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Farmland values and agricultural growth: The case of Chile

Guillermo Donoso[a], José Cancino[b] and William Foster[a]

ABSTRACT: This study analyzes the relationships between farmland values and factors associated with the growth in Chilean agriculture, and identifies agricultural land value's determinants by estimating a log-linear hedonic price function. The results indicate that a parcel's market value varies according to its suitability and productivity for different crops, its location and transport costs, its potential for residential use, and other factors that determine expectations of future income streams. Farms with soil aptitude for fruits, high-valued export-oriented crops that have led Chile's agricultural boom, have higher values than those with forestry soil aptitude.

KEYWORDS: Agricultural land values, Chile, hedonic models.

JEL classification: Q12, Q15, Q24.

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Valores de tierras agrícolas y el desarrollo agrícola: El caso de Chile

RESUMEN: Este estudio analiza la relación entre los valores de los terrenos agrícolas y los factores asociados con el crecimiento de la agricultura chilena, e identifica los factores determinantes del valor de la tierra agrícola mediante la estimación de una función de precios hedónicos log-lineal. Los resultados indican que el valor de un predio agrícola varía en función de su idoneidad y la productividad que presenta para los diferentes cultivos, su ubicación y los costos de transporte, su potencial de uso residencial, y otros factores que determinan las expectativas de flujos de utilidades futuras.

PALABRAS CLAVE: Valor de predios agrícolas, Chile, modelo hedónico.

Clasificación JEL: Q12, Q15, Q24.

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[a] Departamento de Economía Agraria, Pontificia Universidad Católica de Chile, Santiago, Chile.
[b] Universidad Tecnológica de Chile INACAP, Santiago, Chile.

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Dirigir correspondencia a: Guillermo Donoso. E-mail: gdonosoh@uc.cl.

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1. Introduction

Despite the recent general growth in agricultural production in Latin America and the Caribbean, poverty persists in the majority of the region. After a series of domestic and trade policy reforms beginning over two decades ago, which encouraged investment and integration into world markets, agricultural sectoral value added reached a regional average growth during 2000-2005 of 3.2 percent (ECLAC/CEPAL, 2007). Between 1985 and 2007 the value added of the agricultural sectors of all but a few Latin American countries (excluding the Caribbean) grew at over 2.5 percent, in some countries much faster (Valdés *et al.*, 2009). Nevertheless, development analysts who focus on the region (Graziano da Silva *et al.,* 2009) have noted that the modernization of agriculture – in some countries reaching levels of efficiency equal to the developed world – has not translated into a commensurate acceleration of rural poverty alleviation. The question for many is who has benefited from this agricultural boom?

To begin to answer the overall question of the distribution of gains associated with agricultural growth experienced since economic reforms, the researcher must address several issues. The main issues that must be studied are the evolution of the returns to farms of various sizes and product compositions, the returns to family and hired labor, and the myriad of factors determining the returns to labor, capital and land. There is some evidence that agricultural labor as a whole in the region has benefited from the growth of the sector. Valdés *et al.* (2009) make use of periodic household surveys to measure the incomes of three groups in agriculture in five Latin American countries: salaried workers, self-employed workers (small farmers), and employers (medium and larger farmers). They show that in the cases of Brazil, Chile, and Mexico salaried workers in agriculture have captured an increasing proportion of incomes reported in surveys since the early 1990s.

There are limits, however, to the use of household surveys to identify the beneficiaries of the recent agricultural "boom". These surveys provide data on self-reported incomes, and as such, in the case of farmers large and small, they mix the returns to family labor, management, and owned assets. Moreover, incomes earned by owners of farm assets, notably land –who do not identify themselves in surveys as in the agricultural sector– would not be included in this type of survey-based accounting. For example, urban professionals (physicians, lawyers and college professors) might be partners in a Chilean avocado plantation, hiring a farm manager, who in turn hires manual laborers; using a standard household survey, the professionals and their farm-asset-derived incomes are almost certainly counted in non-agricultural sectors, while the farm manager and his labor income would be counted in the agricultural sector.

Agricultural land values are an important source of information for tracing the distribution of benefits generated by agricultural growth. The present paper adds to the question of who has benefited from this agricultural boom by assessing agricultural land values in Chile for the 1998-2008 period, building on previous studies conducted before 2005. Additionally, this paper contributes to the study of agricultural land values at the national scale, while previous studies focused on the Chilean case are conducted at a more reduced geographical scale. More specifically, this paper addresses the question of the determinants of farm land values in Chile, a country that has experienced one of the most notable agricultural booms in Latin America. The analysis employs a hedonic approach, where the geographical and temporal variations in prices of land parcels of distinct attributes contain information regarding the marginal valuations by farmers and other potential buyers of these attributes. A parcel's market value varies according to its suitability and productivity for different crops, its location and transport costs, its potential for residential use, and other factors that determine expectations of the stream of future benefits, whether in terms of money incomes or other benefits that might enter into owners' utility functions. This study analyzes the relationships between farmland values and factors associated with the growth in Chilean agriculture and with development more generally, making use of advertised land prices in Chile's central valley between the Atacama and Los Lagos Regions, for the 1998-2008 period. In addition to productivity-related factors, special attention is given to a land parcel's likely suitability for high-valued, export-oriented crops that have led Chile's agricultural boom, to the possible impact of infrastructure development, and to population growth leading to non-farm factors influencing the land's future income stream.

The paper is structured as follows. The next section reviews the main methodology as well as data and estimation issues. Section 3 presents the results and discussion of the determinants of farmland values. Conclusions are drawn in Section 4.

2. Methodological issues

Policy-related and technological changes affect the expected future stream of agricultural rents, which would be reflected in agricultural land values, a well-investigated phenomenon (e.g., Hayami and Ruttan, 1970; Phipps, 1984; Burt, 1986; Decimavilla *et al.,* 2008). Of course, in attempting to extract information regarding the profitability of agriculture from data on land values one must also account for the impact of rapid urbanization on farm land prices (see e.g. Platinga and Miller, 2001; Guiling *et al.*, 2009).

Maddison (2000) finds that farmland price differentials can be explained by underlying productivity differences. Meloni and Ruiz (2001), with a hedonic price model analyze the different attributes determining the market price of land sites in the city of San Miguel de Tucumán and Gracia *et al.* (2004) apply a hedonic analysis of land prices in the province of Zaragoza, Spain. Several studies have estimated hedonic models of land markets to estimate the impact of agricultural policies on land values (see e.g. Traill, 1979; Goodwin *et al.,* 2003; Just and Miranowski, 1993; Decimavillaa *et al.,* 2008 and Vyn *et al.*, 2012).

Among the factors affecting the value of agricultural land are: geographical location, intrinsic quality or potential soil use, property size, soil improvement in the form of physical works or plantations, and public infrastructure in the area, among others (Schönhaut, 1999, specifically in the case of Chile). Agricultural land price differentials can be associated with particular land characteristics through the use of hedonic agricultural land price models. For example, Miranowski and Hammes (1984) apply a hedonic agricultural land price model to estimate the implicit prices for soil characteristics in Iowa. Brown and Barrows (1985), Ervin and Mill (1985), Palmquist and Danielson (1989) and Roka and Palmquist (1997) use hedonic models to estimate the impact of soil erosion on land productivity and values. Along the same lines, Ready *et al.* (1997) estimate the amenity value to Kentucky residents from horse farm land. More recently, Torell *et al.* (2005) found that farmland location, scenic view, and the desirable lifestyle influenced farmland value more than its income. The impact of conversion pressures from rapidly expanding suburban areas is well documented by Stewart and Libby (1998) and Guiling *et al.* (2009). More recently, hedonic models have been employed in order to estimate the impact of climate change on agricultural productivity and land values (see e.g. Mendelsohn *et al.*, 1994; Kurukulasuriya and Mendelsohn, 2007; Seo and Mendelsohn, 2007).

There have been a few empirical works in Chile that study agricultural land values and their determinants. Bravo-Ureta and Fuentes (2003) estimate the value of agricultural land attributes with a hedonic approach. These authors analyze data from 552 agricultural properties from assessment reports of Tattersall Propiedades S.A., a well-known local real estate firm, which present details on the property values and attributes, covering the period 1981 to 1996. The work of Troncoso and Calderón (2000) and Troncoso and Tobar (2005) shows the evolution of agricultural rents and land prices for the periods 1983-1996 and 1983-2002 using data on advertised sale prices published in the largest national newspaper. Similarly, the study by Hurtado *et al.* (1979) also employs newspaper sales data on sale prices to estimate the value of agricultural land attributes of 794 agricultural farms with surfaces larger than 30 hectares, offered in the different geographic areas of Chile for the periods 1917-1970 and 1974-1978 (excluding the 1971-1973 because of severe political instability). The agricultural land value analysis of Morandé and Soto (1992) is also based on data from advertisements in El Mercurio for the period 1975 to 1989, including a total of 180 agricultural farms with surfaces of at least 30 hectares (although restricting analysis to non-forestry land in the rural Regions between Valparaíso and the Bío-Bío; See Map 1)[1]. Schönhaut (1999) analyzes the prices of agricultural land in Chile with a hedonic approach for the years 1978-1998 also using data from the advertisements of El Mercurio for the period 1978-1983, and from the Revista del Campo for the period 1984-1998, only considering properties larger than 30 hectares to avoid distortions that could be introduced by the relatively high values of smaller suburban plots. This paper contributes to the study of agricultural land values in Chile by building on previous studies conducted before 2005 and conducting the study at the national scale.

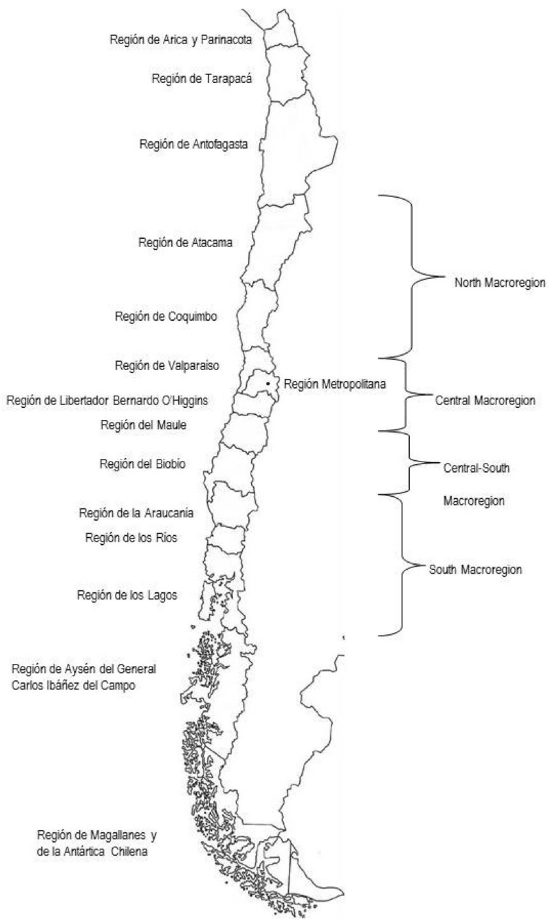
With respect to general results, Hurtado *et al.* (1979), Bravo-Ureta and Fuentes (2003) and Troncoso and Tobar (2005) agree that land prices are greater in the

[1] Also excluded were properties located in the Metropolitan Area of Santiago, Chile's capital city, in order to avoid distorting the estimates due to urban growth pressure.

northern regions of Chile. Hurtado *et al.* (1979) concluded that agricultural land value growth rates are higher in the northern regions; their results indicate that the growth rate of agricultural land values was 12.2% between 1974 and 1978 for the geographic area contained between the Coquimbo region and the northern part of Maule's regions. In the same period, the growth rate was 2.9% for the area between the southern part of the Maule region and the Bío-Bío region.

MAP 1

Macroregions of Chile



Source: http://www.escolares.net.

With regard to agricultural land attributes and their influence on land values, Bravo-Ureta and Fuentes (2003) find that farm infrastructure, higher soil quality and a larger irrigated land area have a positive and significant impact on land values. These authors also conclude that property size and the distance between the farm and the closest city or highway present a significant negative effect on land value. Morandé and Soto (1992) conclude that attributes such as farm infrastructure and the existence of cattle do not affect land value, while the presence of fruit trees and vineyards present a positive impact. Schönhaut (1999) confirms the results obtained by Morandé and Soto (1992), but argues that the lack of significant effects of farm infrastructure is due to its high heterogeneity and that this attribute was included as a binary variable in the hedonic price model thus not reflecting this heterogeneity.

One factor that affects the quality of a hedonic price study is the functional form used. Gracia *et al.* (2004) concludes that a flexible functional form should be employed, and Cropper *et al.* (1988) find that when all attributes are observed, the linear and quadratic Box-Cox specifications perform better; when some attributes are unobserved or are replaced by proxies, linear and linear Box-Cox functions perform best producing lowest mean percentage errors. Wunder and Gutiérrez (1992) conclude, however, that the linear specification does not perform statistically differently from the Box Cox-Linear specification. There appears to be no strong a priori theoretical reason to impose a particular functional form for a hedonic regression (see e.g. Halverson and Pollakowski, 1981). Nevertheless, Follain and Malpezzi (1981), among others, have tested linear functional forms against log-linear specifications. The practical import of this comparison is that, in econometric implementation, the log-linear form has a number of advantages over the linear form, such as mitigating heteroscedasticity and allowing for non-constant marginal willingness to pay for an attribute.

Based on the above considerations, this study estimates a log-linear hedonic function to explain agricultural land values. A base model considers the land parcel's size in hectares (x_{1t}), a time trend expressed in months (x_{2t}), and a binary variable (x_{3t}) that takes the value of one when farm land is offered during the second semester of the year and zero in any other case. This last seasonal dummy variable was found important in initial data explorations and apparently correlates with the nature and type of land sales offers following harvest season (in the southern hemisphere). The simple model is of the form:

$$Ln\ p_t = \beta_0 + \beta_1 \ln(x_{1t}) + \beta_2 x_{2t} + \beta_3 x_{3t} + \varepsilon_t \quad [1]$$

Any excluded effects are captured by ε_t, a stochastic, mean-zero error term.

To this simple model, we add production-related and spatial variables as follows:

$$Ln\ p_t = \beta_0 + \beta_1 \ln(x_{1t}) + \beta_2 x_{2t} + \beta_3 x_{3t} + \sum_{i=1}^{n_1} \gamma_i w_{it} + \varepsilon_t \quad [2]$$

where x_{1t}, x_{2t}, and x_{3t} are as defined in [1] and w_{it} are additional production and spatial variables. The production-related variables are: indicators of the aptitude of the advertised parcel (fruit, forestry, annual field crops, etc.); the presence of irrigation; the price of the main regional crop to account for changes in expected present value of the future flow of agricultural profits[2]; dummy variables representing agro-ecological zones; and the presence of buildings on the property for sale. The spatial variables are: measures of the distance from metropolitan centers (kilometers from the national capital, and kilometers from the regional capital); and macroregional dummy variables to account for possible idiosyncratic effects associated with local infrastructure, transport services, and so on. The macroregions are aggregations of the official Regions of the country, and are shown in Map 1[3].

Finally we incorporate a third group of variables related to residential pressures, and other variables associated with the growth in Chilean agriculture and with development more generally:

$$Ln\, p_t = \beta_0 + \beta_1 \ln(x_{1t}) + \beta_2 x_{2t} + \beta_3 x_{3t} + \sum_{i=1}^{n_1} \gamma_i\, w_{it} + \sum_{i=1}^{n_2} \delta_i\, z_{it} + \sum_{j=3}^{J} \lambda_i x_{2t} x_{jt} + \varepsilon_t \qquad [3]$$

where z_{it} represent a variable related to residential pressure (municipal population density growth rate) and variables associated with agricultural sectoral growth. These latter variables are the proportion of regional agricultural exports relative to regional agricultural GDP, and various interaction terms (between time and land crop aptitude and between time and distance to metropolitan areas). These additional variables in this last model allows us to connect farmland values to changes in Chilean agriculture over the last decade; in particular to estimate the impact of Chile's growing agricultural export orientation on the value of farmland as reflected, albeit imperfectly, in the sales price. Similarly, the interactions between the time trend variable and soil aptitude, distance to the national capital and regional capital allow estimates of how the marginal willingness to pay for these attributes has changed over time. For example, over time have parcels with an aptitude for fruit plantation been growing more valuable relative to other parcels? As the country has developed, has the distance penalty decreased?

The variables considered in the three models are presented in Table 1. Because residual plots and formal tests suggested that these models are heteroscedastic, they are estimated with Generalized Least Squares, using a robust estimator employing White's (1980) correction of the variance co-variance matrix of the parameters to account for possible heteroscedasticity, effectively expanding the confidence intervals around the point estimates. The decision to employ White's (1980) robust variance estimators was adopted after trying various heteroscedasticity correction

[2] The price of the region's main agricultural product is the yearly average price of the principle crop produced in a specific region as indicated from production data of the VII Agricultural Census (2007).

[3] The reader should note that the productivity-related variables reflect underlying intrinsic attributes such as soil qualities and crop aptitude, the presence of irrigation, buildings and water reservoirs in the geographical area surrounding the particular parcel observed. The spatial variables reflect implicit cost-related attributes linked to the distance of the farm to the urban centers, such as transport and logistical costs, both of product sales and input deliveries (not the least of which is farm labor).

procedures. In first place, we estimated the model using Generalized Least Squares (GLS) weighted by the variance of the errors, but this procedure failed to correct the problem. In second place, we studied the source of heteroscedasticity. To analyze this issue, estimates were made using Ordinary Least Squares (OLS) to explain the variance of the errors across different specifications. However, we were unable to identify the cause of the heteroscedasticity. A final strategy was to estimate the model for each region independently. In this case, of the ten regions considered in the study, four regions continued presenting heteroscedasticity problems. Finally we chose to use White's correction (1980)[4].

TABLE 1

Variables included in the farmland value hedonic function

Variable	Type of Variable	Description
Price per hectare	Continous	Natural logarithm of UF/hectare
Surface	Continous	Natural logarithm of the surface (hectares)
Second semester	Binary	Semester Indicator: Takes the value of 1 if the add was published in the second semester, 0 in any other case.
Time Trend	Count	Time Trend (January 1999 = 1, December 2008 = 120)
Fruit aptitude	Binary	Takes the value of 1 when soil aptitude is fruit, 0 in any other case
Forest aptitude	Binary	Takes the value of 1 when soil aptitude is forest, 0 in any other case
Crop aptitude	Binary	Takes the value of 1 when soil aptitude is crop, 0 in any other case
Animal production aptitude	Binary	Takes the value of 1 when soil aptitude is animal production, 0 in any other case
Presence of buildings	Binary	Takes the value of 1 when land has buildings, 0 in any other case
Irrigation	Binary	Takes the value of 1 when land has irrigation infrastructure, 0 in any other case
Distance from the regional capital to the national capital	Continous	Distance of the regional capital to the national capital in kilometers
Distance of the municipal capital to the regional capital	Continous	Distance of the municipal capital to the regional capital in kilometers
North	Binary	Takes the value of 1 when farmland is located in the North Macroregion, 0 in any other case
Central	Binary	Takes the value of 1 when farmland is located in the Central Macroregion, 0 in any other case
Central-South	Binary	Takes the value of 1 when farmland is located in the Central-South Macroregion, 0 in any other case
South	Binary	Takes the value of 1 when farmland is located in the South Macroregion, 0 in any other case

[4] White (1980) demonstrated that such estimates are consistent as the sample size increases, which is our case since we have over 4,000 observations.

TABLE 1 (cont.)

Variables included in the farmland value hedonic function

Variable	Type of Variable	Description
Reservoirs in the Coquimbo Region	Binary	Takes the value of 1 once the reservoirs Puclaro and Corrales were constructed, 0 in any other case
Reservoir in the O´Higgins Region	Binary	Takes the value of 1 once the reservoir Convento Viejo were constructed, 0 in any other case
Municipal population growth rate	Continous	Municipal population growth rate
Proportion of agricultural exports with respect to agricultural GDP	Continous	Proportion of agricultural exports with respect to agricultural GDP
Municipal population density	Continous	Municipal population density, number of inhabitants/ km^2
Interaction between time trend and fruit aptitude	Continous	Evolution of fruit aptitude between January 1999 and December 2008
Interaction between time trend and forest aptitude	Continous	Evolution of forest aptitude between January 1999 and December 2008
Interaction between time trend and crop aptitude	Continous	Evolution of crop aptitude between January 1999 and December 2008
Interaction between time trend and animal production aptitude	Continous	Evolution of animal production aptitude between January 1999 and December 2008
Interaction between time trend and distance of the regional capital to national capital	Continous	Evolution of the distance between the regional capital and the national capital between January 1999 and December 2008.
Interaction between time trend and the distance of the municipal capital to regional capital	Continous	Evolution of the distance between the municipal capital and the regional capital between January 1999 and December 2008.
Municipal population density growth rate	Continous	Municipal population density growth rate
Valley	Binary	Takes the value of 1 when the farm is located in the Valley district, 0 in any other case
Dryland	Binary	Takes the value of 1 when the farm is located in the Dryland district, 0 in any other case
Hill or Isla	Binary	Takes the value of 1 when the farm is located in the Hill or Isla district, 0 in any other case
Mountain range	Binary	Takes the value of 1 when the farm is located in the Mountain Range district, 0 in any other case
Ñadi	Binary	Takes the value of 1 when the farm is located in the Ñadi district, 0 in any other case
Desert	Binary	Takes the value of 1 when the farm is located in the Desert district, 0 in any other case
Price of the region's main agricultural product	Continuos	Price (Chilean Pesos of December 2008) of the species with higher surface per region in 2007.

Source: Own elaboration.

The data on land prices was collected from the contents published every Monday in the sales advertisements of El Mercurio for the period 1999-2008, converted into an inflation-adjusted "investment unit" or UF[5]. The data used in the analysis were restricted to agricultural land properties whose surface was larger than or equal to five hectares, in order to exclude suburban country plots in the sample. The land prices collected cover from the Atacama Region to the Los Lagos Region (see Map 1). Additionally, data on the land's intrinsic attributes such as soil aptitude, existence of buildings and irrigation infrastructure was also collected from the sale advertisements from El Mercurio.

Land price data was complemented with information on spatial attributes such as distance between the property and the main urban centers (regional capital and national capital), presence of irrigation dams in the region, and the location of the property in the north, central, south central, and south macroregions (see Map 1). Macroeconomic variables, population, and time trend variables were collected for the period 1999-2008. The macroeconomic variables were obtained from the Central Bank of Chile database, while population data was compiled from the *Instituto Nacional de Estadísticas*, INE. A concise definition of all variables included in the model is presented in Table 1.

The initial database contained 4,418 land price observations, but 97 price outliers (2% of the total) were detected in an exploratory analysis (identified and excluded using Tukey's (1977) methodology). Excluding outliers the database contained a total of 4,321 observations.

3. Results and discussion

The econometric results are presented in Table 2 through Table 4. As Table 2 shows, the base model (equation 1) explains 48% of variability of the natural log of the per unit land price (Ln UF/hectare). The explanatory variables are statistically significant at least at a 5% level of significance. The size of the parcel for sale has a notable negative effect on per-hectare land value (significant at a 1% level), with a price-surface elasticity of 0.55. This means that when a parcel's size increases 1%, *ceteris paribus* the land's per-hectare price decreases in 0.55%. The negative effect of land area on the per hectare price can be explained in part because of greater transaction costs associated with the sale of larger agricultural farms, and because in many cases more highly productive lands are bundled with less-productive lands in sales of farms as working units. This result is consistent with the results of Schönhaut (1999) and Bravo-Ureta and Fuentes (2003) in their studies for Chile, as well as with the results obtained by Guiling *et al.* (2009) for the State of Oklahoma in the United States.

[5] UF (*unidad de fomento*) is an official, inflation-adjusted unit; it is often used for longer-term contracts. As of July 22, 2013, 1 UF = USD 45.9, and 1 UF = EUR 34.6.

The binary variable which takes the value of one when the land is offered during the second semester and zero in any other case (second semester) presents a negative and significant coefficient, implying that agricultural land prices per hectare published during the second semester are lower than the prices observed during the first semester; advertisements published during the second semester present a reduction in the per hectare price equivalent of 0.06%, compared with the ads published during the first semester[6]. Additionally, the time trend variable has a positive and statistically significant parameter coefficient at the 1% level of significance, implying that agricultural land price has increased steadily at about two-tenths of a percent monthly (or slightly more than 2 percent annually) [7] during the period 1999-2008. This increase may be explained by increases in land productivity over time, the incorporation of new technology, the development of road infrastructure and the evolution of the sector's profitability, in addition to the growth of urban zones and the growing limitation of available agricultural land. The effects of these variables are included explicitly in the following econometric models.

TABLE 2

Estimated coefficients of the base farmland value hedonic function

Variable	Coefficient		Marginal Effect (Elasticity)
Surface	-0.551 (59.97)	***	-0.551
Second semester	-0.062 (2.29)	**	- 0.060
Time trend	0.002 (5.92)	***	0.173
Intercept	7.308 (141.81)	***	
Number of observations	4,321		
F Test (3, 4321)	1.200.81	***	
R^2	0.4771		

*, **, *** indicate statistical significance at 10, 5 and 1%. Absolute values of robust t-statistics are shown in parenthesis.

Source: Own elaboration.

The results of the estimation of the second hedonic price model (equation 2) are presented in Table 3. In general, the model explains well the variability of agricultural land prices (R-square of 0.6). With the addition of the production-related and spatial variables, agricultural land area continues to have a negative effect on per-hectare land values, although the estimated price-area elasticity falls slightly to

[6] The coefficient of the binary variable, second semester, measures the discontinuous effect on land values when the ads are published during the second semester of the calendar year. Following Halvorsen and Palmquist (1980), the percentage effect of this binary variable is 100 $\{e^b-1\}$, where β is the parameter. This procedure was followed to estimate the percentage effect of all of the binary variables included in the models.

[7] The annual rate of increase is the 12-month compounded monthly rate: $1.024 = (1.02)^{12}$.

-0.49%. The parameter associated with the binary variable to account for land offered during the second semester and the parameter associated with the time trend continue to be statistically significant and their values are quite stable, indicating that the seasonality effect and the growth rate of agricultural land prices are not affected by the newly-introduced productive and spatial variables.

TABLE 3

Estimated coefficients of the farmland value hedonic function that considers productive and spatial variables as well as agroecological districts

Variable	Coefficient			Marginal Effect (Elasticity)
Ln (Surface)	-0,49212	(-51.96)	***	-0,4921
Time trend	0,00298	(7.42)	***	0,2075
Second semester	-0,04854	(-1.99)	**	-4,7382
Irrigation	0,25745	(10.08)	***	29,3632
Fruit aptitude	0,21664	(7.32)	***	24,1898
Forest aptitude	-0,26914	(-6.06)	***	-23,5962
Crop aptitude	-0,02415	(-0.66)		-2,3860
Animal Production aptitude	0,13663	(3.37)	***	14,6401
Reservoir Region of O´Higgins	0,33164	(4.74)	***	39,3248
Reservoir Region of Coquimbo	0,07371	(0.45)		7,6496
Distance regional capital to national capital	-0,00045	(-4.24)	***	-0,1622
Distance municipal capital to regional capital	-0,00057	(-2.25)	**	-0,0432
North	0,15538	(0.97)		16,8103
Central	0,52531	(10.96)	***	69,0977
South	0,23846	(3.23)	***	26,9293
Dryland	-0,23583	(-7.02)	***	-21,0086
Hill or Isla	-0,10628	(-1.18)		-10,0827
Desert	-0,78654	(-3.22)	***	-54,4582
Ñadi	-0,26860	(-2.79)	***	-23,5549
Mountain Range	0,05320	(1.54)		5,4641
Price of the region's main agricultural product	-2.64E-06	(-0.02)		-0,0005
Presence of buildings	0,27408	(8.26)	***	31,5317
Constant	6.9289	(126.45)	***	
Number of observations	4,312			
F Test (22, 4289)	288.82		***	
R^2	0.5851			

*, **, *** indicate statistical significance at 10, 5 and 1%. Absolute values of robust t-statistics are shown in parenthesis.

Source: Own elaboration.

In order to determine whether the inclusion production-related and spatial variables (equation 2) is a significant improvement over the base model (equation 1), we tested the null hypothesis that all parameter estimates associated to the production-related and spatial variables are simultaneously equal to zero. The F-statistic with 19 and 4289 degrees of freedom associated with this test is 52.82, which is significant at the 1% level of significance. Thus, model (2) is better than model (1).

Overall the parameter estimates of the productive and spatial variables are statistically significant, although the coefficient estimates associated with the price of the region's main agricultural product is not significant. The presence of farm buildings is positive and significant at the 1% level of significance, presenting a per-hectare land price elasticity of 32%. The percentage effect of the binary variable irrigation is positive and significant at the 1% level of significance, indicating an increase, *ceteris paribus*, of 29% when the sales advertisement indicates the availability of irrigation investments on the property. Fruit, forest, and animal production land aptitudes present statistically significant coefficients, while parameter estimates of field crop aptitudes are not significant. Thus, agricultural land characterized by fruit and animal production aptitudes present per hectare land prices that are 24% and 15% higher, respectively. On the contrary, agricultural land with forest aptitude present per hectare prices that are 24% lower.

Geographic location also has a significant effect on farmland values: farms located in the Central or South macroregions present higher per hectare prices than the Central-South macroregion (69% and 27%, respectively), at the 1% significance level. Table 3 also indicates that the construction of reservoirs in the Libertador Bernardo O'Higgins Region, has positively influenced farmland values in the region; agricultural land values increased by approximately 39% with respect to farms located in regions with no reservoirs[8].

Not all of the agroecological zones where farmland is located have distinct effects (i.e., are significantly different from the reference zone, "Valley"). Farmland located in "Dryland", "Ñadi"[9] or "Desert" districts present, on average, land values that are 21%, 23%, and 55% lower, respectively, with regard to farmlands located in the "Valley" zone, which is the most productive agroecological area. On the other hand, the per hectare farmland values of agricultural lands located in the "Hill or Isla", and "Mountain Range" districts do not present significant differences with respect to farmlands located in the "Valley" zone, given that we are controlling for other characteristics, such as crop aptitude. Spatial attributes also present significant effects on land prices: the negative coefficients associated with the distances between the municipality where the parcel is located and the regional and national capital are statistically significant at the 1% and 5% level of significance. All other things equal, agricultural land values decrease about 4.5% for every additional 100 kilometers farther from Santiago, the national capital, and decrease about 5.7% for every additional 100 kilometers farther from the regional capital.

8 The period analyzed included the startup operation of the Puclaro and Corrales dams in the Region of Coquimbo in 2000, and the startup operation of the Convento dam in the Region del Libertador Bernardo O'Higgins in 2008.

9 Ñadi are wetland areas that might be best described as seasonal wetlands, or seasonal swamps.

The results of the estimation of the third hedonic price model (equation 3), which include residential pressure and macroeconomic variables and the interactions of time and aptitude and time and distance variables, are presented in Table 4. The explanatory power of this model is virtually the same as the previous model as indicated by an R-square of 0.6. The F-statistic associated with the null hypothesis that the additional variables (residential pressure, export-orientation and the interactions of time and aptitude and time and distance) offer no additional information is 4.56, and so the hypothesis is rejected at the 1% level of significance lending support to the more comprehensive model specification. Thus, this model is statistically superior to the previous models.

TABLE 4

Estimated coefficients of the farmland value hedonic function that considers productive, spatial, residential pressure and macroeconomic variables as well as agroecological districts

Variable	Coefficient			Marginal Effect (Elasticity)
Ln (Surface)	-0.4792	(48.40)	***	-0.479
Time trend	0.0012	(1.34)		0.0800
Second semester	-0.0357	(1.43)		-3.51
Irrigation	0.2519	(9.87)	***	28.65
Fruit aptitude	0.2839	(4.56)	***	.32.83
Forest aptitude	-0.3732	(4.37)	***	-31.15
Crop aptitude	0.0384	(0.56)		3.92
Animal Production aptitude	-0.0099	(0.12)		-098
Reservoir Region of O´Higgins	0.2829	(3.80)	***	32.69
Reservoir Region of Coquimbo	-0.0310	(0.19)		-3.05
Distance regional capital to national capital	-0.0009	(5.18)	***	-0.3036
Distance municipal capital to regional capital	-0.0025	(3.87)	***	-0.1755
North	0.4226	(2.60)	**	52.59
Central	0.3218	(5.45)	***	37.96
South	0.3952	(4.14)	***	48.47
Dryland	-0.2537	(7.24)	***	-22.41
Hill or Isla	0.0140	(0.16)		1.41
Desert	-0.9215	(3.77)	***	-60.21
Ñadi	-0.0626	(0.63)		-6.06
Mountain Range	0.0508	(1.44)		5.21
Price of the region's main agricultural product	0.0003	(2.36)	**	0.0522
Presence of buildings	0.2893	(8.30)	***	33.55
Municipal population density growth rate	0.4963	(3.70)	***	0.5335

TABLE 4 (cont.)

Estimated coefficients of the farmland value hedonic function that considers productive, spatial, residential pressure and macroeconomic variables as well as agroecological districts

Variable	Coefficient			Marginal Effect (Elasticity)
Proportion of agricultural exports with respect to agricultural GDP	0.000021	(2.69)	***	0.0836
Interaction time trend Fruit aptitude	-0.0010	(1.33)		-0.0124
Interaction time trend Forest aptitude	0.0027	(2.24)	**	0.0112
Interaction time trend Crop aptitude	-0.0006	(0.67)		-0.0036
Interaction time trend Animal Production aptitude	0.0020	(1.77)	*	0.0093
Interaction time trend distance from regional capital to national capital	-1,48e-8	(0.01)		-0.0003
Interaction time trend distance from municipal capital to regional capital	0.0000142	(1.76)	*	0.0695
Intercept	6.5247	(42.43)	***	
Number of observations	4,051			
F Test (30, 4020)	201.91		***	
R2	0.5977			

*, **, *** indicate statistical significance at 10, 5 and 1%. Absolute values of robust t-statistics are shown in parenthesis.

Source: Own elaboration.

Most notable there is a reduction in the statistical significance of the simple time trend variable, suggesting that the appreciation of land value over time is well-captured by the addition of residential pressure and macroeconomic variables and the interactions of time and aptitude and time and distance variables. The F-statistic with 1 4020 degrees of freedom, associated to the null hypothesis that the parameter estimate of the time trend variable is zero, is 2.4, which is not significant. Thus, there is not sufficient evidence to reject the null hypothesis. Thus the significant positive parameter estimate of the time trend variable in model (1) is partially explained by increases in land productivity over time, the incorporation of new technology, the development of road infrastructure and the evolution of the sector's profitability, in addition to the growth of urban zones and the growing limitation of available agricultural land.

The parameter estimates indicate that the parcels size in hectares continues to have a negative effect on per-hectare land values although the price-hectare elasticity falls slightly to -0.48. Note that the coefficients associated with both the binary variable indicating the sales offer in the second semester and the time trend are no longer statistically significant: the information regarding the variability of land prices that might have been attributed to seasonality and a simple time trend are more likely linked to residential pressures, export orientation, and the changes in land value sensitivity to the parcel's crop aptitude and distance from population centers.

In the more general model, the parameter estimates of the productivity-related and spatial variables present some changes with respect to the previous model. This is due to the correlation of these new variables with those of the previous model. This underlines the importance of these new variables; when they are excluded the parameters associated with production and spatial related variables absorb their influence, and thus are biased as estimates of the marginal effects of the production and spatial related variables.

First, there is a loss of statistical significance of the coefficients associated with Animal Production aptitude and the Ñadi (seasonal wetland) agroecological zones. Second, farms located in the northern macroregion in this model present higher per hectare prices than the Central-South macroregion (16%), at the 1% significance level. Third, and most interestingly, the coefficient estimate associated with the price of the region's main agricultural product is positive and statistically significant at the 5% level.

Both of the parameter estimates of the residential pressure and export-orientation variables are statistically significant. The parameter estimate of the municipal population density growth rate suggests a price elasticity of 0.53%, while that of the proportion of agricultural exports with respect to agricultural GDP suggests an elasticity of 0.08%.

Focusing on the group of variables that capture interactions between time and aptitude, the results indicate that only the interaction of time with forestry and animal production aptitudes present positive significant effects on agricultural land values at the 5% and 10% significance level, respectively. Consequently, land values of farms characterized by these soil aptitudes have increased over time. This has not been the case of agricultural lands that present other soil aptitudes such as crop and fruit. The parameter estimate of the interaction between the time trend variable and the distance of the municipal capital to the regional capital is positive and significant at the 10% level of significance. This indicates that the negative impact of the distance between the municipal capital and the regional capital on farmland values has decreased in the analyzed period, perhaps due to the increase in rural connectivity.

4. Conclusions

This study analyzes the relationships between farmland values and factors associated with the growth in Chilean agriculture and with development more generally. The analysis makes use of advertised land prices in Chile's central valley between the Atacama and Los Lagos Regions, during 1998-2008. In addition to productivity-related factors, attention is given to a land parcel's likely suitability for high-valued, export-oriented crops that have led Chile's agricultural boom, to the possible impact of infrastructure development, and to population growth leading to non-farm factors influencing the land's future income stream.

An obvious, robust result is that agricultural land values per-hectare diminish as the number of hectares offered for sale increases, a finding reported in previous studies (Bravo-Ureta and Fuentes, 2003; Schönhaut, 1999 and Guiling *et al.*, 2009). Likewise, farm infrastructure and irrigation infrastructure have positive impacts on land values. With regard to soil aptitude, the results show that land with an aptitude for fruit production –the export of which has been a key to Chilean agricultural growth– has on average higher value, while land with forest aptitude present lower values. Nevertheless, over time, the negative premium of land more suitable to forestry has been falling, consistent with the changing mix of agro-forestry exports over the last decade. The distance between agricultural land and urban cities has a negative effect on land value, due to transportation costs among other effects, but the evidence suggests that the distance penalty is perhaps declining, at least with respect to distance from regional centers. More interestingly, Chilean agricultural land values increase with municipal population density growth, likely due to a rise in urban pressures, as has been found elsewhere by Guilling *et al.* (2009) and Decimavillaa *et al.* (2008). In addition to finding that per-hectare land values are correlated with a land parcel's likely suitability for export-oriented crops (fruit) associated with the country's agricultural boom, the export-orientation of the region in which the parcel is located also positively influences the land's value.

Finally, a word on spatial attributes, which have significant effects on farmland values: farms located in the North, Central and South macroregions – all other things being equal – have higher per-hectare land values than those located in the Central-South zone, which is the heart of export-oriented agriculture. Similarly, the value of farmland varies with agroecological characteristics which suggest that further research should be done using more specific indicators such as temperature and precipitation, as suggested by Mendelsohn *et al.* (1994).

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