AN ABSTRACT OF THE DISSERTATION OF

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JunJie Wu and Richard M. Adams

To protect and restore environmental quality, efficient and effective conservation policies are needed. Designing policies require a sound understanding of the contributions of natural endowments to economic vitality, and the performance and impacts of conservation programs. This dissertation consists of three essays, and addresses several issues relevant to these two issues.

The first paper analyzes the effects of the Conservation Reserve Program (CRP) on prices of farmland and developed land. A theoretical model that integrates the optimal investment model with the optimal bidding behavior model is developed. Based on the theoretical model, an empirical study is conducted to quantify the effects. Results show that the CRP increases farmland prices by $18 to $25 per acre, on national average. The effects are relatively large in the Mountain, Southern Plains, and Northern Plains areas. The CRP also affects developed land prices, but the effects are small. Agricultural returns account for about 40% of farmland prices, and growth premium and option value together account for the remaining 60%. This result has an important policy implication in the design and implementation of long term conservation program.

The second paper evaluates the tradeoffs between efficiency and equity in the case of the CRP. A reallocation mechanism of conservation funds is developed and applied in simulations to estimate the tradeoffs. Results show that a 13% sacrifice in efficiency can improve the equity by 14%. In addition, findings suggest that under the benefit-cost ratio rule, conservation funds should be targeted to purchase resources in the Mountain, Northern and Southern Plains. However, under the equity rule, conservation funds should be shifted from the Mountain and Great Plains to other regions, especially the Corn Belt. Also, Environmental Benefits Index (EBI) rule is found to be not optimal in terms of efficiency. To improve its performance, more weights should be placed on the environmental factors in the calculation of EBI score.

The third paper explores the interaction between households' location decisions and community characteristics such as natural amenities and public services. To achieve the objective, a theoretical model is developed to analyze the location decisions of households who are affected by natural amenities, public services and other community characteristics. Results show that communities with better natural amenities and public services tend to attract more high income households. In turn, the shares of the low and high income households are negatively and positively associated with the level of public services, respectively. Results provide policy implications in poverty reduction.

Essays on Natural Endowments, Conservation Policy, and Community Characteristics

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APPROVED:

____

Co-Major Professor, representing Agricultural and Resource Economics

____

Co-Major Professor, representing Agricultural and Resource Economics

____

Head of the Department of Agricultural and Resource Economics

____

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Haixia Lin, Author

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CONTRIBUTION OF AUTHORS

Dr. JunJie Wu was involved in the design, analysis, and writing of each manuscript.

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CHAPTER 1

INTRODUCTION

HAIXIA LIN

An area's natural endowments-its climate, natural resources, and isolation-directly determine the area's economic vitality in terms of attracting workers, families, firms and investments. However, environmental degradation caused by governmental policies and economic-development activities undermines the contribution of natural endowments to the economy. To protect and restore environmental quality, efficient and effective conservation policies are needed. Designing policies requires a sound understanding of the contribution of natural endowments to economic vitality, and the performance and impacts of conservation policies. This dissertation, titled "Natural Endowments, Conservation Policy, and Community Characteristics", addresses several issues relevant to these two issues.

The Conservation Reserve Program (CRP) is the most ambitious conservation effort in U.S. history. Since its inception, the CRP has attracted substantial research interest. However, with about 8 percent of the nation's cropland enrolled into the CRP, the effect of the CRP on farmland prices has received relatively little attention. This is surprising, given that about $2 billion all invested in the annual rental payment (U.S. Department of Agriculture, 2004).

The first paper (chapter 2), *Conservation Policy and Land Values: the Conservation Reserve Program*, analyzes the effects of the Conservation Reserve Program (CRP) and natural amenities on prices of farmland and developed land in 10 production regions in the lower 48 states of the United States, and estimates the magnitude of the major components of farmland prices. These objectives are achieved by integrating the optimal investment model and optimal bidding behavior model. To test if results are robust and sensitive to alternative functional specifications and measurements of key variable, we estimate five models in our empirical study. Results show that amenities and the CRP have positive effects on prices of farmland and developed land, although the effect on developed land prices is relatively small.

The CRP increases national farmland prices by $18 to 25 per acre, on average. The effects are largest in the Mountain, Southern Plains, and Northern Plains areas. The agricultural returns component accounts for about 40 percent of farmland prices, while the growth premium and option values account for the remaining 60 percent. This study has important policy implications regarding the design and implementation of conservation programs, particularly the permanent conservation easement program.

Efficiency and equity are two commonly used criteria for policy selection. However, they are often incompatible. In the case of environmental protection and resource conservation, conservation programs supported by public funds have been generally targeted to improve efficiency. While targeting improves efficiency, political considerations often focus on equity issues.

The second paper (chapter 3), *The Tradeoffs between Efficiency and Equity: the Case of the Conservation Reserve Program*, explores tradeoffs between efficiency and equity in the case of the Conservation Reserve Program. More specifically, we investigate the tradeoff in efficiency that has to be made in order to obtain improvements in equity. The tradeoff relationship between efficiency and equity in the case of the CRP is estimated by tracing out an Efficiency-Equity Frontier (EEF) by reallocating conservation funds spatially. We develop a simple budget reallocation mechanism to estimate the EEF using simulations. The estimation of EEF not only enables us to calculate the tradeoffs between efficiency and equity, but also allows us to discover the impacts of different targeting criteria on the distribution of conservation funds. The targeting criteria considered in this study are the benefit-cost ratio rule, the environmental benefit index score (EBI) rule, and the equity rule. We find that a 1 percent loss in efficiency can improve the equity by 1 percent approximately, and also that the targeting criteria heavily influences on the distribution of conservation funds. Under the benefit-cost ratio rule, conservation funds should be invested to target the Mountain and Plains regions. However, under the equity rule, conservation funds should be shifted from these areas to the Corn Belt. Results also suggest that generally the EBI rule is not optimal in terms of efficiency and equity. We propose a remedy to improve the performance of the EBI rule. The above findings provide policy makers with guidance in the design, selection and implementations of alternative targeting criteria under CRP.

The third paper (chapter 4), *Natural Amenities, Income Mixes, and Endogenous Community Characteristics*, explores interactions between community characteristics and households' location decisions. In particular, we investigate how households distribute themselves across communities, and more generally how community characteristics serve to attract alternative income groups, and how these alternative income groups in turn have impacts on community characteristics, especially the demand for public services. To achieve the objective, we develop a theoretical model to analyze the location decisions of households who are affected by natural amenities, public services and other community characteristics such as geographic location, demographic composition and economic situations. Based on the theoretical model, a simultaneous equation system of three equations is estimated. Results show that income mix indeed interacts with the local public services in the communities. Findings suggest that the share of low and high income households in a community is negatively and positively associated with the level of public services, respectively. On the other hand, a 1 percent increase in the level of public services (measured by both general public services spending per capita and public education spending per capita) is negatively associated with the share of low income households in a community, but positively associated with the share of high income households. Other findings include the result that communities with better natural amenities, higher education attainment, and higher share of owner occupied housing, and higher employment rates tend to have more high-income households, and communities more distant from metropolitan areas and with more female-headed households tend to have more low income households. Results also suggest that increasing public education and creating job opportunities for females are effective in poverty reduction.

REFERENCES

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CHAPTER 2

CONSERVATION POLICY AND LAND VALUES: THE CONSERVATION RESERVE PROGRAM

HAIXIA LIN
& JUNJIE WU, PROFESSOR

ABSTRACT

This paper develops theoretical and empirical models to analyze the effects of the Conservation Reserve Program (CRP) on prices of farmland and developed land. The theoretical model integrates the optimal investment model developed by Capozza and Li (1994) with the optimal bidding behavior model developed by Lohmann and Hamsvoort (1997). Based on the theoretical model, empirical models are estimated to quantify the effect of the CRP. Results show that the CRP increases farmland prices by $18 to$25 per acre, on national average. The effects are relatively large in the Mountain, Southern Plains, and Northern Plains areas. The CRP also affects developed land prices, but the effects are small. Agricultural returns account for about 40% of farmland prices, and growth premium and option value together account for the remaining 60%. This result has important policy implications in the design and implementation of long term conservation program.

INTRODUCTION

The Conservation Reserve Program (CRP), the most ambitious conservation effort in U.S. history, was established by the Food Security Act of 1985 and was reauthorized by all subsequent Farm Bills. Under this voluntary program, participants retire highly erodible and environmentally sensitive lands from crop production for a period of 10-15 years. In exchange, the CRP provides participants with annual rental payment, incentive payment, and cost-share assistance. By 2004, over 34 million acres of cropland had been enrolled in the CRP with an annual rental payment of approximately $2 billion (U.S. Department of Agriculture, 2004).

The CRP has generated large environmental and economic benefits (Young and Osborn, 1990; Osborn and Konyar, 1990; Ribaudo et. al., 1990; Sullivan et al., 2004). For example, based on the 33.9 million acres enrolled in signups 1-9, Osborn and Konyar (1990) estimated that the CRP had net economic benefits of $4.2-$9 billion in present value over the life of the program. This included benefits from farm income, timber production, soil productivity, water quality, wild life habitat, and air quality. However, with about 8% of the nation's cropland enrolled into the CRP, the effects of the CRP on farmland prices have received much less attention. Understanding the effect of the CRP on farmland prices is important because farmland is the main asset of the U.S. agricultural sector's balance sheet. The opportunity cost of farmland represents a major production expense from farmers' perspectives (Lence and Mishra, 2003). How farm policy affects agricultural land values is a critical issue in any farm policy debate (Goodwin, Mishra, and Magné, 2003).

The primary objective of this study is to evaluate the effects of the CRP and environmental amenities on the prices of farmland and developed land. To achieve the objective, we first develop a theoretical model to analyze the effect. The theoretical model integrates the optimal investment model developed by Capozza and Li (1994) with the optimal bidding behavior model developed by Lohmann and Hamsvoort (1997). The integration is important in the following ways.

First, the integrated model endogenizes CRP participation and rental payments, both of which are treated as exogenous variables in previous studies. Ignorance of endogeneity will lead to inconsistent estimates of the CRP impacts.

Second, the integrated model takes into account the growth premium and option value when evaluating land prices. Growth premium is the present value of expected increases in land rents after development. Option value is the value that farmland derives from the option of delaying or not carrying out a development project in case of low returns to developed land in the future. Both growth premium and option value are identified as important components of the price of farmland by Capozza and Helsley (1990) and Capozza and Li (1994), but have been ignored in previous studies of the effect of government payments on land values.

Third, the integrated model relaxes the "featureless assumption" made by previous studies, which assume land is homogeneous. The relaxation of this assumption allows us to examine the effect of amenities on the prices of farmland and developed land.

Finally, the integrated model provides a solid foundation for our empirical work. As Lence and Mishra (2003) point out, most previous studies include farm payments as explanatory variables of land price without providing a theoretical foundation. Based on the theoretical analysis, we then conduct an empirical analysis to quantify the effect of the CRP on prices for both farmland and developed land.

Several studies have examined the effects of farm programs on farmland prices and found that the government payments are capitalized into farmland values (Just and

Miranowski, 1993; Barnard et al., 1997). For example, Just and Miranowski (1993) find that government payments account for roughly 15 to 25% of the capitalized value of land. Barnard et al.(1997) examine the effect of eliminating the Agricultural Improvement and Reform Act of 1996 (FAIR) on cropland value, and find that cropland value would be reduced by 12% to 69% in the eight examined regions as a result of eliminating government programs. Limited research examines the effects of the CRP on farmland prices, but produces contradictory results. Lence and Mishra (2003) utilize county-level data from 1996-2000 to examine effects of the CRP and other farm payment programs on cash rental rates in Iowa and find that the CRP has a positive impact on cash rents.[1] Shoemaker (1989) uses the first five CRP sign-up data from 1986 to 1987 to examine the effect of the CRP on farmland prices in the U.S., and finds that the CRP has a minor offsetting (0.5%) effect on the overall decline in land values. Goodwin, Mishra and Magné (2003) apply the traditional present value approach to evaluate the effect of the CRP and other farm programs on farmland price, but find that the CRP has a negative impact on farmland values. No study, to our knowledge, has examined the effect of the CRP on developed land prices.

Numerous hedonic studies have estimated the effect of amenities (or disamenities) on nearby property values. For example, hedonic price models have been applied to estimate the value of proximity to oceans, rivers (Leggett and Bockstael, 2000), forests (Tyrväinen and Miettinen, 2000), and general indicators of open space (Wu, Adams and Plantinga, 2004; Irwin and Bockstael, 2001; Geoghegan, 2002). However, few studies have analyzed the effect of amenities on farmland value. This neglect is surprising given that growth premium and option value are important components of farmland prices (Capozza and Helsley, 1990), both of which are affected by amenities.

THEORETICAL MODEL

Consider a piece of farmland randomly selected from a county. If the land is ineligible to enroll into the CRP, then the owner will receive an annual net return of A from farming. If the land is eligible to enroll into the CRP, the farmer has to decide if he is going to submit a bid to enroll the land into the CRP. If he decides not to submit a bid, his expected return from farming is A; but if he does submit, he will choose the level of bid to maximize the expected return from the CRP, which is affected by both the submitted bid and the probability of the bid being accepted into the program.

Under the current CRP rules, whether a bid is accepted into the CRP or not depends on its cost-adjusted environmental score, which is calculated based on the six environmental scores (N1-N6) and a cost factor (N7). The environmental scores measure the potential environmental benefits of an offered parcel in wildlife habitat (N1), water quality (N2), soil erosion (N3), enduring benefit (N4), air quality (N5), and conservation priority area (N6) (U.S. Department of Agriculture, 1997). The cost factor (N7) is calculated based on the bid submitted by the farmer. Specifically, the cost-adjusted environmental score has two parts: the environmental score $S = \sum_{i=1}^{6} N_i$, and the cost factor ωb, where $\omega > 0$ is the weight placed on the cost. The cost-adjusted environmental score equals $S - \omega b$.

Let $\underline{EBI}$ denote the threshold of the cost-adjusted environmental score, above which a bid will be accepted. Farmers do not know $\underline{EBI}$, but can form their expectation of $\underline{EBI}$ based on the observed program behavior. The probability of a bid being accepted into the CRP equals the probability that the individual cost-adjusted environmental score is greater than the threshold score:

$$p = pr(S - \omega b \geq \underline{EBI}) = F(S - \omega b), \qquad [2.1]$$

where F is the farmer's expected cumulative distribution function of $\underline{EBI}$. If the bid is accepted into the CRP, then the landowners' net return will be b; if the bid is rejected, then the bidder's net return will be A. The farmer will choose b to maximize the expected net payoff $bF(S - \omega b) + A[1 - F(S - \omega b)]$. This maximization problem implicitly defines the optimal bid b^*:

$$b^* = A + [F(S - \omega b^*) / \omega f(S - \omega b^*)] \qquad [2.2]$$

where f is the density function of $\underline{EBI}$. The optimal bid consists of two components: foregone profit from farming and the information premium, which depends on the bidders' private information on the threshold $\underline{EBI}$. For example, farmers may form their expectation on $\underline{EBI}$ based on information such as past rental rates. Given p and b^*, the expected return from the CRP is $pb^* + (1 - p)A$, and the expected return to a randomly selected parcel of farmland under the CRP can be expressed as

$$\begin{aligned} R^{CRP} &= A(1 - m) + mMax(A, pb^* + (1 - p)A) \\ &= Max(A, A(1 - m) + m(pb^* + (1 - p)A) \end{aligned} \qquad [2.3]$$

where m is the probability that the parcel is eligible for the CRP.

In addition to farming and conservational use, landowners can also convert their land to development. Under the current CRP rules, participants can request an "early-out release" from the program any time without much penalty.[2] When the farmland is developed, the land earns the developed land rent. The price of farmland at time t at location z under the CRP can be written as

$$p^a(t, z) = E\{\int_t^{t+s} R^{CRP} e^{-r(\tau - t)} d\tau + \int_{t+s}^{\infty} R(\tau, z) e^{-r(\tau - t)} d\tau - Ce^{-rs} \mid R(t, z)\} \qquad [2.4]$$

where $R(\tau, z)$ is the developed land rent at time τ at location *z*, *C* is the cost of converting one acre of farmland to development, *r* is the interest rate, E{} is the expectation operator, and $t+s$ is the time when the land is developed. Equation [2.4] states that price of farmland equals the present value of the expected returns to farmland (including farming return and government payment) up to the date of conversion plus the present value of the expected returns to developed land, minus the conversion cost. The price of one unit of developed land at location z at time t is

$$p^d(t,z) = E\{\int_t^\infty R(\tau,z)e^{-r(\tau-t)}d\tau \mid R(t,z)\} \qquad [2.5]$$

Extending Capozza and Li (1994), the rent of developed land is specified as $R(t,z) = R(t) + R(z, a(z))$, where the temporal component of the rents, $R(t)$, is specified as following the Brownian motion process with upward drift g and variances σ^2 : $R(t) = gt + \sigma B(t)$, $t \geq 0$; [3] and the spatial component of the development land rents $R(z, a(z))$ is determined by the level of amenities $a(z)$ and the transportation cost at location z. Assuming that the landowner chooses the conversion time to maximize the expected value of land, following Capozza and Helsley (1994), we can show that the land is converted to development when the developed land rent is greater than or equal to a reservation rent:

$$R(t,z) \geq R^* \equiv R^{CRP} + rC + (r - \alpha g)/\alpha r \qquad [2.6]$$

where $\alpha = [(g^2 + 2\sigma^2 r)^{1/2} - g]/\sigma^2$. Without the CRP, the reservation land rent is $A + rC + (r - \alpha g)/\alpha r$, which is lower since A $< R^{CRP}$. Because the CRP increases the hurdle of conversion, it may cause delay in development and reduce the total developed area. Following Capozza and Helsley (1990), the prices of farmland and developed land can be derived as follows:

$$p^a(t,z) = \frac{1}{r}R^{CRP} + \frac{g}{r^2}e^{\alpha[R(z,a(z))-R(z^*,a(z^*))]} + \frac{r-\alpha g}{\alpha r^2}e^{\alpha[R(z,a(z))-R(z^*,a(z^*))]}, z > z^* \qquad [2.7]$$

$$p^d(t,z) = \frac{R^{CRP}}{r} + C + \frac{g}{r^2} + \frac{r-\alpha g}{\alpha r^2} + \frac{R(z,a(z)) - R(z^*,a(z^*))}{r}, z \le z^* \qquad [2.8]$$

where z^* is the boundary of the developed area. Equation [2.7] shows that the price of farmland consists of three components: expected net returns from agriculture (including farming return and government payments), growth premium, and option value. Equation [2.8] states that the price of developed land consists of five components: expected net return from agriculture, conversion cost, growth premium, irreversibility premium, and amenities and accessibility premium. Irreversibility premium represents the cost of not being able to convert the land back to agricultural use once developed. Amenities and accessibility premium represents the value of amenities and the value of proximity to the city center.

The CRP can increase or decrease values of farmland and developed land, depending on the relative magnitude of the effects on various components of the land prices. The CRP increases the agricultural return component (because $R^{CRP} > A$), but reduces growth premium, option value for each parcel of farmland because the distance from the parcel to city boundary is increased as a result of reduction in total developed area. In addition, it also reduces the accessibility premium because the relative distance to the Central Business District (CBD) is increased.

Prices for both farmland and developed land are increasing functions of $R(z,a(z))$. This implies that locations with better amenities and lower transportation costs have higher value regardless whether they are farmland or developed land. This result implies that location and amenities affect farmland prices as well as developed land prices.

EMPIRICAL SPECIFICATIONS

Equations [2.1], [2.2], [2.7], and [2.8] provide the theoretical basis for the empirical analysis. A *Logit* specification is used to model the probability of bid acceptance:

$$p = F(S - \omega / b^*) = e^{\delta X} / (1 + e^{\delta X}) \qquad [2.9]$$

where X is a vector of variables affecting bid acceptance, including environmental score (S), bid price (b^*), and all variables affecting the expected distribution function $F(\bullet)$. The variables affecting farmers' expectations about $\underline{EBI}$ may include average rental rates in previous sign-ups (b_{-1}) and the percentage of land already enrolled in the CRP (CRP_{-1}). Thus, equation (9) can be rewritten as

$$\ln\left(p/(1-p)\right) = \delta_0 + \delta_1 S + \delta_2 b^* + \delta_3 b_{-1} + \delta_4 CRP_{-1} + \varepsilon_1 \qquad [2.10]$$

where ε_1 is an error term.

Based on equation[2.2], the optimal bid is a function of net farming return, A, environmental score, *S*, and variables affecting individuals' expectations about $\underline{EBI}$. Thus, the optimal bid is specified as

$$b^* = \xi_0 + \xi_1 A + \xi_2 S + \xi_3 b_{-1} + \xi_4 CRP_{-1} + \varepsilon_2 \qquad [2.11]$$

where ε_2 is an error term.

To derive the farmland and developed land price equations that can be estimated econometrically, we express the sum of growth and irreversibility premium as a function of farmland price and rewrite equation [2.7]and [2.8] as follows:

$$\begin{aligned} p^a &= \psi_0 + \psi_1 R^{CRP} + \varepsilon_3 \\ p^d &= \phi_0 + \phi_1 p^a + \phi_2 R^{CRP} + \varepsilon_4 \end{aligned} \qquad [2.12]$$

where ε_3 and ε_4 are error terms,

$$\psi_0 = (1/\alpha)e^{\alpha[R(z,a(z))-R(z^*,a(z^*))]}/r\ ,$$

$$\psi_1 = 1/r,$$

$$\phi_0 = C + [R(z,a(z)) - R(z^*,a(z^*))]/r\ ,$$

$$\phi_1 = e^{-\alpha[R(z,a(z))-R(z^*,a(z^*))]},$$

$$\phi_2 = (1 - e^{-\alpha[R(z,a(z))-R(z^*,a(z^*))]})/r$$

ψ_0 is the product of $1/\alpha$ and a exponential term. $1/\alpha$ is approximated by the first order linear function of all variables included in α, that is g and σ. The exponential term, ϕ_1, ϕ_2 and ϕ_0 are also approximated by a first order linear function of all variables included. The exponential term, ϕ_1 and ϕ_2 include variables R^{CRP}, a, z, $R(t)$, g and σ. ϕ_0 includes variables C, R^{CRP}, a, z, and $R(t)$. But C is excluded from the approximation of ϕ_0 since it is assumed constant. Substituting these approximations into equations (14) and (15) produces the feasible estimation function:[4]

$$\begin{aligned} p^a = {} & \theta_1 R^{CRP} + \theta_2 g * R^{CRP} + \theta_3 g * a + \theta_4 g * z + \theta_5 g * R(t) + \theta_6 g * g + \theta_7 g * \sigma \\ & + \theta_8 \sigma * R^{CRP} + \theta_9 \sigma * a + \theta_{10} \sigma * z + \theta_{11} \sigma * R(t) + \theta_{12} \sigma * \sigma + \varepsilon_3' \end{aligned} \qquad [2.13]$$

$$\begin{aligned} p^d = {} & \eta_0 + \eta_1 p^a * R^{CRP} + \eta_2 p^a * a + \eta_3 p^a * z + \eta_4 p^a * R(t) + \eta_5 p^a * g + \eta_6 p^a * \sigma \\ & + \eta_7 R^{CRP} * R^{CRP} + \eta_8 R^{CRP} * a + \eta_9 R^{CRP} * z + \eta_{10} R^{CRP} * R(t) + \eta_{11} R^{CRP} * g \\ & + \eta_{12} R^{CRP} * \sigma + \eta_{13} z + \eta_{14} R(t) + \eta_{15} a + \varepsilon_4' \end{aligned} \qquad [2.14]$$

Regional dummies or interactive terms between regional dummy and relevant variables are included in the estimation to explore regional differences in the prices of farmland and developed land. The first term in the equation [2.13] is the agricultural return, and the rest terms are the sum of growth premium and option value. This specification allows us to evaluate the effect of the CRP on individual components of farmland prices. To test whether results are sensitive to the functional form, we also estimate a more general specification by writing equations [2.7]and [2.8] as

$$\begin{aligned} p^a &= \kappa_0 + \kappa_1 R^{CRP} + \varepsilon_3{}' \\ p^d &= \vartheta_0 + \vartheta_1 + \vartheta_2 R^{CRP} + \varepsilon_4{}' \end{aligned} \qquad [2.15]$$

where $\varepsilon_3{}'$ and $\varepsilon_4{}'$ are error terms, κ_0 is the sum of growth premium and option value in the equation [2.7] , ϑ_0 and ϑ_1 are the sum of growth and irreversibility premium, and the sum of accessibility and amenities premium in the equation [2.8], respectively. κ_0 , ϑ_0 and ϑ_1 are approximated by the first- and second-order linear function of variables including all interaction terms. For example, ϑ_0 is approximated by $\omega_0 + \omega_1 g + \omega_2\sigma + \omega_3 g^2 + \omega_4\sigma^2 + \omega_5 g\sigma$ Substituting these approximations into the equation [2.15] yields feasible function form as follows

$$\begin{aligned} P^a = (&\xi_0 + \xi_1 g + \xi_2\sigma + \xi_3 R^{CRP} + \xi_4 a + \xi_5 z \\ &+\xi_6 g^2 + \xi_7\sigma^2 + \xi_8 (R^{CRP})^2 + \xi_9 a^2 + \xi_{10} z^2 \\ &+\xi_{11} g\sigma + \xi_{12} gR^{CRP} + \xi_{13} ga + \xi_{14} gz + \xi_{15}\sigma R^{CRP} + \xi_{16}\sigma a \\ &+\xi_{17}\sigma z + \xi_{18} R^{CRP} a + \xi_{19} R^{CRP} z + \xi_{20} az) + \kappa_1 R^{CRP} + \varepsilon_3' \end{aligned} \qquad [2.16]$$

$$\begin{aligned} P^d = &(\omega_0 + \omega_1 g + \omega_2\sigma + \omega_3 g^2 + \omega_4\sigma^2 + \omega_5 g\sigma) \\ &+(\omega_6 + \omega_7 R^{CRP} + \omega_8 a + \omega_9 z + \omega_{10} (R^{CRP})^2 + \omega_{11} a^2 \\ &+\omega_{11} z^2 + \omega_{12} R^{CRP} a + \omega_{13} R^{CRP} z + \omega_{14} az) + \vartheta_2 R^{CRP} + \varepsilon_4' \end{aligned} \qquad [2.17]$$

$\xi_3 R^{CRP}$ and $\kappa_1 R^{CRP}$ in the equation [2.16] will be summed in order to estimate the coefficient. Similarly, ω_0 and ω_6 , and $\omega_7 R^{CRP}$ and $\vartheta_2 R^{CRP}$ in the equation [2.17] will be are added together for estimation.

For convenience, we name the equation [2.12] as model I, and equation [2.15]as model II. In these two models, we use total road mileage to approximate the distance to the city z, and create three amenity indices (climate, recreation, and water) to approximate the amenities a.

To test whether road mileage and the created three amenity indices are good measures, three alternative models (model III-V) with the same functional form as model II are estimated. In these models, we use the urban influence codes (UIC) and the natural amenity index created by Economic Research Service (ERS) to approximate the distance to the city or the amenities. In models III-V, UIC and created amenities indices, road mileage and ERS amenity index, and UIC and ERS amenity index approximate the distance to the city and the amenities, respectively. In contrast to model I, models II-V cannot evaluate the effects of the CRP on the individual component of farmland prices.

Estimating the Effect of the CRP

Based on the estimated models, the effects of the CRP on the prices of farmland and developed land are evaluated. Take model I for example, based on equation[2.13], the effect of the CRP on farmland prices equals

$$p^a_{CRP} - p^a_0 = \hat{\theta}_1(R^{CRP} - A) + [\hat{\theta}_2 g^*(R^{CRP} - A) + \hat{\theta}_8 \sigma(R^{CRP} - A)] \qquad [2.18]$$

where p^a_{CRP} and p^a_0 are the farmland price with and without the CRP, respectively. The first term on the right hand side of equation [2.18] measures the direct effect of the CRP on agricultural returns, and the second term (in the brackets) measures the effect of the CRP on growth premium and option value. $(R^{CRP} - A)$ is the difference in the expected annual return to farming with and without the CRP. The effect of the CRP on developed land prices can be evaluated according to the equation [2.14] by the formula

$$\begin{aligned} p^d_{CRP} - p^d_0 = & [(\hat{\eta}_2 a + \hat{\eta}_3 z + \hat{\eta}_4 R(t) + \hat{\eta}_5 g + \hat{\eta}_6 \sigma)(\hat{\theta}_1 + \theta_2 g + \hat{\theta}_9 \sigma) \\ & + \hat{\eta}_8 a + \hat{\eta}_9 z + \hat{\eta}_{10} R(t) + \hat{\eta}_{11} g + \hat{\eta}_{12} \sigma] * (R^{CRP} - A) \\ & + \hat{\eta}_1 (R^{CRP} p^a_{CRP} - A p^a_0) + \hat{\eta}_7 (R^{CRP^2} - A^2) \end{aligned} \quad [2.19]$$

where p^d_{CRP} and p^d_0 are the developed land price with and without the CRP, respectively. Similarly, we can evaluate the effects of the CRP on prices of farmland and developed land in the models II to V by applying the same method.

ECONOMETRIC ISSUES AND ESTIMATION METHODS

Equations [2.10], [2.11], and [2.12] (or [2.10], [2.11] and [2.15]) comprise the empirical model for this analysis. Three econometric issues arise in the estimation of the model: endogeneity, spatial autocorrelation, and contemporaneous correlations. These issues are addressed using the generalized spatial three stage least square (GS3SLS) developed by Kelejian and Prucha (2004).

The GS3SLS estimator contains three steps. In the first step, the model parameters are estimated using two stage least squares (2SLS) and instrumental variable techniques. All exogenous variables are chosen as instrumental variables. The residuals from the 2SLS estimates are used to test for spatial autocorrelation using Moran's I statistic $I = N(\hat{e}'W\hat{e})/M(\hat{e}'\hat{e})$,[5] where N is the number of observations, $\hat{e}$ is the vector of estimated residuals, W is the spatial weight matrix indicating spatial structure of the data, and M is the standardization factor equal to the sum of the elements of W. We assume the error structure takes the form $\varepsilon = \rho W \varepsilon + \upsilon$, where ρ is a scalar and υ is a vector of spherical disturbance with zero mean. W is constructed in ArcView 3.2 using rook contiguity criteria, which uses common boundaries to define neighbors; 1 if two counties are adjacent and 0 otherwise.[6]

If the spatial autocorrelation is identified, then in the second step the residuals from the 2SLS are used to estimate the spatial autoregressive parameter ρ for each equation utilizing the generalized moment estimator (Kelejian and Prucha, 1999). After the spatial autoregressive parameter ρ is estimated, data are transformed using the matrix $\hat{P} = I - \hat{\rho}W$, where I is N by N identity matrix.

Finally, in the third step, after the endogeneity and spatial autocorrelation are corrected in the first two steps, two simultaneous equation systems, probability of acceptance and optional bid equation system, and the prices of farmland and developed land equation system, are estimated separately using seemingly unrelated regression (SUR) estimators. They are estimated separately, because they have different number of observations.[7]

DATA

The empirical specification suggests that to estimate the equation systems, data are needed on the prices of farmland and developed land, on agricultural returns, income, amenities, and on CRP participations. The study areas include 2851 counties in the contiguous 48 states.[8] All data used in this study come from 1997. Variables and descriptive statistics are listed in table 2.1.

The CRP data are provided by the Economic Research Service (ERS). The data contain individual contract information for sign-up 15, which was held in March 1997 based on new program rules that expanded the base of eligible land to more than 240 million acres, including about 65 percent of U.S. cultivated cropland.[9] With the farm-level contract information, we are able to estimate the county level probability of acceptance by calculating the ratio of the total accepted bids to total bids submitted in sign-up 15. The average county bidding rent per acre is computed by $(\sum_{i=1}^{n} b_i * acre_i) / \sum_{i=1}^{n} acre_i$, where b_i is the bid rent per acre and $acre_i$ is acres offered, and n is the total bids submitted. Using the farm-level CRP data, the average county environmental score is computed. The average past CRP rental rates and percentage of land already enrolled in the CRP in a county may provide important information for individuals to form their expectation on the $\underline{EBI}$. These two variables are constructed using historical county-level CRP data from ERS. The average past CRP rental rates are calculated using rental rates from all previous signups (i.e., signups 1-14). The percentage of land enrolled in the CRP is computed as the ratio of total land enrolled to total cropland in a county in December 1996. Eligible land data are obtained from the 1997 National Resource Inventory (NRI 1997). The percentage of eligible land in a county is the ratio of total eligible land to total cropland.

Net returns to farmland, farmland prices, and developed land prices are obtained from Plantinga, Lubowski and Stavins, who use Census of Agriculture data to calculate the average farming returns and farmland prices.[10] The average return to farmland, A, is calculated by (TR+GP-TC)/TA, where TR is the total revenues from the agricultural products sold, GP is the total government payments except CRP payments, TC is the total farm production expenses, and TA is the total farmland acres. The farmland price (p^a) measures the value of land and buildings per acre, and is the county-level average of self-reported estimates by landowners. Developed land price (p^d) is the county-level average price of recently developed land.[11]

The amenity data used in this study are generated by the National Outdoor Recreation Supply Information System (NORSIS), [12] developed and maintained by USDA Forest Service's Wilderness Assessment Unit, Southern Research Station, and Athens, Georgia. The amenity data are a comprehensive county level data set with more than 250 variables, including climate, natural amenity, man-made amenity and geographic information.

In order to capture the information contained in the vast amenity variables, one practice within the literature is to condense a set of related variables into a single scalar which retains the information in original data (Miller, 1976). The primary advantage of this approach is that variables are not removed from the empirical analysis due to multi-collinearity problems or limited degree of freedom (Wagner and Deller, 1998).

Following Deller et al. (2001), this study uses the principal component analysis to calculate amenity scores for each county. The principal component analysis is an approach to compress higher dimension variables into a single scalar. The single scalar is called score which is, in essence, the linear combination of the original variables where the weights are the eigenvectors of the correlation matrix for the factor variables. Because the principal component is very sensitive to scale, all variables used in the principal component analysis are standardized to zero mean and unit variance and the score is calculated by $score = \sum_{l=1}^{L} \lambda_l \tilde{x}_l$, where λ_l is the eigenvector computed from the variance-covariance matrix of the original data, $\tilde{x}_l$ is the standardized amenity variables and L is the number of variables in a category. We separate the amenity variables into three categories: climate (e.g., January sunny day, July temperature), man-made recreation facilities (e.g., the number of golf courses, the number of swimming pools and the number of campgrounds) and natural recreational resources (e.g., total outstanding river miles, white water miles). We include four variables to represent a region's climatic conditions, fourteen variables to describe the man-made recreation facilities, and four to portray water resources.[13]

Unlike our amenity indices, ERS creates an index of natural amenities based on six factors: warm winter (average January temperature), winter sun (average January days of sun), temperate summer (low winter-summer temperature gap), summer humidity (low average July humidity), topographic variation (topography scale), and water area (water area proportion of total county area) (Economic Research Service, 2005). In this study, both amenity data are used in different models to examine their effects on the prices of farmland and developed land.

Total road mileage is used to capture the effect of development pressure and transportation costs on land prices, and is the mileage of interstate and other principal arterial roads (for example, state highways). The data on road mileage are obtained from the Bureau of Transportation Statistics. One alternative measurement is the 1993 UIC, which divides U.S. counties into 9 categories based on population and commuting data from the 1990 census of population. The 1993 UIC is obtained from ERS.

Based on Capozza and Helsley (1990), we use the annual income growth and variance of income growth to approximate g and σ because of lack of time series data on land rent prices. g and σ are calculated using the average county median household income data from 1993 to 1997. Income data are compiled by the Small Area Income and Poverty Estimates (SAIPE) program of the U.S. Census Bureau.

Regional dummy variables are included to capture regional differences. The ERS divides the contiguous U.S. into 10 farm production regions from west coast to east coast: the Pacific, Mountain, Northern Plains, Southern Plains, Lake States, Corn Belt, Delta States, Northeast, Appalachian, and the Southeast. The Southeast is used as the referenced region. CRP acres were historically concentrated in the Great Plains (Northern Pains and Southern Plains) and Western Corn Belt, with some increases in the Mountain region since the 15th signup.

EMPIRICAL RESULTS

Estimated parameters for the two simultaneous equation systems are presented in tables A1-A5 in the appendix. Overall, the models fit the data well as indicated by the System Weighted R-Square 0.57 for the bid and acceptance equation system and about 0.87 for the land prices equation system for all five models. Most coefficients of interest are statistically significant at the 5% level or better. Spatial autocorrelations are detected in all models and specifications and are adjusted for each of the equations. Moran's I-statistics, with the standard deviation listed in parentheses, is 0.13 (0.0135), 0.45 (0.0135), 0.31 (0.0115), and 0.27(0.0115) for the acceptance, bid, farmland price, and developed land price equations (model I), respectively. Assuming an approximate standard normal distribution for $\boldsymbol{I}$, the null hypothesis of no spatial autocorrelation is rejected at 1% level in each case. The estimated values of the spatial autocorrelation parameter ρ are 0.30, 0.68, 0.56, and 0.52, respectively.

Table A1 reports the estimated parameter for the acceptance and bid equations. All coefficients except regional dummies in the acceptance equation are statistically significant at 1% level. The environmental score positively affects the probability of acceptance. Higher environmental score is usually associated with environmentally fragile land, which is the primary target of the CRP and therefore more likely to get accepted into the program. The level of bid affects the probability of acceptance negatively as expected. A 1% increase in the bid rent causes a 9% decrease in the probability of acceptance. The amount of the existing CRP land has a negative effect on the probability of acceptance, because the U.S. Department of Agriculture is more likely to target land for the CRP in areas where CRP participation has been low. Past rental rates have a positive effect on the probability of acceptance, because high past rental rates may indicate a high bid cap which will lead to a high acceptance rate. The probability of acceptance does not vary across regions, since most regional dummies are statistically insignificant.

The parameter estimates for the bid rent equation are also reported in Table A1. All variables (except the regional dummies) are statistically significant at the 1% level. Environmental score affects current bids negatively, because a higher environmental score may be associated with a lower land quality and lower opportunity costs for participation. Past rental rates and net farming returns have a positive effect on bid rents. A $1 increase in the past rental rate results in $0.75 increase in the current bid, and a $1 increase in net farming returns, increases the current bid by three cents. This suggests that farmers put a large weight on past rental rates to decide their optimal bids. The amount of land already enrolled in the CRP has a negative effect on the bid rents.

Table A2 and A3 reports the estimated parameters for the farmland and developed land prices in model I, and tables A4 and A5 report the estimated parameter for the prices of farmland and developed land for models II-V, respectively. Because of interaction terms and nonlinear relationships, the sign and magnitude of individual coefficient do not have clear interpretations. To facilitate interpretation of results, we calculate the marginal effect of amenity variables and UIC on prices of farmland and developed land and report the results in table 2.2. F-statistics for the null hypotheses that the marginal effects are zero were calculated to indicate the statistical significance (Judge et al., pp. 456-59).

Over all, the amenities have a positive and significant effect on prices of both farmland and developed land. The results derived from both the ERS amenity and from our created amenity indices are generally consistent. Climate appears to have a positive effect on land prices, although it is insignificant in the developed land prices in models I and II. The positive sign suggests households prefer location with better climate.

Man-made recreation facilities have positive and significant effects on both farmland and developed land prices. The recreation facility index is driven by the availability of parks, tennis courts, and golf courses, among other things. Therefore counties with more man-made recreation facilities are more attractive to households. The coefficient on the water index is sensitive to specification in both of the equations for land prices, but it seems that it has little effect on farmland prices given that the index measures the length of white-water, streams, and rivers.

Table 2.2 also reports the marginal effects of UIC on prices of farmland and developed land. The effects of UIC on land prices are negative and statistically significant, suggesting locations far away from the city have lower prices.

Effects of the CRP on Land Values

The effects of the CRP on the prices of farmland and developed land are evaluated using each of the model specifications, and the results are reported in tables 2.3 and 2.4. The CRP has positive and significant effects on prices of farmland in all regions based on each of the models. This result is robust in terms of the sign and relative magnitude of the effects. On average, the CRP increases farmland prices by $18-$25 per acre (or 1.3%-1.8%) nation wide. The CRP has relatively large impacts on farmland prices in the Mountain area, the Southern Plains, and the Northern Plains in all five models; it increases farmland prices in these regions by 5.2-14.0%, 3.7-6.4%, and 2.7-5.3%, respectively. This is not surprising, given that more than 60 percent of CRP lands are located in these three regions and that the CRP rental rates are considerably higher than net farming returns in the three regions. Net farming returns are lower than $30 per acre in the Mountain area and in the Southern Plains, and lower than $50 per acre in the Northern Plains. Compared with farming, participation in the CRP turns out to be a more profitable alternative, and the value of this profitable use is capitalized into farmland prices. Furthermore, the percent increases in farmland prices are enhanced by the lower farmland prices in these three regions, where they are lower than $630 per acre, compared to the national average of $1362 per acre.

Compared to the above three regions, the CRP has mild absolute effects but small relative effects on farmland prices in the Corn Belt, in Appalachia and in the Pacific. The mild absolute effects result from the moderate CRP enrollment and the moderate difference between CRP rental rates and net farming returns in these regions. The mild absolute effects account for only a small percentage of farmland prices, because farmland is rather productive and valuable in these regions, with an average price higher than $1600 per acre. The effect of the CRP on farmland prices is smallest in the Lake States, followed by the Northeast. In the Lake States, there is little difference between CRP rental rates and net returns to farming. The Northeast had the smallest CRP enrollment among the 10 regions. Only about 0.5% of the total CRP enrollment is located in the Northeast.

Generally, the CRP had a positive and statistically significant effect on developed land prices. However, the effect is small. On national average, the CRP increases developed land prices by \$6-\$274 per acre, which accounts for less than 0.6 % of developed land prices. The CRP has relatively large impacts in the Mountain, Southern Plains, Appalachian, and the Corn Belt regions. It is not surprising that effects of the CRP on developed land prices are relatively large in the Mountain areas and Southern Plains, where the positive and larger effects of the CRP on farmland prices directly contribute to the large increases in developed land prices. However, it is unexpected to find that the effects of the CRP on developed land prices are relatively large in Appalachia and the Corn Belt, given the effects of the CRP on farmland prices are moderate there. One possible explanation is that Appalachia is highly developed, while the Corn Belt has highly productive farmland. A small reduction in developable land caused by the CRP translated into a relatively large increase in prices for developed land in these regions. The effect of the CRP on developed land prices is smallest in the Northeast and the Pacific region. In the Northeast, the small effects of the CRP on farmland price and the small CRP acreage explain the small effects on developed land prices. In the Pacific Region, the absolute effect of the CRP on developed land prices is relatively large, but it accounts for only a small percentage because developed land prices are the highest of all the 10 regions, with an average price \$174,157 per acre.

The spatial distribution of the CRP effects on farmland prices are shown in the figure 2.1. Overall, the spatial distribution of the CRP effects on farmland prices is consistent with the spatial distribution of the CRP acreages. The CRP has relatively large impacts on the prices of both farmland and developed land in Mountain areas, Plains states, west Corn Belt, and some counties in west Appalachia and the Southwest, where CRP participation is more profitable than farming.

Table 2.5 reports the magnitude of the major components of farmland price and the effect of the CRP on those components based on model I. On average, agricultural returns account for 40% of farmland prices. Of the 10 regions, the weight of agricultural returns in farmland prices is relatively high in the Mountain and Northern Plains regions, where the farmland prices are relatively low due to low net returns to farming and low development pressure. On national average, growth premium and option value together account for 60% of farmland prices. The Northeast has the highest growth premium and option value, which accounts for about 68% of farmland values. Consistent with the theory, the CRP had a positive impact on agricultural returns, but a negative impact on growth premiums and option values. Specifically, the CRP increases agricultural returns by about $37 per acre, but reduces growth premiums and option values by $12 per acre on national average.

POLICY IMPLICATIONS FOR PERMANENT EASEMENT PROGRAMS

By retiring highly erodible and other environmentally sensitive cropland for 10-15 years, the CRP provides significant benefits to the environment. However, a permanent easement program has an obvious advantage. In recent years, several states including Minnesota and Maryland have used the Conservation Reserve Enhancement Program (CREP) and other USDA programs to convert short term easements to permanent conservation easements. It has been suggested that since the present discount value of rental payments during a 15-year contract equals about 75% of the value of a perpetual program (assuming a 10% discount rate), states only need to pay 25% more to secure permanent easements. If true it would be particularly appealing to secure a permanent easement, however, our results suggest that 25% additional funding is generally not sufficient to convert a 15-year contract to a permanent easement.

The CRP payment is calculated based on the relative productivity of soils within the county and the local dry land cash rent. That is to say, the easement payments only reflect the stream of agricultural returns, but not growth premium and option value. Our empirical results show that agricultural and conservational returns account for only 40% of the total farmland value, and growth premium and option value account for the other 60%. Growth premium and option value are generated by potential development beyond the CRP period (otherwise, the land would not be enrolled into the CRP). CRP payments during the contract period account for only about 30% (0.75*0.40) of land value, where 0.75 represents the percentage of the value of agricultural returns covered by CRP payments during a 15-year contract (assuming a 10% discount rate). In order to convert a 15-year CRP contract to a permanent easement, the remaining 70% of land value must be compensated. That would be about $70\%/30\% = 2.6$ times of the total CRP payment. Thus, in areas where growth premium and option value are higher, states would need to pay much more than 25% to convert a 15-year contract to a permanent easement. However, in rural areas where growth premium and option value are minimal, 25% additional funding may be sufficient.

CONCLUSIONS

As the largest conservation program in the U.S. history, the CRP has been evaluated in a number of studies for its environmental benefits. However, the effects of the CRP on

farmland prices have received relatively little attention. The limited existing research generates contradictory results. This paper develops theoretical and empirical models to evaluate the effects of the CRP on prices of farmland and developed land. The theoretical results suggest that the CRP can increase or decrease land prices, depending on the relative magnitude of the effects of the CRP on agriculture returns, growth premium, option value and accessibility premium. Based on the theoretical analysis, five empirical models are specified to quantify the effect of the CRP on prices of farmland and developed land. Results show that the CRP increases farmland prices by 1.3-1.8% on national average. The effects are largest in the Mountain, Southern Plains, and Northern Plains, where the CRP increases farmland prices by 5.2-14.0%, 3.7-6.4% and 2.7-5.3%, respectively. The CRP has a positive effect on developed land prices, but the effect is small (less than 0.6%). Results also show that agricultural returns account for about 40% of farmland price, and growth premium and option value together account for the remaining 60%. Climate and recreation amenities have positive effects on farmland prices because they increase both growth premium and option value. These results provide useful information for the design of permanent easement programs.

ENDNOTES

[1] The effect of the CRP on cash rents is significant when they assume that no spatial autocorrelation exists across the residuals, but insignificant when the spatial autocorrelation is corrected.

[2] This is not a restrictive assumption, given the fact that the Secretary of Agriculture announced two early-out opportunities in December 1994 and March 1996; and the new Federal Agricultural Improvement and Reform Act (1996 Farm Bill) provided authority for producers withdraw most lands from the CRP at anytime, subject to 60-day notice to U.S. Department of Agriculture (USDA) if their contracts were established before January 1, 1995, and have been in effect for at least 5 years.

[3] $B(t)$ is a standard Brownian motion with zero drift and variance 1.

[4] Polynomial function forms have been used in several previous studies (e.g., Plantinga and Miller, 2001).

[5] Moran's I is a spatial analogue to Pearson's correlation coefficient. For its statistic property, see Anselin (1989).

[6] Two criteria are usually used to create spatial weight. One is contiguity-based spatial weight and the other is distance-based spatial weight. The contiguity-based spatial weight usually uses two criteria: rook and queen contiguity. The former uses common boundaries, and the latter uses common points (boundaries and vertices) in the definition. Distance-based spatial weight defines the neighbors according to the specified distance, or the specified k-nearest neighbors. The spatial weight matrix can be created in a variety of softwares such as ArcView 3.2 and ArcGIS 9.0.

[7] Participation data, and farmland and developed land data are obtained from different sources. The former contains about 2000 observations, while the latter contains about 3000 observations. To make full use of the information in the data, each system is estimated separately.

[8] One hundred and ninety counties are omitted due to missing data or absence of agricultural land.

[9] We thank Shawn Bucholtz of the Economic Research Service for providing the data.

[10] We thank Plantinga, Lubowski and Stavins for providing data.

[11] See Plantinga, Lubowski and Stavins (2002) for the estimate of developed land price.

[12] We thank Steve Deller of University of Wisconsin for providing the NORSIS data.

[13] Variables in each category and its corresponding eigenvector are available upon request.

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Table 2.1. Variables and Descriptive Statistics

Variables	Description	Mean	Std
b_{-1}	Past CRP rental rates from signups 1-14 ($)	54	16.16
A	Net farming returns ($)	77	78.45
R^{CRP}	Max(A, A(1-m)+m(pb+(1-p)A))	81	74.10
p^a	Farmland Prices ($)	1362	961.93
p^d	Developed land prices ($)	48837	45052.50
b	Bid price at signup 15 ($)	50	22.46
P	Probability of acceptance at signup 15	0.65	0.31
S	Sum of (N1-N6)	140	34.90
y	Median household income in 1997 ($)	32377	7514.83
g	Mean of annual income growth 1993-1997 ($)	640	2161.27
σ^2	variance of income change 1993-1997	3420	2402.17
Amenity	Amenity index created by ERS	-0.60	1.83
Climate	First principal component of climate	0	1.00
Recreation	First principal component of recreation facility	0	1.00
Water	First Principal component of water	0	1.00
CRP_{-1}	Percentage of land enrolled in the CRP in signups	4.20	4.70
m	Percentage of land eligible for the CRP	45.30	29.40
Road	Interstate and principal arterial road (1,000 miles)	58	86.43
UIC	1993 Urban influence codes	5.60	2.64
r1	1 if counties in the Pacific, 0 otherwise	0.04	0.20
r2	1 if counties in the Mountain, 0 otherwise	0.08	0.27
r3	1 if counties in the Northern Plains, 0 otherwise	0.11	0.31
r4	1 if counties in the Southern Plains, 0 otherwise	0.11	0.31
r5	1 if counties in the Lake States, 0 otherwise	0.08	0.27
r6	1 if counties in the Corn Belt, 0 otherwise	0.17	0.38
r7	1 if counties in the Delta States, 0 otherwise	0.07	0.26
r8	1 if counties in the Northeast , 0 otherwise	0.07	0.26
r9	1 if counties in the Appalachian, 0 otherwise	0.16	0.36
r10	1 if counties in the Southeast, 0 otherwise	0.10	0.31

Table 2.2. The Marginal Effect of Independent Variables on Price of Farmland and Developed Land

Variables	Model I	Model II	Model III	Model IV	Model V
	Marginal Effect on Farmland Prices ($/per acre)				
ERS Amenity				42***	60***
climate	45*	129***	93***		
recreation	199***	406***	206***		
water	8	-44	7		
UIC			-60***		-67***
	Marginal Effect on Developed Land Prices ($/per acre)				
ERS Amenity				20	1249**
climate	293	2191	2312*		
recreation	16229***	24707**	4671***		
water	-2090***	-121***	1460*		
UIC			-5543***		-5425***

***significant at 1% level, **significant at 5%level, *significant at 10% level.

Table 2.3. Effects of the Conservation Reserve Program on Farmland Prices, by Region

Regions	Farmland Prices ($/per acre)				
	Model I	Model II	Model III	Model IV	Model V
Pacific	36***	44***	35***	35***	18***
	(2.25)	(2.74)	(2.18)	(2.18)	(1.12)
Mountain	60***	85***	52***	55***	32***
	(9.79)	(13.87)	(8.48)	(8.97)	(5.22)
Northern Plains	28***	33***	24***	17***	11***
	(4.52)	(5.32)	(3.87)	(2.74)	(1.87)
Southern Plains	40***	29***	23***	35***	30***
	(6.41)	(4.65)	(3.69)	(5.60)	(4.81)
Lake States	3***	6***	6***	2***	2***
	(0.22)	(0.43)	(0.43)	(0.15)	(0.15)
Corn Belt	24***	26***	23***	17***	18***
	(1.35)	(1.46)	(1.29)	(0.96)	(1.91)
Delta States	18***	12***	9***	12***	10***
	(1.62)	(1.08)	(0.81)	(1.08)	(0.90)
Northeast	8***	9***	8***	7***	7***
	(0.33)	(0.37)	(0.33)	(0.29)	(0.29)
Appalachia	28***	24***	21***	21***	21***
	(1.51)	(1.30)	(1.13)	(1.13)	(1.13)
Southeast	18***	11***	9***	11**	11***
	(1.19)	(0.73)	(0.59)	(0.73)	(0.73)
U.S.	25***	25***	22***	18***	18***
	(1.84)	(1.84)	(1.61)	(1.32)	(1.32)

Percentages are in parenthesis. ***significant at 1% level, **significant at 5%level, *significant at 10% level.

Table 2.4. Effects of the Conservation Reserve Program on Developed Land Prices, by Region

Regions	Developed Land Prices ($/per acre)				
	Model I	Model II	Model III	Model IV	Model V
Pacific	540***	549***	203***	715***	158***
	(0.31)	(0.12)	(0.12)	(0.41)	(0.09)
Mountain	843***	809***	341**	901***	233**
	(0.78)	(0.74)	(0.31)	(0.83)	(0.21)
Northern Plains	275***	277***	-20	-139**	-191***
	(0.60)	(0.60)	(-0.04)	(-0.30)	(-0.41)
Southern Plains	244**	202**	19	368***	249***
	(0.61)	(0.50)	(0.05)	(0.92)	(0.59)
Lake States	63	75***	31***	-57***	-33
	(0.15)	(0.18)	(0.07)	(-0.14)	(-0.08)
Corn Belt	277***	271***	155***	10**	78
	(0.67)	(0.65)	(0.37)	(0.02)	(0.30)
Delta States	118***	119***	15	45	33
	(0.45)	(0.45)	(0.06)	(0.17)	(0.05)
Northeast	186***	184***	137***	42	53***
	(0.26)	(0.26)	(0.19)	(0.06)	(0.07)
Appalachia	347***	297***	205***	64	125***
	(0.98)	(0.84)	(0.58)	(0.18)	(0.35)
Southeast	150	114***	57*	79**	94***
	(0.44)	(0.33)	(0.17)	(0.23)	(0.27)
U.S.	274***	273***	155***	6	73
	(0.56)	(0.56)	(0.32)	(0.01)	(0.15)

Percentages are in parenthesis. ***significant at 1% level, **significant at 5%level, *significant at 10% level.

Table 2.5. Values of the Major Components of Farmland Prices and the Effects of the Conservation Reserve Program on These Components, by Region

Regions	Value of Agricultural Returns		Value of Growth Premium and Option value		Effect on Value of Agricultural Returns		Effect on Value of Growth Premium and Option Value	
	$/ acre	% of pa	$/ acre	% of pd	$/acre	%	$/acre	%
Pacific	813	50.7	792	49.3	51	6.3	-15	-1.9
Mountain	261	42.5	353	57.5	83	2.2	-23	-6.5
Northern Plains	364	58.6	256	41.4	42	11.7	-14	-5.4
Southern Plains	229	36.8	397	63.2	59	6.2	-19	-4.8
Lake States	588	43.0	782	57.0	7	1.2	-4	-0.5
Corn Belt	655	36.8	1125	63.2	39	6.0	-13	-1.1
Delta States	535	48.2	575	51.8	25	4.7	-7	-1.2
Northeast	762	31.6	1648	68.4	15	2.0	-7	-0.4
Appalachian	688	37.2	1165	62.8	38	5.6	-10	-0.9
Southeast	608	40.1	903	59.9	24	4.0	-6	-0.7
U.S.	542	39.8	820	60.2	37	6.9	-12	-1.5

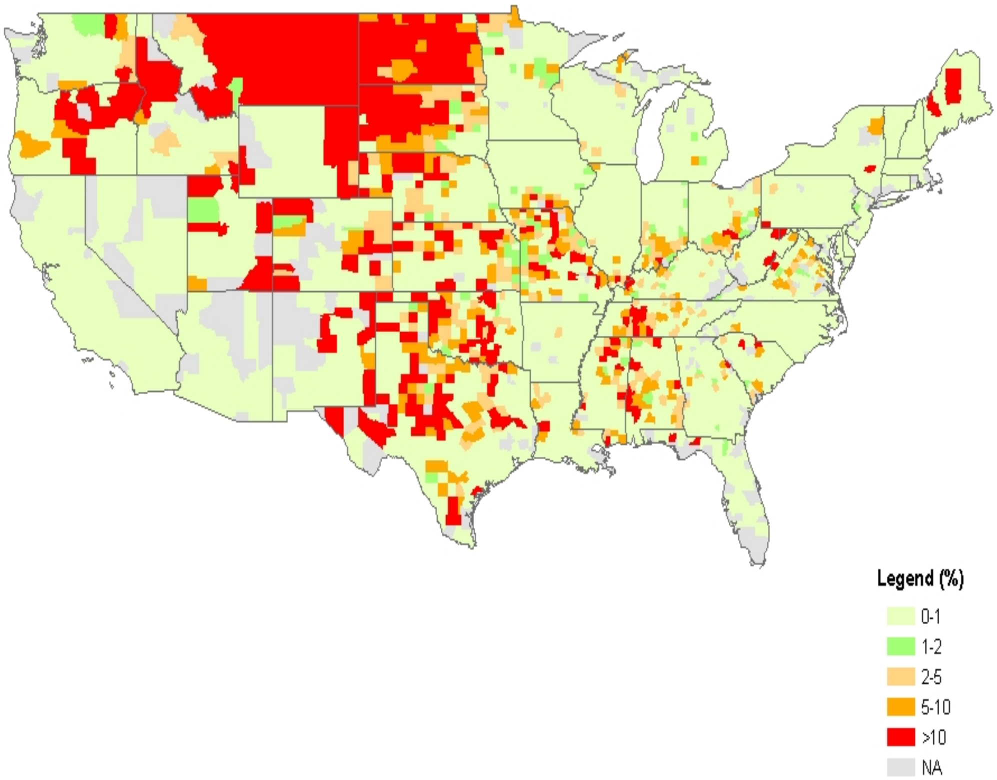

Figure 2.1 The Percent increase in farmland prices under the Conservation Reserve Program

APPENDIX

Table A1. Parameter Estimates of the Probability of Acceptance and Optimal Bid Equations

Variables	Acceptance Equation		Optimal Bid Equation	
	Estimate	Std	Estimate	Std
Intercept	-5.19***	0.349	2.85***	0.443
b_{-1}	0.06**	0.024	0.75***	0.023
A	—	—	0.03***	0.002
S	0.08***	0.002	-0.02***	0.005
CRP_{-1}	-4.00***	1.406	-12.79***	4.604
b	-0.10***	0.019	—	—
r1	0.12	0.486	-5.56***	1.867
r2	-0.27	0.336	-1.88	1.274
r3	0.15	0.294	-0.31	1.364
r4	-0.31	0.307	-0.17	1.192
r5	0.06	0.322	1.39	1.384
r6	-1.15***	0.331	11..93***	1.363
r7	0.16	0.338	-3.16**	1.406
r8	0.29	0.380	0.93	1.566
r9	-0.13	0.290	2.51**	1.154
Number of observations		2206		
System Weighted R^2		0.57		

***significant at 1% level, ** significant at 5% level.

Table A2. Parameter Estimates of the Farmland Prices Equations for Model I

Variables	Farmland Price Equation Estimates	Std
R^{CRP}	6.6769***	0.2667
g* Road mile	-7.16e-6***	0.0001
g *y	2.4e-6***	7.76e-7
g*g	5.0e-6*	2.65e-6
g* R^{CRP}	-0.0007***	4.6e-5
g *climate	0.0386***	0.0100
g *Recreation	0.0263***	0.0110
g* Water	-0.0047	0.0066
g*r1	0.2081***	0.0367
g*r2	0.0513*	0.0283
g*r3	0.0377	0.0287
g*r4	-0.0275	0.0234
g*r5	0.0584	0.0343
g*r6	0.0158	0.0248
g*r7	0.0047	0.0273
g*r8	0.0209	0.0313
g*r9	-0.0249	0.0214
σ *Road	-0.0064	0.0051
σ *y	0.0010***	0.0001
σ * σ	-0.2271***	0.0167
σ * R^{CRP}	-0.0304***	0.0041
σ *climate	0.2820	0.5023
σ *recreation	3.3102***	0.4262
σ *water	0.1636	0.2687
σ *r1	-2.4834	2.0121
σ *r2	-6.4826***	1.5631
σ *r3	-7.9109***	1.4745
σ *r4	-3.4203**	1.3269
σ *r5	-5.8818***	1.8168
σ *r6	-1.8051	1.3335
σ *r7	0.2520	1.5160
σ *r8	8.2746***	1.1676
σ *r9	3.6615***	1.1730
σ *g	0.0004*	0.0003
Number of observations	2851	
System Weighted R^2	0.87	

*** Significant at 1% level, ** significant at 5%,* significant at 10%.

Table A3. Parameter Estimates of Developed Land Prices Equations for Model I

	Developed Land Price Equation	
Variables	Estimates	Std
Intercept	-2757.18	2547.0000
p^a * Road	0.0317***	0.0107
p^a *y	0.0004***	0.0001
p^a *g	-0.0005***	0.0002
p^a * σ	-0.0235	0.0216
p^a * R^{CRP}	-0.0114	0.0061
p^a *climate	-2.9862**	1.0399
p^a *recreation	-6.3869***	0.9050
p^a *water	1.9253**	0.9361
R^{CRP} *Road	-0.3720***	0.1258
R^{CRP} *y	0.0007	0.0007
R^{CRP} *g	0.0063**	0.0033
R^{CRP} * σ	0.0377	0.2894
R^{CRP} *max	0.0430	0.0243
R^{CRP} *climate	5.1441	9.4251
R^{CRP} *recreation	61.6576***	10.5946
R^{CRP} *water	3.7066	8.2816
Road	-12.6217	19.6437
y	0.9562***	0.1755
Climate	3324.58*	1745.2000
Recreation	21679.98***	2096.2000
Water	-4966.70***	1434.4000
r1	139878.5***	5926.1000
r2	71433.5***	4598.5000
r3	14793.9***	4398.3000
r4	9657.0**	4060.6000
r5	-12048.5**	5280.2000
r6	-4365.1	4110.7000
r7	6096.9	4341.9000
r8	-4884.6	5106.7000
r9	-3621.5	3688.1000
Number of observations	2851	
System Weighted R^2	0.87	

*** Significant at 1% level, ** significant at 5%,* significant at 10%.

Table A4. Parameter Estimates for Farmland Prices Equation for Model II-V

Variables	Estimates			
	Model II	Model III	Model IV	Model V
Intercept	247.94***	224.04***	194.83***	248.81***
R^{CRP}	4.41***	6.14***	2.66***	6.11***
g	6.05e-3	0.01	-5.01e-3	0.03*
σ	0.02**	0.06***	7.60e-3	0.04***
Amenity			51.23***	126.35***
climate	227.90***	215.83***		
recreation	252.44***	358.06***		
water	49.15	-1.84		
road	0.85		2.04***	
UIC		27.32		-24.46
R^{CRP^2}	- 7.00e-5***	-9. 00e-5***	2.00e-6	-7.00e-5***
g^2	-6.35e-6**	-7.87e-6***	-9.67e-6***	-7.67e-6***
σ^2	1.29e-6**	1.24e-6**	2.36e-6***	1.65e-6***
$Amenity^2$			5.51**	1.52
$climate^2$	66.18***	60.76***		
$recreation^2$	- 76.21***	-10.18***		
$water^2$	- 7.64	-8.40*		
$road^2$	- 0.01***		-7.70e-4**	
UIC^2		-2.32***		1.67
R^{CRP} *g	- 2.10e-4***	1.50e-4***	-2.50e-4***	-1.8e-4***
R^{CRP} * σ	1.47e-4***	1.26e-4***	1.82e-4***	1.39e-4***
R^{CRP} *Amenity			0.43***	0.15***
R^{CRP} *climate	- 1.27***	-1.28***		
R^{CRP} *recreation	0.70***	0.08		
R^{CRP} *water	- 0.68***	-0.55***		
R^{CRP} *road	- 4.59e-3**		4.58e-3***	
R^{CRP} *UIC		-0.46***		-0.57***
g* σ	- 1.69e-6*	5.02e-7	-6.47e-7	6.91e-7
g*Amenity				
g*climate	- 8.40e-3	-2.37e-3		
g*recreation	0.02**	0.02**		
g*water	- 1.82e-3	-4.66e-3		
g*road	1.01e-4		2.67e-4***	
g*UIC		5.88e-4		-3.32e-3

Table A4. Parameter Estimates for Farmland Prices Equation for Model II-V (Cont.)

Variables	Estimates			
	Model II	Model III	Model IV	Model V
σ*Amenity			-7.16e-3***	-6.64e-3***
σ*climate	2.92e-3	4.92e-4		
σ*recreation	5.00e-3	-4.16e-3		
σ*water	- 5.40e-4	7.27e-4		
σ*road	1.47e-4***		8.2e-5	
σ*UIC		-7.29e-3***		-5.74e-3***
road*Amenity			-0.26***	
road*climate	- 1.10			
road*recreation	1.17***			
road*water	0.17			
UIC*Amenity				-10.55***
UIC*climate		-3.53		
UIC*recreation		-28.18***		
UIC*water		9.55*		
r1	935.61***	793.48***	642.28***	685.39***
r2	160.56	118.21	-29.11	90.69***
r3	-104.41	-87.58	-92.06	-16.94
r4	-324.87***	- -309.14***	-90.17	-68.70
r5	278.46**	250.33*	319.19**	398.91***
r6	601.30***	572.09***	688.39***	716.95***
r7	-5.31	36.63	177.76	195.03
r8	1640.10***	1 1616.72***	2095.62***	2027.49***
r9	708.56***	707.32***	770.56***	760.79***
Number of observations	2851			

*** Significant at 1% level, ** significant at 5%,* significant at 10%.

Table A5. Parameter Estimates for Developed Land Prices Equation for Model II-V

Variables	Estimates			
	Model II	Model III	Model IV	Model V
Intercept	11886.58***	32700.81***	6849.01***	39437.21***
R^{CRP}	61.58***	111.10***	12.34	108.13***
g	-2.18***	- 0.96**	-2.74***	- 1.34***
σ	2.72***	1.57***	2.87***	1.44***
g^2	2.31e-4	3.39e-4**	1.50e-4	0.42e-
σ^2	- 8.00e-	-8.00e-5**	7.00e-5**	-1.00e-4***
g* σ	- 1.60e-4**	-1.60e-4**	-1.20e-4**	-1.30e-
Amenity			-1258.77**	4031.25***
climate	4963.67***	-1952.48		
recreation	17786.51***	20396.41***		
water	-1749.59	-1872.00		
road	82.40***		194.99***	
UIC		-21086.50***		-25281.40***
${R^{CRP}}^2$	-2.70e-3***	-3.40e-3***	-6.80e-4*	-3.31e-3***
$Amenity^2$			732.89***	818.07***
$climate^2$	-1125.00	1864.22**		
$recreation^2$	-4769.40***	-359.80***		
$water^2$	-277.41	-372.33*		
$road^2$	-0.42***		-0.09***	
UIC^2		1495.91***		1862.91***
R^{CRP} *Amenity			25.30***	12.06***
R^{CRP} *climate	-14.10*	- 11.52*		
R^{CRP} *recreation	26.44***	2.49		
R^{CRP} *water	10.80	14.49**		
R^{CRP} *road	-0.21**		0.07	
R^{CRP} *UIC		- 14.81***		
road*Amenity			1.84	-15.59***
road*climate	-28.10**			
road*recreation	82.83***			
road*water	13.03			-496.14***
UIC*Amenity				
UIC*climate		927.94***		
UIC*recreation		- 2844.45***		
UIC*water		385.45		
r1	160295.60***	161634.40***	123496.40***	133580.80***
r2	85559.43***	100585.80***	64044.16***	87345.16***
r3	21190.61***	30427.77***	13566.22***	27505.60***
r4	8077.42*	15395.77***	8102.67*	19246.03***
r5	6969.76	14190.87***	2699.35	14891.74***
r6	9380.34**	15595.50***	10059.34**	16544.13***
r7	1553.03	11147.64**	4159.05	13820.66***
r8	17926.73***	23784.98***	33193.82***	37402.49***
r9	2707.72	12918.97***	5117.96	12326.99***
Number of observations	2851			

*** Significant at 1% level, ** significant at 5%,* significant at 10%.

CHAPTER 3

TRADEOFFS BETWEEN EFFICIENCY AND EQUITY: THE CASE OF THE CONSERVATION RESERVE PROGRAM

HAIXIA LIN
& JUNJIE WU, PROFESSOR

ABSTRACT

The paper estimates the tradeoffs between efficiency and equity in the case of the Conservation Reserve Program. We develop a simple reallocation mechanism of conservation funds to trace out the Efficiency-Equity Frontier (EEF) based on the benefit-cost ratio targeting criteria. The estimation of EEF is achieved by applying the designed budget reallocation mechanism to the CRP data on the 18th sign-up through simulations. Based on the estimated EEF, we calculate the tradeoffs between efficiency and equity. 1% losses in the efficiency result in approximately 1% gains in the equity. In addition, we identify the distribution patterns of conservation funds under three alternative targeting criteria (benefit-cost ratio rule, EBI rule, and equity rule) in the 10 production regions in the U.S., and evaluate the performances of these targeting criteria in terms of their efficiency and equity. Important policy implications to the design, selection and implementation of targeting criteria for the CRP are derived based on the estimated EEF.

INTRODUCTION

A broad array of policy tools or instruments has been established over the years to encourage landowners to adopt conservation practices, and environment-friendly production techniques (USDA, 2003). Resource purchasing funds have become a primary instrument for resource conservation and environmental protection (Wu, Zilberman, and Babcock 2001). The administrative agent uses this tool to take lands out of production, and place the lands under conservational practices. Current Conservation Reserve Program (CRP) and Wetland Reserve Program (WRP) are such examples. Because of the large variability in land characteristics and cost, these programs are generally targeted to improve efficiency. While targeting improves efficiency, political considerations often focus on equity issues.

Policy analysts often must deal with efficiency and equity, which are perhaps the two most important criteria for policy selection. However, these two criteria are often incompatible, and their conflict as declared by Okun (1975) is inescapable. Much of what society attempts to do in pursuit of equity tends to impair efficiency, and on the other side almost anything which is done to improve efficiency tends to impair distributional equity (Stanford 1996)

The CRP, established by the Food Security Act of 1985, is the largest private-land conservation program both in acres enrolled and in dollars spent in the U.S. (Farm Service Agency, 2006). Its primary goal is to help agricultural producers preserve environmentally sensitive land, and thereby decrease erosion, restore wildlife, and safeguard ground and surface water, and also provide income supports for farmers (USDA 2004). Owners of eligible lands can submit bids to join the program. The submitted bids compete nationally based on their Environmental Benefit Index score (EBI), which is calculated according to submitted parcels' potential environmental benefits and annual rental rates requested by the submitted bids. If bids are accepted into the program, then owners will receive payments as a compensation of retiring their lands. Over 34.9 million acres of cropland were enrolled in the CRP in 2005, providing about $2 billion annual rental payments to land owners and operators (Farm Service Agency 2005). However, significant variation exists in the distribution of conservation payments across geographic regions. Eight states in the Plains and Western Corn Belt received 57 percent of CRP payments and about 46 percent of all conservation payments in 2005 (United State Department of Agriculture 2006). This significant variation in the distribution of conservation payments has given rise to the political considerations of equity. Some argue that conservation funds should be shifted from the Mountain and Great Plains regions to other regions.

In this study, we take into account efficiency and equity simultaneously and explore the tradeoffs between efficiency and equity in the case of the CRP. Specifically, we examine how much efficiency has to be given up in order to improve equity through redistributing conservation funds geographically. To achieve this goal, we treat total conservation funds as an input for two outputs, the efficiency and the equity, and attempt to find its production possibility frontier, which is called the Efficiency-Equity Frontier (EEF). Every point on the frontier represents an optimal allocation of conservation funds and gives a unique level of efficiency and equity corresponding to the optimal allocation. We design a simple budget reallocation mechanism of conservation funds in order to estimate the EEF. Then, we use simulations to trace out the EEF by applying the reallocation mechanism to CRP data on the 18^{th} sign-up. Based on the estimated EEF, we calculate the tradeoffs between efficiency and equity, and identify the distribution patterns of conservation funds under alternative targeting criteria (EBI rules, benefit-cost ratio rule, and equity rule). We derive important policy implications on the design, selection and implementation of targeting criteria for the CRP.

Since its inception, the CRP has attracted substantial research interest. Some studies estimate the environmental and economic benefits of the CRP (e.g., Young and Osborn 1990; Osborn and Konyar 1990; Ribaudo et. al. 1990; Sullivan et al. 2004). Some studies evaluate the impacts of the CRP on land values (e.g., Lence and Mishra, 2003; Goodwin, Mishra, and Magne 2003; Shoemaker 1989; Lin and Wu 2005). For example, Lin and Wu find that the CRP increases farmland prices by $18 to $25 per acre, on national average, and the effect are the largest in the Mountain, Northern and Southern Plains. Some studies investigate optimal payments for a cost-effective CRP program (e.g., Parks and Schorr 1997; Tegene et al, 1997).

Several studies have recently analyzed the efficiency of alternative targeting criteria in the case of the CRP. Babcock et al. (1996) evaluate the relative efficiency of the CRP under three targeting criteria (environmental maximization, environmental sensitivity, and acreage maximization) for four indicators of environmental benefits: water erosion, wind erosion, surface water quality, and wildlife habitat. Babcock(1997) investigate how the joint spatial distribution of cost and environmental benefits affect efficiency losses from following targeting rules based on cost or benefits, rather than based on the benefit to cost ratio. They find that the relative variability of costs and benefits and the correlation between the two are primary determinants of efficiency losses. Wu, Zilberman, and Babcock (2001) develop an analytical framework to analyze the environmental and distributional impacts of conservation targeting strategies. They show that ignoring the output price effect of purchasing funds reduces environmental gains and in some cases may make purchasing fund counterproductive, and argue that optimal design of targeting criteria must consider the price feedback effect.

However, these studies, without exception, ignore the equity side of budget allocation and provide no insight into the tradeoff between efficiency and equity in the case of the CRP.

This is surprising given that annual rental payments invested in this program is about $2 billion, which accounts for about 30% of total USDA' s expenditure (USDA, 2005).

In the rest of this paper, we first discuss the measurements of efficiency and equity and data used in this study. Then, we present simulation methods, followed by simulation results. Finally, we conclude.

MEASUREMENTS OF EFFICIENCY AND EQUITY

An allocation of a resource is said to satisfy the efficiency criteria if the benefits obtained from using the resource are maximized (Tietenberg 2006). According to Babcock(1997), maximization of environmental benefits obtained from a fixed budget is achieved if program managers purchase environmental goods with the highest benefit-cost ratio until conservation funds are spent. Although this simple targeting rule is often not followed in practice by public program administrators, there is growing tendency to apply this criterion in environmental purchasing activities (Wu, Zilberman, and Babcock 2001). For example, during the first nine CRP sign-up, lands were enrolled into the program largely according to their costs rather than their benefit-cost ratio, but since the 10th sign-up, Environmental Benefit Index (EBI) calculated based on environmental and cost factors is used to prioritize bids. EBI, in essence, is a benefit-cost index rather than benefit-cost ratio, although it takes both environmental factors and cost factors into account.

Suppose total budget available to a certain CRP sign-up is M . Let EB_{ij} and C_{ij} denote environmental benefits per acre associated with and rental payment per acre requested by bid

j in county i. Hence, $BC_{ij} = EB_{ij} / C_{ij}$ is the benefit-cost ratio associated with the parcels offered by the bid j in county i. Under the benefit-cost ratio criteria, bids are accepted according to their benefit-cost ratio rankings. Let n_i denote the number of total submitted bids, bi the number of accepted bids, and M_{ij} the conservation funds allocated to the accepted bid j in county i, and N the number of counties. Then, $BC_{ij}M_{ij}$ is the total environmental benefits obtained from accepted bid j in county i. The total environmental benefits (EB) obtained from M is computed as follows

$$EB = \sum_{i=1}^{N} \sum_{j=1}^{bi} BC_{ij} M_{ij} \qquad [3.1]$$

Corresponding to every budget allocation, there is a unique equity level associated it. Traditionally, Gini coefficient developed by the Italian Statistician Corrado Gini provides a mathematical expression of the degree of concentration of wealth or income, and it is frequently used as a summary measure of distributional inequality. For instance, Babcock et al.(1996) use Gini coefficients to measure the effectiveness of spending under alternative targeting criteria. Similarly, in this study, we use Gini coefficient to measure the budget allocation inequality in the CRP.

Let P denote the total population in the N counties, P_i and M_i ($M_i = \sum_{j=1}^{bi} M_{ij}$) the population and allotted conservation funds in the county i ($i = 1, \cdots, N$). Thus, M_i / P_i are the conservation funds per capita in county i. We rank M_i / P_i in an ascending order and let k ($k = 1, \cdots, N$) represent its order, and use the notation $x_{i,k}$ to express the conservation funds per capita in the county i and its rank. Therefore, $x_{i,k}$ equals M_i / P_i in value and ranks the k th among N counties. With these notations, Gini coefficient (G) in formula is

$$G = \frac{2}{N^2 \overline{X}} \sum_{k=1}^{N} k(x_{i,k} - \overline{X}) \qquad [3.2]$$

where $\overline{X}$ is the national average of conservation funds per capita, and equals M / P. The theoretical maximum of Gini coefficient is 1, representing the ultimate inequality. This situation would occur if one county is allotted all budgets and all other counties receive nothing. The minimum value of Gini is 0, representing perfect equity. This happens when conservation funds are equally distributed across the whole population p, that is $x_{i,k} = M / P$.

DATA

The measurements of efficiency and equity suggest that data on the CRP, especially the individual bid data, and population are required. The CRP data are obtained from the Economic Research Service.[1] Population data are from Census Bureau 2000 and reflect the population status in the mid-year of 1999. The descriptive statistics are reported in table 3.1.

There are two types of CRP sign-up: general sign up and continuous sign-up. General sign-up refers to the specific sign-up period that producers with eligible lands compete nationally for acceptance into the program based on their EBI scores, and continuous sign-up refers to the sign-up period that producers with eligible lands may enroll certain high priority conservation practices such as filter strips and riparian buffers at any time during the year without competition (Farm Service Agency 2005). Since the inception of the CRP till

2005, there are 18 general sign-up including sign-up 1-13, 15, 16, 18, 20, 26, and 29, and 10 continuous sign-up including sign-up 14, 17, 19, 21-25, 27, and 30. In this study, we use the CRP enrollment data in the sign-up 18, which was held during the period between October 26 and December 11, 1998, and all accepted contracts were for the fiscal year 2000.[2]

In the sign-up 18, EBI rule was used as the targeting criteria. Seven factors were included to calculate EBI scores. These seven components are:1) N1, wildlife habitat benefits (0 to 100 point); 2)N2, water quality benefits from reduced erosion, runoff, and leaching (0 to 100 points); 3) N3, on-farm benefits from reduced erosion (0-100 points); 4) N4, enduring benefits beyond the CRP contract(0 to 50 points); 5) N5, air quality benefits (0-35 points); 6) N6, conservation priority area benefits (0 to 25 points) and 7) N7, rental payment per acre requested by bidders (0-150 points).[3] The rental payment is translated to points according to the formula a*(1-(annual rental rate per acre/b)), where a and b equaled 125 and 165, respectively in the sign-up 18.[4] The formula is set by Farm Service Agency (FSA), and the values of a and b are determined after sign-up and unknown to bidders. Thus, total EBI points are $(N1+N2+N3+N5+N6)+125(1-rent/165)$, the sum of the environmental and cost points. The total points are 560, of which 410 is from environmental components and 150 from the cost. Evidently, the environmental benefit scores account for 73 percent in the calculation of EBI score, reflecting the primary goal of the program. The national average of EBI score is about 250, with the maximum and minimum scores equal to 423.6 and 60.5, respectively.

There are about 90306 total individual contracts submitted in the sign-up 18 from 43 states.[5] 61559 bids were accepted based on EBI rule. The annual payments invested were about $226 million. However, the distribution of the conservation funds was quiet spatially uneven because the targeting criteria, the EBI rules, primarily focus on environmental benefits.

Eight states in the Great Plains and Western Corn Belt used up about 56 percent total conservation funds. These states include Illinois, Iowa, Kansas, Missouri, Montana, Minnesota, North Dakota, and Texas. The unevenness in the distribution of conservation funds is also reflected by Gini Coefficient, which is about 0.85. Gini coefficient can also be estimated using trapezoidal rule from Lorenz curve. [6] We rank the county level fund per capita under the EBI rule, and use 27 points to construct the Lorenz curve as shown in the figure 3.1, [7] where the 45^0 degree line represents perfect equality, x-axis is the share of counties and y-axis is the share of budget allotted to the counties. The Lorenz curve suggests that about bottom 80% counties receive only about 25% conservation budget, and top10% counties receive about 60% conservation funds. This, consistent with Gini coefficient, indicates a distributional inequality of conservation funds under the EBI rules.

As claimed by Johnson and Clark (2001), under the EBI rules, the CRP maximizes the environmental index per dollar spent rather than the environmental benefits per dollar. Hence, in this study, we use the benefit-cost ratio as the targeting criteria to select bids. To compute the benefit-cost ratio, data on environmental benefits and cost per acre are needed. However, measurements of environmental benefits have long been a challenge to most researchers. Some researchers use contingent valuation methods to estimate willingness to pay (WTP) to preserve the environment, and take WTP as the proxy of the environmental benefits (e.g., Bergstrom et al. 1985; Bowker and Didychuk 1994, Krieger 1999). However, a commonly agreed data on measures of environmental benefits are unavailable.

Because EBI scores measure the expected environmental benefits that land resource provides, we use the sum of environmental benefits index scores per acre in wildlife habitat (N1), water quality (N2), erosion reduction (N3), enduring benefits (N4), air quality (N5), and benefits from conservation priority area (N6) to approximate EB, the environmental benefits per acre associated with land resource offered by bid j in the county i. The nationally average EB is about 166, with the minimum and maximum equal to 16 and 339, respectively. EB_{ij} varies significantly from parcel to parcel with the standard deviation equal to about 44. The rental rate per acre requested by bidders is used to approximate C_{ij}, the cost per acre. On average, the annual rental rate per acre is about \$54. The maximum and minimum annual rental rates per acre requested are \$165 and \$7, respectively.

With the above information, we are able to construct benefit-cost ratio BC_{ij} using the formula $(N1+N2+N3+N4+N5+N6)/C_{ij}$. The benefit-cost ratio on average is 3.66, meaning that one dollar conservation fund invested can obtain 3.66 unit environmental benefits. The maximum and minimum environmental benefits one dollar can obtain is 17 and 0.24, respectively. This suggests that environmental benefits per dollar vary with location greatly. The environmental benefits from each parcel offered are calculated as the product of BC_{ij} and M_{ij}, which is the conservation funds allotted to the accepted bid j in the county i. The mean of environmental benefits per acre (EB), cost, benefit-cost ratio (BC), and county population (POP) by region are reported in the table 3.2.[8] Environmental benefits per acre are the largest in the Corn Belt, and the smallest in the Delta states. Costs per acre are the largest in the Corn Belt since lands in this region are rather productive. In the Mountain, the rental rate per acre requested is only \$34, the smallest among 10 regions, because lands are quite less productive in this area. As for benefit-cost ratio, it is the highest in the Mountain due to low costs there, and the lowest in the Corn Belt because of the highest costs in this area. Among 10 regions, the Northeast is the most densely populated with county average population equal to 157733, much greater than the national average 53643. The Northern Plains is the most sparsely populated with county average population equal to 18740, about one third of the national average.

SIMULATION METHODS

In order to trace out the EEF, we need to reallocate the conservation funds geographically. To trace out the EEF, we begin at the most efficient point, where the environmental benefits are maximized.[9] If we follow benefit cost ratio rule, then the starting point is uniquely defined given the CRP data in the 18th sign-up. Therefore, in this study we start from the most efficient situation and trace out the EEF until the sacrifices in the environmental benefits improve the equity no more. Next, we describe how the most efficient point is defined.

Following the current practice in the acceptance of the CRP bids, all submitted bids are ranked according to their benefit-cost ratios in a descending order, and accepted from the highest benefit-cost ratio until conservation funds are fully spent. For discussion convenience, we call the allocation under the benefit-cost ratio rule as our baseline allocation. Recall that bi represents the total number of bids being accepted into the program in county i. Ranking all accepted and rejected bids by their benefit-cost ratios in a descending order within counties yields the matrix of benefit-cost ratio as follows:

$$BC_0 = \begin{array}{c} \text{County1} \quad \text{County 2} \cdots \text{County i} \cdots \text{County N} \\ \begin{pmatrix} BC_{11} & BC_{21} & \cdots & BC_{i1} & BC_{N1} \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ BC_{1b1-1} & BC_{2b2-1} & \cdots & BC_{ibi-1} & BC_{NbN-1} \\ BC_{1b1} & BC_{2b2} & \cdots & BC_{ibi} & BC_{NbN} \\ \hline BC_{1b1+1} & BC_{2b2+1} & \cdots & BC_{ibi+1} & BC_{NbN+1} \\ \vdots & \vdots & & \vdots & \vdots \\ BC_{1n1} & BC_{2n2} & \cdots & BC_{ini} & BC_{NbN} \end{pmatrix} \end{array} \qquad [3.3]$$

In [3.3], bids above the line are accepted and those under the lines are rejected due to their low benefit-cost ratios. Usually, n_i, the total number of bib submitted,[10] and bi, the total number of bids accepted in a county, vary across counties. Under the baseline allocation, we are able to compute the total environmental benefits and Gini coefficient, which are denoted as EB_0 and G_0, respectively. EB_0 is the maximum total environmental benefits that can be achieved given the constant budget M.

EB_0 and G_0 together define the starting point S, and the possible location of the EEF shown in figure 3.2, where the x-axis and y-axis represent Gini coefficient (G) and total environmental benefits (EB), respectively. There is no allocation that can increase the total environmental benefits given the fixed conservation funds. This indicates that there is no point in the C and D areas, where points are associated with total environmental benefits greater than EB_0. It is possible for budget allocations to produce points in the areas E and F. Compared to the baseline allocation, however, allocations that generate points in the area F are inferior in terms of efficiency and equity since total environmental benefits obtained in the F are lower than EB_0 and Gini coefficients are larger than G_0, suggesting greater inequity. This leaves the shaded area E as the only possible area for the EEF. Therefore, once the point

S is defined, the location of the EEF is defined as well. Our interest is to find those allocations that generate points in the shade area E, where points, compared to S, are associated with improved equities but lower total environmental benefits. This is exactly the purpose of this study-to evaluate the tradeoffs between the efficiency and equity. Next, we discuss how we start from the point S and estimate the EEF in the area E through reallocations of conservation funds.

There are two reallocation ways to reallocate conservation funds in order to improve equities. One is to reallocate conservation funds from accepted bids to rejected bids, and the other is to reallocate conservation funds between counties. In essence, the effect of these two reallocation methods on the equity is same. Below we provide explanations.

For the time being, assume that $\Delta M = \$1$ are reallocated between any accepted and rejected bid. Recall from the equation [3.2] that equity is affected by county-level fund per capita M_i / P_i, and their ranks. Therefore, where ΔM is taken from county i, no matter which accepted bid ΔM is taken from, the county level conservation funds per capita after reallocation, is same; for the county j which ΔM is given to, no matter which rejected bid receives the fund, $(M_j + \Delta M) / P_j$ is same; and more importantly, no matter who the giver (the bid gives the money) is in county i and who the receiver (the bid receives the money) is in county j, all counties' relative rankings are same as long as ΔM is reallocated from the county i to j. This suggest as long as the fund is reallocated between county i and j, the impact of budget reallocation between these two counties on the equity is same. This also implies that reallocation of conservation funds does not happen within a county due to its zero effect on the equity.

However, it matters that who the giver is in the county i and who the receiver is in the county j in term of the effect on environmental benefits. The allocation that makes the minimum sacrifices in the environmental benefits is optimal given that the changes in the equity due to budget reallocation between county i and j are same. We propose that the following produces the optimal allocations.

Claim: ΔM should be taken from the bid with the lowest benefit-cost ratio among the accepted bids in the county i, and redistributed to the bid with the highest benefit-cost ratio among rejected bids in the county j ($j \neq i$).

Proof: suppose $i = 1$, and $j = 2$. Remember that in equation [3.3] all accepted and rejected bids are arranged in a descending order according to their benefit-cost ratio. Thus, BC_{1b1} is the minimum benefit-cost ratio among all accepted bids in the county 1 and BC_{2b2+1} is the maximum benefit-cost ratio among all rejected bids in the county 2. That is,

$$BC_{1b1} < BC_{1b1-1} < \cdots < BC_{11} \qquad [3.4]$$

$$BC_{2b2+1} > BC_{2b2+2} > \cdots > BC_{2n2} \qquad [3.5]$$

We can write any benefit-cost ratio greater than BC_{1b1} as

$$BC_{1b1} + \alpha_l,\ l = 1, \cdots, b1 - 1, \alpha_l > 0 \qquad [3.6]$$

Similarly, we can express any benefit-cost ratio smaller than BC_{2b2+1} as

$$BC_{2b2+1} - \beta_\tau,\ \tau = b2 + 1, \cdots, n2, \beta_\tau > 0 \qquad [3.7]$$

With equation [3.6] and [3.7], we can derive the following equations

$$(BC_{1b1} - BC_{2b2+1}) < (BC_{1b1} + \alpha_l - BC_{2b2+1}) \qquad [3.8]$$

$$(BC_{1b1} - BC_{2b2+1}) < (BC_{1b1} - (BC_{2b2+1} - \beta_\tau)) = (BC_{1b1} - BC_{2b2+1} + \beta_\tau) \qquad [3.9]$$

$$(BC_{1b1} - BC_{2b2+1}) < [(BC_{1b1} + \alpha_l) - (BC_{2b2+1} - \beta_\tau)] = (BC_{1b1} - BC_{2b2+1} + \alpha_l + \beta_\tau) \qquad [3.10]$$

Equation [3.8] to [3.10] show that the loss in the benefit-cost ratio from the accepted bids with the lowest benefit cost ratio in the county i to the rejected bids with the highest benefit cost ratio in the county j is minimized. Multiplying ΔM on both sides of equation [3.8] to [3.10] yields the losses in the environmental benefits due to the reallocation of ΔM . Since multiplying ΔM on both sides of equation [3.8] to [3.10] does not change the direction of the equations, reallocating ΔM from the accepted bids with the lowest benefit-cost ratio in the county i to rejected bids with the highest benefit-cost ratio in the county j ($j \neq i$) minimizes the losses in the environmental benefits.

Following the above reallocation mechanism of conservation funds, the total number of reallocation approaches are $N \times (N-1)$, where N is the total number of source ΔM can come from, and $N-1$ is the total number of receiver counties that ΔM that can go. Here it is a good place to define the reallocation process. We call the reallocation process between any two counties as one-time transfer, and the reallocation process among all counties as one round of transfers. That is, one round transfer includes $N \times (N-1)$ one-time transfers. Every one-time transfer generate one reallocation approach which produces a unique pair of EB and G . Among these $N \times (N-1)$ allocation approaches, we are interested in the one that results in gains in equity at the minimum cost of efficiency. That is, the marginal substitution ratio (MRS) of efficiency to equity is the smallest. Thus, the budget reallocation problem can be formulized as follows

$$\underset{(M_1,\cdots M_N)}{Min} \; MRS = \frac{\Delta TB}{\Delta G}, \; \Delta TB < 0, and \Delta G < 0 \qquad [3.11]$$

where ΔEB and ΔG are losses in the total environmental benefits and gains in equity compared to the baseline allocation, and $(M_1,\cdots M_N)$ is the set of funds allotted to every county associated with every one-time transfer.

Since there is one MRS corresponding to each reallocation approach, the first round of transfer of ΔM creates a vector of MRS1, which include $N \times (N-1)$ elements. The reallocation approach that generates the minimum MRS in the MRS1 defines the second point on the frontier and a new set of accepted and rejected bids. This optimal allocation is called OA1. Then, based on OA1, we repeat the above budget allocation mechanism until no further reallocation that can improve the equity at the cost of efficiency. That is, reallocations terminate when $\Delta G = 0$. Because every round of transfer produces a point, connecting all points creates the EEF under the reallocation of ΔM.

Above we assume $\Delta M = \$1$, which the giver is able to give and the receiver is able to take. Under the case of reallocating a relatively large amount such as $5000, then one situation may occur is that when reallocation amount is large, the bid having the lowest benefit-cost among the accepted bids in the county i may not have enough money to offer, and the bids having the highest benefit-cost ratio among the rejected bids in the county j may not request such big money. Under this situation, the money is first taken from the one with the lowest benefit-cost ratio in county i, and then from the one with the second lowest benefit-cost ratio and so on until the reallocation amount is collected. In the county j, the money first goes to the one with the highest benefit-cost ratio among the rejected bids, and then the left money goes to the one with the second highest benefit-cost ratio and so on until the total reallocation money is spend. To make the reallocation of large amount feasible, we make one assumption that the bidders are willing to enroll their lands proportionately. This assumption is necessary especially when money is only enough to purchase a portion of their offered land. Also, with this assumption, it is guaranteed that no money is left unused.

ΔM, the reallocation amount affects the EEF as well, particularly the ending part of the EEF. Compared to the reallocation of large amount, the reallocation process in the case of small amount such as $1 converges at a greater equity level, because with small reallocation amount we can make slight changes of conservation funds among counties and be able to further improve the equity at slight sacrifices in efficiency. However, it is too time consuming for the process to converge in the small reallocation amount case, because the effect of reallocating small amount results in tiny effects on the changes of equity, and if the total possible improvement in equity is quite constant as we show below, then it takes tremendous rounds of transfer for the reallocation process to finish. Given the advantages and disadvantages associated with reallocation of large and small amount, we need to analyze their feasibilities and decide what amount to transfer in our simulations.

FEASIBILITY ANALYSIS OF SIMULATION METHODS

The above reallocation mechanism described is quite simple and is applied in simulations to estimate the EEF in the case of the CRP. However, one big concern is its feasibility in terms of simulation time. The simulation time is determined by two factors. One factor is the time needed to finish one round of transfer to define one point in the frontier under modern computation technique, and the other is the number of round of transfers needed for the reallocation process to converge, that is $\Delta G = 0$.

According to the above reallocation mechanism, one round of transfer includes $N \times (N-1)$ times of one-time transfer. Namely, $N \times (N-1)$ times of calculation create a point on the EEF. There are 2015 counties in our data, and it means 4058210 times of calculation are needed to produce a point. Given modern computation capacity, our test simulation suggests that in the case of reallocating \$1, 10000 times of calculation takes about 1 minute. Thus, it takes about 7 hours to generate one point. It is anticipated from our test simulation that at lease 20 million points are needed to finish the reallocation process for 10 percent sample data. Obviously, it is too time consuming.

One way to reduce time needed for one round of transfer is to reallocate \$1 from rich counties to poor counties, because equity measures the distribution of wealth and it can be improved only if wealth is distributed from the rich to the poor. For example, if $C1, C2, C3, \cdots CN$ is the ranked county order based on M_i / P_i, and then reallocation of funds only goes from $C1$ to $C2$, $C1$ to $C3$, $\cdots$, and until $C1$ to CN, but not the other way, that is, ΔM does not go from $C2$ to $C1$, $C3$ to $C1$, $\cdots$, and CN to $C1$. As a result, $N \times (N-1)/2$ times of transfer are needed to define one point. It takes about 3.5 hours in the case of 2015 counties to generate a point.

Although the above refinement in simulation method greatly reduces the time, it is still infeasible. Therefore, instead of using the full data, we randomly select 10% sample from the original data. A 10% sample includes approximately 200 counties, and hence it decreases the computation time of one point to about 4 second.[11] Using sample data can greatly reduce the time needed for the generation of one point, but it can not reduce the round needed to finish the process. Reallocation amount affects the number of rounds of transfer to finish the reallocation process, but it is hard to decide what amount is reasonable.

To examine how sensitive an EEF is to large and small reallocation amounts, and how robust the patterns of EEF are to alternative samples, we take three 10% random samples from the original data for our simulations.[12] Using sample 1, we try three reallocation amounts, \$500, \$1000, and \$5000 to test the sensitivity of EEF to reallocation amounts. Using sample 2 and 3, we conduct simulations based on a reallocation amount of $500 to examine how robust the patterns of EEF are.

To identify the distribution pattern of conservation funds, a simulation based on full data is conducted.[13] Because 2015 counties are involved, it takes one-time transfer long time to finish. Given the limit of computation capacity, we need to reallocate a relatively amount in the transfer to make simulation feasible. Since the average budget requested by county is $156542, and the average county population is about 53643, thereby we choose $50000 as our reallocation amount. Test simulation shows that transfer of $50000 improves the equity by 0.001 approximately. Thus, transferring some small amount is infeasible because it would increase the computation time dramatically. This simulation based on the full data also can demonstrate how the sample data represents the full data.

SIMULATION RESULTS

Based on the above simulation mechanism, we estimate six EEFs.[14] Among these six EEFs, three of them are estimated under the reallocation amount of $500, $1000, and $5000 based on sample 1. Another two EEFs are estimated under the reallocation amount of $500 based on sample 2 and 3. The last EEF is estimated based on the full data by reallocating $50000. Based on these six EEFs, we are able to discover the patterns of EEF and tradeoffs between efficiency and equity. More importantly, we identify the distribution pattern of conservation funds among 10 examined regions based on the EEF estimated from the full data.

Tradeoffs between Efficiency and Equity

The three EEFs estimated under different reallocation amounts based on sample 1 are shown in the figure 3.3, where EEFs in the panel (a), (b) and (c) correspond to the reallocation amount of \$500, \$1000, and, \$5000, respectively. In the figure 3.3, EBI_1 represents the point generated under EBI rule and $S1$ the starting point defined by the baseline. These three EEFs share the same EBI_1, and $S1$, because they are all estimated based on sample 1. At EBI_1 and $S1$, total environmental benefits obtained are 99281318 and 91224951, respectively; Gini coefficient is 0.8732, and 0.8355, respectively. This result proves that the environmental benefits obtained under benefit-cost ratio rule are greater than that under the EBI rule, suggesting that benefit-cost ratio rule is more efficient than EBI rule. Although both targeting rules ignore equity, benefit-cost ratio rule results in a more unequal allocation of conservation funds since its Gini coefficient is greater than that under EBI rule. Z_1^{500}, Z_1^{1000}, and Z_1^{5000} in the figure 3.3 represent those allocations under the three reallocation amount of \$500, \$1000, and \$5000 that generate the same equity level as EBI_1 but higher environmental benefits. This suggests that the allocation under EBI rule is not optimal because there exists one allocation on the frontier that generates larger environmental benefits, or there exists one allocation (not shown in the graph) that can achieve the same level environmental benefits but at a better equity level.

Q_1^{500}, Q_1^{1000}, and Q_1^{5000} in the figure 3.3 denote the end point of EEFs under the reallocation amount of \$500, \$1000, and \$5000. Table 3.3 reports the environmental benefits and Gini coefficients at the end point under these three reallocation amounts based on sample 1. The largest and smallest environmental benefits are obtained at Q_1^{5000} and Q_1^{500}, respectively, and the difference in the environmental benefits between them is 5.2E+5. Gini coefficient is the smallest (0.6916) at Q_1^{500}, and largest (0.6985) at Q_1^{1000}. The difference in the Gini coefficient between the smallest and largest is only about 0.007. This indicates that reallocation of small amount results in a slightly greater level of equity when reallocation process converges.[15] These findings imply that reallocation amount affects the end point of the EEFs, but the effect is quite small. This finding is graphically displayed in the figure 3.4, where most parts of the three EEFs overlap, except that the ending part of green curve diverges from the end part of the other two curves slightly.

Comparison of environmental benefits and Gini coefficients between the starting and ending point gives the tradeoffs between efficiency and equity. The final level of equity achieved at Q_1^{500}, Q_1^{1000}, and Q_1^{5000} is about 0.69, which is improved by 20 percent compared to the equity level at $S1$ (0.8732). The environmental benefits at these three end points are about 8.1E+7, which is approximately 18 percent less than the environmental benefits (9.9E+7) obtained at $S1$. These results reveal that 18 percent sacrifices in the environmental benefits can result in at most 20 percent gains in the equity under sample 1.

Table 3.3 also reports the number of points and time needed for the reallocation process under the three reallocation amounts to converge. Result shows that reallocation amount affects the number of points and time needed for the reallocation process to converge as well. In the case of reallocating \$500, 26908 points are needed for reallocation process to converge, and the whole reallocation process takes about 26 hours. While in the case of reallocating \$5000, 2322 points are needed and it takes only about 4 hours for the reallocation process to converge. Therefore, it is time-effective to reallocate a large amount. This result combined with the small effects of large reallocation amount on the EEF suggests that reallocating a large amount is more feasible than reallocating a small amount.

To examine the robustness of the pattern of EEFs, we conduct another two simulations based on sample 2 and 3. The estimated EEFs under the reallocation amount of $500 and the position of EBI points based on these two samples are shown in the figure 3.5. EBI_2 and EBI_3 are points defined by EBI rule based on sample 2 and 3. $S2$ and Q_2 , and $S3$ and Q_3 are the starting and end points based on sample 2 and 3, respectively. Although different samples affect the position of the frontiers, these two EEFs show similar patterns as those observed in sample 1 in terms of the shape of EEF, and the relative position of EBI point.

EEF estimated based on full data under the reallocation amount of $50000 is illustrated in the figure 3.6, which shows similar patterns as those in the three samples. Thus, we conclude that our samples represent the full data quite well, and it is helpful to obtain preliminary results based on samples to shed lights on the patterns of EEFs in the case of large size data. In the figure 3.6, EBI_F is the point defined by EBI rule and locates below the frontier. Environmental benefits at EBI_F equal 9.3E+8, smaller than 10.1E+8, the environmental benefits at the starting point, S_F, defined by the benefit-cost ratio rule. Gini coefficient at S_F is 0.8852, larger than 0.8497, the Gini coefficient at EBI_F. The point with the same equity level as EBI_F is denoted as Z_F, where the environmental benefits are 9.9E+8, 6E+7 greater than the environmental benefits at EBI_F.

We are able to discover the maximum tradeoffs between efficiency and equity by comparing changes in the total environmental benefits and Gini coefficient between the starting and ending points on the EEF. Q_F in the figure 3.6 is the ending point. At Q_F, total environmental benefits are 8.78E+8, about 13 percent less in the environmental benefits compared with benefits at S_F. These 13 percent losses in the total environmental benefits result in about 14 percent gains in the equity, Gini coefficient decreasing from 0.8852 to 0.7625. This shows that approximately a 1% sacrifice in the efficiency leads to a 1% gain in the equity.

If a small reallocation amount is transferred, then the equity would be further improved as suggested by the results based on sample 1. However, it would be extremely time-consuming for the reallocation process to converge under the full data, since it takes the reallocation process 114 hours to converge under the reallocation amount of $50000 and totally 1418 points are generated.

Comparisons of Distributions of Conservation Funds

Comparison the shares of conservation funds at different points reveals the distribution pattern of conservation funds. Table 3.4 reports the share of conservation funds under four allocations in the 10 examined regions. The four allocations correspond to the points at EBI_F, S_F, Z_F, and Q_F. Below we compare the distribution pattern of conservation funds among these four points. Four comparisons are presented: EBI_F vs S_F , S_F vs Q_F, and Z_F vs EBI_F.

EBI Rule vs. Benefit-Cost Ratio rule

We first compare distributions of conservation funds under EBI rule (EBI_F) and benefit-cost ratio rule (S_F). Under EBI rule, conservation funds in the sign-up 18 concentrated in the Northern Plains (25.85%), Corn Belt (20.17%), and Mountain areas (16.58%), where about 63 percent of total conservation funds are invested. Under benefit-cost ratio rule, the Mountain (20.86%) and Northern Plains (34.32%) receives a higher share of conservation funds than that under EBI rule because benefit-cost ratios are relatively high in these regions due to the low costs and large amount of submitted bids. However, under the benefit-cost ratio rule, the Corn Belt receives only 5.26 percent of conservation funds, about 15 percent less than the share received under the EBI rule. This striking difference in the share of conservation funds in the Corn Belt is caused by targeting criteria. Under EBI rule which places a heavy weight on environmental benefits rather than costs of resources, bids in the Corn Belt have the priority to get accepted into the program because the environmental benefits per acre are the largest among 10 regions. Yet, since the average costs (annual rental rate) in the Corn Belt are about $82 per acre, the greatest among 10 regions due to the productive lands in this region, the benefit-cost ratios are the lowest among the 10 regions. As a consequence, under benefit-cost ratio rule, bids lose the priority to get accepted into the program in the Corn Belt.

The shares of conservation funds in the Northeast and Appalachia are the two smallest among the 10 regions under benefit-cost ratio and EBI targeting criteria because the number of bids submitted in the Northeast is quite small, and both benefit-cost ratios and EBI scores in the Appalachia are relatively low among the 10 regions. In other regions, the shares of conservation funds under these two rules are quite close, although the shares under benefit-cost ratio rule are slightly larger than that under EBI rule for most regions.

<u>Efficiency vs. Equity</u>

Q_F, the ending point of the frontier, represents the allocation with the greatest equity under the reallocation amount of $50000. Recall that equity measures the distribution of conservation funds across population. Hence, the share of conservation funds allocated to a region is affected by the population within the region. In addition, the share is also affected by the number of bids submitted, or more specifically by the total amount of funds requested in this region. At Q_F, the Mountain, Northern and Southern Plains receive 46 percent of conservation funds, which is about 23 and 8 percent less than the share received at S_F (benefit-cost ratio rule) and EBI_F (EBI rule), respectively. This is because the Mountain, Northern and Southern Plains are relatively sparsely populated, with average county population smaller than the national average 54643. The Corn Belt receives over 23 percent of conservation funds at Q_F, 18 percent larger than the shares obtained at S_F This is because the Corn Belt is densely populated compared to the Mountain and Great Plains and large amount of bids were submitted in the sign-up 18. Remember that comparison of S_F and Q_F show that 13 percent sacrifices in the efficiency result in approximately 14 percent gains in the equity. These tradeoffs between efficiency and equity are mostly attributed to the transfer of conservation funds from the Mountain and Plains to the Corn Belt.

In other regions, the shares of conservation funds are slightly larger at Q_F than S_F. The Lake States is allocated relatively greater share of conservation funds at Q_F since the population here is dense with average county population equal to 74255, larger than the national average. The Northeast receives the least share of conservation funds due to the small amount of submitted bids, although this region has a very dense population.

Evaluation of EBI Rule

At Z_F, the equity level is same as the equity level at EBI_F. However, the environmental benefits (6E+7) are larger than that obtained at EBI_F. Understanding the gains in the efficiency at Z_F is helpful for policy makers to improve the performance of EBI rule in efficiency. Comparison of the share of conservation funds in the Corn Belt at Z_F and EBI_F shows that the gains in efficiency at Z_F are achieved mostly by transferring conservation funds from the Corn Belt to the Mountain, Northern and Southern Plains. This makes sense because the benefit-cost ratios in these three regions are larger than the ratios in the Corn Belt.

POLICY IMPLICATIONS

Our simulation results have implications on the policy design and implementation of the CRP. The EEFs based on three small samples suggest that the reallocation of large amount has a small effect on an EEF in terms of the convergence level of equity and simulation time. Therefore, if the study area is small such as one region, it is desirable and feasible to transfer a large amount of conservation funds to estimate an EEF in order to provide policy makers with the tradeoffs between efficiency and equity. For a large study area, an EEF based on reallocation of large amount can provide preliminary results about the patterns of EEF, performance of alternative targeting criteria, and the rough estimation of tradeoffs between efficiency and equity. Such information helps policy makers select targeting criteria, and decide whether it is worthwhile to estimate the EEF based on full data to disclose the tradeoff between efficiency and equity because preliminary results may suggest insignificant tradeoffs between efficiency and equity.

Results suggest that about a 1 percent gain in the equity are obtained at a 1 percent cost of efficiency. This tradeoff relationship can help policy makers evaluate the magnitude of losses in efficiency in order to achieve their desired equity level. For instance, suppose that 0.8 is the value of Gini coefficient desired by policy makers in the case of CRP in sign-up 18, and compared to equity level under benefit-cost ratio rules the equity has improved by 9.6 percent

(9.6=100%*(0.8852-0.8)/0.8852). According to the estimated tradeoff relationship, 9.6 percent gains in equity require approximately 9.6 percent losses in efficiency.

Furthermore, findings about the distribution pattern of conservation funds under alternative targeting rules imply that if maximizing environmental benefits is the sole goal of the program, then benefit-cost targeting criteria are more efficient than EBI rule and the conservation funds should be targeted to purchase resources in the Mountain and Great Plains; if equity is another concern of the program, then conservation funds should be diverted from the Mountain and Plains to the Corn Belt.

We also evaluate the performance of EBI rule in this study, and we find that EBI rule is not optimal in terms of efficiency and equity, because there is one allocation on the EEF that generates larger environmental benefits with the same level of equity; and there is one allocation on the EEF that achieves a better equity level but with same level of efficiency. Consequently, in order to improve the efficiency of EBI rule, more weights should be put on the environmental factor in the calculation of EBI score. This policy implication is consistent with the changes in EBI scoring structure between the 15th sign-up and 18th sign up. The weight of environmental factor (N1+N2+N3+N4+N5+N6) has increased from 67% in the 15th sign-up to 73% in the 18th (USDA, 2005).[16] Since the 18th sign-up, the weight of environmental factor is remained at about 73%, although some changes were made in the scoring rules within the subcategories of N1 to N6.

CONCLUSIONS

Efficiency and equity are perhaps the two most important criteria for policy selection. However, these two criteria are often incompatible. In the case of resource conservation and environmental protection, purchasing funds are usually targeted to improve efficiency. While targeting improves efficiency, political considerations often focus on equity issues. In this study, we examine the tradeoffs between efficiency and equity in the case of the CRP. The estimation of the tradeoffs is fulfilled by estimating the Efficiency-Equity Frontier (EEF) by reallocating conservation funds among geographic regions. Results suggest that our reallocation mechanism works well in the estimation of the EEFs, and that the reallocation of a large amount is feasible given its small effect on an EEF and simulation time.

On the basis of the estimated EEF using full data, the tradeoffs between efficiency and equity are calculated. It is found that a 13% sacrifice in the efficiency can improve the equity by 14%. On average, a 1 percent gain in the equity can be achieved at a 1 percent sacrifice in the efficiency. This finding enables policy makers to estimate the losses in the efficiency at different levels of equity, thus, can help policy maker select the optimal policy.

We compare the shares of conservation funds under alternative targeting criteria in the 10 examined agricultural production regions, and discover the spatial distribution patterns of conservation funds. Under the benefit-cost ratio rule, a large share of conservation funds should be targeted to purchase the resource in the Mountain and Plains, and a relatively small share should be invested in the Corn Belt. However, under the equity rule, a relatively higher share of conservation funds should be invested in the Corn Belt, and a moderate share of conservation funds in the Mountain and Plains.

Evaluation of the performance of EBI rule is presented in this study as well. Results imply that EBI rules are not optimal in the purchase of environmental benefits. To improve the efficiency of EBI rule, we suggest that more weight should be placed on the environmental factor in the calculation of EBI score.

ENDNOTES

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[1] We thank Shawn Bucholtz of the Economic Research Service for providing the CRP data.

[2] The contract year for the fiscal year 2000 began from October 1, 1999.

[3] N1, N2 and N5 are composed of several subfactors. N1 includes six subfactors: N1a-wildlife habit cover benefits (50 points), N1b-endangered species (15 points), N1c-proximity to water (10 points), N1d-adjacent protected area (10 point), N1e-wildlife enhancement (5) and N1f-restored wetland and upland cover (10 points). The formula to compute N1 score is N1=(N1a/50)x(N1a+N1b+N1c+N1d+N1e+n1f). N2 includes four subfactors: N2a-loation points (30 points), N2b-ground water quality benefits points(20 points), N2c-surface water quality benefits points (40 points), and N2d-wetland benefits points(10 points). The formula to calculate N2 is N2=N2a+n2b+N2c+N2d. N5 includes three subfactors: N3a-wind erosion impact (25), N5b-wind erosion soils (5 points), and N5c-air quality zone(5). The formula to calculate N5 is N5=N5a+N5b+N5c. Data source is United States Department of Agriculture(USDA,1999)

[4] a equals 125 in sign-up 20, 26, and 29. b increases to 185 in sign-up 26 and 29, and to 200 in sign-up 33.

[5] In the simulation, 420 contracts are excluded due to missing value.

[6] Lorenz curve is a graphic representation of the proportionality of a distribution (the cumulative percentage of the values).

[7] The ratio of F to $F+G$ in the figure 3.1 is defined as the Gini coefficient.

[8] The Economic Research Service (ERS) divides the contiguous U.S. into 10 farm production regions from west cost to east coast as the Pacific, Mountain, Northern Plains, Southern Plains, Lake States, Corn Belt, Delta States, Northeast, Appalachian, and the Southeast. We divide the contiguous U.S. into the above 10 regions.

[9] Because EEF captures the tradeoffs between efficiency and equity, there are two ways to begin our budget reallocation. The first one is to begin at the most equitable situation, and the other is to begin with the most efficient situation. The most equitable situation is that conservation funds are distributed equally across population. Under this situation, every county receives conservation funds equal to $P_i(M/P)$. However, the total conservation funds requested by counties may be greater or smaller than $P_i(M/P)$. Hence, we need to deal with the extra money from some counties. Then, the question is how to allocate the extra funds to those counties that request funds more than $P_i(M/P)$. Should we allocate the extra money following equity rule or efficiency rule? Since different rules generate different starting point, it affects EEF.

[10] One assumption we make is that when equity is taken into account the total number of bids

does not change. Without this assumption, our simulation mechanism still works but we are not able to use the data to conduct simulations.

[11]In the case of 200 counties, there are 40,000 times of computations are needed to yield a point. 10,000 times of computations in the case of 200 counties takes about 1 second instead of 1 minute in the case of 2015 counties, because the internal machine computation time involved in the former case is much less than in the latter case. That is why 40,000 times of computations only take about 4 seconds.

[12] Ideally, it would be desirable to conduct more simulations. However, it is time-consuming to conduct one simulation; thus, we only conduct simulations based on three samples.

[14] All simulations are conducted in SAS, and all graphs are created using the software SigmaPlot.

[15] Actually, to investigate what equity level the reallocation process can possibly achieve, we take the Q_1^{500} as the starting point and reallocate \$1 to examine how much gains in equity can be obtained. The result shows the equity level can be further improved only by 0.009, which takes 14 hours to generate extra 66482 points for the process to converge.

[16] In the 15th sign-up, the total points are 600, of which 200 are the points of cost factor (N7). Hence, cost factor accounts for 33% of total scores.

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Table 3.1. Variable Descriptions and Statistics

Variables Descriptions	Mean	Std	Min	Max
N1: EBI score in wildlife habitat	54.1	20.9	0.0	100.0
N2: EBI score in water quality	37.3	18.4	0.0	93.0
N3: EBI score in soil Erosion	40.5	32.7	0.0	100.0
N4: EBI score in enduring benefits	17.5	16.4	0.0	50.0
N5: EBI score in air quality benefits	6.75	7.00	0.0	35.0
N6:EBI score in conservation priority benefits	7.67	12.4	0.0	25.0
EB: Sum of N1-N6	165.9	43.5	16.0	339.0
EBI: Sum of N-N7	249.5	31.6	61.5	422.6
Cost: Annual rental rate per acre	52.0	24.5	7.0	165.0
BC: Benefit-cost ratio	3.6	1.5	0.2	17.0
Budget: Fund requested per contract($)	3508.5	4933.3	10.9	2.4E+5
CB: Average fund requested by county($)	1.6E+5	3.4E+6	60.0	5.3E+6
Acres: Acres under CRP contract	78.6	117.2	0.1	6422
POP: average county population	53643	96946.5	356.0	1.1E+6

Table 3.2. Comparison of Statistics of Major Variables by Region

Region	EB	Cost	BC	EBI	POP
Pacific	173	45	4.3	263.6	74894
Mountain	163	34	5.1	262.3	43371
Northern Plains	159	45	3.9	250.1	18740
Southern Plains	155	35	4.4	252.8	35060
Lake States	162	57	3.2	243.2	74255
Corn Belt	182	82	2.4	245.0	56098
Delta States	150	38	4.2	245.7	36153
Northeast	171	46	4.1	261.5	157733
Appalachia	156	49	3.3	243.9	56129
Southeast	156	37	4.5	253.2	48001
U.S.	164	52	3.6	249.5	53643

Table 3.3 Environmental Benefits (EB) and Gini Coefficient (G) at End Point under Three Reallocation Amounts Based on Sample 1

Reallocation Amount (End Point)	Environmental Benefits		Gini Coefficient		Number of Points	Time (hrs)
	EB	% of Loss	G	% of Gain		
\$500 (Q_1^{500})	8.093e+7	18.48	0.6916	20.80	26908	26
\$1000 (Q_1^{1000})	8.106e+7	18.36	0.6926	20.68	12804	14
\$5000 (Q_1^{5000})	8.145e+7	17.96	0.6985	20.01	2322	4

Table 3.4. Distributions of Conservation Funds under Four Allocations
Based on Full Data, by Region

Regions	Shares of Funds Allotted (%)			
	S_F	Z_F	EBI_F	Q_F
Pacific	5.22	4.45	5.80	5.53
Mountain	20.86	19.74	16.58	11.82
Northern Plains	34.32	30.94	25.85	22.63
Southern Plains	13.36	13.35	10.98	11.30
Lake States	10.51	11.43	10.30	13.51
Corn Belt	5.26	9.26	20.17	23.34
Delta States	4.27	4.35	3.91	4.80
Northeast	0.31	0.30	0.36	0.38
Appalachia	1.45	1.50	1.86	1.96
Southeast	4.44	4.00	4.20	4.73

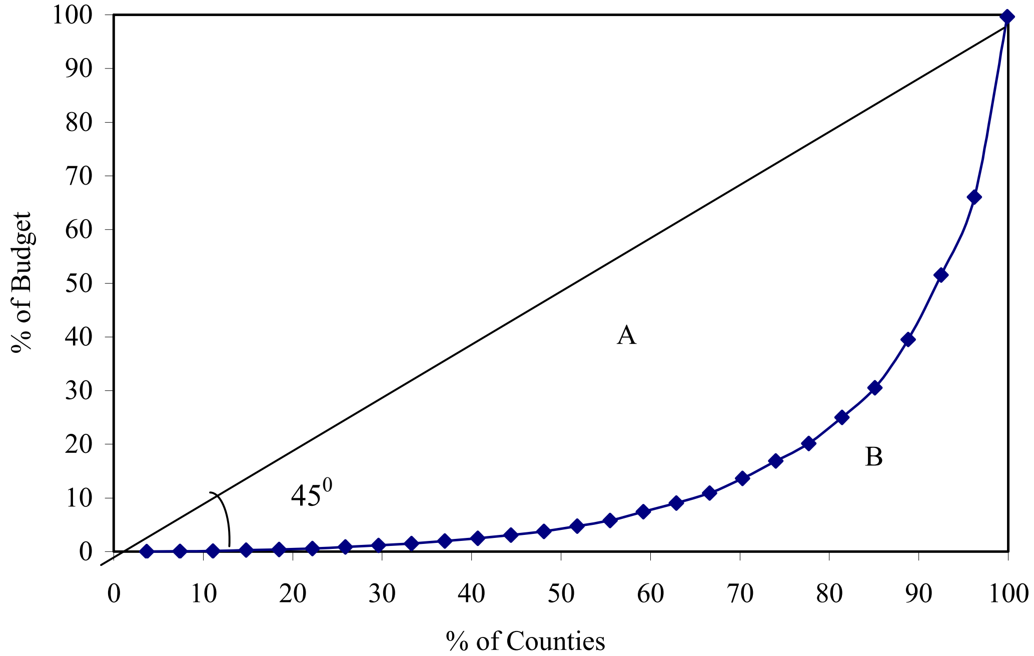

Figure 3.1. Budget Allocation Lorenz Curve under EBI Rule

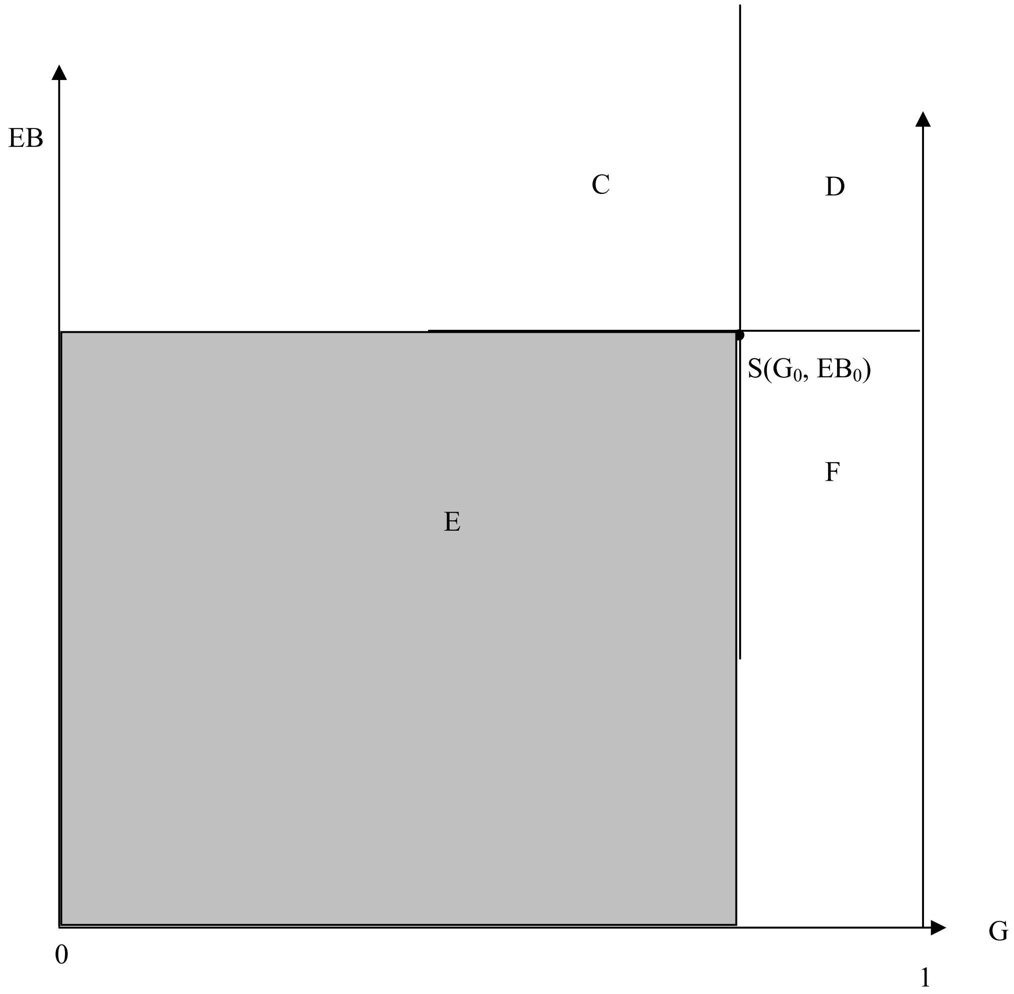

Figure 3.2. The Location of the Efficiency and Equity Frontier

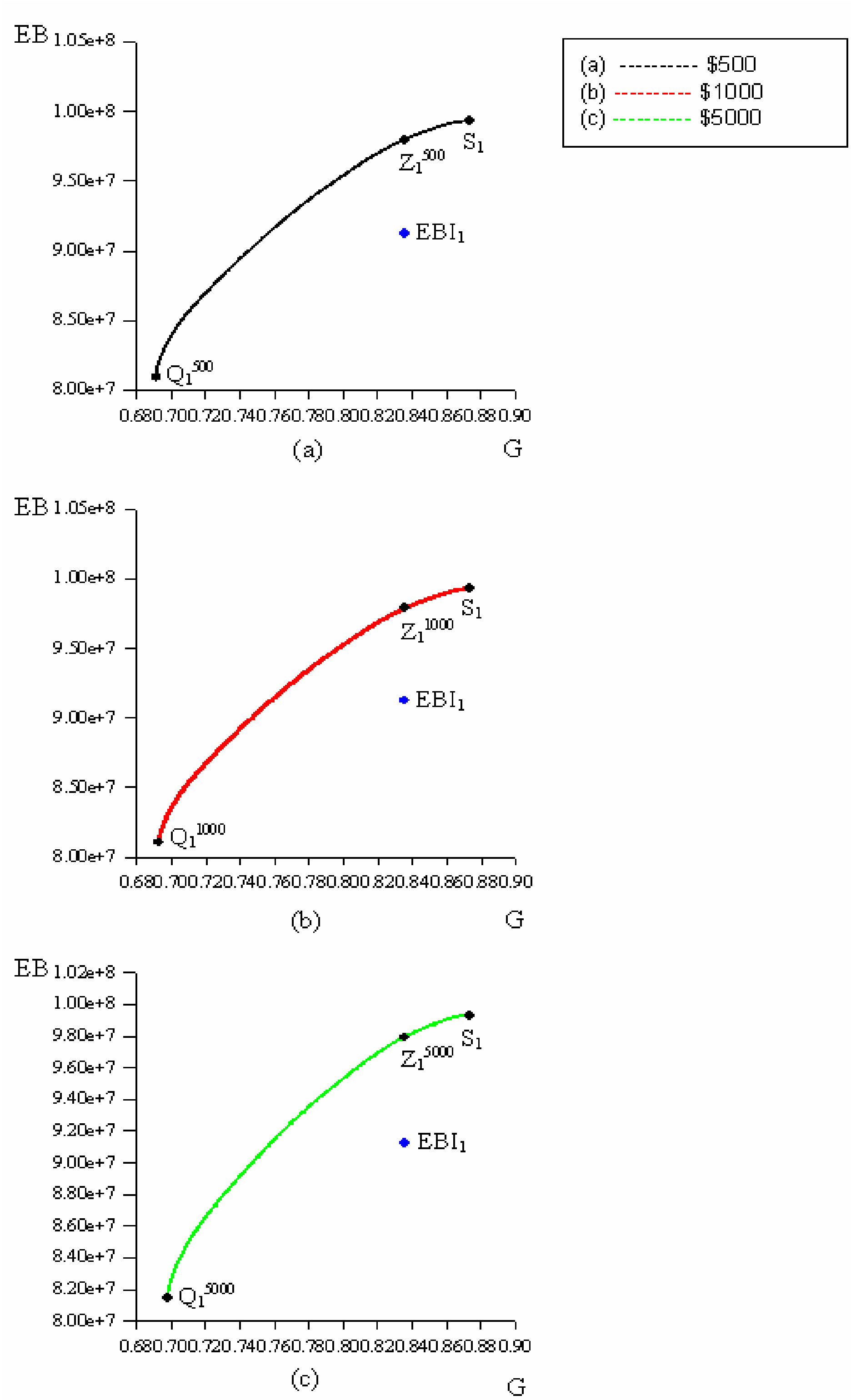

Figure 3.3. Efficiency Equity Frontiers under Three Allocations Based on Sample1

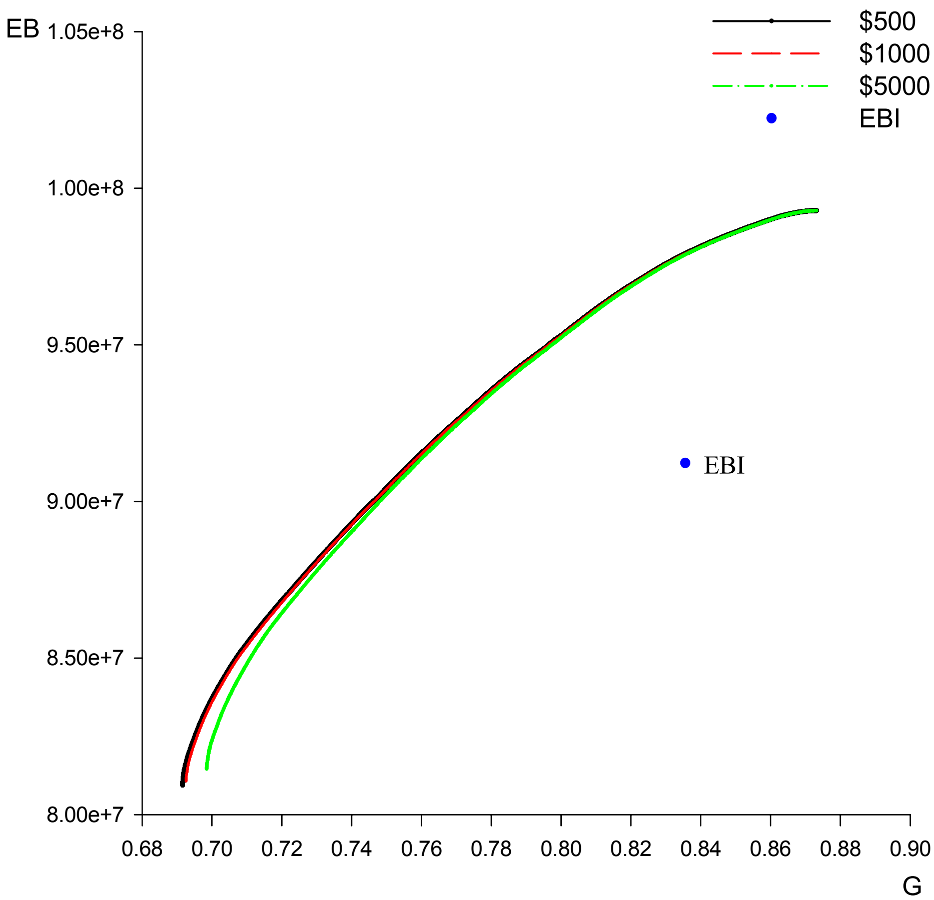

Figure 3.4. Comparison of Efficiency-Equity Frontiers under Three Allocations Based on Sample1

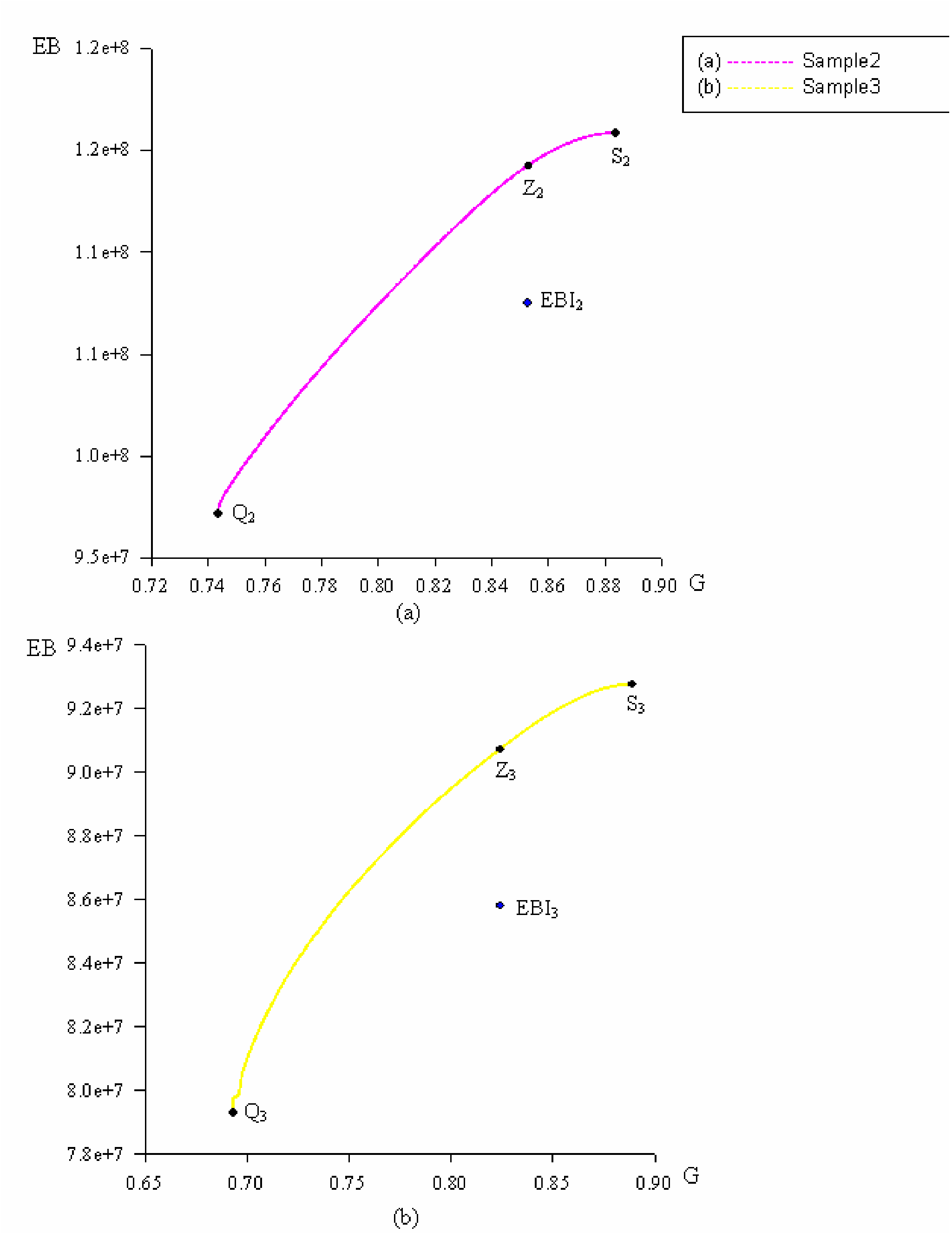

Figure 3.5. Efficiency-Equity Frontiers under $500 Reallocation Based on Sample2 and 3

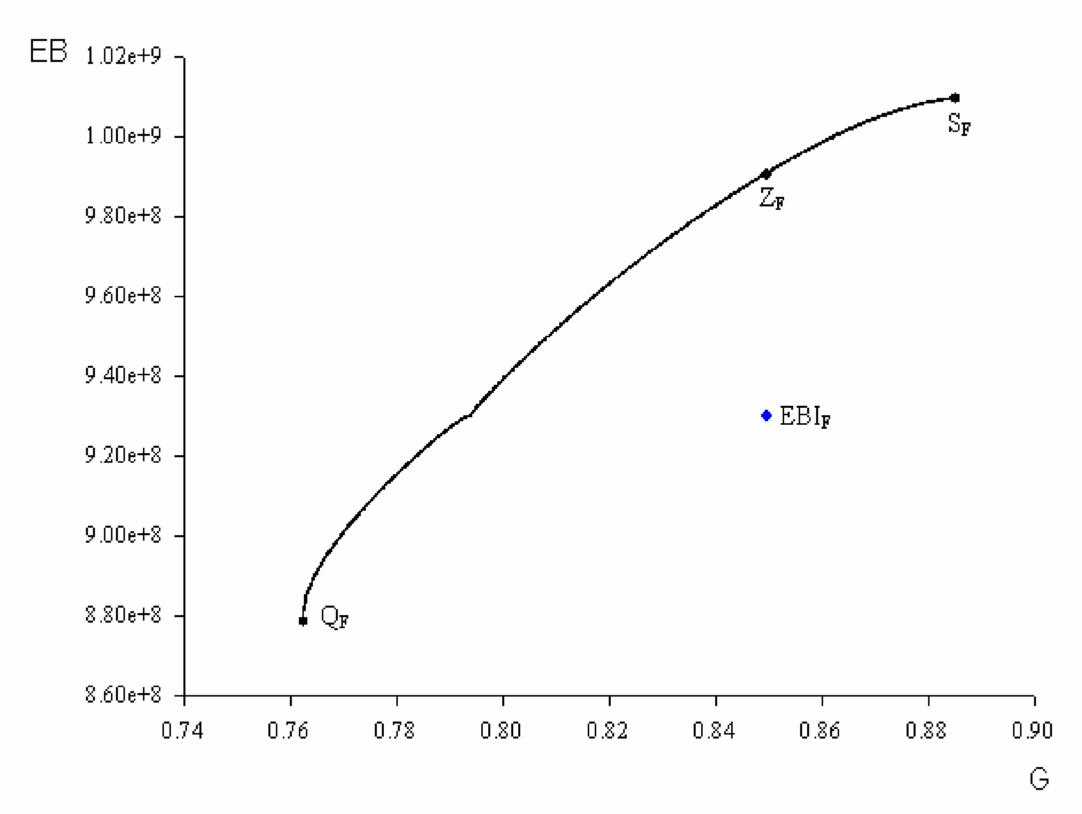

Figure 3.6. Efficiency-Equity Frontier Based on Full Data

CHAPTER 4

NATURAL AMENITIES, INCOME MIXES, AND ENDOGENOOUS COMMUNITY CHARACTERISTICS

HAIXIA LIN
& JUNJIE WU, PROFESSOR

ABSTRACT

The paper explores the interaction between location decision of different income groups and community characteristics. A theoretical model is developed to analyze the location decisions of households who are affected by natural amenities, public services and other community characteristics. Based on the theoretical model, a simultaneous equation system is estimated. Results show that income mixes indeed interact with the local public services in the communities. The share of low and high income households is negatively and positively associated with the level of public services, respectively. The level of public service is negatively associated with the share of low income households, but positively associated with the share of high income households. Communities with better natural amenities, higher education attainment, higher share of owner occupied housing, and higher employment rates tend to have more high-income households, and communities more distant from metropolitan and with more female-headed households tend to have more low-income households. Results also have important policy implications for poverty reduction.

INTRUDUCTION

Substantial income variation is present across communities in the United States. Some communities are inhabited largely by high-income households, others by those largely in poverty. For example, over 50% of households in Douglas County in Colorado had incomes above $75,000 in 2000, while more than 50% of households in Buffalo County, South Dakota were in poverty (Census Bureau 2000). On the other hand, there exists significant variation in public services across communities. Take public education as an example. Public education spending per capita is as high as $6,539 in Lake County in Colorado, but only $39 in Platte County in Suffolk City in Virginia, much lower than the national average $1,128. The question then is what causes variations in income and public services across communities, and do these two variations affect each other? To answer the above questions adequately, we need to understand how households with various incomes make location decisions.

The primary objective of this study is to investigate how households distribute themselves across communities, and more generally how community characteristics serve to attract alternative income groups, and how these alternative income groups in turn have impacts on community characteristics, especially public services. The answers to these questions are important because income distribution directly affects a community's economic base and vitality, and because understanding the attraction of community characteristics to alternative income groups is critical to local policy makers.

A number of studies have examined households' location decisions. In the public finance literature, Tiebout sorting has been traditionally the theoretical foundation of community selection. The argument, first proposed by Tiebout (1956), is that households sort themselves across local jurisdiction according to their public good preferences. The Tiebout framework has been the basis for numerous economic and political science articles (Rhode and Strumpf 2003). These studies, for example, include Epple, Filimon and Romer (1984), Epple and Romer (1991), Fernandez and Rogerson (1997), and Wooders (1999), among others. Some recent examples include Nechyba (1999;2000), who study education spending; Perroni and Scharf (2001), who analyze generic local public goods.

Several other theories have been advanced to explain why rich households make different location decision than poor households. For instance, Schmidheiny (2002;2006) proposes that the progressivity of local income taxes as a new theoretical explanation for income segregation of the population; and Ross and Yinger (1999) in their literature survey suggest that property tax explains the income sorting.

In the urban economic literature, the classic monocentric-city model, developed by Alonso-Mills-Muth, assumes that the income elasticity of housing demand is greater than the income elasticity of commuting costs, and thus, wealthier households tend to live in suburbs. However, the validity of the assumption is called into question by empirical evidence from Wheaton (1977).

The other important factor affecting location decisions by income group is the heterogeneity of amenities across jurisdictions. Brueckner et al. (1999) suggest that even if the income elasticity of housing demand is identical to the income elasticity of commuting cost, income segregation is likely to occur if amenities are spatially heterogeneous across communities. Brueckner et al. use this amenity-based theory of residential location decisions to explain why high-income households in the urban United States tend to live in suburbs, but in the city center in Paris. Wu and Cho (2002) study the income distribution and suggest that the ignorance of amenities would result in a biased estimate of preference parameters. Wu (2006) develops a theoretical model to analyze the residential location decisions and community's characteristics and finds that socioeconomic characteristics of communities are heavily influenced by their environmental characteristics.

Compared to the rich literature on income segregation theories, there are far fewer empirical studies on income segregation. In the limited empirical work, metropolitan areas are frequently the study areas. Friedman (1981), Nechyba and Strauss (1998) study the location choice of households in the San Francisco area and suburbs of Philadelphia, respectively, and find that public expenditures are an important locational factor. Epple and Sieg (1999a), and Epple, et al. (2001) empirically model community choice as the result of sorting on public goods provision and housing prices in 92 communities in the Boston areas. Feld and Kirchgässner (2001) find that the income tax rate has a negative impact on the share of rich households in Swiss cantons and main cities. They use instrumental variables of lagged observations to solve the generic endogeneity of income tax rate, but this treatment may be insufficient to eliminate the endogeneity problem (2006). Schmidheiny (2006) also study Switzerland and reaches the same results by assuming constant public goods across communities and controlling other segregation factors such as social interaction and distance from the central business district.

Our study makes two contributions to the literature. First, different from previous studies which typically treat provisions of public goods as given, our study endogenizes provisions of public services which are determined by location decisions of different income groups (Epple and Romer 1991;Epple and Sieg 1999a). Second, we explicitly take into account environmental amenities which have been ignored in most previous studies, except Feld and Kirchgässner (2001), who use the ranks of three criteria 'silence', 'landscape' and 'beauty of the locality' of the survey of Swiss recruits to approximate the amenity level in the canton.

FRAMEWORK

Assume there are three income groups, with $i = h, m, l$ denoting high-, median, and low-income groups, respectively. Given certain community characteristics Z_j in community j, households derive their utility, U_i, from public services (g_j), and environmental amenities (a_j) and consumptions of private goods. Public services such as public education represent the social amenities, and are determined endogenously by income mix in community j. Environmental amenities are exogenously provided by geographic feature and vary across communities, but are homogenous within each community. This assumption indicates households living in a community share the same environmental amenities, but households in different communities enjoy different amenities. The utility function for income group i in community j is

$$U_{ij} = U[g_j, a_j, Z_j, y_i - C_i(g_j)] \qquad [4.1]$$

where $y_i - C_i(g_j)$ is the available budget for consumptions of private goods, with y_i denoting household income, $C_i(g_j)$ the amount of tax that a household in income group i has to pay to finance local public services, and $C_i'(g_j) \geq 0$. Thus, income group i's desired public services level g_j^* is

$$g_{ij}^{*} = argmaxU[g_j, a_j, Z_j, y_i - C_i(g_j)], \quad i = l, m, h. \qquad [4.2]$$

As in previous models of local jurisdiction (Epple and Romer 1991;Epple and Sieg 1999a), the level of public services in a community is determined by majority vote of its residents. For example, if a lower income household group is the dominant resident group, then by majority rule the level of public services preferred by low-income group is the level of the public service in that community. We define the level of public services decided by the majority rule in a community as g_{Mj}^{*}. Households' indirect utility can be expressed as

$$V_{ij}^{*} = U_{ij}[g_{Mj}^{*}, a_j; Z_j, y_i - C_i(g_{mj}^{*})] \qquad [4.3]$$

Given the exogenous income y_i, a household would reside in the community j if V_{ij}^{*} obtained in the community j is greater than the indirect utility obtained from any other communities. Because the household's indirect utility is unobservable, V_{ij}^{*} can be considered as a random variable as follows

$$V_{ij}^{*} = \beta_{ij} X + \varepsilon_{ij} \qquad [4.4]$$

where β_{ij} are parameters, X is a vector including the level of public services, natural amenities, and other exogenous community characteristics Z_j in demography (DEMO), economics(ECON), geography (GEO), and politics (POL), and ε_{ij} is a random error term. If the random error term is assumed to follow a Weibull distribution, then the probability that the income group i live in the community j is given by Multinomial logit model (Maddala 1983)[1]

$$P_{ij} = \frac{\exp(\beta_i ' X_j)}{\sum_i \exp(\beta_i ' X_j)}, \quad i = l, m, h \qquad [4.5]$$

Because individual household data are not available, we use county level aggregate data, the share of alternative income groups ($\overline{P_{ij}}$), to approximate the p_{ij} . Normalization of each share by the share of median income group ($\beta_m = 0$) yields

$$\overline{p_{ij}} = \frac{\exp(\beta_i X_j)}{1 + \sum_{i=l,h} \exp(\beta_i X_j)}, \qquad [4.6]$$

and the share of the reference group is

$$\overline{p_{mj}} = \frac{1}{1 + \sum_{i=l,h} exp(\beta_i X)} \qquad [4.7]$$

Marginal effects of changes of explanatory variables on the share of alternative income groups in a community are nonlinear combinations of the explanatory variables and can be written as (Greene)

$$ME = \frac{\partial \overline{p_{ij}}}{\partial x_k} = (\hat{\beta}_{ik} - \sum_{i=l,h} \bar{\hat{p}}_i \hat{\beta}_{ik}) \bar{\hat{p}}_{ij} \qquad [4.8]$$

where x_k is a specific community characteristic k , $\hat{\beta}_{ik}$ is the estimated coefficient of x_k ($\hat{\beta}_{ik}$ =0 when $i = m$), and $\bar{\hat{p}}_i$ is the estimated share of households in income group i $(i = l, h)$. The sign and magnitude of this marginal effect have no direct relationship with any specific coefficient.

Empirically, the following logarithmic transformations are used to estimate $\hat{\beta}_i s$

$$\log \frac{\overline{p_{lj}}}{p_{mj}} = \beta_l X_j + \varepsilon_{lj}, \qquad [4.9]$$

$$\log \frac{\overline{p_{hj}}}{p_{mj}} = \beta_h X_j + \varepsilon_{hj} \qquad [4.10]$$

The vector of community characteristics, X_j , is exogenous, except the community public service, g_{Mj}^* , which is endogenously defined by equation [4.2]. We assume that g_{mj}^* takes a linear functional form as follows

$$g_{Mj}^* = \gamma W_j + \varepsilon_{Mj} , \qquad [4.11]$$

where W_j includes not only environmental amenities, variables in Z_j (DEMO, ECON, GEO, and POL), but also local property tax, and shares of low- and high- income group in community j. Local property tax is included because local public services in U.S. are mainly funded by local property tax revenues. One objective of this study is to examine the effect of income mix on the provision of public goods, thus, shares of alternative income groups are included in equation [4.11].[2] Equations [4.9], [4.10], and [4.11] form the simultaneous equation system of our empirical study.

ESTIMATION METHOD

The above simultaneous equation system is estimated using county level data because a county is a basic political unit that local government fulfills its administrative duty such as providing local public service, and is the smallest geographic unit for which most economic data are available. Since county-level data are cross-sectional and a random shock in a county may affect neighboring counties as well, potential spatial autocorrelation exists. Not correcting spatial dependence can result in misspecification, which further leads to biased and inconsistent OLS estimates (Anselin 1988). Given this, the system is estimated using generalized spatial three-stage least square estimator (GS3SLS) developed by Kalijian and Prucha (2004).

In the first step, two-stage least square estimator is used to estimate equation [4.9], [4.10], and [4.11]. In the second step, Moran's I test is used to test if spatial autocorrelation exists for each equation using residuals from the first step. If spatial autocorrelation is identified, then the spatial autocorrelation parameter ρ is estimated using equation (7) in Kelejan and Prucha (1999). We assume that in this study the spatial dependence operates through the error term ε and follow the structure $\varepsilon = \rho\varpi\varepsilon + \mu$,[3] where ϖ is the spatial weight matrix created based on the geographic adjacency rule,[4] and μ has a $N(0, \sigma^2 I_n)$ distribution. Using the estimated $\hat{\rho}$, $(I - \hat{\rho}\varpi)^{-1}$ is used to adjust the original data to correct the spatial autocorrelation. Finally, after correcting for endogeneity and spatial autocorrelation, in the third step, a Lagrange Multiplier statistic (λ_{LM}) is used to test whether cross-equation correlation exists or not (Greene 2003).[5] If cross-equation correlation is identified, then the Seemingly Unrelated Estimator (SUR) is applied to correct the contemporaneous correlation.

DATA AND VARIABLE DESCRIPTIONS

The objective of this study is to investigate the interaction between community characteristics and income segregation. Data on community characteristics and income segregation are required to conduct our empirical study, which covers 2992 counties in the lower 48 states. Our data come from a range of sources including Census Bureau (2000), Economic Research Service (ERS), Census of Government (1997), Natural Resource Inventory (NRI 1997) and USA Today. Table 4.1 lists variable descriptions and statistics.

Dependent Variables

As mentioned above, households are grouped into three categories: low-, median-, and high income groups. Income distribution data are from Census Bureau 2000 Summary File 3 (SF3), which represents measurements of variables in 1999. The summary file provides a rich set of information on population and housing at the county level. In particular, SF 3 reports the number of households in the 16 income categories.

Low income households are defined according to the poverty definition set by the Census Bureau. Households are low income households (or under poverty) if their family pre-tax money income in a given year is below the poverty threshold for their family size and age composition. The 1999 average poverty threshold for a family of four persons was $17,092. Poverty thresholds were applied on a national basis and were not adjusted for regional, state or local variations in the cost of living. In 1999, the national average poverty rate was about 14%.

High-income households are defined as the households whose pre-tax income is above $75,000. This definition is following Mallett (2001) who defined household of members over 5 with annual income above $75,000 in 1995 as high income household. In 1999, the national average household size is 2.26, and the maximum county average household size is 4.48, lower than 5. Consequently, taking into account household size and cost of living in 1999, $75,000 is a reasonable threshold to defined high income households. The share of high income household is the ratio of total high income households to total households in a community. Nationally the mean of share of high income households is about 12% on average, in 1999. The maximum share of high income is as high as 55%, and the minimum is only about 1.5%, an indication of dramatic variation in income across communities. Households except low and high income households in a community are defined as median income households. The mean of share of median income is about 74% in 1999.

Community public services are one of the important community characteristics affecting income segregation, and are multidimensional (education, public safety, public welfare, etc.). Since the level of public services is not directly observed and there is no officially available index to measure the quality and quantity of public services, we rely on proxy variables. As in previous studies (Epple and Sieg 1999b; Bergstrom and Goodman 1973; Borcherding and Deacon 1972), we approximate the quantity of community public services by dollars of local direct general expenditure per capita. The direct general expenditure mainly consists of spending in education, social service, transportation, public safety, environment and housing, government administration, and interest on general debt. The local government expenditure data at the county level are from Census of Governments and for the year 1997. It would be ideal to use local government finance data for the year 1999, but such data are not available since a Census of Governments is taken at 5-year intervals as required by law under Title 13, United State Code, and Section 161. The mean of local direct general spending per capita in 1997 is $2,506. Because other data are for the year 1999, the government expenditure data are adjusted to the same year using Consumer Price Index (CPI).

Alternatively, public education is taken as a proxy of local public service quality not only because local spending on education is the largest category of local expenditures, but also public education is likely the central concern in locational choices of most households. According to Census of Government, education includes local government-operated elementary and secondary schools, and any universities, colleges, junior, or community colleges operated by the local government. Ideally, a measure of average test scores in the community would be a good proxy of education quality in the community. However, these types of measurements are not available at the county-level. Hence, following Alesina et al. (1999), and Nechyba and Strauss (1998), we use local expenditure on education per capita to approximate local education quality. One of the limitations of such a measurement in the literature is that increasing expenditure on education does not necessarily translate into greater student achievement. Education expenditures are also collected from the Census of Governments 1997. The mean of education spending per capita is about $1,128 in 1997, and the minimum and maximum are roughly $40 and $6, 539, respectively.

Explanatory Variables

As stated in the theoretical model, the household location decision is affected by natural amenities and other community characteristics Z_j, which consists of demographic, economic, geographic, and political variables.

Natural amenities are attributes that enhance a location as a place to live; thereby it affects a household's location decision. We draw on an amenity index developed by Economic Research Service (ERS) to measure natural amenities. The ERS amenity index is created to capture the physical rather than social or economic environment, thus, man-made amenities such as historical buildings, golf courses, and casinos are excluded. Six measures are selected to reflect the physical beauty of a location in terms of climate, topography and water area. They are warm winter (average January temperature), winter sun (average January days of sun), temperate summer (low winter-summer temperature gap), summer humidity (low average July humidity), topographic variation (topography scale), and water area (water area as proportion of total county area). The greater the index, the higher the amenity level is in a community. More details about the amenity index are available in ERS web site.

Demographic composition in a county is likely to affect income segregation and the demand for public goods as well. In this study, education, age composition, household structure, and local housing tenure are used to measure the demographic composition. Education attainment affects income and demand for public goods directly. We use the percent of population 25-years old and over with a college and above degree as a proxy of the education attainment in a county.

Age not only affects one's income, but more importantly age structure is a determinant of preference for public goods (Alesina, Baqir, and Easterly 1999). In this study, the share of population older than 65 is used to estimate the effect of age composition on income mix and demand for public goods. The more elders may depend more on retirement pensions and public welfare programs as an income source. Thus, a community having a high percent of old people is more likely to have high share of low income group. On the public service size, the life cycle hypothesis would predict that persons over 65 years of age tend to spend a larger portion of their current income on current consumption than younger people, thus they may demand more public services than younger people, but different types of public goods. Poterba (1997) finds that the larger the share of elderly in a jurisdiction, the lower the public spending on education. However, the elder prefer aging-related public service such as public health, medical care, and senior recreation services.

Household structure is measured by percent of the households headed by women. The reason why female-headed household is taken into account is because female family heads are usually disproportionately young, less educated and less skilled, and therefore a female-headed family is more likely to live under poverty (Levernier, Partridge, and Rickman 2000).

Housing tenure is measured by the percent of housing occupied by owners. It is believed that renters have different tastes in public goods from the remainder of the population, because renters do not believe that they pay the entire property tax on their housing, and tend to vote for more public expenditures than home-owners with the same income (Bergstrom and Goodman 1973;Bergstrom and Goodman 1973). Therefore, it is expected that a high percent of owner-occupied housing is negatively associated with public services. Also, it is anticipated that the share of owner-occupied is positively related to the share of high income group in the county, but negatively related to low income group because wealthier households tend to buy houses rather than rent houses compared to low income household.

The economic situation in a community directly affects the employment opportunity of households and the public services as well. Economic situation is approximated by local labor market. Previous studies have used variables such as the employment rate, job growth rate, industrial composition, and occupational structure.[6] In our study, the employment rate is used as the measure of local labor market. It is expected that community with high value of this variable would tend to have larger share of high income group but small share of low income group, and a large amount of commercial and industrial activities. As a result, it may be that larger amounts of public services must be provided in order to attract and retain such activities (Bergstrom and Goodman 1973). However, the types of public services needed for commercial and industrial sectors may vary from residential need. For example, residents may put a heavy weight on education quality in the community, while commercial and industrial activities may put more emphasis on public safety and transportation services. Data on the employment rate is obtained from US Department of Labor Bureau of Labor Statistics.

Community public services are funded largely through property tax revenues in the U.S., which are raised mainly from taxes on real property (building and lands) with the remainder derived from personal property tax. However, county-level property tax data are not directly available. Instead, we calculate the ratio of county property tax revenue to the population in a community as a proxy of property tax per capita. It is expected that public services are positively related to property tax. County property tax revenue data are also from Census of Government 1997.

Urban Influence Codes 1993 (UIC) from the Economic Research Service are taken as the measurement of geographic adjacency to a metropolitan area. Adjacency to a metropolitan is an important factor determining the location decision of a household. UIC data divide counties into 9 categories, with 1 representing a metropolitan, 9 representing a remote area not adjacent to any metropolitan area or town. It is expected that locations close to a metropolitan area is positively associated with high income groups, but negatively with low income group.

Political factors can affect the income mix and provision of public goods. Political competitiveness in a county is utilized to measure the political leadership's commitment to economic development and political issue. We construct a political competitiveness variable based on the method developed by Levitt and Poterba (1999). The variable is created as the differences in the number of votes for the Democratic presidential candidate Al Gore between county and national average in 2000. Counties with vote outcomes equal to the national average are more highly competitive politically. Positive and negative values of this variable reflect that the county is Democratic or Republic, respectively.

RESULTS

Equations [4.9] to [4.11] are estimated respectively for the two proxies of public services, local direct general expenditure per capita and public education spending per capita. For convenience, the simultaneous equation system with the measurement of local direct general expenditure per capita is identified as Model 1, and the one with public education spending per capita as Model 2. Test of spatial autocorrelation is conducted for both models. In model 1, spatial autocorrelations are identified in equation [4.9] and [4.10] but not in equation[4.11], and the estimated spatial autocorrelation parameters are 0.227 and 0.162, both of which are statistically significant at the 1% level. In model 2, spatial autocorrelations are identified and statistically significant at the 1% level for all three equations[4.9] to [4.11]. The estimated spatial autocorrelation parameters are 0.242, 0.157, and 0.079, respectively. The significance of the spatial autocorrelation parameters suggest that a random shock that affects the income segregation and public services level in a particular county triggers a change not only in that county but also in its neighboring counties. In addition, the LM test rejects the hypothesis that no cross-equation correlation exists across all three equations. Consequently, the simultaneous equation system is estimated by GS3SLS. Results show that the model fits the data quite well, since the system weighted R-Square for Model 1 and 2 are both 68%. Most coefficients are statistically significant at 1% level. Estimated results are reported in Table 4.2 and 4.3 with standard deviations in the parenthesis for both models. LOGLM and LOGHM represent the log ratio of the share of low and high income households to the share of median income, respectively.

Column 1 in the table 4.2 and 4.3 reports the estimated coefficients for the public services equation in model 1 and 2. It shows that income mixes indeed are a factor that influences public services. A 1% increase in the share of low income households in a community is associated with a 0.46% and 0.23% decrease in the local general spending and public education spending per capita. This finding is not surprising because public services are funded mainly through property tax, since low income households usually live in low value housing, revenue from property taxes is low in communities with a high share of low income households. This result also shows that public education is less responsive to the share of low income households than general public services, reflecting that low income households become more aware the importance of education. In contrast, public services are positively associated with the share of high-income households, although the magnitude is quite small. This supports Tiebout's argument that high income households prefer communities with better public services.

Property taxes are positively related to public services, and the coefficients are statistically significant in both models. This is expected because public services are funded primarily by local property taxes. The natural amenity variable is positively associated with public services. This indicates that locations with better natural amenities tend to have better public services, because natural amenities enhance a place as a residence and households may be willing to pay more to live in a community with a better natural amenity.

Educational attainment is negatively related to public services in both models. This result is unexpected because communities with more educated residents tend to demand better public education and other public services. This may reflect the mixed effect of educated individuals with and without child (children) on the public education. Educated individuals without child (children) may have less demand for public education than those with child (children).

The employment rate has a positive and statistically significant effect on local direct public services, but a negative and statistically significant effect on public education. A 10% increase in the employment rate in a community results in a 1% increase in general public expenditures, but a 1.3% decrease in public education. This implies that the increased commercial and industry activities demand more public services such as public transportation and safety to support such activities.

Female-headed households are positively related to public services in both models. A 1% increase in the percent of female-headed households leads to a 0.88% and 0.41% increase in models 1 and 2, respectively. The reason is that female-headed households are usually single mothers, and more likely to rely on public welfare. Thus, communities with a high percent of female-headed households tend to have higher expenditures in public services.

The percent of owner-occupied housing is negatively associated with public services in both models. This result is consistent with Bergstrom and Goodman (1973) and supports the hypothesis that renters tend to vote for more public expenditures than homeowners with the same income.

As discussed early, the elderly may have different demands for public services in terms of quantities and types. Results show that the percent of the aged is negatively associated with public education. Specifically, a 10% increase in the percent of the elderly lead to 1 percent decrease in public education expenditures. Although life cycle hypothesis suggests that the elderly may spend more on public services, especially aging-related public goods, our results show that the higher the share of the elderly in a community, the lower the local direct general expenditure. The reason may be that despite the fact that the elderly may demand more for aging-related public services such as public welfare, the effect on general public services is washed out by their lower demands for other public services, particularly the public education.

The effect of political factors on public services is positive with respect to the local direct public service, but negative with respect to the public education. However, both effects are not statistically significant. Marginal effect of size of a county on public services is positive and statistically significant.

Because each independent variable has a nonlinear effect on the range of the dependent variable in equation [4.9] and [4.10], it is difficult to interpret the effect directly. Instead, the marginal effect is calculated using equation [4.8], and table 4.4 reports the marginal effects of explanatory variables in models 1 and 2, with elasticity in parentheses.

The marginal effect of public services is negative with respect to the share of low income households, but positive with respect to the share of median and high income households in both models. A 1% increase in public service is associated with a 0.26% and 0.24% reduction in the share of low income households, but with a 0.28% and 0.18% rise in the proportion of high income households in models 1 and 2, respectively. This result supports the argument that public services are a determinant of income segregation because middle and upper class households are willing to pay more for public services. Feld and Kirchgässner (2001) obtain a similar result using a ranking of education, medical services and public traffic as the proxy of public services.

The marginal effect of natural amenities on the share of high income household is positive, indicating high income households prefer locations with more natural amenities. Surprisingly, the marginal effect of natural amenities on the share of low income household is also positive. The possible explanation is that low income households prefer locations with low living costs and usually live in rural areas, where the natural amenity index is high because the natural amenity index reflects amenities in climate, topography and water. However, the magnitude of marginal effects is quite small.

Educational attainment, measured by the percent of population with bachelors and above degrees, increases the proportion of the high income group, while reducing the share of median and low income groups in a community. The marginal effect is statistically significant at the 1% level. A 1% increase in the percent of population with college and above degree increases the share of the high income group by 0.54% and 0.65% in models 1 and 2, and causes a reduction in the share of low income group by 0.22% and 0.26%. This result is consistent with other empirical evidences (Levernier, Partridge, and Rickman 2000;Rupasingha and Goetz 2003), which suggest that increasing educational attainment is effective in the reducing poverty rate because improved technical skills effectively move people out of poverty.

The marginal effect of the employment rate is negatively and significantly related to the share of low income households. A 1% increase in the employment rate decreases the share of the low income group by 0.57%, suggesting that job accessibility plays a key role in poverty reduction. In contrast, communities with a high employment rate tend to have more median and high income households. A 1% increase in the employment rate causes a rise in the shares of median and high income households by 0.12% and 0.21% in model 1, and 0.13% and 0.16% in model 2.

Household structure, approximated by the percent of female-headed households, has a positive and significant effect on the share of the low income group, but a negative and significant effect on the proportion of the median and high income groups. This finding supports the convention that female-headed households tend to have a higher poverty rate across all racial groups (Blank and Hanratty 1992), because female heads, as stated by

Levernier et al. (2000), are usually the sole wage earner for the family, and disproportionately young, less educated, and less skilled. The marginal effect of female-headed households on the share of low-income group is the largest among all explanatory variables in both models. A 1% rise in the female-headed households causes about 1.1% increase in the share of low-income households, a finding similar to previous studies (Weinberg 1987;Lichter and Mclaughlin 1995). Conversely, a 1% rise in female-headed households decreases the share of the middle and high income group by over 0.11% and 0.55% in both models, respectively.

Housing tenure, measured by the percent of owner-occupied housing, affects the share the of low and median income group negatively, but the share of the high income group positively in both models. This result is anticipated because median and low income households are more likely to rent a place rather than purchasing a house compared to high income households. Also, communities with a higher percent of owner-occupied houses tend to have less median and low income households, but more high income households. A 1% increase in the percent of owner-occupied housing causes approximately 1.50% decrease in the share of the low income households, but 2.0% rise in the share of high income households.

The share of the elderly has a negative effect on the share of high and low income households, but a positive effect on the share of the median income group. This makes sense because the elderly largely rely on retirement pensions or social security as their income sources. A 1% increase in the elderly results in a 0.34% reduction in the proportion of high income households in a community in both models. A 1% increase in the share of the aged is associated with a 0.20% decrease in the proportion of low-income group. Traditional poverty literature often suggests that the elderly are more likely to live under poverty. However, recent empirical research (Levernier, Partridge, and Rickman 2000) reaches similar results as ours. Lichter and MaLaughlin (1995) also find that increase in the elderly population is the strongest predictors of declines in county poverty rate, with a 1 percent increase in the elderly population leading to 0.32 percent reduction in county poverty between 1980 and 1990.

The marginal effects of Urban Influence Codes (UIC) on the share of low and median income households are positive, but negative on the share of high income group. A 1% increase in the UIC results in a 0.27% rise in the share of low income group, but a 0.43% reduction in the share of high income groups in both models. UIC not only represents adjacency to a metropolitan area, but may also implicitly reflect historical and modern amenities such as museums, restaurants, and theaters. Hence, low income households tend to live more distant from metropolitan areas to avoid high living costs, but high income households prefer communities close to metropolitan areas, where historical and modern amenities are more abundant. This finding is consistent with Brueckner et al. (1999) who find that the wealthy live in the central Paris because of rich historical and modern amenities there, while the poor live in suburb due to low living costs.

CONCLUSIONS

This study focuses on the interaction between households' location decisions and community characteristics such as public services. Results show that income mixes indeed interact with the local public services in communities. Findings suggest that a 1% increase in public education expenditures is associated with a 0.26% decrease in the share of low-income household in a county, but is associated with 0.28% increase in the share of high-income households. The share of the low-income group is negatively associated with general public expenditures (a 0.46% decrease) and a 0.23% decrease in public education expenditures. The share of the high-income households is positively associated with general public expenditures and public education expenditures. Communities with better natural amenities, higher share of owner-occupied housing, and higher employment rates tend to have more high income households. Communities more distant from metropolitan areas and with more female-headed households tend to have more low income households.

Results also have important policy implications in poverty reduction. Results show that higher educational attainment is associated with lower poverty rates, suggesting that increasing education is effective in poverty reduction. Policies that increase labor force participation are effective in alleviating poverty as well. This is particularly true to lift low income households out of poverty. Findings reveal that the familial status of women is strongly associated with poverty. Consequently, it is important for policy makers to develop local economic strategies that promote the entry of women into the labor market.

ENDNOTES

[1] The multinomial logit model has been widely used in farmer's land allocation decisions (Wu and Segerson 1995), the choice of irrigation technology and alternative crop management practices (Caswell and Zilberman 1985;Wu and Babcock 1998).

[2] To avoid perfect collinearity, only shares of low- and high- income group are included.

[3] The other type of spatial dependence is called spatial lagged dependence, which is operated through the lagged term of dependent variables.

[4] Two criteria are usually used to create spatial weight. One is contiguity-based spatial weight and the other is distance-based spatial weight. The contiguity-based spatial weight usually uses two criteria: rook contiguity, which uses common boundaries to define neighbors, and the queen contiguity which uses common points (boundaries and vertices) in the definition.Distance-based spatial weight defines the neighbors according to the specified distance, or the specified k-nearest neighbors. The spatial weight matrix can be created in a variety of softwares such as Arcview 3.2, ArcGIS 9.0, SpaceStat, and Geoda.

[5] LM statistic has a limiting chi-squared distribution with M(M-1)/2 degree of freedom, where M is the number of equations in the simultaneous system. For details about the Lagrange Multiplier statistic, please check page 350 in Green (5th edition, 2003).

[6] However, as Weber (2005) states "each of these variables captures some aspects of local labor conditions that may affect poverty, but none is without flaws."

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Table 4.1. Variable Descriptions and Statistics

Variable	Descriptions	Mean	Std	Min	Max
Low	Share of low income household (%)	0.14	0.06	0.02	0.48
Median	Share of median income household(%)	0.74	0.06	0.43	0.90
High	Share of high income household (%)	0.12	0.07	0.02	0.55
School	Public expenditure on local education ($1000/per capita)	1.13	0.36	0.40	6.54
Public	General public expenditure ($1000/ per capita)	2.51	1.10	0.18	21.41
Tax	Local property tax ($/per capita)	0.63	0.50	0.03	10.50
Amenity	ERS amenity index	0.04	2.29	-6.40	11.17
College	Percent of population 25+ with college or higher degree (%)	0.10	0.04	0.03	0.39
Old	Percent of population 65+ (%)	0.15	0.04	0.02	0.35
Fehu	Percent of female-headed household (%)	0.22	0.05	0.04	0.43
UIC	ERS urban influence code	5.56	2.73	1.00	9.00
Size	Total areas of a county (thousand acres)	630.56	836.88	28.60	12868.20
Political	Political competition	0.09	0.07	0.00	0.45
Emprate	Employment rate	0.46	0.07	0.14	0.89
Occupied	Percent of owner-specified occupied houses (%)	0.85	0.09	0.23	0.98

Table 4.2. Estimated GS3SLS Results for Model 1

Variables	Public	LOGLM	LOGHM
Intercept	2.916*** (0.350)	-0.327*** (0.053)***	-2.781*** (0.055)
Low	-8.184*** (0.796)		
High	1.106 (1.946)		
Tax	1.106*** (0.042)		
Public		-0.106*** (0.008)	0.055*** (0.008)
Amenity	0.061*** (0.009)	0.021*** (0.002)	0.004 (0.002)
College	-4.420** (1.809)	-1.894*** (0.141)	5.001*** (0.131)
Emprate	0.562*** (0.289)	-1.463*** (0.081)	0.116 (0.076)
Fehu	10.078*** (1.196)	6.278*** (0.137)	-1.499*** (0.126)
Occ	-3.039*** (0.708)	-1.863*** (0.072)	2.083*** (0.068)
Old	-1.895*** (0.667)	-2.043*** (0.132)	-2.564*** (0.123)
UIC	0.109*** (0.020)	0.049*** (0.002)	-0.069*** (0.002)
Political	0.061 (0.187)	-0.286*** (0.047)	0.181*** (0.044)
Size	1.9E-4*** (2E-5)	3.5E-5*** (3E-6)	-3.0E-5*** (6E-6)
ρ		0.227***	0.162***
System Weighted R-Square: 68.14%; $\lambda_{LM} = 234$			

*** significant at 1%, ** at 5%, and *at 10%

Table 4.3. Estimated GS3SLS Results for Model 2

Variables	School	LOGLM	LOGHM
Intercept	1.453 (0.105)	-0.209*** (0.056)	-2.901*** (0.059)
Low	-1.843*** (0.262)		
High	1.100* (0.644)		
Tax	0.373*** (0.014)		
School		-0.256*** (0.025)	0.168*** (0.023)
Amenity	0.004*** (0.003)	0.017*** (0.003)	0.006** (0.002)
College	-2.366*** (0.597)	-2.244*** (0.138)	5.162*** (0.126)
Emprate	-0.326*** (0.096)	-1.521*** (0.081)	0.144* (0.075)
Fehu	2.097*** (0.392)	6.040*** (0.139)	-1.372*** (0.126)
Occ	-0.901*** (0.232)	-1.833*** (0.073)	2.089*** (0.068)
Old	-0.708*** (0.222)	-2.217*** (0.133)	-2.469*** (0.122)
UIC	0.036*** (0.007)	0.048*** (0.002)	-0.068*** (0.002)
Political	-0.195 (0.062)	-0.316*** (0.047)	0.208*** (0.044)
Size	6.4E-5*** (7E-6)	3.0E-5*** (6E-6)	-3.0E-5*** (6E-6)
ρ	0.079***	0.242***	0.157***
System Weighted R-Square: 67.88%; $\lambda_{LM} = 262$			

*** significant at 1%, ** at 5%, and *at 10%

Table 4.4. Marginal Effect and Elasticity of Explanatory Variables for Model 1 and 2

Variables	Marginal Effect for Model 1			Marginal Effect for Model 2		
	Low	Median	High	Low	Median	High
Amenity	0.0024 (0.0008)	-0.0024 (-0.0001)	0.0001 (3E-5)	0.0017*** (0.0006)	-0.0022*** (-0.0002)	0.0005*** (0.0002)
Public/ School	-0.0133*** (-0.2393)	0.0047*** (0.0158)	0.0087*** (0.1819)	-0.0319*** (-0.2570)	0.0024*** (0.0037)	0.0295*** (0.2769)
Old	-0.1885 (-0.2019)	0.4614*** (0.0935)	-0.2729*** (-0.3411)	-0.1911*** (-0.2047)	0.4943*** (0.1002)	-0.3031*** (-0.3789)
College	-0.3148*** (-0.2249)	-0.3291*** (-0.0445)	0.6439*** (0.5366)	-0.3597*** (-0.2569)	-0.4233*** (-0.0572)	0.7830*** (0.6525)
Fehu	0.7572*** (1.1890)	-0.4558*** (-0.1355)	-0.3014*** (-0.5526)	0.6964*** (1.0944)	-0.3701*** (-0.1100)	-0.3232*** (-0.5981)
UIC	0.0070*** (0.2778)	0.0023*** (0.0174)	-0.0093*** (-0.4317)	0.0068*** (0.2689)	0.0039*** (0.0296)	-0.0107*** (-0.4965)
Occ	-0.2558*** (1.5714)	-0.0328*** (-0.0381)	0.2886*** (2.0682)	0.2476*** (1.5212)	-0.0893*** (-0.1038)	0.3370*** (2.4149)
Emprate	-0.1720*** (0.5653)	0.1302 (0.0809)	0.0419 (0.1605)	-0.1710*** (-0.5618)	0.1175* (0.0730)	0.05349* (0.2050)
Political	-0.0366*** (-0.0003)	0.0092*** (1.5E-5)	0.0274*** (0.0003)	-0.0394 (0.0003)	0.0029*** (4E-6)	0.0364*** (0.0004)
Size	5E-6*** (0.0209)	-3E-7*** (-0.0003)	-4E-6*** (-0.0227)	4E-6 (0.0179)	10E-7*** (0.0008)	-4E-6*** (-0.0259)

*** significant at 1%, ** at 5%, and *at 10%

CHAPTER 5

CONCLUSIONS

HAIXIA LIN

Chapter 1 analyzes the effects of the CRP and natural amenities on prices of farmland and developed land. A theoretical model, which integrates the optimal investment model developed by Capozza and Li (1994) and the optimal bidding behavior model developed by Lohmann and Hamsvoort (1997), is first developed to examine the effects of the CRP and natural amenities on prices of farmland and developed land. Then, based on the theoretical model, we conduct an empirical study to quantify the effects. Results show that generally amenities increase the prices of farmland and developed land. The CRP increases farmland prices by $18 to $25 per acre on national average. The effects are the largest in the Mountain, Southern Plains, and Northern Plains. The CRP has a positive effect on developed land prices, but the effect is small (less than 0.6%). Results also show that agricultural returns account for about 40% of farmland price, and growth premium and option value together account for the remaining 60%. This result has important policy implications on design and implementation of permanent easement program. In particular, this result helps policy makers decide how much compensation payments are needed in order to induce farmers to participate into the perpetual easement program.

Chapter 2 examines the tradeoffs between efficiency and equity in the case of the CRP. We first develop a reallocation mechanism of conservation funds to estimate the Efficiency-Equity Frontier (EEF). Then, we conduct simulations to trace out the EEF. On the basis of estimated EEFs, we evaluate the tradeoffs between efficiency and equity in the case of the CRP, and identify the distribution patterns of conservation funds under alternative targeting criteria including the EBI rule, the benefit-cost ratio rule and the equity rule. Results suggest that the designed reallocation mechanism works well in the estimation of EEFs. On the basis of the estimated EEF, the tradeoffs between efficiency and equity are calculated. It is found that a 13 percent sacrifice in the efficiency can improve the equity by 14 percent. We compare the shares of conservation funds under alternative targeting criteria in the 10 examined agricultural production regions, and find that targeting criteria affect the distribution of conservation funds greatly. Under the benefit-cost ratio rule, a large share of conservation funds should be targeted to purchase the resources in the Mountain and Plains, and relatively a small share of conservation funds should be invested in the Corn Belt. However, under the equity rule, conservation funds should be shifted from the Mountain and Great Plains to other regions, especially the Corn Belt. In addition, results imply that current EBI rule is not optimal in terms of efficiency and equity. To improve the performance of the EBI rule in efficiency, we suggest that more weights should be placed on the environmental factor in the calculation of EBI score.

Chapter 4 focuses on the interaction between community characteristics and location decision of alternative income groups. Specifically, we explore how community characteristics attract alternative income households and how the location decisions of alternative income households affect community characteristics such as amenities and public services. Empirical results show that income mixes indeed interacts with communities characteristics. It is found that a 1% increase in public education expenditures is associated with a 0.26% decrease in the share of the low income households in a county, but associated with 0.28% increase in the share of the high income households. Conversely, we find that the higher the share of the high income households in a community, the higher the level of public services; but the higher the share of the low income households, the lower the level of public services. In addition, communities with better natural amenities, higher employment rate, and more owner-occupied housing tend to have more high income households. Communities more distant from a metropolitan area and with more female-headed households tend to have more low-income households. Results have policy implications in poverty reduction. Findings show increasing education and creating more job opportunities for females are effective in poverty reduction. Consequently, it is important for policy makers to develop local economic strategies that enhance workers' technique skills and promote the entry of women into labor markets.

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