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# Using a Bundled Amenity Model to Estimate the Value of Cropland Open Space and Determine an Optimal Buffer Zone

Nicolai V. Kuminoff

This study investigates how proximity to cropland influences residential property values and considers the public policy implications. The hedonic model generalizes previous studies by recognizing that the bundle of externalities generated by crop production may increase the price of some homes and decrease the price of others, depending on their respective locations. Using an instrumental variables approach to estimate the model for San Joaquin County, California, suggests that proximity to cropland increases the value of most, but not all, single-family homes near the agricultural-urban edge. The results imply an agricultural buffer zone of 68 meters would mitigate most cropland disamenities.

*Key words:* amenity value, buffer zone, cropland, hedonic, land use, open space

## Introduction

Commercial agriculture has both positive and negative effects on the surrounding environment. Farms can provide wildlife habitat and scenic views for their urban neighbors, while the carbon sequestered by vegetation grown on that land can help to mitigate global warming. At the same time, noise, dust, and odors produced by normal farming operations can annoy urban residents, and runoff of pesticides, fertilizer, and animal waste can lead to water pollution downstream. The economic values that society places on these by-products of agricultural production are rarely captured by private markets for farmland and crops. When market prices fail to reflect the impact of farming on the surrounding environment, farmers are left with little or no incentive to incorporate the value of off-farm environmental quality into their land management decisions. This type of market failure can justify government intervention.

Over the past 20 years, state and local governments have increasingly sought to enhance the positive externalities associated with agricultural production by funding easement programs which preserve farmland by purchasing the right to develop that land for urban uses. Economists have helped to inform this process by measuring the extent to which the positive amenities generated by farmland increase residential property values. This hedonic literature indicates that forests (Tyrvaenen and Miettinen,

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2000), pasture (Irwin, 2002), and farms preserved by easements (Geoghegan, 2002) can all increase the value of nearby residential properties. Conversely, negative externalities generated by confined animal feeding operations and other intensive farming practices have been found to decrease housing prices (Palmquist, Roka, and Vukina, 1997; Ready and Abdalla, 2005). Policy makers have sought to mitigate these negative externalities, and the resulting nuisance lawsuits, by establishing “right-to-farm” laws and requiring buffer zones between productive farmland and residential subdivisions.

While the literature is clear about the effects of proximity to animal feeding operations, forests, pasture, and agricultural easements, the relationship between the price of a home and its proximity to productive cropland is less well understood. Previous studies have typically aggregated cropland together with other categories of privately owned farmland, such as pasture, grasslands, and forests, to develop a single measure of “agricultural open space” rather than attempting to distinguish their individual impacts (e.g., Bell and Bockstael, 2000; Geoghegan, 2002; Ready and Abdalla, 2005). It is important to consider the amenity value of cropland separately because it accounts for 46% of all farmland in the United States and is located in close proximity to many residential neighborhoods (U.S. Department of Agriculture, 2004). Furthermore, since cropland tends to be more intensively farmed than pasture, forests, and grasslands, it may generate more negative externalities for nearby homeowners.

This study investigates how proximity to cropland influences residential property values and considers the implications for land use policy. The analysis begins by developing a hedonic model for the relationship between the price of housing and the bundle of amenities generated by nearby farming operations. A distinguishing feature of the model is its recognition that an individual cropland parcel can generate multiple positive and negative amenities, which may differ in how they are dispersed across the agricultural-urban landscape. This framework generalizes the existing hedonic literature on valuing agricultural amenities by allowing the amenity bundle to increase the price of some homes and decrease the price of others, depending on their respective locations. For example, noise, smoke, and pesticide drift may be largely absorbed by the urban residents who live closest to cropland, outweighing the price effect of positive amenities. Homes slightly farther away may be sheltered from the disamenities, while still providing access to farmers’ markets, scenic views, and opportunities for wildlife viewing.

In the empirical application, the bundled amenity model is estimated using data from one of the largest agricultural counties in the nation—San Joaquin County, California. Located in the middle of California’s central valley, San Joaquin has an annual farm gate value well over a billion dollars. While most of the county consists of productive cropland, it has also been experiencing rapid urban growth. Its population grew by more than 16% between 1990 and 2000 to over half a million residents, making it an ideal location to estimate the relationship between housing prices and intensively farmed cropland. From an econometric perspective, the key challenge is recognizing that measures of proximity to cropland are likely to be endogenous (Irwin and Bockstael, 2001; Irwin, 2002; Ready and Abdalla, 2005). This issue is addressed by developing instruments for the opportunity cost of farmland conversion from data on soil quality, irrigation, and crop prices.

Results from two-stage least squares (2SLS) estimation indicate that proximity to cropland increases the value of most, but not all, single-family homes near the

agricultural-urban edge. Specifically, the estimates imply that converting one acre of cropland to urban development would decrease the value of homes located within a quarter mile of the converted property by 2.2%, on average. Yet, for a small number of properties located closest to farmland (approximately 5% of all homes), crop production appears to serve as a net disamenity. This result is consistent with the land use conflicts reported between farmers and their urban neighbors and with the increasing use of agricultural buffer zones to mitigate these conflicts (Sokolow, 2003). If the goal of establishing a buffer zone is to ensure that the bundle of cropland amenities does not decrease housing prices, the results suggest the optimal length for an agricultural buffer zone is approximately 68 meters.

### **Hedonic Pricing of Bundled Cropland Amenities**

Hedonic property value models are frequently used to estimate the willingness to pay for marginal changes in environmental amenities. Consider open space. While homeowners do not pay anyone directly for scenic views of nearby open space, homeowners purchase the right to have access to these views on a regular basis through the price of their home. Therefore, regressing housing prices on a measure for access to open space, while controlling for other housing and location-specific characteristics, offers the potential to reveal the marginal price that households implicitly pay for access to open space.<sup>1</sup>

Over the past decade, economists have increasingly sought to use hedonic methods to inform policy makers about the value of maintaining open space in residential areas. Examples include Geoghegan, Wainger, and Bockstael (1997); Bell and Bockstael (2000); Tyrvaenen and Miettinen (2000); Irwin and Bockstael (2001); Irwin (2002); Ready and Abdalla (2005); and Kopits, McConnell, and Walls (2007). These studies find that access to open space from forests, pasture, easements, and nature preserves increases the value of residential properties located nearby. For example, Irwin (2002) investigates how different types of agricultural open space influence property values in suburban and exurban counties in central Maryland. Results from her baseline model suggest that converting one acre of privately owned pasture to commercial/industrial development would decrease residential property values by 2.56% within a 0.25 mile radius of the converted acre.

To formalize ideas, suppose the price of a home ( $P$ ) can be expressed as a function of its proximity to open space ( $o$ ) and a vector ( $\mathbf{x}$ ) which contains all other structural features of the home together with all other amenities and characteristics of the neighborhood. Using this notation, the hedonic price function can be expressed as  $P = P(o, \mathbf{x})$ . Equation (1) illustrates how the hedonic price function enters a household's utility maximization problem. Households are assumed to choose a quantity of  $b$ , the composite numeraire, and a house with any combination of open space and other characteristics to maximize their utility, given their heterogeneous preferences  $\alpha$ , and income  $y$ :

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<sup>1</sup> Rosen (1974) demonstrated that the hedonic price function can be interpreted as an equilibrium relationship resulting from the interactions between all the buyers and sellers in a market. He also suggested that the price function could be used to infer consumers' willingness to pay for marginal changes in product characteristics. See Palmquist (2005) for a review of the literature on hedonic property value models.

$$(1) \quad \begin{aligned} & \max_{b, o, \mathbf{x}} U(b, o, \mathbf{x}; \alpha) \\ & \text{s.t.: } y = b + P(o, \mathbf{x}). \end{aligned}$$

A key result of the hedonic property value model lies in the first-order conditions to the utility maximization problem. The first-order condition for proximity to open space is constructed as:

$$(2) \quad \frac{\partial P(o, \mathbf{x})}{\partial o} = \frac{\partial U / \partial o}{\partial U / \partial b}.$$

This equation implies that households will maximize their utility by choosing a home which provides them with the amount of open space at which their marginal willingness to pay for an additional unit exactly equals its marginal implicit price. The supply of housing is assumed to be fixed so that the amount of open space does not depend on the household's location choice.

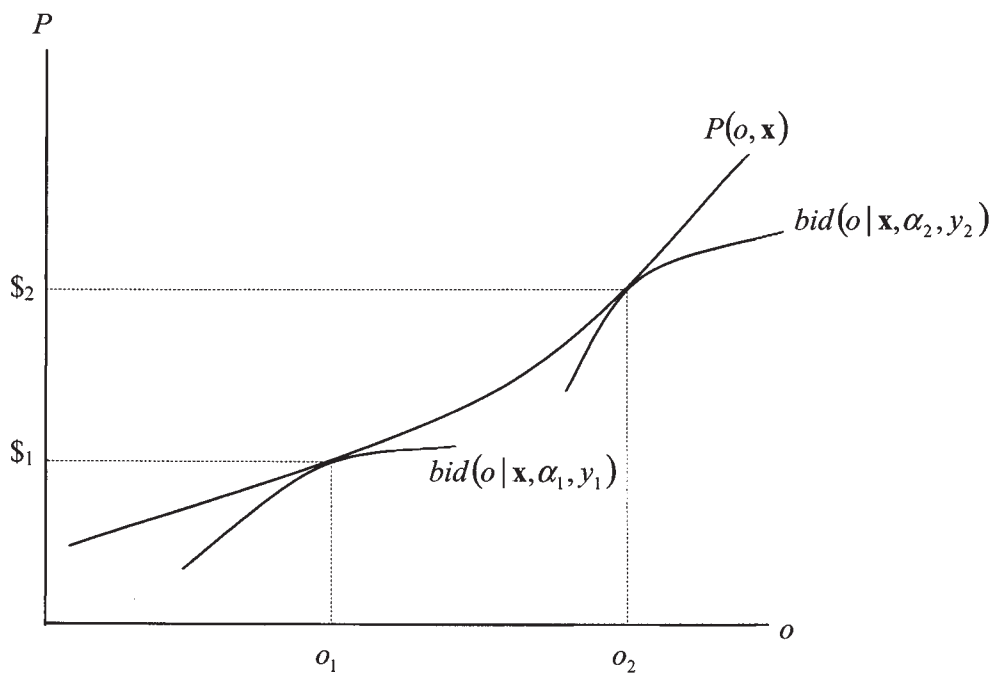
Figure 1 illustrates the first-order condition to the location choice problem. It shows bid functions for housing in the  $o$  dimension for two households. The bid functions express each household's maximum willingness to pay for housing as a function of  $o$ , given levels of all the other housing characteristics, and the household's preferences and income. Each household will select the quantity of  $o$  where its bid function is tangent to the hedonic price function. In the figure, the two households purchase homes that are identical except in their proximity to open space. Household 1 spends  $\$_1$  on a house that provides  $o_1$  units of the open space, and household 2 spends  $\$_2$  on a house with  $o_2$ . Therefore,  $(\$_2 - \$_1)$  is the effective cost of consuming  $(o_2 - o_1)$  additional units of  $o$ , given the levels of all the other housing characteristics.

Figure 1 is consistent with the studies cited above in that it depicts "proximity to open space" as having a strictly positive effect on housing prices. Of course, this is not always the case. While farmland can provide positive amenities such as wildlife habitat, recreation opportunities, and scenic views, intensive farming operations can also produce negative amenities such as noise, dust, and odors. The disamenities tend to be especially pronounced for confined animal feeding operations and intensively farmed cropland (Sokolow, 2003).

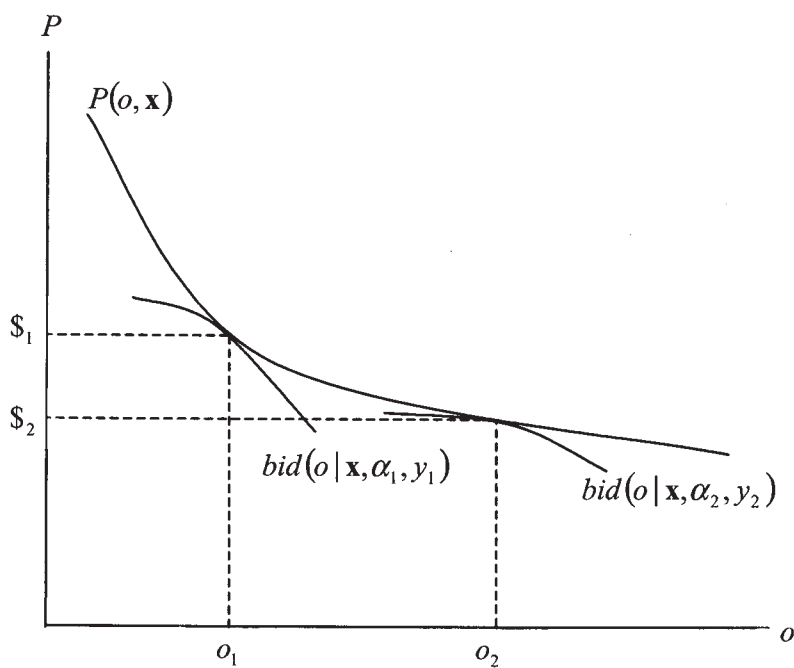
Figure 2 illustrates the first-order condition for a hedonic model in which proximity to open space is mainly associated with disamenities. In this case,  $(\$_2 - \$_1)$  measures the discount for being exposed to more of the disamenities. Palmquist, Roka, and Vukina (1997) and Ready and Abdalla (2005) used the hedonic framework to quantify this discount rate for homes located near animal feeding operations. For example, using data on housing transactions in Berks County, Pennsylvania, Ready and Abdalla found that removing a confined animal feeding operation would increase housing prices by 6.4% within a 0.3 mile radius of the operation.

The existing literature on measuring the implicit price of proximity to open space indicates that forests, pasture, and nature preserves increase residential housing prices, while intensive animal feeding operations decrease residential housing prices. For cropland, however, the results are less clear. When cropland open space is included as an independent variable in a hedonic property value regression, estimates for its econometric coefficient can be unstable. For example, Geoghegan, Wainger, and Bockstael (1997) report that the coefficient on the measure of open space in their model (which





**Figure 1. Agricultural open space as a positive amenity in a hedonic equilibrium**



**Figure 2. Agricultural open space as a negative amenity in a hedonic equilibrium**

includes cropland together with other types of open space) changes sign as they increase the size of the neighborhood around each home in which open space is measured. This instability makes it difficult to interpret the results and convey them to policy makers.<sup>2</sup>

One possible explanation for the unstable coefficient on cropland open space is that a single parcel can provide a bundle of positive and negative amenities. Previous studies have generally assumed that cropland open space enters the hedonic price function as an additively separable linear term, effectively restricting it to have either a strictly positive effect on housing prices, or a strictly negative effect. If cropland open space actually provides a bundle of positive and negative amenities, such that their net effect depends on the amount of open space, we might expect its sign to be sensitive to the size of the neighborhood used to measure the amount of open space around each home.

### *Measuring the Implicit Price of an Amenity Bundle*

A seemingly simple solution to the bundling problem would be to measure the level of each amenity at each home and then use a hedonic regression to disentangle their relative effects on property values. Unfortunately, this approach poses two difficulties. First, data on amenities are rarely collected at the level of an individual home. While spatially explicit micro data have become increasingly available over the past 15 years, these data typically describe land cover or land use rather than specific amenities produced as by-products of those land uses (Bell and Irwin, 2002). Pleasant scenery is difficult to quantify, and information on noise, dust, and odors from commercial farming is simply not collected in most areas. Even in rare cases where data on some of these amenities may be available, a second difficulty is that high correlation in their spatial dispersion may make it difficult to disentangle their relative effects econometrically. Nevertheless, if the spatial dispersion of multiple amenities is one-dimensional, their bundled effect on property values can be measured by the implicit price of proximity to cropland.

To illustrate the hedonic implications of bundling, equation (3) rewrites utility in more explicit terms by replacing the proximity to open space variable ( $o$ ) with a specific positive amenity ( $g$ ) and a specific negative amenity ( $s$ ) produced as by-products of nearby crop production:<sup>3</sup>

$$(3) \quad U(b, g, s, \mathbf{x}; \alpha).$$

Now suppose the spatial dispersion of  $g$  and  $s$  is one-dimensional in the sense that, at a point in space, the level of each amenity is determined solely by a univariate measure of its proximity to cropland so that  $g = g(o)$  and  $s = s(o)$ . This condition effectively bundles  $g$  and  $s$  together by guaranteeing that each value for  $o$  corresponds to a specific  $(g, s)$  combination.<sup>4</sup> Equation (4) illustrates the implications of this restriction for utility maximization:

<sup>2</sup> Irwin (2002) reports a similar sign change for a direct measure of cropland open space. However, her result is not statistically different from zero.

<sup>3</sup> The two amenities are depicted as scalars for simplicity. All arguments generalize to the case where there are vectors of positive and negative amenities.

<sup>4</sup> The dimensionality restriction in spatial dispersion of an amenity is mathematically analogous to the "verticality" restriction on relative preferences for different public goods in Smith et al. (2004) and Walsh (2007). The key difference is that the current model restricts the way households perceive spatial variation in a set of amenities, rather than restricting their relative preferences for those amenities.

$$\begin{aligned}
 (4) \quad & \max_{b, o, \mathbf{x}} U[b, g(o), s(o), \mathbf{x}; \alpha] \\
 & \text{s.t.: } y = b + P[g(o), s(o), \mathbf{x}].
 \end{aligned}$$

Households are not free to choose  $g$  and  $s$  separately; their choice of  $o$  conveys a specific  $(g, s)$  bundle. Therefore, the partial derivative of the equilibrium hedonic price function with respect to  $o$  measures the implicit price of the change in the amenity bundle associated with a marginal change in  $o$ . For example, if  $o$  were to represent distance to the nearest cropland parcel, as in Parker and Munroe's (2007) model of an "edge-effect externality,"  $\partial P / \partial o$  would measure the implicit price of the change in the amenity bundle associated with a marginal movement away from cropland. Whether this movement increases or decreases property values will depend on whether households perceive the net effect of  $g$  and  $s$  to be positive or negative at their current distance from cropland.

The hedonic framework for amenity bundling in (3) and (4) relates to recent work on the general equilibrium implications of urban growth by Caruso et al. (2007) and Walsh (2007). Caruso et al. develop a theoretical model of urban growth where households make location choices based on their preferences for a composite farmland amenity and a composite urban amenity, both of which increase utility. As population growth increases residential density, the urban amenity increases and the farmland amenity decreases. Land prices, location choices, and the levels of each amenity are all endogenous in this general equilibrium framework, allowing the authors to express the equilibrium levels of amenities as a function of household preferences. Similarly, Walsh estimates an equilibrium sorting model of household location choice where people get utility from the open space provided by the neighborhood where they live. His subsequent simulation exercise demonstrates how strong preferences for open space can increase the rate at which farmland is converted to urban development, decreasing the neighborhood's total amount of open space in the long run.

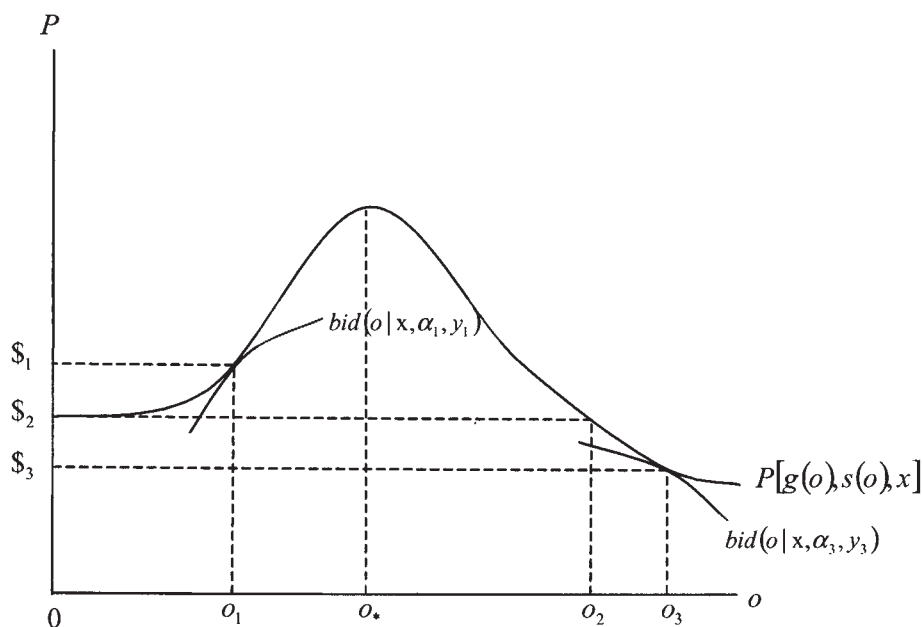
Like the present model, Caruso et al. (2007) and Walsh (2007) both restrict the open space amenity to be dispersed along a single dimension.<sup>5</sup> While the hedonic framework in equation (4) abstracts from the richness of detail provided by their general equilibrium models, its characterization of equilibrium in the housing market generalizes two important features of the household's location choice problem. First, it avoids the need to impose a specific functional form for utility (like the CES function in Walsh or the Cobb-Douglas function in Caruso et al.) and it relaxes the preference homogeneity restriction from Caruso et al. Second, the hedonic framework is consistent with the idea that an individual household's marginal utility from open space may be positive or negative depending on the composition of the bundle of amenities conveyed by the proximity of its home to nearby open space. In contrast, Walsh and Caruso et al. both restrict marginal utility to be either strictly positive or strictly negative, regardless of proximity.<sup>6</sup>

Figure 3 illustrates how a bundle of positive and negative amenities from cropland open space could influence housing prices in a hedonic equilibrium. The figure is drawn so that positive amenities dominate for homes with very small amounts of open space, and negative amenities dominate for homes with very large amounts of open space.

<sup>5</sup> The dimensionality restriction is also applied in models depicting the transmission of a negative externality from conventional to organic agriculture (Parker, 2007; Parker and Munroe, 2007).

<sup>6</sup> While Caruso et al. (2007) restrict marginal utility from the farmland amenity to be strictly positive or strictly negative, the utility tradeoff between farmland amenities and urban amenities is central to the equilibrium concept in their model.





**Figure 3. Agricultural open space as a bundled amenity in a hedonic equilibrium**

Intuitively, figure 3 implies that negative amenities from cropland, such as pesticide drift, noise, dust, and odors, are largely absorbed by the nearest urban neighbors, while houses somewhat farther away are protected from negative amenities but still enjoy the positive ones. For example, houses located a quarter mile from cropland may be buffered from the negative externalities, while still being within walking distance to scenic views, wildlife habitat, and local farmers' markets.

The point  $o_*$  in figure 3 denotes the amount of cropland open space that would maximize the price of a home. This is the point at which the differential between positive and negative amenities is largest. As the amount of open space decreases from  $o_*$  to  $o_1$ , so do the positive amenities it provides, and so does the price of housing. Increasing the amount of open space above  $o_*$  decreases the price of a home as the marginal effect of noise, dust, and odors associated with normal farming operations exceeds the marginal effect of the positive amenities associated with access to open space. At  $o_2$ , the positive and negative amenities exactly offset one another so that access to open space has zero net effect on housing prices. In other words, a home with  $o_2$  units of open space is priced the same as a home with no access to open space. At  $o_3$ , the disamenities dominate so that the bundle of open space amenities has a negative net effect on housing prices.

Figure 3 is consistent with the empirical evidence on interactions between farmers and their urban neighbors at the agricultural-urban fringe. The notion that productive cropland generates disamenities for nearby homes is consistent with the frequent stories of "edge conflicts" between farmers and urban residents reported in the popular media. It also helps to explain the emergence of buffer zones, disclosure statements, "right-to-farm" laws, and other policy instruments designed to help farmers avoid nuisance lawsuits in agricultural communities experiencing high rates of urban growth (Sokolow,

2003). Likewise, the idea that the net price effect of bundled cropland amenities can be positive for most homes is consistent with the growing popularity of state and local easement programs for preserving productive farmland. The tension between negative amenities and positive amenities at different distances from cropland also offers an explanation as to why the coefficient on the share of a neighborhood in cropland changes sign as Geoghegan, Wainger, and Bockstael (1997) change the length of the radius used to define a neighborhood around each home. Increasing the size of a neighborhood will change the shares of the different land types in that neighborhood. This may overstate or understate the actual contribution of open space to housing prices, depending on the “true” neighborhood size and land use patterns. Finally, notice that figure 3 is consistent with the idea that as one moves very far from cropland, the marginal effect of moving farther away is likely to be close to zero, as the positive and negative amenities are both diminished.

### *Using Buffer Zones to Adjust the Transmission of Cropland Amenities*

Understanding how a bundle of cropland amenities influences urban property values can be important for evaluating land use policies at the agricultural-urban fringe. Communities in these areas are increasingly requiring that buffer zones be established between farms and houses to mitigate the effect of negative agricultural amenities on residential homeowners while helping farmers to avoid nuisance lawsuits (Hammond, 2002). A buffer zone is a physical barrier, such as a wall, a pond, or native vegetation, which limits the flow of externalities between otherwise adjacent parcels. Mandatory buffer zones have some theoretical justification. Households’ inability to affect the farming practices that generate positive and negative amenities can drive a wedge between the size of a socially optimal buffer zone and the privately optimal buffer zone that would emerge from unconstrained urban development (Parker, 2007).<sup>7</sup> In the absence of government intervention, the bundle of cropland amenities may impose a negative externality on nearby homes, decreasing their resale value.

In practice, the size of a socially optimal buffer zone could be determined by weighing the cost of developing the buffer against the benefits it would provide to homeowners and farmers. A full assessment of these costs and benefits would be a major undertaking. Determining the opportunity cost of establishing a buffer would require assessing the potential development value of that land as well as the values of all the private and public benefits which would stem from using that land for agricultural production. Likewise, while homeowners living near the buffer may be the immediate beneficiaries of reduced pesticide drift, the buffer could also benefit people downstream by reducing the transmission of pesticides and fertilizer through urban wastewater systems. One could also consider general equilibrium implications. Establishing a greenbelt buffer between farmland and homes could mitigate the transmission of externalities and provide additional open space in the short run. Yet, as one referee observes, if the buffer were permanent it could induce “leapfrog” development in the long run. Developing a general equilibrium model capable of evaluating all of these

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<sup>7</sup> Households’ inability to change farmers’ production practices can lead to market failure despite the fact that the households depicted in (4) are free to adjust their exposure to amenities by varying their proximity to cropland. This follows from result 4 in Parker (2007).

tradeoffs would significantly improve our ability to assess the distributional welfare implications of buffer zones and other land use policies at the agricultural-urban fringe. The remainder of the paper takes a step in this direction by illustrating how the bundled amenity model can be used to evaluate the cumulative effect of positive and negative amenities on residential property values.

From an urban homeowner's perspective, the ideal buffer zone would be defined such that access to agricultural open space has a strictly positive effect on housing prices. In figure 3, this would mean setting the buffer such that no home has more than  $o_2$  units of open space. Using a hedonic regression to identify  $o_2$  could help to inform land use policy in agricultural communities experiencing rapid urban growth. California's San Joaquin County is one such community.

### **Application to San Joaquin County, California**

Located in the middle of California's central valley, San Joaquin is one of the largest agricultural counties in the nation, with annual production value well over a billion dollars (Kuminoff, Sumner, and Goldman, 2000). Three quarters of its 564,000 residents live in seven cities: Escalon, Lathrop, Lodi, Manteca, Ripon, Stockton, and Tracy. Each city is immediately surrounded by productive cropland. In acreage terms, 86% of the county is used for agriculture, and only 8% is classified as urban according to California's Farmland Mapping and Monitoring Program. The remaining 6% of the county consists of water bodies, native vegetation, and very low-density housing.

San Joaquin's recent growth patterns have led to increased interaction between farmers and their urban neighbors. Overall, 95% of the land in the county is privately owned, and development restrictions are relatively lax by California standards (Froeliger and Sokolow, 1995)—e.g., buffer zones are not required between agriculture and residential developments. As a result, the county's urban population rose significantly in the 1990s. Between 1990 and 2000, San Joaquin grew by about 16% in terms of both acreage and its urban population. The increased interaction between urban residents and production agriculture makes San Joaquin an ideal area for investigating how housing prices are affected by the proximity to intensively farmed cropland.

#### *Empirical Model and Data Sources*

The first question to consider in a hedonic property value study is: What defines the market? Palmquist (2005) suggests that if there are a "reasonable" number of households who would consider living in two separate areas, then the two areas should be treated as a single market. The seven cities in San Joaquin County appear to fit this criterion. Table 1 shows selected characteristics of these cities and road mileages between them. In terms of mean housing price (reported in year 2000 dollars), the seven cities are very similar. The largest difference is between Stockton (\$132,047) and Tracy (\$200,706). However, this difference is diminished when prices are normalized to control for house size, using square feet of the building. Furthermore, as the largest two cities in the county, Stockton and Tracy have many similarly priced homes.

Table 1 also reports the road mileage between each pair of cities and the distance from each city to San Francisco. By California commuting standards, all seven cities are reasonably close. While data on city-to-city commuting patterns are not available for the

**Table 1. City Characteristics and Road Mileage in San Joaquin County**

City	Population	Mean House Price (\$)	Mean \$/Sq. Foot	Mean Commute Time (minutes)
Escalon	6,350	149,302	96	22
Lathrop	11,600	150,848	104	27
Lodi	59,400	152,671	103	15
Manteca	5,500	156,273	101	21
Ripon	11,150	161,562	102	20
Stockton	253,800	132,047	88	17
Tracy	65,600	200,706	116	28

( extended → )

study period, table 1 reports the average commute time for workers living in each city. Based on 1990 Census data, the average one-way commute time ranges from 15–17 minutes in Lodi and Stockton to 27–28 minutes in Lathrop and Tracy. As two of the three largest cities, Lodi and Stockton are likely to offer more local employment opportunities, helping to explain their relatively short commute times. In contrast, the relatively long commute times for workers living in Lathrop and Tracy probably reflect a higher proportion of workers choosing to exploit their relatively close proximity to the San Francisco Bay area. Overall, the proximity between San Joaquin's seven cities and the similarity in their housing prices suggests they can be treated as a single market.

The price of each home is assumed to depend on its structure features, on its access to different types of open space, and on the local public goods provided by the neighborhood in which the home is located. Data on these characteristics were collected from a variety of sources. Micro data on the sale price, structural features, and geographic coordinates of all homes sold in San Joaquin County between 1990 and 1998 were purchased from TransAmerica Intellitech, a commercial vendor. The structural characteristics include the number of bedrooms (*bedrooms*), the number of bathrooms (*bathrooms*), lot size (*sqftlot*), square feet of the home (*sqftbuilding*), age of the home (*age*), and the improved percentage (*improved\_*%). Dropping nonresidential properties, farmhouses and other rural properties, observations with missing variables, transactions between family members, and apparent data entry errors left 22,316 observations in San Joaquin's seven cities—11% of all the homes in the county.

The empirical literature on the role of local public goods in household location choice often uses school district boundaries to define mutually exclusive neighborhoods (Smith et al., 2004; Walsh, 2007; Banzhaf and Walsh, 2008). A key advantage of this approach is that school districts map directly into a widely studied local public good—school quality. Students are required to attend schools located within the geographic boundaries of the district in which they live, creating a link between the choice of a home and public school quality. At the same time, there are many other spatially delineated amenities that can vary systematically across school districts and may influence where people choose to live. Examples include proximity to shopping areas, proximity to employment centers, landscaping, crime rates, recreation opportunities, and even the demographic composition of the neighborhood. Since it is not possible to observe all of

**Table 1. Extended**

Road Mileage to						
Escalon	Lathrop	Lodi	Manteca	Ripon	Stockton	San Francisco
						88
17						73
33	25					97
12	5	24				75
13	13	31	8			82
23	11	14	15	22		82
28	13	37	14	22	22	62

these attributes, indicator variables for each school district are used to control for the composite property value effect of all the local public goods and amenities provided by each of several school districts in the county.<sup>8</sup>

Land use data were obtained from the California Department of Conservation Farmland Mapping and Monitoring Program (FMMP). FMMP has used a combination of aerial photography and ground checking to map land use in California's agricultural counties in every even year since 1990.<sup>9</sup> It distinguishes between urban areas, water areas, and four categories of cropland: prime, statewide importance, local importance, and unique. The different categories primarily reflect differences in soil quality and irrigation. ArcView GIS software was used to measure the amount of water area and cropland open space in a neighborhood around each home in the year in which that home was sold. First, each home's neighborhood was defined by a circle around the home with a 400-meter radius.<sup>10</sup> Then cropland and water area were measured as percentages of this neighborhood and included as independent variables in the hedonic regression. This is a common approach to developing a proxy measure for access to open space (e.g., Geoghegan, Wainger, and Bockstael, 1997; Bell and Bockstael, 2000; Irwin, 2002).

### *Developing Instruments to Address Endogeneity of Open Space Measures*

In general, proxy variables for access to open space will be endogenous in a hedonic property value regression. Irwin and Bockstael (2001) were the first to point out that the same market forces which determine housing prices also determine whether nearby privately owned land is developed for urban use. As a result, any omitted variable which is not independently distributed across space may be correlated with measures of access

<sup>8</sup> Banzhaf and Walsh (2008) provide another recent example of this "local fixed effects" approach to controlling for unobserved spatial amenities.

<sup>9</sup> ArcView was used to reconstruct the urban edge in odd years. Taking 1991 as an example, the first step was to identify urban polygons built between 1990 and 1992. New homes built in 1991 were then overlaid on top of the new urban polygons. Finally, each new urban polygon with any homes built on it in 1991 was added to the urban land base in 1991. This generally meant keeping 50% of the new urban polygons. The idea is that the new urban polygons represent housing developments, many of which take years to build. Once construction starts, it seems reasonable to assume that people shopping for a nearby house will be aware of the development plan.

<sup>10</sup> Four hundred meters is equivalent to 0.2485 miles. This is the same distance used by Irwin (2002) in her baseline econometric specification and subsequent policy analysis.



to open space. Irwin and Bockstael suggest addressing the endogeneity of open space measures by using 2SLS regression with measures of land conversion costs as instruments. Irwin (2002) and Ready and Abdalla (2005) both apply this technique, after developing instruments based on measures of soil suitability for construction and placement of septic tanks, and the physical features of the land including slope, drainage, soil quality, and an agricultural productivity index. These instruments are all indirect measures for the opportunity cost of converting land from agricultural to urban uses.

Endogeneity in the measure for access to cropland open space in San Joaquin County is addressed using an instrumental variables approach similar to the studies by Irwin (2002) and Ready and Abdalla (2005). First, indicator variables for three different categories of cropland (*prime*, *statewide importance*, and *local importance*) are used as instruments because variation in soil quality and irrigation is likely to be correlated with land conversion costs. Then, a new instrument is developed based on the farm gate prices of the bundle of crops grown on each agricultural parcel. Holding real production costs constant, temporal variation in prices should be correlated with agricultural profitability, providing an additional measure for the opportunity cost of converting cropland to urban uses.

The agricultural profitability instrument is constructed from data on crop prices, using pesticide application records to determine where each crop is grown. California's Environmental Protection Agency (EPA) requires all farmers and professional pesticide applicators to submit records every time they apply a pesticide.<sup>11</sup> The information submitted for each application includes date, crop, and the township-range-section (TRS) where that crop was grown. Each TRS corresponds to a specific square mile "cell" in the California Public Lands Survey System grid, making it possible to identify which crops were actually grown in the 400-meter radius "neighborhood" around each home. Between 1990 and 1998, a total of 72 different crops were grown in the 171 TRS cells intersecting housing neighborhoods.

The instrument for agricultural profitability was calculated as a three-year moving average of farm gate prices for the crops grown between 1990 and 1998 on the TRS in which each home is located. This process used county-level price data from the California Agricultural Statistics Service. First, separate price indices were developed for each of the 72 crops, using 1990 as the base year. Then the instrument for TRS  $j$  in year  $t$  was calculated by taking a simple average over the index values in years  $t - 1$ ,  $t$ , and  $t + 1$  for each crop grown in that TRS. Equation (5) provides a formal expression for the construction of this instrumental variable:

$$(5) \quad Z_{j,t} = \frac{\sum_{i=1}^{N_j} \sum_{s=t-1}^{t+1} \tilde{P}_{i,s}}{3N_j},$$

where  $\tilde{P}_{i,s}$  is the value of the price index for the  $i$ th crop grown in TRS  $j$  in year  $s$ , and  $N_j$  is the total number of crops grown in TRS  $j$  between 1990 and 1998. The final step

<sup>11</sup> The California EPA (2004) definition of a pesticide is broad. In addition to all chemically produced pesticides, it includes organic pesticides such as sulfur and insecticidal soap, and biopesticides such as pheromones and beneficial insects. Thus, the pesticide application records should provide fairly comprehensive coverage of the commercially grown crops in San Joaquin County.

in constructing the instrument is simply to match each home that is sold with the corresponding value for  $Z_{j,t}$  in the TRS where the sale occurred.<sup>12</sup>

The price index and the soil quality indicator variables are admittedly crude proxies for agricultural profitability. For them to serve as relevant instruments, the opportunity cost of crop production must be correlated with variation in soil quality, with variation in the mix of crops across space, or with variation in real crop prices over time. While it seems likely that these correlations will be present, one would certainly prefer to have direct data on the net present value of expected crop returns. The difficulty is that spatially delineated data on production costs or farmers' expectations about future profitability are simply not available for all 72 crops. Without access to direct data on returns, the price index and soil quality indicators may be the best instruments available.

### Econometric Results and Policy Implications

Table 2 reports summary statistics for the data used in the estimation. For the average home, approximately 8% of the surrounding neighborhood consists of cropland open space and 0.2% consists of water areas. In the econometric model, housing prices are regressed on all the structural characteristics and open space variables summarized in table 2, and on vectors of spatial and temporal dummy variables (**Dspace** and **Dtime**). The main specification is expressed as:

$$(6) \quad \ln(P_j) = \beta_0 + \beta_1 \ln(\text{bedrooms}_j) + \beta_2 \ln(\text{bathrooms}_j) + \beta_3 \text{improved\_}\%_j \\ + \beta_4 \ln(\text{sqftbuilding}_j) + \beta_5 \ln(\text{sqftlot}_j) + \beta_6 \ln(\text{age}_j) \\ + \beta_7 \text{commute\_time}_j + \beta_8 \text{watershare}_j + \beta_9 \text{cropshare}_j \\ + \beta_{10} \text{cropshare}_j^2 + \delta \times \mathbf{Dtime}_j + \gamma \times \mathbf{Dspace}_j + \varepsilon_j.$$

Housing prices and values of the continuous variables are measured in logs, while variables which may take on zero values are measured in levels. Dummy variables for year and month were used to control for seasonal and annual housing market trends; dummy variables for each city are used to control for variation in city services, policies, traffic, and proximity to cultural amenities; and dummy variables for each school district are used to control for variation in school quality and other local public goods. Finally, adding a quadratic term for the share of the neighborhood in cropland allows the econometric model to provide a rough approximation to the conceptual model of a bundled amenity in figure 3. Thus, the sign and statistical significance of the coefficient on  $\text{cropshare}_j^2$  provide a test on the hypothesis that cropland open space serves as a bundled amenity in San Joaquin County.

#### *Restricting Cropland to Have a Constant Marginal Effect on Housing Prices*

Before testing whether cropland serves as a bundled amenity, the model was first estimated under the assumption that cropland has a constant marginal effect on housing

<sup>12</sup> In cases where the 400-meter radius "neighborhood" around a home overlapped two different TRS cells with cropland, the information from the closer of the two was attached.

**Table 2. Summary Statistics for Housing Sales ( $N = 22,316$ )**

Variable	Mean	Std. Dev.	Minimum	Maximum
Sale Price (\$)	153,120	61,984	31,693	467,720
<b>Structural Characteristics:</b>				
<i>bathrooms</i>	1.95	0.61	1	6.5
<i>bedrooms</i>	3.11	0.72	1	20
<i>improved_%</i>	64.0	10.3	4.0	95.0
<i>sqftbuilding</i>	1,554	509	320	7,880
<i>sqftlot</i>	7,718	6,162	1,250	99,752
<i>age</i>	22	21	1	98
<b>Neighborhood Amenities:</b>				
<i>commute_time</i>	19.95	5.62	5	32
<i>watershare</i>	0.002	0.02	0.00	0.42
<i>cropshare</i>	0.08	0.14	0.00	0.70
<b>Instruments:</b>				
<i>cropland type 1</i>	0.07	0.26	0	1
<i>cropland type 2</i>	0.62	0.48	0	1
<i>cropland type 3</i>	0.29	0.45	0	1
<i>price index</i>	116.73	21.03	63.19	160.24

Note: Prices are reported in constant year 2000 dollars using the CPI deflator.

prices (i.e.,  $\beta_{10} = 0$ ). This serves as a connection to the existing literature and as a basis for comparison. Table 3 presents the results from five different specifications. Column [1] shows the OLS results from the basic model without any dummy variables. This small set of covariates explains 63% of the variation in the log of housing prices. Not surprisingly, the coefficients on *sqftbuilding*, *sqftlot*, and *bathrooms* are positive, the coefficient on *age* is negative, and all four are economically important and statistically significant at conventional levels.<sup>13</sup> Likewise, the results suggest that increased access to water areas and cropland open space both tend to increase the price of housing. While both coefficients are statistically significant, the magnitude of the coefficient on *cropshare* is quite small. Its coefficient would imply that decreasing the share of the neighborhood in cropland by 1% would decrease the price of a home by less than one-tenth of 1%. The magnitude of this effect is much smaller than the estimates for similar open space amenities reported by Irwin (2002) and Ready and Abdalla (2005). The negative coefficient on *improved\_%* and the positive coefficient on *commute\_time* are also surprising. All else constant, one would expect structural improvements to a home to increase its price and a longer commute time to decrease its price.

Columns [2] and [3] present the results from OLS estimation after adding dummy variables for time and space. While the year and month fixed effects have virtually no impact on the estimated coefficients, the fixed effects for cities and school districts are quite important. Using the city and school district dummies to control for spatial variation in unobserved variables decreases the coefficient on *cropshare* by more than 50%.

<sup>13</sup> After controlling for the size of the home, it is difficult to anticipate how subdividing it into more rooms will affect its price. In this case, the coefficient suggests that adding another bedroom will tend to decrease the price.

**Table 3. Results from Restricting Cropland to Have a Constant Marginal Effect**

Variable	Model Specifications				
	[1]	[2]	[3]	[4]	[5]
<i>bathrooms</i>	0.155 (0.009)	0.167 (0.009)	0.137 (0.008)	0.124 (0.010)	0.109 (0.027)
<i>bedrooms</i>	-0.057 (0.012)	-0.056 (0.011)	-0.020 (0.010)	-0.001 (0.011)	0.026 (0.029)
<i>improved_%</i>	-0.004 (0.000)	-0.003 (0.000)	0.003 (0.000)	0.003 (0.000)	0.003 (0.001)
<i>sqftbuilding</i>	0.757 (0.011)	0.753 (0.011)	0.578 (0.010)	0.578 (0.012)	0.558 (0.034)
<i>sqftlot</i>	0.067 (0.006)	0.067 (0.006)	0.109 (0.006)	0.157 (0.009)	0.182 (0.037)
<i>age</i>	-0.041 (0.002)	-0.032 (0.002)	-0.034 (0.002)	-0.079 (0.006)	-0.065 (0.021)
<i>commute_time</i>	0.010 (0.000)	0.011 (0.000)	-0.007 (0.001)	-0.008 (0.001)	-0.007 (0.002)
<i>watershare</i>	0.871 (0.075)	0.902 (0.075)	1.697 (0.081)	1.550 (0.084)	1.575 (0.220)
<i>cropshare</i>	0.079 (0.012)	0.083 (0.012)	0.037 (0.012)	-1.147 (0.138)	-0.689 (0.382)
Intercept	5.671 (0.075)	5.646 (0.075)	6.813 (0.187)	7.333 (0.266)	6.795 (0.323)
Model	OLS	OLS	OLS	2SLS	2SLS
Year dummies		x	x	x	x
Month dummies		x	x	x	x
City dummies			x	x	x
School district dummies			x	x	x
Nearest neighbors omitted					x
$R^2$	0.63	0.63	0.72		
No. of observations	22,316	22,316	22,316	22,316	2,203

Note: Values in parentheses are heteroskedasticity-robust standard errors.

It also changes the magnitudes of the coefficients on the structural characteristics and changes the signs on *improved\_%* and *commute\_time* to be intuitively plausible.

The results from 2SLS estimation are presented in column [4]. Using the soil type variables and price index as instruments for *cropshare* changes the sign and magnitude of its coefficient, implying that cropland is a net disamenity.<sup>14</sup> This result should be treated with caution, however, because spatial error autocorrelation presents a second potential source of bias in the coefficient on cropland and its standard errors. While the spatial fixed effects for cities and school districts control for the “macro” effect of unobserved variables that vary across urban jurisdictions, they do not control for the

<sup>14</sup> The  $p$ -value from a Durbin-Wu-Hausman test is approximately 0, suggesting *cropshare* is endogenous. The  $F$ -value from the Staiger-Stock test for weak instruments is 82.46, indicating the instruments are sufficiently strong to rule out finite sample bias as a serious concern. A value of 82.46 implies that the finite sample bias associated with 2SLS estimation is approximately 1.2% of the bias from OLS estimation.

“micro” effect of unobserved variables concentrated in small areas within particular districts. Following Irwin (2002), local unobserved variables are addressed by drawing a random sample of observations that excludes all houses within 200 meters of each other.<sup>15</sup> Column [5] illustrates how excluding these “nearest neighbors” and estimating the model using the remaining 2,203 observations decreases the absolute magnitude of the coefficient on cropland and increases its standard error. After addressing both endogeneity and spatial autocorrelation, the results indicate that increasing the share of the neighborhood in cropland by 1% would *decrease* the price of housing in that neighborhood by 0.69%.

The overall pattern of results in table 3 is similar to findings reported in the existing literature. For example, Irwin (2002) and Ready and Abdalla (2005) both report that using instruments to control for the endogeneity of open space measures changes the signs and magnitudes of some of their key open space variables. Likewise, access to water open space has been found to increase the price of housing in previous work (Leggett and Bockstael, 2000; Kopits, McConnell, and Walls, 2007). Perhaps the most surprising result from table 3 is that when cropland is restricted to have a constant marginal effect, the 2SLS results imply cropland open space in San Joaquin County is, on average, a net disamenity relative to additional urban development. It is difficult to make a direct comparison between this result and the existing literature where more inclusive measures of open space, which aggregate cropland together with other land uses, have been found to increase housing prices (e.g., Geoghegan, 2002; Ready and Abdalla, 2005). One explanation for the opposite finding here is that production agriculture simply tends to be more intensive in California’s central valley than in the Maryland and Pennsylvania counties which have been the focus of previous work. Or, the relatively flat landscape and wind patterns in San Joaquin may expose urban residents living there to more of the agricultural disamenities. Another possibility is that the negative sign on cropland open space reflects a functional form misspecification associated with the maintained assumption that increasing cropland open space has a constant marginal effect on housing prices.

### *Treating Cropland as a Bundled Amenity*

Table 4 reports the results from the more general version of the model where cropland is treated as a bundled amenity, using the same five specifications as in table 3. The signs and magnitudes of the coefficients on all the structural characteristics and on *watershare* are essentially unchanged from the restricted version of the model. The main result in table 4 is that every specification fails to reject the bundled amenity model of access to cropland open space in the sense that all of the coefficients on the cropland variables are statistically significant at conventional levels. The positive coefficients on *cropshare* and the negative coefficients on *cropshare*<sup>2</sup> jointly indicate that increasing the share of the neighborhood in cropland increases the price of housing, up to a point, after which it decreases. This pattern is consistent with the bundled amenity model in figure 3.

<sup>15</sup> In theory, the most efficient way to address spatial autocorrelation is to specify the true parametric form of the weights matrix and estimate the appropriate spatial error/lag model. Yet, in practice, the true weights matrix is unknown and a large sample size limits opportunities for parametric experimentation. Spatial sampling and spatial fixed effects are less efficient, in theory, but they avoid the risk of biasing estimates by specifying the weights matrix incorrectly. Investigating the relative performance of these alternative strategies for addressing spatial autocorrelation is an important topic for future research.



**Table 4. Results from Treating Cropland as a Bundled Amenity**

Variable	Model Specifications				
	[1]	[2]	[3]	[4]	[5]
<i>bathrooms</i>	0.153 (0.009)	0.165 (0.009)	0.136 (0.008)	0.058 (0.024)	0.073 (0.047)
<i>bedrooms</i>	-0.058 (0.012)	-0.057 (0.012)	-0.021 (0.010)	-0.028 (0.020)	0.001 (0.045)
<i>improved_%</i>	-0.004 (0.000)	-0.003 (0.000)	0.003 (0.000)	0.003 (0.000)	0.003 (0.001)
<i>sqftbuilding</i>	0.759 (0.011)	0.755 (0.011)	0.580 (0.010)	0.658 (0.028)	0.574 (0.054)
<i>sqftlot</i>	0.067 (0.006)	0.067 (0.006)	0.109 (0.006)	0.199 (0.022)	0.218 (0.072)
<i>age</i>	-0.040 (0.002)	-0.032 (0.002)	-0.033 (0.002)	-0.093 (0.011)	-0.056 (0.036)
<i>commute_time</i>	0.010 (0.000)	0.011 (0.000)	-0.007 (0.001)	-0.013 (0.002)	-0.013 (0.004)
<i>watershare</i>	0.876 (0.075)	0.907 (0.075)	1.700 (0.081)	1.578 (0.106)	1.723 (0.292)
<i>cropshare</i>	0.212 (0.033)	0.229 (0.033)	0.159 (0.030)	3.817 (1.254)	4.642 (2.212)
<i>cropshare</i> <sup>2</sup>	-0.290 (0.071)	-0.318 (0.071)	-0.271 (0.064)	-14.020 (3.616)	-11.666 (4.938)
Intercept	5.654 (0.075)	5.628 (0.075)	6.824 (0.185)	8.558 (0.628)	7.402 (0.567)
Model	OLS	OLS	OLS	2SLS	2SLS
Year dummies		x	x	x	x
Month dummies		x	x	x	x
City dummies			x	x	x
School district dummies			x	x	x
Nearest neighbors omitted					x
<i>R</i> <sup>2</sup>	0.63	0.63	0.72		
No. of observations	22,316	22,316	22,316	22,316	2,203

Note: Values in parentheses are heteroskedasticity-robust standard errors.

As before, moving from OLS to 2SLS estimation produces large changes in the magnitude of the *cropshare* coefficients, while dropping “nearest neighbors” to control for spatial autocorrelation leads to small changes in estimates for all the coefficients and moderate increases in estimates for their standard errors. The economic implications of this specification are summarized in the first column of table 5. In terms of the bundled amenity model in figure 3, the econometric results imply that, all else constant, the share of cropland open space in the neighborhood that would maximize the price of a home is  $\sigma^* = 19.9\%$ . Increasing the share above 19.9% would decrease the price of the home, although the net effect would be positive up until the share reached  $\sigma_2 = 39.8\%$ . In other words, the results imply that the net effect of access to cropland open space on housing prices is positive for neighborhood shares less than 39.8% and negative for neighborhood shares above 39.8%. This threshold is approximately 4.5 times the mean

**Table 5. Economic Implications of the Bundled Amenity Model of Cropland Open Space**

Variable	Model Specifications		
	[1]	[2]	[3]
Nearest neighbors (meters)	200	250	300
No. of observations	2,203	1,579	1,239
<i>Cropshare</i> coefficient (standard error)	4.642 (2.212)	5.466 (2.683)	3.757 (2.071)
<i>Cropshare</i> <sup>2</sup> coefficient (standard error)	-11.666 (4.938)	-12.381 (6.322)	-7.446 (4.495)
Price-maximizing share ( $o^*$ )	0.199	0.221	0.252
Threshold share ( $o_2$ )	0.398	0.442	0.505
Mean distance from cropland for all $o > o_2$ (meters)	73	71	70
Estimated threshold buffer length (meters)	93	70	36
Predicted price effect of converting 1 acre of cropland to urban development (%):			
<i>cropshare</i> = 0	-0.037	-0.044	-0.030
<i>cropshare</i> = 0.04	-0.030	-0.036	-0.025
<i>cropshare</i> = 0.08	-0.022	-0.028	-0.021
<i>cropshare</i> = 0.12	-0.015	-0.020	-0.016
<i>cropshare</i> = 0.16	-0.007	-0.012	-0.011
<i>cropshare</i> = 0.20	0.000	-0.004	-0.006
<i>cropshare</i> = 0.24	0.008	0.004	-0.001
<i>cropshare</i> = 0.28	0.015	0.012	0.003
<i>cropshare</i> = 0.32	0.023	0.020	0.008
<i>cropshare</i> = 0.36	0.030	0.028	0.013

neighborhood share (table 2). Less than 6% of the homes in the data have shares above this threshold.

The results from the bundled amenity model can be used to calculate the implicit price of cropland open space as a function of the neighborhood share in cropland. The last 10 rows of table 5 report the predicted price effect of converting one acre of cropland to additional urban development. More precisely, this is the impact on the price of an individual home, expressed in percentage terms, of decreasing the amount of cropland in the home's neighborhood by one acre (or 0.8% of the neighborhood).<sup>16</sup> Consider a home with a cropland share of 4%, for example. This relatively small share indicates that while the home is not far from cropland, it is mainly surrounded by other homes which may serve as a buffer for noise, dust, odors, and other disamenities. The 2SLS estimates imply that the net price effect of cropland open space is positive and increasing for this home, so that it corresponds to a point like  $o_1$  in figure 3. Converting an additional acre of cropland would decrease the price of the home by 3%. In contrast, a home with 20% of cropland open space has close to the price-maximizing amount of open space,  $o^*$ , so that the marginal price effect of farmland conversion to urban development is near zero. Finally, consider a home with a neighborhood share of 36%. Its close proximity to cropland

<sup>16</sup> Measuring the implicit price of a less than 1% change is consistent with the idea that the results from a "first-stage" hedonic model are appropriate for calculating the willingness to pay for a marginal change in an amenity (Palmquist, 2005).

leaves it largely exposed to the negative amenities from agricultural production. For this home the marginal price effect of urban conversion is positive (3%) and the bundle of cropland amenities decreases housing prices. This is similar to the point  $o_3$  in figure 3.

The most appropriate comparison between these results and the existing literature is to Irwin's (2002) estimates for the price impact on the average home of different types of one-acre conversions in four Maryland counties: Anne Arundel, Calvert, Charles, and Howard. To compare her estimates to the results in our table 5, recall that the average home in San Joaquin County costs \$153,120 and has 8% of its neighborhood in cropland (table 2). The results from the bundled amenity model imply that decreasing the amount of cropland in this home's neighborhood by one acre would decrease its price by 2.2%, which is equivalent to \$3,368 (year 2000 dollars). These figures lie above Irwin's (2002) baseline 2SLS estimates for low-density urban development and below her estimates for commercial/industrial development. Since the cities in San Joaquin can be classified as medium- to high-density residential, the comparison to Irwin's results seems to suggest a monotonic relationship for the marginal price effect of increased development density.

An important caveat to the comparison with Irwin (2002) is that her results were found to be sensitive to the distance used to define "nearest neighbors" for the purpose of addressing spatial autocorrelation. To address this possibility in the bundled amenity model, columns [2] and [3] of table 5 report the sensitivity of the results to increasing the distance used to define nearest neighbors from 200 meters to 250 meters, and then to 300 meters. While this changes the coefficients on *cropshare* and *cropshare*<sup>2</sup>, as well as the magnitude of the predicted price effects, the 95% confidence intervals of all three sets of coefficients are overlapping.

What do these results imply for the "optimal" size of a buffer zone between cropland and residential neighborhoods in predominantly agricultural areas which are experiencing rapid urban growth? If the objective is to ensure that access to cropland open space has a strictly positive net effect on housing prices, a conservative interpretation of the results in table 5 would indicate the buffer should be designed such that no home has more than 39.8% of cropland in its neighborhood (i.e., in a circle around the home with a 400-meter radius). In practice, however, it may be impractical to design a buffer zone based on neighborhood shares calculated for every individual home in a residential community. The common approach to buffer zone design is to mandate a minimum distance between two different land uses. For example, the state of California restricts applications of the fumigant methyl bromide within 91 meters of homes and school property (California EPA, 2004).

One strategy for converting the threshold neighborhood shares in table 5 into distance-based buffer zones is to calculate the average distance to the nearest cropland parcel for all the homes exceeding the threshold neighborhood share. For homes above the 39.8% threshold, the average distance to the nearest cropland parcel is 73 meters. Increasing the threshold to 50.5% (using the results from column [3] of table 5) only decreases the average distance to 70 meters. The small size of this change reflects the irregular shape of the agricultural-urban edge. While the average distance to the nearest cropland parcel is quite robust to different choices for the threshold neighborhood share, a disadvantage of using an average is that it can be sensitive to outlying observations.

A second approach to evaluating the optimal buffer distance is to predict *distance to the nearest cropland parcel* as a function of *cropshare*, using the statistical correlation

between the neighborhood share of each home and the linear distance between that home and the nearest cropland parcel. The results from a linear regression of *distance to the nearest cropland parcel* on *cropshare* imply that a neighborhood share of 39.8% would correspond to a distance of 93 meters.<sup>17</sup> This approach to calculating the optimal buffer length is less robust than the approach based on average distance. Increasing the threshold neighborhood share to 50.5% decreases the implied buffer length to 36 meters, revealing a much wider range of estimates than the 70–73 meter range based on average distance. Nevertheless, the midpoints of the two ranges are quite close at 64.5 meters and 71.5 meters, respectively. Taking a simple average of these two figures provides an overall point estimate for the optimal buffer length of 68 meters. A more conservative approach would be to treat the 36 meter and 93 meter distances as bounds on a point estimate for the optimal buffer length.

### Conclusions

Farmers produce a bundle of positive and negative externalities. This paper has proposed a hedonic model for measuring how the bundle of externalities affects the prices of nearby homes. The key feature of the model is that it recognizes that both the direction and the magnitude of the price effect may vary with the proximity of an individual home to cropland open space. This can have important implications for land use policy, especially if the homeowners who live closest to cropland view it as a net disamenity relative to additional urban development.

Estimating the model for San Joaquin County suggested that access to cropland open space increases the value of most homes in the county's urban communities. Converting one acre of cropland to additional urban development within a quarter mile of the average home would decrease its price by 2.2%. The magnitude of this effect is broadly consistent with the existing literature on valuing open space amenities. Yet, for a small share of properties which are located closest to productive cropland, the results indicate that cropland serves as a net disamenity. For these 3% to 7% of homes, a marginal urban conversion would actually increase their prices. This result is consistent with reports of conflict between farmers and their urban neighbors at the agricultural-urban edge. It is also consistent with the growing use of public policy instruments designed to minimize edge conflicts, such as "right-to-farm" laws, agricultural disclosure statements, and buffer zones.

If the goal of establishing a buffer zone is to ensure that the bundle of agricultural externalities does not decrease housing prices, the results from San Joaquin County suggest the length of the buffer should lie somewhere between 36 and 93 meters, with 68 meters as the best point estimate. However, there are at least two reasons why these estimates should be treated as a rough approximation. First, the econometric analysis does not measure the extent to which property values reflect homeowners' expectations about the future pattern of urban development. If people expect cropland surrounding certain parts of the city to be converted to urban development in the near future, and if their expectations are capitalized into housing prices, estimates for the optimal buffer length may be biased downward. Second, planting 68 meters of native vegetation as a buffer may be a less-than-perfect substitute for 68 meters of housing. Native vegetation

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<sup>17</sup> The  $R^2$  from this regression is 0.70.

may be less effective at absorbing noise and other disamenities from agricultural production. At the same time, by providing additional wildlife habitat and scenic views, native vegetation may increase the positive amenities for adjacent homes.

The bundled amenity model is best suited to predicting the short-run effects on property values from small changes in cropland at the agricultural-urban fringe. For these predictions to be theoretically consistent, land uses and location choices must be held constant. In the long run, however, land use policies may induce households and farmers to adjust their behavior. For example, a large increase in public open space may increase the demand for housing and accelerate the rate at which the remaining farmland is converted to urban uses. Vehicle miles traveled and roadway congestion may also increase if residents near the city center have to drive to the open space to enjoy it. Recent simulation-based studies have suggested that these feedback effects can be quite important for property values, household welfare, and urban spatial structure (Caruso et al., 2007; Walsh, 2007; Homans and Marshall, 2008; Klaiber, 2008). Extending this literature to recognize that cropland provides both positive *and* negative amenities would provide a spatially explicit framework for assessing the general equilibrium optimality of buffer zones and other land use policies. This is an important direction for future research.

Another topic for further research is to relax the maintained assumption that the spatial dispersion of amenities is one-dimensional. This assumption is routinely made in hedonic property value studies, and its role in identifying the implicit price of open space and other spatially delineated amenities is unclear. The hedonic estimator developed by Cameron (2006) offers one possible strategy for measuring amenity values which have continuously varying directional effects. Extending the bundled amenity model to incorporate her idea would allow one to determine whether spatial variation in wind patterns and planted crops would imply different buffer lengths for different cities, or an optimal buffer zone that varies in length and width as one circumnavigates the city.

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## References

- Banzhaf, H. S., and R. P. Walsh. "Do People Vote with Their Feet? An Empirical Test of Tiebout's Mechanism." *Amer. Econ. Rev.* 98(2008):843–863.
- Bell, K. P., and N. E. Bockstael. "Applying the Generalized-Moments Estimation Approach to Spatial Problems Involving Micro-Level Data." *Rev. Econ. Statist.* 82(2000):72–82.
- Bell, K. P., and E. G. Irwin. "Spatially Explicit Micro-Level Modelling of Land Use Change at the Rural-Urban Interface." *Agr. Econ.* 27(2002):217–232.
- California Environmental Protection Agency, Department of Pesticide Regulation. "DPR Announces Regulations for Methyl Bromide Use." News Release, DPR, Sacramento, CA, 4 November 2004.
- Cameron, T. A. "Directional Heterogeneity in Distance Profiles in Hedonic Property Value Models." *J. Environ. Econ. Mgmt.* 51(2006):26–45.
- Caruso, G., D. Peeters, J. Cavailhes, and M. Rounsevell. "Spatial Configurations in a Periurban City: A Cellular Automata-Based Microeconomic Model." *Regional Sci. and Urban Econ.* 37(2007): 542–567.
- Froeliger, D. J., and A. D. Sokolow. "Farmland Protection in the General Plan: A Comparison of Seven Central Valley Counties." Res. Rep. No. 2, California Farmland and Open Space Policy Series, University of California Agricultural Issues Center, Davis, 1995.



- Geoghegan, J. "The Value of Open Spaces in Residential Land Use." *Land Use Policy* 19(2002):91-98.
- Geoghegan, J., L. A. Wainger, and N. E. Bockstael. "Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS." *Ecological Econ.* 23(1997):251-264.
- Hammond, S. V. "Can City and Farm Coexist? The Agricultural Buffer Experience in California." Great Valley Center, Modesto, CA, 2002.
- Homans, F. R., and E. P. Marshall. "Modeling Recreational Amenities in an Urban Setting: Location, Congestion, and Substitution Effects." *Agr. and Resour. Econ. Rev.* 37(2008):257-272.
- Irwin, E. G. "The Effects of Open Space on Residential Property Values." *Land Econ.* 78(2002):465-480.
- Irwin, E. G., and N. E. Bockstael. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values." *Amer. J. Agr. Econ.* 83(2001):698-704.
- Klaiber, H. A. "Valuing Open Space in a Locational Equilibrium Model of the Twin Cities." Unpub. Ph.D. diss., Dept. of Agr. and Resour. Econ., North Carolina State University, Raleigh, 2008.
- Kopits, E., V. McConnell, and M. Walls. "The Trade-off Between Private Lots and Public Open Space in Subdivisions at the Urban-Rural Fringe." *Amer. J. Agr. Econ.* 89(2007):1191-1197.
- Kuminoff, N. V., D. A. Sumner, and G. Goldman. "The Measure of California Agriculture." University of California Agricultural Issues Center, Davis, CA, 2000.
- Leggett, C. G., and N. E. Bockstael. "Evidence of the Effects of Water Quality on Residential Land Prices." *J. Environ. Econ. Mgmt.* 39(2000):121-144.
- Palmquist, R. B. "Property Value Models." In *Handbook of Environmental Economics*, vol. 2, eds., K.-G. Mäler and J. Vincent. Amsterdam: North-Holland Press, 2005.
- Palmquist, R. B., F. M. Roka, and T. Vukina. "Hog Operations, Environmental Effects, and Residential Property Values." *Land Econ.* 73(1997):114-124.
- Parker, D. C. "Revealing 'Space' in Spatial Externalities: Edge-Effect Externalities and Spatial Incentives." *J. Environ. Econ. and Mgmt.* 54(2007):84-99.
- Parker, D. C., and D. K. Munroe. "The Geography of Market Failure: Edge-Effect Externalities and the Location and Production Patterns of Organic Farming." *Ecological Econ.* 60(2007):821-833.
- Ready, R. C., and C. W. Abdalla. "The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model." *Amer. J. Agr. Econ.* 87(2005):314-326.
- Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *J. Polit. Econ.* 82(1974):34-55.
- Smith, V. K., H. Sieg, H. S. Banzhaf, and R. Walsh. "General Equilibrium Benefits for Environmental Improvements: Projected Ozone Reductions Under EPA's Prospective Analysis for the Los Angeles Air Basin." *J. Environ. Econ. Mgmt.* 47(2004):559-584.
- Sokolow, A. D. "California's Edge Problem: Urban Impacts on Agriculture." In *California Agriculture: Dimensions and Issues*, ed., J. Siebert. Giannini Foundation of Agricultural Economics, University of California, 2003.
- Tyrvaainen, L., and A. Miettinen. "Property Prices and Urban Forest Amenities." *J. Environ. Econ. Mgmt.* 39(2000):205-223.
- U.S. Department of Agriculture. *2002 Census of Agriculture*. USDA/National Agricultural Statistics Service, Washington, DC, June 2004. Online. Available at <http://www.agcensus.usda.gov/Publications/2002/USVolume104.pdf>.
- Walsh, R. L. "Endogenous Open Space Amenities in a Locational Equilibrium." *J. Urban Econ.* 61(2007):319-344.