Land Quality in an International Comparison: It's Importance in Measuring Productivity

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Abstract

The purpose of this paper has been to present quality-adjusted values for land in the United States and nine European countries using price and quantity data for 1990. Disregarding such differences in the quality-adjusted land input would generate biased estimates of the land input and thus of total factor productivity. Land quality adjustments could potentially be enhanced further with additional data on soil characteristics, climate, and other productivity-related characteristics.

Key words: total factor productivity, hedonic techniques, soil stress, quality-adjusted land.

Land Quality in an International Comparison: It's importance in measuring Productivity

In productivity analysis spatial differences in land quality prevent the direct comparison of observed prices. Land in agricultural production is typically quite heterogeneous in terms of soil type, associated soil characteristics, and other productivity-related factors across countries and districts or states within countries. Failing to account for these differences would lead to a biased measure of the land input, and thus also of productivity levels and growth rates. The purpose of this paper is to present hedonic regression techniques to adjust land prices for quality in the U.S. and nine European countries using price and quantity data for 1990.

Literature Review

The quality-adjustment issue was recently highlighted in the agricultural productivity literature in Ball et. Al. (1997), where productivity measures incorporated quality adjustments for labor, fertilizer and pesticides, and in Ball et. al. USDA (2000) and Ball et.al. (JPA 2000) where quality-adjusted land measures were added to U.S. and international productivity accounts. Other recent efforts to address the land quality issue in the productivity literature include an analysis of productivity growth in Pakistan (Ali and Byerlee) and an analysis of technical efficiency in a cross-section of 110 countries (Malcolm and Soule).

A properly formed measure of aggregate land or any other input must incorporate substitution possibilities among disaggregated input or land classes. Excluding quality-adjustments in disaggregated input measures--that is treating an hour worked by a highly educated skilled worker as equivalent to an hour worked by a less educated, unskilled worker-or and acre of high quality land as equivalent to and acre of low quality land-is tantamount to assuming away input substitution possibilities, and results in a biased measure of productivity as first noted by Jorgenson and Gollop.

Empirical analyses based on the hedonic approach must address the two following questions posed by Griliches (1971):

(a) What are the relevant characteristics?

(b) What is the form of the relationship between prices and characteristics?

With regard to the first question, the early hedonic price models on automobile prices used three car characteristics: size, power, and accessories: Chow's (1967) analysis of the mainframe computer industry had two characteristics: memory capacity and speed of the instruction cycle. Agricultural land markets present a much larger number of potentially relevant characteristics. Conceivably, characteristics that define the productivity of land could include agronomic factors such as texture, pH, etc.; pedo-climatic factors representing temperature/moisture regimes; and factors such as population and irrigation. For example, Ball et al (2000) include all of these factors in constructing quality-adjusted land prices in the U.S. Moss et. al. extend this model and decompose quality-adjusted land into agronomic and urbanization effects using hedonic techniques.

With regard to Griliches' second question, the specification of the functional from in the price-characteristics relationship, a number of hedonic price model studies in the literature use linear, semilog (the dependent variable, price, being logarithmic), or doublelog functional forms.

Implicit prices may be calculated from the estimated coefficients. While most empirical studies have preferred the use of the semilog (Court, Griliches, Madison) or log-log (Chow), the functional from of the hedonic function is entirely an empirical matter (Triplett). Ball et. al (1997) employ a linear form for estimating quality-adjusted fertilizer prices and a log-log form for estimating quality-adjusted pesticide prices; Ball et al (USDA 2000) employ a semilog form for estimating quality-adjusted land prices. Additionally, Box-Cox procedures have often been employed to select the most appropriate functional form.

Methodogy and Results

To estimate the stock of land in each country, we construct intertemporal Fisher price indexes and implicit quantities of land in farms. Observations on land input in each country are differentiated by state and by land type (*i.e.,* arable and meadow). Land area idled by government programs is excluded from the stock of land.

Spatial differences in land quality prevent the direct comparison of observed prices. Land in agricultural production across the ten countries analyzed is heterogeneous in terms of soil type, associated soil characteristics, and other productivity-related factors. Failing to account for these differences would lead to a biased measure of the land input, and thus also of productivity levels and growth rates. To account for these differences, indexes of relative prices of land are constructed from hedonic regression results.

Following Fernandez-Cornejo and Jans our price hedonic model modified by Box-Cox procedures is

(1) $P(\lambda_1) = \mathbf{X}_t(\lambda_2) + \mathbf{D}_\gamma + \varepsilon$

where P is the price of land , $\mathbf{X_t}$ is a vector of stress characteristics, $\mathbf{D}_\gamma$ a vector of dummy variables taking on the unit value for country L and zero otherwise, ε is a stochastic disturbance, $P(\lambda_1)$ is the Box-Cox transformation of the dependent variable price, and $\mathbf{X}_t(\lambda_2)$ is the Box-Cox transformation of the continuous quality variables. We used area of agricultural land to weight the observations in order to remove heteroscedasticity due to dramatically different agricultural area by country. Using Box-Cox procedures we found that the (λ_1=0 and λ_2=.80) form provided the best functional form in terms of goodness of fit. When the log of price is related to linear country dummy variables as in (1), a hedonic price index can be calculated from the antilogs of the δ_i coefficients and can be interpreted as the quality-adjusted price for land. For the semilogarithmic specification used here, a consistent estimate of the parameter δ_i is given by $\exp(\hat{\delta}_i) - 1$ (Halverson and Palmquist).

The World Soil Resources Office of USDA's Natural Resource Conservation Service has compiled data on attributes that capture the differences in land quality. These attributes include soil acidity, salinity, and moisture stress, among others. The "level" of each attribute is measured as the percentage of the land area in a given region that is subject to stress. A detailed description of the attributes is provided in table 1, while figure 1 depicts their level. The spatial incidence of environmental stress can be seen in figures 2 and 3. The environmental attributes most strongly influencing the price of land in major agricultural areas in Europe are moisture deficit and soil acidity. In the United States, these environmental characteristics are also important influences on land prices with moisture deficit dominating in the Northern and Southern Plains, and soil acidity in the East and Southeast. Additionally, moisture stress is the dominant environmental attribute in the western United States. In areas with moisture stress, agriculture is not possible without irrigation. Hence irrigation (i.e. the percentage of cropland that is irrigated) is included as a separate variable. Because irrigation mitigates the negative impact of acidity on plant growth, the interaction between irrigation with and soil acidity is also included in equation (1).

In addition to environmental attributes, we also include a "population accessibility" score for each region. The population accessibility score reflects the relative size and proximity of population centers. This variable is a proxy for distance to market and, hence, transportation costs. For simplicity, let us assume that the only characteristic distinguishing farms is their distance to market. Assuming that transportation costs increase with distance, prices received (net of transportation costs) will decrease as distance to market increases. Because farms are otherwise identical, this difference generates corresponding rents, decreasing with distance to market

It is important to note that our objective here is to measure the price of agricultural land holding constant the characteristics that define the agricultural productivity of the land, such as soil moisture and acidity. This is different from explaining differences in agricultural land prices, which would require incorporating all factors that might potentially affect agricultural land prices—including those that are unrelated to agricultural productivity. For example, factors such as the potential value of agricultural land in alternative uses do not themselves contribute to land quality, but may affect the cost of obtaining those attributes that determine land quality.

The statistical results of our hedonic analysis are shown in table 2. Our model succeeds in explaining 98 percent of the spatial variation in land prices. As expected, the price of land is positively correlated with population accessibility, high organic matter, and irrigation. The coefficient on the soil acidity/irrigation term was also positive. The price of land is negatively correlated with continuous moisture deficit and low water holding capacity. Only the positive coefficient on soil salinity appears counterintuitive. One possible explanation for this result is the positive correlation between irrigation and soil salinity.

We compute the price of land of "constant quality" in each country by taking the antilogs of the coefficients on the country dummy variables. The resulting land prices are compared with unadjusted land prices in table 3. These prices are denominated in national currencies. We construct the purchasing power parities for land as the ratio of the quality-adjusted price of land in each country relative to that in the United States. The parities, in turn, are used to convert the stock of land to the currency of the United States.

A comparison of the purchasing power parities and the nominal exchange rate provides information regarding relative land prices. For example, the ratio of the parity of land in France to the nominal exchange rate was 2.34 in 1990 (i.e. 12.76/5.45). This suggests that the price of land of constant quality in France was approximately double that in the United States.

SUMMARY AND CONCLUSIONS

The purpose of this paper has been to present quality-adjusted values for land in the United

States and nine European countries using price and quantity data for 1990. Disregarding such differences in the quality-adjusted land input would generate biased estimates of the land input and thus of total factor productivity. Land quality adjustments could potentially be enhanced further with additional data on soil characteristics, climate, and other productivity-related characteristics.

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Table 1 Definition of variables in the data set

Variable	Unit	Definition
Land price	Local currency per hectare	Price of agricultural land
Land area	Hectares	Total land area
Population density	Index	A measure of the size and proximity of nearby population centers
Ice cover	Percent of total land area	Covered by ice
Ocean	"	Covered by ocean
Inland water	"	Covered by lakes or rivers
Low temperature	"	Having soils with mean annual temperature < 0^oC and mean summer temperature < 10^oC
Salinity	"	Having soils with pH > 9.0 (i.e. where the salt concentration is so high that it prevents plant growth)
Acidity	"	Having soils with pH < 5.2 (i.e. where soil acidity reduces root growth and prevents nutrient uptake)
Moisture deficit	"	Experiencing soil moisture stress for 4 or more months in a year
Moisture stress	"	Experiencing continuous soil moisture stress
Low water storage	"	Having soils with low ability to store moisture
Excess water	"	Having soils saturated with water during long periods of the year
High organic matter	"	Having peats or organic soils
Low nutrients	"	Having sandy soils or soils with clays with a low capacity to hold nutrients
High shrink swell	"	Having soils dominated by a mineral that causes soils to crack during the dry season
High anion exchange	"	Having volcanic soils where phosphate is made unavailable to plants
Irrigation	"	Irrigated
Few constraints	"	Having soils with few or no major soil-related constraints and a generally temperate climate

Source: World Soils Group, Natural Resource and Conservation Service.

Figure 1. Major stresses in Countries Analyzed

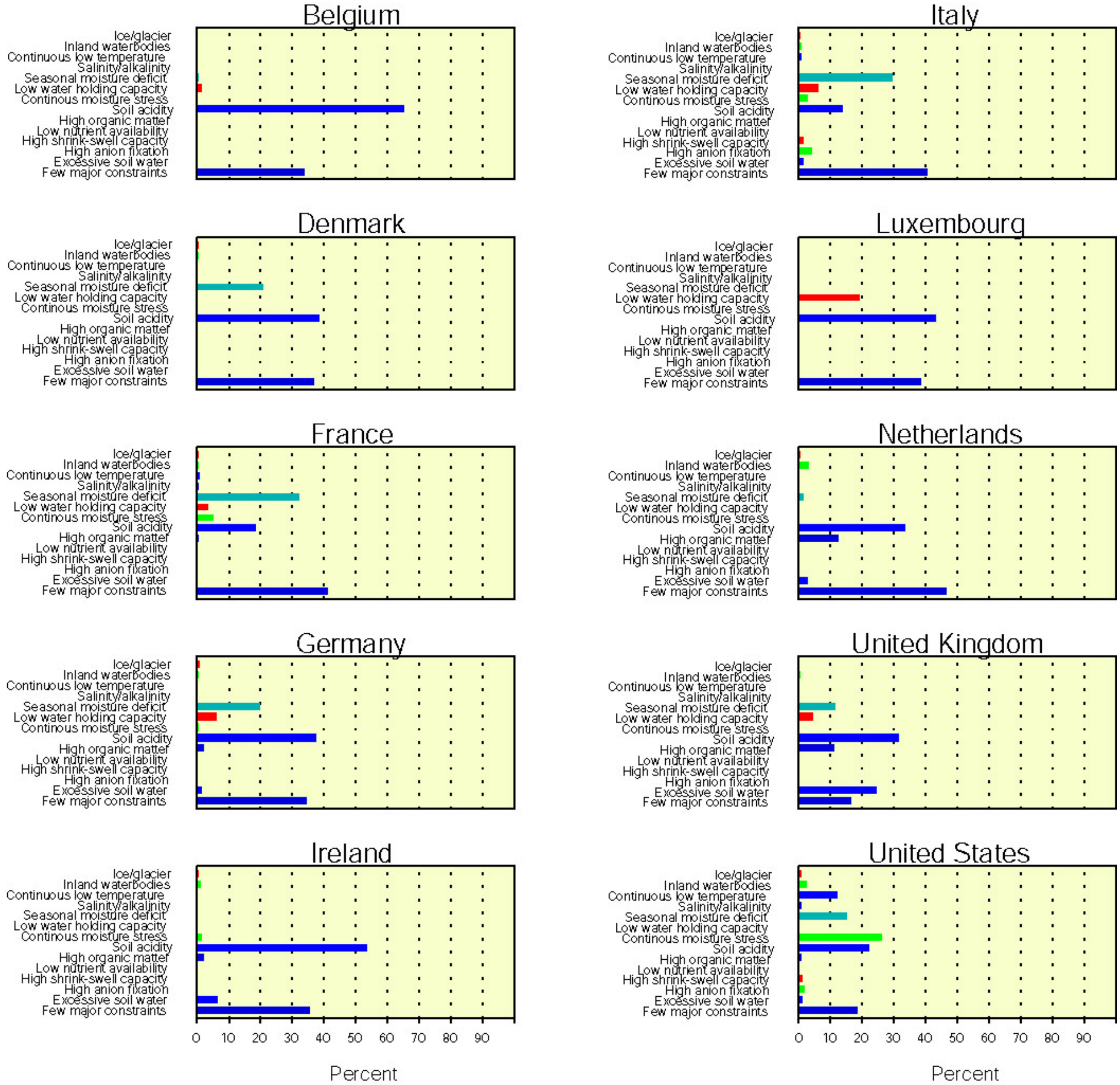

Table.2: Hedonic regression results for land price as a function of productivity-related characteristics

Variable	Coefficient	t-statistic
D_1 (US dummy)	6.795***	43.28
D_2 (UK dummy)	7.756***	16.62
D_3 (Ireland dummy)	7.942***	10.27
D_4 (Belgium dummy)	12.078***	10.11
D_5 (Denmark dummy)	9.724***	8.35

D_6 (France dummy)	9.341***	24.74
D_7 (Germany dummy)	9.581***	21.85
D_8 (Greece dummy)	14.174***	18.63
D_9 (Italy dummy)	15.279***	28.45
D_{10} (Netherlands dummy)	8.828***	7.69
Inland water	-0.157***	3.77
Ice cover	-0.039***	4.59
Ocean	-0.010	0.40
Low temperature	-0.026***	11.77
Salinity	0.033***	5.46
Moisture deficit	-0.002	0.77
Moisture stress	-0.021***	9.12
Acidity * irrigation	0.307***	2.93
Few constraints	0.004*	1.71
Low water	-0.134***	3.15
High organic matter	0.134***	6.91
Low nutrients	-0.004	0.71
High shrink swell	0.004	0.31
High anion exchange	0.010	0.78
Excess water	-0.009	1.10
Population density	0.001***	4.30
Irrigation	0.032***	6.28
Number of observations	396	
R^2	0.989	
Adjusted R^2	0.988	
F Value	1074.89	

Note: Acidity*irrigation is the interaction of acidity and irrigation, *** denotes significance at the one percent level, ** denotes significance at the 5 percent level, and * denotes significance at the 10 percent level.

Table 3: Land prices and purchasing power parities, 1990

Country	Land Price		Purchasing Power Parity
	Nominal	Quality-adjusted	(quality-adjusted)
U.S.	1,650	893	1.00
U. K.	3,673	2,334	2.61
Ireland	3,709	2,812	3.15
Belgium	444,616	176,052	197.25
Denmark	50,000	16,721	18.73
France	19,883	11,390	12.76
Germany	33,639	14,495	16.24
Greece	1,476,553	1,430,450	1,602.66
Italy	6,894,000	4,370,901	4,897.11
Netherlands	44,814	6,824	7.65

Note: Land price is in local currency per hectare .

Figure 2. Stress Categories in Europe

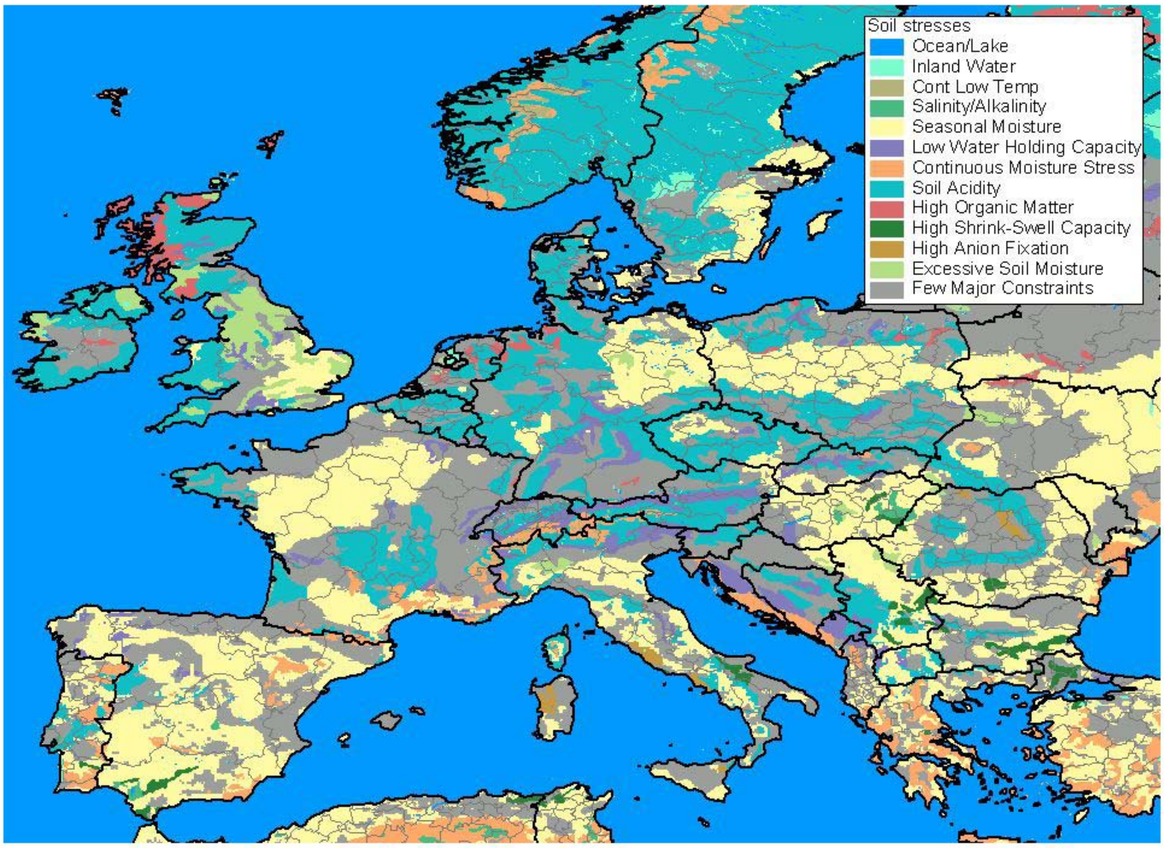

Figure 3. Stress Categories in the United States