Investment Effects of Endogenous and Exogenous Depreciation: Improved Pastures in Uruguay

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Abstract

The depreciation rate for capital assets may have endogenous and exogenous components. Change in the exogenous component depends on technological change and/or environmental factors, shifts the production function, and independently affects profitability and investment. Change in the endogenous component does not. These hypotheses are tested using data on Uruguayan grass-legume pastures.

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Introduction

Most analyses of asset depreciation have attempted to determine whether depreciation occurs at a constant (geometric) rate or at a variable rate that responds to changes in economic factors such as input and output prices and the cost of investment goods, e.g., Ramm, Cagan, Wykoff 1970, 1989, Ohta and Griliches, Hulten and Wykoff 1977, 1980, 1981a, b, Hulten et al., and Nelson and Caputo. We analyze depreciation to determine its effect on desired asset stocks. We hypothesize that depreciation of many capital assets contains exogenous and endogenous components. Changes in the exogenous component should affect asset profitability and, thereby, investment decisions, while changes in the endogenous component should not.

We define the endogenous component of depreciation as depending primarily on current input and output prices. Producers respond to these prices in determining the desired levels of asset use and of maintenance expenditures. Changes in endogenous depreciation involve no change in the underlying technology. We define the exogenous component as depending primarily on the technology embodied in the investment good and/or on environmental factors that directly influence asset performance, independently of producers' decisions. Exogenous depreciation may change as these factors change.

Agricultural technologies are particularly subject to obsolescence due partly to pests' increasing immunity to prevailing control methods and to more aggressive attacks from disease and undesirable plants. Technologies lose productivity and become less profitable if new control methods are not found or improved technology is not introduced. This decline in productivity can appear as a higher rate of depreciation. Alternatively, improved control methods or more resistant plant varieties can augment productivity.

This paper tests whether the depreciation rate of certain types of assets can be divided into exogenous and endogenous components and whether the exogenous component can change over time. We then analyze how these two components interact with other factors in determining investment. Throughout, we utilize data on Uruguayan fertilized grass-legume pasture stocks and pasture investments. Depreciation rates are usually estimated from time series of prices of new and used capital assets (e.g., Wykoff 1970, 1989, Nelson and Caputo). We calculate the rate of depreciation directly from panel data on pasture stocks and investments. We then analyze how variations in the ecological and economic contexts have affected the observed rates of pasture depreciation and whether there have been any systematic shifts over time, reflecting either an improvement to or a deterioration in Uruguayan pasture technology. We find that pasture depreciation responded systematically to changes in input and output prices, supporting the hypothesis that depreciation has a significant endogenous component. We also find evidence of changes over time in the exogenous component of extensive pasture depreciation, though not of intensive pasture depreciation. When the forecast value of exogenous depreciation was included in the extensive pasture stocks regression, higher exogenous depreciation resulted in a lower desired stock of extensive pastures.

The introduction and use of improved pastures in Uruguay

Improved pasture technology was introduced to Uruguay in the late 1950s. Two broad types of pasture were used. One involved the introduction of grass and/or legume seeds into an existing sward and application of moderate amounts of phosphate fertilization, with minimal soil tillage. This type of improved pasture, called extensive pastures, was intended for use in upgrading large areas of Uruguay's natural grasslands.

The other type involved deep soil tillage, heavy application of phosphate fertilizer and seeding of grass and legume species into a prepared bed. This type, called intensive pastures, was mainly used in rotation with crops as part of a ley system. Productivity or each type depended primarily on the maintenance of a proper balance between grasses and legumes. This balance was gradually lost as the legume component of the pasture deteriorated in response to grazing pressure, weather stress, and pressure from competing species, disease, and pests. The area planted to both types of pastures steadily expanded until 1975. From 1975 to 1990, extensive pastures declined from 1.3 million ha to 500,000 ha, while intensive pastures increased from 400,000 ha to 700,000 ha. Some suggest that the declining stock of extensive pastures was related to a rising challenge from diseases, pests and competing species (e.g., Sheath et al.). We hoped a unique panel data set on pasture stocks and investment would provide important evidence on this issue.

Depreciation and investment

Models based on adaptive expectations and partial adjustment of the capital stock were a major development in the analysis of on-farm investment (Nerlove 1960, 1979; Askari and Cummings). Subsequently, investment models based on rational expectations were introduced (Eckstein, 1984, 1985; Holt and Johnson). These papers assumed a constant geometric depreciation rate. Depreciation affected investment decisions by influencing the end-period capital stock, but depreciation had no direct effect on profitability. This view follows Hicks' original analysis; a firm combines its beginning-of-period stocks of quasi-fixed inputs with variable inputs to produce outputs as well as end-of-period stocks. Thus, the firm effectively chooses its depreciation rate, subject to input and output prices and the underlying technology. In our model, the endogenous depreciation component behaves similarly and should not influence investment choices.

In contrast, changes in the exogenous component the production function. These changes may be caused by technological improvements and/or by variations in the ecological environment. Information on these factors can be included in the regression analysis, if available. If not, changes in the exogenous component can be approximated by time trends, though we can measure only net changes in the exogenous component.

Calculation of Depreciation Rates

Data on pasture stocks and pasture investments were obtained from the *Dirección de Contralor de Semovientes, Frutos del País, Marcas y Señales y Aspectos Anexos (DI.CO.SE.)*. Since improved pastures are perennials, improved pasture area at the end of year t is equal to the improved pasture area at the end of year t-1, plus pasture investments in year t, less depreciation during year t. This yields

1) $$P_{ijt}^{m} \equiv \left(1-\delta_{ijt}^{m}\right)P_{ijt-1}^{m} + I_{ijt}^{m}$$

where P_{ijt}^{m} is the stock of pasture of type m in farms of size i in *departamento* j, I_{ijt}^{m} is pasture investment of type m, and δ_{ijt}^{m} is the depreciation rate for pasture of type m, all in year t. The depreciation rate, including both endogenous and exogenous components, is

2) $$\delta_{ijt}^{m} = 1-\left(P_{ijt}^{m} - I_{ijt}^{m}\right)/\, P_{ijt-1}^{m}$$

DI.CO.SE. aggregates farm data into nine farm size groups, the smallest being farms having less than 50 ha and the largest being farms having more than 10,000 ha. Data for these nine groups are available for each of the 19 *departamentos* in Uruguay. We observe depreciation only when a pasture is plowed under or is declared by its owner to have lost its productive value. The decline in the pasture's value can occur either because of physical deterioration or because, as a result of economic changes, it has become profitable to replace the pasture with another asset.

If a farmer plows under a pasture, it is a clear indication that he/she believes the value of the pasture is zero. When their productive life is considered complete, intensive pastures are almost always plowed under and replaced with a crop or another intensive pasture. Extensive pastures are also often reestablished through reseeding and refertilization. Sometimes, however, extensive pastures are not replaced, but simply allowed to deteriorate until their productivity is the same as a natural pasture. In the later case, the owner must decide when to declare that the productivity of the asset has diminished to the point that it is no longer an improved pasture. The evaluation is subjective because the now-depreciated pasture remains in use (as a "natural" pasture). We assume that producers' subjective declarations are accurate. There are no tax or other known incentives that would cause producers to consciously misstate actual depreciation.

The sample used runs from 1981 until 1991. The first observation was lost in the calculation of the depreciation rate, leaving a total of 1,710 observations, each one containing the data for a set of farms of given size in a particular *departamento* in a given year. The metropolitan *departmento* of Montevideo was eliminated because it contains almost no agricultural units. Other cross sections were eliminated whenever a farm size group had no improved pastures during the sample period. After these deletions, 1,540 observations remained for the intensive pastures and 1,530 for the extensive.

The average rates of depreciation for extensive pastures varied across *departamentos* from 0.13 to 0.28, and for intensive pastures from 0.23 to 0.38. As expected, the rates follow well known differences in soil characteristics, weather, and other environmental factors. These depreciation rates point to a shorter average life for extensive pastures than previously documented (e.g., Jarvis) and perhaps to a longer average life for intensive pastures. The average depreciation rates also varied over time, from 0.17 to 0.25 for extensive pastures and from 0.19 to 0.35 for intensive pastures.

Econometric modeling of depreciation

A number of farm size groups in some *departamentos* reported no improved pastures, creating a potential econometric problem. Improved pastures could be absent because the local ecology did not allow viable pasture establishment or because improved pastures were not profitable for those farmers at the prevailing input and output prices. In the first case, the excluded farms do not belong to the universe being analyzed and estimators obtained from the reduced data set are unbiased. In the second case, the data are censored and a suitable econometric technique should be used to obtain unbiased estimators. The available information, does not allow us to distinguish between these causes. One solution to censored data is to estimate a tobit model by maximum likelihood methods. However, tests for heteroskedasticity and autocorrelation rejected the hypothesis of spherical errors. The methodology for estimating a tobit model in the presence of serial correlation and heteroskedastic variances is not well developed (Green). Green reports that scaling OLS estimates by the reciprocal of the proportion of non limit observations in the sample often provides an estimate close to the ML estimators. The marginal effects for the tobit model are very close to the least squares estimates. Accordingly, we estimated the model using GLS corrected for first order serial correlation and heteroskedasticity following Kmenta. Due to a degrees of freedom constraint, a number of a priori restrictions were imposed: i) prices were assumed equal for all farms and affected them equally, ii) the autocorrelation coefficient was assumed constant across years, iii) the autocorrelation coefficient was equal across farm sizes and departments, iv) farmers of similar size in different departments behaved similarly and farmers of different sizes in the same *departamento* behaved differently. Consequently, variances were allowed to vary across farm sizes, but were restricted to be equal across departments and time periods. Finally, all covariances were restricted to zero. As a result, only 10 additional parameters had to be estimated. The first observation was conserved in the correction for autocorrelation.

The large number of regressors caused serious multicollinearity. One solution was to use principal components, but the estimated coefficients would have had no clear economic interpretation being linear combinations of the parameters of interest. Instead, we premultiplied the vector of estimated parameters by the matrix containing the eigenvectors associated with the matrix of cross-products, using the F-test proposed by Mundlak to identify the principal components to be retained. This yielded estimates of the parameters in terms of the original variables, unaffected by multicollinearity.

Econometric results for the depreciation rate

In specifying the equations for the depreciation rate, endogenous depreciation was assumed to depend on the major input and output prices for years t and t-1 in the regression. The exogenous depreciation component was assumed to depend on soil quality, weather, and farm location, as well as on linear and quadratic time trends that could theoretically yield either a positive or a negative effect, depending on whether research efforts offset any growing environmental challenge. The exogenous component of depreciation was allowed to vary over time and over space, while the endogenous component of depreciation was assumed to vary only over time. Dummies were used to account for the effect of outliers and for the effect of calculated depreciation rates that were out-of-range. Some observations contained obvious internal inconsistencies, e.g., the calculated depreciation rate was smaller than 0 or larger than 1. There were 297 out-of-range observations for intensive pastures and 470 out-of-range observations for extensive pastures. Outliers were identified by means of an auxiliary regression and the use of the Chebyshev inequality, with a probability of 90 percent. A total of 18 outliers were identified for extensive pastures and 143 outliers for intensive pastures. To increase the degrees of freedom, farm sizes were aggregated into 4 groups. D*epartamentos* were aggregated into 11 regions according to agronomic similarity, as identified by *DI.CO.SE.* All *departamentos* (except Montevideo) and farm sizes were represented in the sample.

The estimated equations explaining the depreciation rates of extensive and intensive pastures performed well according to standard statistical criteria. See Table 1. The results supported the hypothesis that pasture depreciation had an important endogenous component. The exogenous component of depreciation for intensive pastures did not change over time; the component for extensive pastures did change. The coefficients on the two time trends in that equation had offsetting signs. On balance, the exogenous component of extensive pastures decreased from 1982 to 1987, and rose from 1988 to 1991. This unanticipated result suggested that the flow of new technologies counterbalanced any ecological challenge over most of the period. A rise in exogenous depreciation cannot have caused the decline in extensive pastures. Nonetheless, by the end of the period, the exogenous component of depreciation was increasing. To validate the model, the last 15 observations were excluded from the estimation process. The estimated parameters were then used to obtain out of sample forecasts for the dependent variables (depreciation rates and pasture stocks). The forecast mean and the mean square error (mse) were calculated exclusively with the out of sample observations; in all cases, the forecast mean was very close to the observed mean. The mse of forecasts was small for the pasture stock equations and the depreciation rate of extensive pastures, but considerably larger for the depreciation rate of intensive pastures, though the equation fit of the latter is better, because of two unusual observations in the last farm size group.

Econometric modeling and results for pasture stocks

Pasture stocks were modeled as a capital stock adjustment model. Because the estimators obtained with a correction for autocorrelation are biased when the lagged dependent variable is a regressor, we estimated these equations using instrumental variables, with all the exogenous variables in time t and t-1 used as instruments (Green). Theoretically, profit maximizing changes in the depreciation rate that result from price changes should have no independent influence on desired asset stocks. For example, if a firm decides to utilize an improved pasture more intensively in response to an increase in the price of beef, the resulting higher pasture depreciation does not indicate a decline in the profitability of improved pastures. To the contrary, the higher price will have increased the expected profitability of pasture use. However, that effect should be captured by the beef price when it is included in the equation explaining pasture stocks.

In contrast, changes in the exogenous component of the depreciation rate should be included separately in the pasture stock regression equation. Changes in asset productivity are often treated as "technical change" and some measure of this change is included in the regression equation. In this case, changes in the rate of exogenous depreciation were thought to indicate changes in asset productivity and its forecast value was included in the pasture stocks equation.

The results are shown in table 2. Changes in the exogenous component of the extensive pasture depreciation rate were captured by using the forecast level of exogenous depreciation, achieved by summing the effects of the soil quality and the two trend terms in the extensive pasture depreciation equation, i.e., the measure combined cross-section and time-series terms. As hypothesized, the coefficient was negative and highly significant. A higher level of (expected) depreciation reduced producers' desired level of extensive pasture stocks. This relationship occurred although the exogenous component of depreciation decreased during most of the period. To ensure that the negative coefficient on forecast exogenous depreciation did not depend on soil quality, we included the cross-section and time series parts separately. The time-related part retained its negative sign and remained highly significant, though the soil quality-related part did not, probably because of the inclusion of another soil quality index.

We conclude that a higher rate of exogenous depreciation reduced the desired stock of pastures as expected, both in the cross section and over time. Nonetheless, although changes over time in the exogenous level of depreciation had the expected effect on desired pasture stocks, the level of exogenous depreciation declined instead of increasing over most of the period studied. Accordingly, a higher rate of exogenous depreciation cannot be the main reason for the decline in the area planted to extensive pastures in Uruguay since 1975. A rise in the external challenge to the pasture technology, while it may be a long-term problem, is not the explanation for the decreased area planted to extensive pasture technologies to date.

Table 1 Equations for the Pasture Depreciation Rate, 1982-1991						
Variable	Intensive		Elasticity	Extensive		Elasticity
Beef price in year t				0.19***	(5.58)	4.96
Beef price squared in year t				-0.35***	(4.59)	-1.74
Beef price in year t-1	-0.13***	(4.65)	1.38			
Milk price in year t-1	0.0079	(1.44)	0.00			
Fertilizer price in year t	2.53**	(2.56)	7.35	-0.018	(0.33)	-0.13
Fertilizer price squared in year t	-2.41**	(2.31)	-3.40			
Wheat price in year t				0.012***	(4.75)	0.01
Barley price in year t				0.0067***	(4.54)	0.00
Time trend (t = 1,...,10)				-0.041***	(4.47)	-3.38
Time trend squared				0.0031***	(3.74)	1.81
Log of index of soil quality				-0.038**	(2.37)	2.62
Departamento 2	0.017***	(6.31)	1.98			
Departamento 17	0.021***	(11.96)	0.01			
D1	-3.21***	(39.27)		-1.87***	(27.22)	
D2	1.45***	(3 .53)		0.90***	(8.74)	
D3	-0.53***	(27.31)		-0.38***	(29.46)	
D4	0.99***	(17.42)		1.16***	(18.46)	
Constant	-0.37*	(1.89)		0.23***	(7.71)	
R2 adjusted	0.72			0.63		
DW	2.02			2.03		
Statistical Rank	9			8		

The numbers in parenthesis are t ratios. D1 and D2 identify negative and positive outliers, respectively, via an auxiliary regression. D3 identifies observations with depreciation rates less than 0 and D4 identifies observations with depreciation rates larger than 1. The mean of the dependent variable is larger than 1 because the latter was transformed to eliminate autocorrelation and heteroskedasticity. Significance level: * ** 1% **5% * 10%

Table 2. Equations estimating the pasture stock equation, 1982-1991						
Variable	Intensive	Elast.	Extensive	Elast.	Extensive	Elast.
Respective pasture stock in year t-1	0.85*** (36.95)	0.83	0.26*** (16.74)	0.27	0.26*** (16.95)	0.27
Beef price in year t			-322*** (3.15)	-0.22	-259** (2.61)	-0.18
Beef price in year t-1			569*** (9.01)	0.39	565*** (9.01)	0.39
Beef/fertilizer price, year t-1	843*** (8.54)	0.24				
Fertilizer price in year t-1			606*** (2.92)	-0.11	-615*** (2.96)	-0.11
Milk price in year t-1	430*** (7.95)	0.11				
Wheat price in year t-1	-1966*** (9.16)	-.02	-46742*** (9.49)	-0.92	46859*** (9.49)	-0.92
Barley price in year t-1	-1395*** (9.16)	-0.01	35541*** (5.97)	0.47	35688*** (5.98)	0.47
Log of soil quality index	4363*** (9.25)	4.94	960*** (4.50)	1.71	966*** (4.52)	1.72
Δ exogenous depreciation due to soil quality & time			-56*** (3.67)	0.18		
Δ exogenous depreciation due to increase in time					-296*** (8.89)	-0.20
Δ exogenous depreciation due to var in soil quality					15 (1.42)	0.06
Region 1	540*** (4.05)	0.05				
Region 4A6C	360*** (2.86)	0.04				
Region 4B	1330*** (8.54)	0.07	-212 (1.55)	-0.02	-215 (1.57)	-0.02
Region 6B	-613*** (3.03)	0.03				
Region 6C			1804*** (12.43)	0.08	1777*** (12.25)	0.08
Farm size groups 3-4	341*** (2.89)		917*** (8.73)	0.08	917*** (8.73	0.08
Farm size groups 5-6	486*** (3.43)		400*** (3.38)	0.04	394*** (3.33)	0.04
Constant	-21271*** (9.17)		3895*** (3.94)		3932*** (3.97)	
R2 adjusted	0.73		0.55		0.55	
DW	1.89		1.57		1.57	

Statistical Rank	5	13	13
The numbers in parenthesis are t ratios. Size 1 comprises farms up to 49 ha, size 2 has farms between 50 ha and 99 ha, size 3 has farms between 100 ha and 199 ha, size 4 has farms between 200 ha and 499 ha, size 5 has farms between 500 ha and 999 ha, size 6 has farms between 1,000 ha and 2,499 ha, size 7 has farms between 5,000 ha and 9,999 ha, and size 9 has all farms above 10,000 ha. Ri indicates an agronomic region. The forecast mean was not converted to the original units. Significance level: *** 1% ** 5% * 10%			

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