Agricultural landscape value and irrigation water policy

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Abstract

Water is a limiting factor of agricultural production in an increasing number of regions. There is also ample empirical evidence to suggest that the economic value of agricultural landscape is substantial, which has been used to justify agricultural support programs in developed economies. We investigate the link between the environmental amenity of agricultural landscape and the value of water in crop production. We find that the environmental externality gives rise to a social derived demand for water which differs from the market-based (private) derived demand for water. Policy implications regarding irrigation water allocation and pricing are drawn. An empirical example illustrates the methodology and main findings.

JEL classification: Q15, Q51, Q58

Keywords: Willingness to pay, environmental amenity, social value of water, hedonic pricing.

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1 Introduction

Land and water are primary inputs in crop production and, as such, in the ensuing (byproduct) supply of environmental amenities such as farm landscape and ecosystem services. These environmental amenities have often been used to motivate agricultural policies such as land set-aside payments and land targeting or zoning, yet their implications regarding water allocation policies remain unexplored. The latter is particularly relevant for perennial crops, where a water shortage below the minimal water needed for the crop survival inflicts a large loss, thus deterring farmers from growing the crop. In this work we study implications of farm landscape vis-à-vis irrigation water policies.

Our work is related to the growing literature on the external effects of agricultural landscape in the context of urban-rural land allocation [see, e.g., 21, 23, 8, 3, 20, 19, 18, 7]. Farmland amenities and disamenities have been estimated in a number of countries (see the surveys by [8, 3]), including Austria [13], USA [4, 2, 14, 24, 16], UK [15, 26], Canada [6] and Israel [11, 12]. Agricultural landscape values have been differentiated according to basic activities (tilled land, pasture and woodland) by [9, 27, 7], and [12] provided landscape values for a variety of crops. Policy implications of agricultural landscape values have focused mainly on land policies such as land subsidies, targeting and zoning.

As the demand for water by other sectors (mainly households) increases with the population growth and higher living standards, water is becoming the limiting factor of agricultural production in many regions. The result is a

\begin{footnote}
Farming often entails negative externalities (pollution runoff due to fertilizers and pesticides, emission of greenhouse gases associated with tillage practices), the regulation of which has been studied extensively. Here we focus on the positive externality associated with agricultural landscape.
\end{footnote}
transfer of cultivated area into fallow or urban areas – a process that cannot easily be reversed. It is therefore important to understand the links between farmland policies and the demand for irrigation water. Here we study such links in the context of policies aimed at internalizing crop-specific landscape values and show how such policies can be implemented via irrigation water policies.

We first provide a theoretical framework aiming at incorporating the landscape value within the value generated by irrigation water. We extend the traditional notion of private derived demand for water to define the social derived demand and show how the landscape values can be internalized via water allocation policies. Then, we make use of an empirical case study based on the hedonic price approach to illustrate the application of the methodology. In particular, based on actual property transactions data collected in the North East of Italy, we estimate farm landscape values of agricultural crops and discuss potential effects on policies related to the allocation of irrigation water.

The paper proceeds as follows: section 2 summarizes the notion of agricultural landscape value. Section 3 focuses on the social derived demand for water and its allocation policies. Section 4 provides an empirical example and Section 5 concludes.

2 The landscape value of farmland

We consider a region whose land area is allocated between urban (dwelling, services, industry) and farming. Farmland is allocated among $K$ crop groups (open space and parks could be considered as a crop group), scattered spatially
across the region. Let $L_i = (l_{i1}, l_{i2}, \ldots, l_{iK})$ represent the allocation of farmland to the $K$ crops in the locality of household $i$, defined as the surrounding area affecting the household’s utility. Occasionally it will be useful to represent $L_i$ in the equivalent form $(l_{ki}, L_{-ki})$, where $L_{-ki} = (l_{i1}, \ldots, l_{i_{k-1}}, l_{i_{k+1}}, \ldots, l_{iK})$ represents land allocation to all crops excluding the $k$’th crop.

Household $i$ derives utility from a composite market good $\zeta_i$ with a unit price and from dwelling characteristics $(Z_i, L_i)$ according to the utility function $u_i(\zeta_i, Z_i, L_i)$, where $Z_i$ represent house-specific characteristics such as property’s area, number of bedrooms, number of bathrooms, age, type (townhouse, apartment, villa). The indirect utility is defined by

$$v_i(y_i, L_i) = \max_{\zeta_i, Z_i} u_i(\zeta_i, Z_i, L_i) \text{ s.t. } \zeta_i + h(Z_i, L_i) \leq y_i,$$

where $h(Z, L)$ is the (equilibrium) housing hedonic price function [25] and $y_i$ is the household’s income.

Given $L_{-ki}$, the willingness to pay to preserve $l_{ki}$ (crop $k$ area in household $i$’s locality) against the alternative of not cultivating $l_{ki}$ (leaving it fallow) is denoted $WTP_{ki}$ and defined by

$$v_i(y_i, 0, L_{-ki}) = v_i(y_i - WTP_{ik}, l_{ik}, L_{-ki}).$$

The above WTP index is defined with respect to a particular alternative, namely that of leaving the $l_{ik}$ area fallow. Other alternatives, e.g., replacing the $l_{ik}$ area with another crop or transferring $l_{ik}$ into urban area, will give rise to different WTP indexes.

Summing over all households in the region gives the total willingness to pay (WTP) to preserve crop $k$ area (against the alternative of leaving it fallow):

$$WTP_k = \sum_i WTP_{ik}.$$
Notice that any hectare of crop $k$ appears in the WTP of all households that reside close enough to this hectare (i.e., all households for which this hectare is in their vicinity). In the above summation, therefore, the landscape value of any of crop $k$’s hectares appears in many $WTP_{ki}$ terms, which is a manifestation of the public good nature of agricultural landscape.

Let $A_k$ represent crop $k$’s area (number of hectares) in the region. The per-hectare landscape value of crop $k$ is

$$W_k = \frac{WTP_k}{A_k}. \quad (2.4)$$

### 3 Landscape values and water allocation

The derived demand for irrigation water is the value marginal product of water generated by marketable output (crop yield). We extend this notion to include landscape amenity. Incorporating landscape values gives rise to a distinction between the private and social demand for water. We first explain this distinction and then discuss implications for water allocation.

#### 3.1 Private vs. social demand for irrigation water

Crop $k$’s output is produced by the input vector $(Q_k, X_k, A_k)$ according to the production function $F_k(Q_k, X_k, A_k)$, where $Q_k$ is water input, $A_k$ is land input and $X_k$ is a vector of all other inputs (e.g. labor, capital, fertilizers). Assuming that $F_k$ admits constant returns to scale, it can be expressed as

$$F_k(Q_k, X_k, A_k) = A_k \tilde{f}_k(q_k, x_k),$$

where $q_k = Q_q/A_k$ is the per-hectare water input, $x_k = X_k/A_k$ is the vector of per-hectare inputs other than water and land, and $\tilde{f}_k$ is the per-hectare production function.
Let
\[
\tilde{x}_k^*(q_k) = \arg \max_{x_k} \left\{ p_k \tilde{f}_k(q_k, x_k) - p_x \cdot x_k \right\}
\] (3.1)
with the ensuing profit
\[
\tilde{\pi}_k(q_k) \equiv p_k \tilde{f}_k(q_k, \tilde{x}_k^*(q_k)) - p_x \cdot \tilde{x}_k^*(q_k),
\] (3.2)
where the output and input prices \((p_k \text{ and } p_x)\) are suppressed as arguments of \(\tilde{\pi}_k(\cdot)\) for convenience. Under common conditions, involving input-output prices and production technology properties (increasing and strictly concave over an admissible input range), \(\tilde{\pi}_k(\cdot)\) is positive above some critical water input \(q_k > 0\). The \(x\)-inputs demands are given by
\[
x_k^*(q_k) = \begin{cases} 
\tilde{x}_k^*(q_k) & \text{if } q_k \geq q_k^0 \\
0 & \text{otherwise}
\end{cases}
\] (3.3)
and the water-yield function is defined by
\[
f_k(q_k) = \begin{cases} 
\tilde{f}_k(q_k, x_k^*(q_k)) & \text{if } q_k \geq q_k^0 \\
0 & \text{otherwise}
\end{cases}
\] (3.4)

We maintain the common properties that \(f_k(\cdot)\) is increasing and strictly concave over \([q_k, \bar{q}_k], 0 < q_k < \bar{q}_k \leq \infty\), where \(\bar{q}_k\) is the water input at which \(f_k(\cdot)\) reaches its maximum. The water demand function
\[
\tilde{\varphi}_k(p_q) = \arg \max_{q_k} \left\{ p_k f_k(q_k) - p_q q_k - p_x x^*(q_k) \right\} = f_k^{-1}(p_q/p_k)
\] (3.5)
is thus well-defined over the water price range \([0, \bar{p}_q^k]\), where
\[
\bar{p}_q^k \equiv p_k f_k'(q_k).
\] (3.6)
(To verify the rightmost term of (3.5) note, recalling (3.1), that the term multiplying \(x^*(q)\) vanishes.)
When the water price is \( p_q \in [0, \hat{p}_q^K] \), crop \( k \)'s growers will demand the per hectare water input \( \hat{\phi}_k(p_q) \) if the ensuing profit \( p_k f_k(\hat{\phi}_k(p_q)) - p_q \hat{\phi}_k(p_q) \) is nonnegative; otherwise, they will demand no water. Define \( g_k \) as the break-even water price, satisfying

\[
p_k f_k(\hat{\phi}_k(g_k)) - g_k \hat{\phi}_k(g_k) = 0.
\] (3.7)

The per-hectare water demand by crop \( k \)'s growers can now be defined by

\[
\phi_k(p_q) = \begin{cases} 
\hat{\phi}_k(p_q) & \text{if } p_q \in [0, g_k] \\
0 & \text{if } p_q > g_k
\end{cases}.
\] (3.8)

Figure 1 provides a graphical illustration. At a water price \( p_q \), crop \( k \) growers will demand the irrigation water input \( \hat{\phi}(p_q) = f'气候变化(\hat{\phi}(p_q)) \) if the revenue (the area beneath \( p_k f'_k(\cdot) \) between \( q_k \) and \( \hat{\phi}(p_q) \)) does not fall short of the water cost \( p_q \hat{\phi}(p_q) \). At a water price \( g_k \), the revenue just equal the water cost (in Figure 1 the area \( g_k b \hat{\phi}(g_k)0 \) just equals the area \( q_k ab \hat{\phi}(g_k) \)). When the water price \( p_q \) is above \( g_k \), any use of a positive quantity of irrigation water will generate a loss, hence no irrigation water will be demanded. At a water price below \( g_k \), water will be demanded up to the point where its value of marginal product just equals the water price, i.e., along the \( p_k f'_k(\cdot) \) curve, as depicted in Figure 1.

**Figure 1**

We refer to \( \phi_k(\cdot) \) as the *private* water demand per-hectare (Figure 1). The “private” qualifier signifies that this demand is driven solely by market forces and ignores extra-market effects such as the landscape value of farmland.

Growers are compensated for the output they sell in the marketplace, but not for the landscape amenities they generate. The former is given by the
producer surplus \( p_k f_k(\varphi(p_q)) - p_q \varphi(p_q) \) and the latter by \( W_k \), specified in equation (2.4) – both indexes are measured in \( \mathcal{E} \) per hectare. The private demand for irrigation water, discussed above, accounts only for surpluses associated with the harvested crop. The social demand, defined below, incorporates the landscape value generated by the water input.

Let

\[
\phi_s(p_q) = \begin{cases} 
\varphi(p_q) & \text{if } p_q \in [0, g_k] \\
q_k & \text{if } p_k \in (g_k, w_k] \\
0 & \text{if } p_q > w_k 
\end{cases}
\]  

(3.10)

represent the surplus per m\(^3\) generated by the water input \( q_k \) due to the landscape amenity.\(^2\) Suppose that \( w_k > g_k \), as depicted in Figure 1. We know (cf. equation (3.8)) that when the price of water \( p_q \) exceeds \( g_k \), farmers will cease the production of crop \( k \) (after some time, if not immediately). However, from a social point of view, as long as \( p_q \leq w_k \) it pays to use at least the water input \( q_k \), since this water input generates the surplus \( w_k \times q_k \) (= the landscape value \( W_k \)), which exceeds the water cost \( p_q \times q_k \). Thus, as long as \( p_q \leq w_k \), the demand for water owing to the landscape value is \( q_k \). Combining the latter with the private demand, specified in (3.8), gives the social demand for water when \( w_k > g_k \):

(If \( w_k \leq g_k \), the social and private demands are the same.) The social demand for water is depicted together with the private demand in Figure 1.

\(^2\)Since \( W_k \) is measured in \( \mathcal{E} \) per hectare and \( q_k \) is measured in m\(^3\) per hectare, \( w_k \) is measured in \( \mathcal{E} \) per m\(^3\) units.
3.2 Optimal water allocation

The optimal water allocation is obtained at the point where the social derived demand for water and the marginal cost of water supply intersect.\(^3\) Figure 1 depicts the social and private demands for water. Suppose, for simplicity, that the cost of water supply is linear in the quantity of water supplied (measured, say, in million m\(^3\) per year), so that the marginal and average costs of water supply are equal to the same constant, denoted \(m\). The marginal cost pricing rule implies setting \(p_q = m\) (\(p_q\) indicates the price of water). If \(p_q = m < g_k\), then crop \(k\) growers will demand the quantity \(\varphi(p_q) = \varphi^*(p_q)\), so the marginal cost pricing rule gives rise to the (socially) efficient allocation without any intervention. Arguably, there is a case for compensating crop \(k\) growers for the landscape value of \(W_k\) € per hectare (or \(w\) € per m\(^3\)) they provide, but efficiency is achieved irrespective of such compensations.

If, however, \(p_q = m \in (g_k, w_k)\), then the private demand for water vanishes, \(\varphi(p_q) = 0\), while the social demand equals \(\varphi^*(p_q) = q_k\) (see Figure 1). In this case some intervention is needed to implement the socially optimal allocation. Such an intervention can take different forms. One possibility is to pay crop \(k\)’s growers the per-hectare subsidy \(W_k = w_k \times q_k\). Another possibility is to subsidize the first \(q_k\) m\(^3\) of irrigation water by the rate \((m - g)\) € per m\(^3\) for each hectare of crop \(k\) produced. We further discuss these policies in the concluding section, with the hindsight of the empirical example considered next.

\(^3\)To simplify and allow a sharp focus on the effects of landscape values, we ignore long term consideration associated with fixed (capital) cost of water supply [for a discussion of the effects of fixed cost on water pricing rules see 28].
4 An empirical illustration

We estimate farm landscape values in Vicenza, Italy, for vineyards and orchards and discuss their possible effects on irrigation water allocation and pricing.

4.1 Estimating landscape values

There are different ways to estimate agricultural landscape values [see 12, for estimates based on contingent valuation as well as a discussion of other examples]. Here we use the hedonic price method based on actual property transactions data collected in the Vicenza region of northeast Italy. This methodology has been widely used in valuing extra-market traits in general and environmental amenities in particular [see 22, 5, and reference they cite].

Underlying a hedonic price valuation is the hedonic price function

\[ P = h(Z, L) \]

characterizing equilibrium in the region’s housing market, where \( P \) is the price of a property with specific characteristics \( Z \) (number of rooms, location, garden area, etc.) and environmental characteristics (surrounding cropland in the present context) \( L \). On the demand side, household \( i \) derives utility from housing characteristics \( Z_i \), the surrounding cropland allocation \( L_i \) and consumption of a composite good \( \xi_i \). In equilibrium, the household’s chosen location \( L_i \), housing characteristics \( Z_i \) and composite good \( \xi_i \), maximize utility subject to the budget constraint \( h(Z_i, L_i) + \xi_i = y_i \). A change in \( L_i \) may lead to a change in any of the choice variables and may affect also the supply of housing characteristics, which in turn can lead to a change in the equilibrium hedonic price function \( h(\cdot) \). This feature complicates welfare evaluation and
may turn the estimation of hedonic price functions intractable [10].

If, however, the transaction costs of moving are such that the change in $L_i$ does not induce relocation, then the ensuing welfare change can be deduced from the ensuing change in the average property value. In such a case, a change in the cropland allocation from the original situation $(l_{ki}, L_{-ki})$ to $(0, L_{-ki})$ induces the change

$$\Delta P_{ik} = h(Z_i, l_{ki}, L_{-ki}) - h(Z_i, 0, L_{-ki}) \quad (4.1)$$

in the property value (obviously, $\Delta P_{ik} = 0$ if $l_{ik} = 0$ in the original allocation).

We adopt the translog specification for the hedonic price function

$$P_i = \sum_{m=1}^{n_i} z_{im} \alpha_m + \sum_{k=1}^{K} \ell_{ki} \beta_k + \sum_{k} \sum_{j} \ell_{ki} \ell_{ji} \gamma_{kj} \quad (4.2)$$

with $\gamma_{kj} = \gamma_{jk}$, where lowercase variables represent the log of their respective uppercase variables for continuous variables (for dummy, zero-one, variables the lower-case and upper-case variables are the same). A positive landscape amenity of crop $k$ entails a positive $\beta_k$ while diminishing marginal effects imply that the $\gamma_{kk}$ are negative. The sign of the cross effects $\gamma_{kj}$, $k \neq j$, depend on whether crops $k$ and $j$ landscapes are complimentary (positive $\gamma_{jk}$) or substitutable (negative $\gamma_{jk}$).

The cropland data used in the estimation below consist of dummy variables, indicating the presence of the $k$’s cropland near the property, i.e., $\ell_{ki} = 1$ if crop $k$ land exists within 1 km of household $i$’s dwelling and $\ell_{ki} = 0$ otherwise. Thus, under the translog specification (4.2), equation (4.1) becomes

$$\Delta P_{ki} = \begin{cases} P_i \left[ 1 - e^{-\beta_k - \sum_j \gamma_{kj}} \right] & \text{if } \ell_{ki} = 1 \\ 0 & \text{if } \ell_{ki} = 0 \end{cases} \quad (4.3)$$

where $P_i = e^{P_i}$ is the actual property price. This change in property value measures the present value of an indefinite benefit stream. The annual equivalent
value is obtained by multiplying $\Delta P_{ki}$ by the interest rate $r$. The annual WTP to preserve crop $k$'s landscape in subregion (municipality, district, county) $M$, defined in (2.3), specializes here to

$$WTP^M_k = \sum_{i \in M} r \Delta P_{ki}. \quad (4.4)$$

Dividing $WTP^M_k$ by the number of hectares of crop $k$ in subregion $M$ (denoted $A^M_k$) gives $W^M_k$ – the per-hectare WTP for crop $k$, specified in (2.4). Dividing $W^M_k$ by $q^M_k$ (the minimal irrigation requirement of crop $k$ in subregion $M$) gives $w^M_k$ – the WTP per cubic meter allocated to crop $k$ in subregion $M$, specified in (3.9).

### 4.2 Data

Data of 121 housing transactions, carried out during 2007 in the Vicenza region, were collected from real-estate agents that carried out the transactions and could identify the property and its characteristics, including the agricultural landscape and livestock farming within its vicinity, where orchard, vineyard and meadows are within the household’s vicinity if they exist in the surrounded area within 1 km from the household and a livestock is within the household vicinity if a livestock farm can be seen from the household (which may be further away than 1 km).\(^4\) The specific dwelling characteristics include dwelling type (apartment, house or villa), dwelling area ($m^2$), garden area ($m^2$), number of bedrooms, number of bathrooms, maintenance level (grades 1-3), age of dwelling (years), distance to train station (minutes of driving), proximity to industrial or commercial areas (grades 0-2) and municipality (12 dummy variables for the 13 municipalities).

\(^4\)The landscape variables are dummies, assuming the value 1 if the landscape (or livestock) exists within the household’s vicinity and 0 otherwise.
Four crop groups are considered: vineyards, orchards, meadows and livestock. These crops comprise the majority of the rural landscape of the area under study, where livestock refers to farms with barnyards. This activity entails a negative externality due to noise and smell, but it may also give rise to a positive externality if cows are allowed to graze in the meadows. The net impact of livestock consists of the sum of these conflicting effects. Due to the hilly character of the area of study, field crops comprise a negligible fraction of land and are therefore not included.

A crop group is represented by a dummy variable, indicating whether farmland of this type exists within 1 km of the property. Also include are variables indicating the presence of urban parks near the property. Regarding potential multicollinearity problems, we looked at correlation values among explanatory variables and found no indication of highly collinear explanators. Table 1 presents summary statistics of the data used to estimate the hedonic price equation (4.2).

### Table 1

#### 4.3 Estimation results and landscape values

Table 2 presents estimates of the parameters of the hedonic price equation (4.2). The $\alpha$-estimates (of the coefficients of the dwelling specific characteristics) are mostly significant and with the expected sings. A villa commands a high premium: an average increase in the property value of 65% relative to an apartment or a house (the difference between the latter two was found insignificant). As expected, closeness to a commercial area decreases the property value and the driving time to a train station has a negative but insignificant effect (possibly due to nonlinearities, as we expect that living too close or too
far from a train station are both not desirable, whereas in between might be more desirable).

The $\beta$-estimates of vineyards, orchards and meadows are positive, as expected and significant for vineyards and meadows. Since livestock entails also undesirable features (noise, odor, dust), its $\beta$-coefficient is expected to be negative, as verified by the estimate. The $\gamma$-estimates (interaction effects) are statistically insignificant.

Table 2

The data and estimates of Table 2 are used to calculate $\Delta P_{ki}$, specified in equation (4.3), for each household in the sample. We then calculate the sample average of $r\Delta P_{ki}$ to obtain the WTP for preserving crop $k$’s landscape by an average household in 5 municipalities. By multiplying these average per-household WTPs by the number of households in each municipality, we obtain estimates of $WTP_k^M$, specified in equation (4.4). Dividing the latter estimates by the crop areas (see Table 3) gives the per-hectare WTP, specified in (2.4), and further dividing by the minimal water requirements gives the WTP per cubic meter, specified in (3.9). These estimates are presented in Table 4 for the two irrigation-dependent crops – vineyards and orchards. The $w_k$ values (the WTP per m$^3$) are obtained by dividing the per-hectare values by the minimal water requirement (see equation (3.9)). The values in parenthesis use the minimal irrigation water needs in southern Italy, where the more arid climate entails larger irrigation water requirements.$^5$

$^5$Minimal irrigation requirements where taken from [1]. Irrigation water in the Vicenza region is usually charged on a per-hectare basis and rates range between €40 and €50 per hectare. The values inside the parenthesis (based on water requirements in southern Italy) are for illustrative purpose only. Obtaining genuine estimates for other regions requires estimating the landscape values in these regions as well.
4.4 Discussion

The WTP per m$^3$ estimates of vineyard (Table 4) range between € 7.8 (2.3) per m$^3$ in Longare and € 48.6 (14.6) per m$^3$ in Vicenza. This difference can be attributed to the different populations and vineyard areas in the two municipalities: in a more densely populated municipality (Vicenza), an hectare of vineyard is likely to affect more households (cf. equations (4.3)), increasing the total WTP (cf. equation (4.4)); indeed, this effect is where the public good nature of agricultural landscape is most pronounced. Dividing the total WTP by a smaller area (see Table 3) further increases the per-hectare value in Vicenza compared to Longare.

The WTP per hectare of vineyard is smaller than that of orchards (Table 4). This difference stems from two sources. First, the two crops affect property values differently: Using equation (4.3), with the estimates of Table 2, reveals that the presence of orchards or vineyards near a property accounts for 10.5 % or 9.5 % of the property value, respectively. Second, the crop areas differ. The latter effect is likely to be small since crop area decreases both the numerator and denominator of equation (2.4). The difference in WTP per hectare is therefore mainly due to the first effect and is quite moderate. The difference in WTP per m$^3$ (Table 4, rightmost columns) is more pronounced due to the different water needs of the crops: the minimal water inputs of vineyards and orchards are 900 m$^3$ per hectare (3000 m$^3$ per hectare in southern Italy) and 2000 m$^3$ per hectare (3600 m$^3$ per hectare in southern Italy), respectively.
5 Concluding comments

The economic value of agricultural landscape has been found to be substantial in a number of studies. Consequently, this environmental amenity has been used to justify (some of) the public support given to agriculture in developed economies. One way to incorporate farm landscape amenities within agricultural policy is to subsidize farmers for the landscape amenity they provide based on their crop areas. As landscape values differ across crops, the landscape subsidies per hectare should vary accordingly. This approach works well in places where land input is the limiting factor of agricultural production.

In regions where irrigation water is the limiting factor of agricultural production, channeling the landscape subsidy via irrigation water pricing could be an effective policy. In such cases, it is important to understand the links between crop areas and the ensuing water demands. This allows us to infer how a certain farm policy aimed at internalizing crop landscape values affects water demands as well as how to design water policies (pricing and quotas) to internalize the environmental amenities associated with agricultural landscape. This paper explains how to accomplish this task. The empirical example demonstrates these links in our particular case.

Actual policy recommendations should be based on a comprehensive sample of property prices, with spatial crop landscape characteristics. Recent development of satellite and GIS technologies make such comprehensive empirical analysis feasible [see, e.g., 17].
References


Figure 1: Social and private demands for water.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>Max</th>
<th>Min</th>
<th>Std. Dev.</th>
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<tbody>
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<td>Price</td>
<td>transaction values (€)</td>
<td>27,147</td>
<td>1,150,000</td>
<td>78,000</td>
<td>163,863</td>
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<td>area of the property (sqm)</td>
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<td>370.0</td>
<td>40.0</td>
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<td>4000.0</td>
<td>0.0</td>
<td>654.3</td>
</tr>
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<td>5.0</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Bathrooms</td>
<td>number</td>
<td>2.0</td>
<td>4.0</td>
<td>1.0</td>
<td>0.8</td>
</tr>
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<td>Maintainance</td>
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<td>1.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Age of house</td>
<td>number of years</td>
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<td>307.0</td>
<td>0.0</td>
<td>32.7</td>
</tr>
<tr>
<td>Villa</td>
<td>= 1 if villa, 0=no</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Commercial</td>
<td>=1 if commercial area nearby, 0=no</td>
<td>0.1</td>
<td>1.0</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Train</td>
<td>driving time to train station (min.)</td>
<td>20.7</td>
<td>35.0</td>
<td>5.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Cattle</td>
<td>=1 if cattle nearby, 0=no</td>
<td>0.1</td>
<td>1.0</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Orchards</td>
<td>=1 if orchards nearby, 0=no</td>
<td>0.3</td>
<td>1.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Vineyards</td>
<td>=1 if vineyards nearby, 0=no</td>
<td>0.6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Meadows</td>
<td>=1 if meadows nearby, 0=no</td>
<td>0.6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Urban parks</td>
<td>=1 if urban parks nearby, 0=no</td>
<td>0.6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 1: Descriptive statistics. The qualifier “nearby” means “within 1 km of the property”.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>53.767</td>
<td>12.562</td>
<td>4.280</td>
<td>0.000</td>
</tr>
<tr>
<td>Dwelling area&lt;sup&gt;C&lt;/sup&gt;</td>
<td>0.266</td>
<td>0.098</td>
<td>2.717</td>
<td>0.008</td>
</tr>
<tr>
<td>Garden area&lt;sup&gt;C&lt;/sup&gt;</td>
<td>0.027</td>
<td>0.012</td>
<td>2.327</td>
<td>0.022</td>
</tr>
<tr>
<td>Number of bedrooms&lt;sup&gt;C&lt;/sup&gt;</td>
<td>0.168</td>
<td>0.097</td>
<td>1.731</td>
<td>0.087</td>
</tr>
<tr>
<td>Number of bathrooms&lt;sup&gt;C&lt;/sup&gt;</td>
<td>0.246</td>
<td>0.083</td>
<td>2.975</td>
<td>0.004</td>
</tr>
<tr>
<td>Level of maintenance</td>
<td>0.097</td>
<td>0.052</td>
<td>1.868</td>
<td>0.065</td>
</tr>
<tr>
<td>Age of house&lt;sup&gt;C&lt;/sup&gt;</td>
<td>-5.662</td>
<td>1.663</td>
<td>-3.404</td>
<td>0.001</td>
</tr>
<tr>
<td>Villa&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.653</td>
<td>0.131</td>
<td>4.979</td>
<td>0.000</td>
</tr>
<tr>
<td>Commercial area nearby&lt;sup&gt;D&lt;/sup&gt;</td>
<td>-0.171</td>
<td>0.078</td>
<td>-2.026</td>
<td>0.045</td>
</tr>
<tr>
<td>Driving time to train station&lt;sup&gt;C&lt;/sup&gt;</td>
<td>-0.080</td>
<td>0.066</td>
<td>-1.219</td>
<td>0.226</td>
</tr>
<tr>
<td>Cattle operation nearby&lt;sup&gt;D&lt;/sup&gt;</td>
<td>-0.194</td>
<td>0.096</td>
<td>-2.029</td>
<td>0.045</td>
</tr>
<tr>
<td>Orchards nearby&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.316</td>
<td>0.280</td>
<td>1.126</td>
<td>0.263</td>
</tr>
<tr>
<td>Vineyards nearby&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.157</td>
<td>0.065</td>
<td>2.400</td>
<td>0.018</td>
</tr>
<tr>
<td>Meadowss nearby&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.182</td>
<td>0.065</td>
<td>2.815</td>
<td>0.006</td>
</tr>
<tr>
<td>Orchards x Meadows&lt;sup&gt;D&lt;/sup&gt;</td>
<td>-0.147</td>
<td>0.133</td>
<td>-1.104</td>
<td>0.272</td>
</tr>
<tr>
<td>Orchards x Vineyards&lt;sup&gt;D&lt;/sup&gt;</td>
<td>-0.057</td>
<td>0.266</td>
<td>-0.215</td>
<td>0.830</td>
</tr>
<tr>
<td>Urbanparks&lt;sup&gt;D&lt;/sup&gt;</td>
<td>0.062</td>
<td>0.052</td>
<td>1.188</td>
<td>0.238</td>
</tr>
</tbody>
</table>

R-squared 0.863

<sup>C</sup> Continuous variable.

<sup>D</sup> Dummy (0-1) variable.

Table 2: Parameter estimates of the translog equation (4.2) (estimates of the municipal coefficients are not presented).

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Population (households)</th>
<th>Households near vineyards (%)</th>
<th>Households near orchards (%)</th>
<th>Vineyards area (ha)</th>
<th>Orchards area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altavilla</td>
<td>13643</td>
<td>50</td>
<td>33</td>
<td>362.3</td>
<td>31.1</td>
</tr>
<tr>
<td>Arcugnano</td>
<td>3032</td>
<td>60</td>
<td>40</td>
<td>80.1</td>
<td>15.7</td>
</tr>
<tr>
<td>Longare</td>
<td>2165</td>
<td>100</td>
<td>22</td>
<td>239.8</td>
<td>17.6</td>
</tr>
<tr>
<td>Sovizzo</td>
<td>2641</td>
<td>83</td>
<td>42</td>
<td>123.0</td>
<td>10.4</td>
</tr>
<tr>
<td>Vicenza</td>
<td>44442</td>
<td>23</td>
<td>19</td>
<td>181.1</td>
<td>58.7</td>
</tr>
</tbody>
</table>

Table 3: Relevant data for five Municipalities.
Table 4: WTP per hectare and WTP per m$^3$ for vineyards and orchards in 5 municipalities. The minimal water needs are 900 (3000) m$^3$ per hectare of vineyards and 2000 (3600) m$^3$ per hectare of orchards. The values inside the parenthesis represent water needs in the hotter climate of southern Italy. The water needs are taken from [1].

<table>
<thead>
<tr>
<th>Municipality</th>
<th>$W_k$ (€/hectare)</th>
<th>$W_k$ (€/hectare)</th>
<th>$w_k$ (€/m$^3$)</th>
<th>$w_k$ (€/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vineyards</td>
<td>Orchards</td>
<td>Vineyards</td>
<td>Orchards</td>
</tr>
<tr>
<td>Altavilla</td>
<td>14558</td>
<td>16153</td>
<td>16.2 (4.9)</td>
<td>8.1 (4.5)</td>
</tr>
<tr>
<td>Arcugnano</td>
<td>17574</td>
<td>19499</td>
<td>19.5 (5.9)</td>
<td>9.7 (5.4)</td>
</tr>
<tr>
<td>Longare</td>
<td>6983</td>
<td>7748</td>
<td>7.8 (2.3)</td>
<td>3.9 (2.2)</td>
</tr>
<tr>
<td>Sovizzo</td>
<td>13835</td>
<td>15351</td>
<td>15.4 (4.6)</td>
<td>7.7 (4.3)</td>
</tr>
<tr>
<td>Vicenza</td>
<td>43784</td>
<td>48580</td>
<td>48.6 (14.6)</td>
<td>24.3 (13.5)</td>
</tr>
</tbody>
</table>