dz > 0$) and equation (11), we have[7]

$$\frac{\partial r}{\partial z} = \frac{u'(z)}{u'(r)} \cdot \frac{1}{1 - \beta F(r)}. \quad (12)$$

Since $r > z$, we have, $u(z) > u'(r)$, $u'(z) = u'(r)$, and $u'(z) < u'(r)$ for risk-averse, risk-neutral, and risk-loving owners, respectively.

We have already shown that policies that increase farm income also increase the reservation price. Proposition 3 suggests that the increase in the reservation price is greater if land owners are risk-loving. If we assume that other agents are risk-loving or less risk-averse than farmers, then Proposition 3 suggests that at the urban fringes, when Propositions 2 and 3 are considered, farmland preservation policies designed to help farmers keep land in agriculture may be disproportionately helping speculators. Further, under the risk-neutrality assumption from which equation (9) was developed, although it is true that as the reservation price increases, land remains in agriculture longer, under the assumption that farmers are more risk-averse than other agents, and by implication have lower reservation prices, land in agricultural production exits farming at a faster rate with preservation policies and without reservation policies.[8] Hence, it appears that when risk preferences are considered, farmland preservation policy, such as use-value assessment that increases current farm income, while effectively protecting the interest of other agents, is less effective in serving the needs of farming and farm-held open space.

## Summary and Conclusion

We used a search-theoretic approach to extend the literature on farmland preservation by incorporating risk preference into the analysis through its impact on the reservation price of land owners. We developed a framework to show how risk preference influences land-use decisions in the absence and presence of government farmland preservation policy. We further analyzed the impact of risk neutrality, risk aversion, and risk-loving preferences on the preservation price of farmers. Implications for farmland preservation policy were explored.

The analysis suggests that when risk preferences are considered, a government policy that increases

[6] This statement implies that $dT/dr > 0$. From equation (10), $dT/dz > 0$. We know that $dr/dz > 0$ (equation [8]), therefore $dT/dr > 0$.

[7] Notice that $\beta F(r) \neq 1$. Therefore $\frac{1}{[1 - \beta F(r)]}$ is also greater than 1.

[8] We recognize that in the case of a farmer speculator the land would simply be under different ownership. However, our operating hypothesis is that acceptance of an offer means that the land leaves farming.

farm income favors landowners who are less risk-averse. If we grant that farmers are more risk-averse than are other agents, an implication of the relationship between risk preference and government farmland preservation policy is that agricultural land held by farmers in a preservation program exits farming at a faster rate than that held by other agents. Or put another way, when risk preferences are considered, farmland preservation policy appears to protect the interest of other agents more effectively than that of farmers.

The model could be extended so that we have different reservation prices in each period. An implication of this approach is that, following Proposition 2, the optimal search policy would be characterized by one sequence of reservation prices (not just one price) for farmers and one for other agents. Further, we have concentrated on the fixed offer probability and the acceptance decision. The focus could also shift to the determinants of the offer price and, for example, investigate how the number and types of buyers in the farmland market affect the distribution of the offer price or concentrate on search intensity, which would endogenize the offer distribution. The whole analysis in this paper is based on the assumption that farmers and other agents have the same income and subjective distribution of offer prices. This assumption can be relaxed to examine the role of asymmetric information in the determination of reservation price. These extensions are areas for further research.

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