The Economic Returns to Public Agricultural Research in Uruguay

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ABSTRACT. We use newly constructed data to model and measure agricultural productivity growth and the returns to public agricultural research conducted in Uruguay over the period 1961–2010. We pay attention specifically to the role of levy-based funding under INIA, which was established in 1990. Our results indicate that the creation of INIA was associated with a revitalization of funding for agricultural R&D in Uruguay, which spurred sustained growth in agricultural productivity during the past two decades when productivity growth was stagnating in many other countries. The econometric results were somewhat sensitive to specification choices. The preferred model includes two other variables with common trends, a time-trend variable and a proxy for private research impacts, as well as a variable representing the stock of public agricultural knowledge that entailed a lag distribution with a peak impact at year 24 of the 25-year lag. It implies a marginal benefit-cost ratio of 48.2, using a real discount rate of 5 percent per annum and a modified internal rate of return of 24% per annum. The benefit-cost ratio varied significantly across models with different lag structures or that omitted the trend or the private research variable, but across the same models the modified internal rate of return was very stable, ranging from 23% per annum to 27% per annum. These results suggest that the revitalized investment in research spending under INIA has been very profitable for Uruguay, and that a greater rate of investment would have been justified.

Key Words: Public agricultural R&D; levy-based funding; Uruguay; agricultural productivity; rates of return; spillovers; knowledge stocks; R&D lags.

JEL Codes: C52, Q16, Q18

1. Introduction

Around the world, public support for investments in agricultural R&D continues to wane in spite of both consistently high reported rates of return to agricultural R&D and emerging evidence of slowing rates of agricultural productivity growth (Pardey and Alston, 2010). One approach for economists, to address this persistent paradox, is to provide more complete and more compelling evidence about the economic implications of alternative agricultural science policies. Formal studies of national agricultural research systems (NARSs), agricultural productivity patterns, and the returns to national agricultural R&D investments, have mostly been undertaken for high-income countries for which relatively good data sources and other resources are available, or for the large middle-income countries, such as China and Brazil (Alston et al., 2000). Relatively little is known about the performance of the NARSs in the vast number of countries that do not belong in either of these categories.

Uruguay is an example: as well as being of interest in its own right, and as an example of a small middle-income country, the NARS of Uruguay has some interesting characteristics that make it worthy of study as a potential source of more general lessons. In Uruguay, public agricultural research was transformed in 1990, with the introduction of a new institution, INIA (the National Institute for Agricultural Research), to be supported substantially using funds generated by a levy on agricultural production. In 2010, a review of INIA was undertaken, to evaluate its accomplishments in its first 20 years (Pareja et al. 2011). Information gathered in the process of performing that review provides the foundation for the work in this article.

We begin by describing the main changes in Uruguayan agriculture during the past 30–40 years. This provides some context for a formal analysis of growth in agricultural inputs, outputs, and productivity, which is presented next. The indexes of multifactor productivity (MFP) are Fisher Ideal discrete approximations to Divisia indexes that reflect a careful effort to account for variation over time in the composition of the aggregates of inputs and outputs, and thereby minimize the role of index number problems. Then we describe the economic history of agricultural research institutions and investments in Uruguay. These elements are combined in an econometric model of multi-factor productivity (MFP) in Uruguayan agriculture over the period 1980–2010, as a function of public investments in agricultural R&D over the years 1960–2010, using an approach that parallels closely that of Alston, Andersen, James, and Pardey (2010). The results are expressed as benefit-cost ratios and *modified* internal rates of return, as suggested by Alston, Andersen, James, and Pardey (2011).

As argued by Alston and Pardey (2001), accurate attribution is always a challenge in this kind of work, whether we are attempting to attribute benefits to Uruguayan public agricultural research investments, versus other sources, or to identify impacts from the creation of INIA. The general attribution problem may be more pronounced for a small country, such as Uruguay, which is likely to benefit substantially from international agricultural research and technology spillovers from its large near neighbors, Brazil and Argentina, as well as other general sources of agricultural technology such as the United States and the international agricultural research system (including the CGIAR centers). In the penultimate section of the paper we discuss the interpretation of our results. To illustrate the role of fundamental factors, we compare the resulting estimates with simple approximations that abstract from the detail of the temporal aspects and apply alternative attribution rules. We also look informally for evidence of an acceleration or slowdown of productivity growth that might be attributable to the creation of INIA. The paper ends with a brief conclusion, which summarizes our main findings and their implications.

2. Agricultural Production Patterns

Uruguay (or, more formally, the Eastern Republic of Uruguay) is one of the most economically developed countries in South America, with a GDP per capita of $12,000 in 2010. It is a relatively urbanized nation in which 92% of its 3.5 inhabitants live in urban areas; more than half live in the capital, Montevideo and its metropolitan area. Uruguay has about 15 million hectares of agricultural land of which, at present, 1.8 million hectares are cropland, 1 million hectares are forest land, 1 million hectares are cultivated pastures, and the rest, 11.2 million hectares are natural grasslands, improved pastures (i.e., natural grasslands to which clover seed and fertilizers have been applied), and natural forests (Table 2-1). Bordered by Brazil to the north, Argentina to the south and west, and the Atlantic Ocean to the east, Uruguay is spread across a latitude of 30 to 35 degrees south (a range comparable to that of New South Wales), and its agriculture is based primarily on a mixture of dry-land cropping and grazing that is similar in many ways to that of southern Australia.

[Table 2-1: *Uruguay's Agriculture in Brief (2010)*]

Agriculture in the Economy

In 1985, the economically active population in agriculture totaled 182.5 thousand people, including farmers and rural workers, living in the farms as well as in small towns. In 2009, according to the Social Security records, there were 192 thousand farmers and rural workers, which accounted for 12% of the country's economically active population. Agriculture continues to contribute significantly to the national economy but, reflecting relatively rapid growth in the rest of the economy, Ag-GDP as a share of total GDP shrank from 13–14% in the 1980s to 8.2% in 2009. After two decades of relatively stagnant economic performance, with Ag-GDP growing at an annual rate of 0.4% in the period 1970–1990, we have seen two decades of strong growth with Ag-GDP growing at an annual rate of 2.5% in the period 1990–2010 (Figure 2-1). The relatively strong recent economic performance of the agricultural sector, combined with a weakening U.S. dollar, is reflected in a very significant jump in farmland prices since 2000, driven in particular by the expansion of forestry plantations and soybeans (Figure 2-2).

[Figure 2-1: *Growth in Real Agricultural Value Added*, *1983–2010*]

[Figure 2-2: *Real Farmland Values in Uruguay*, *1970–2010*]

Policy Changes and Other Influences

Developments in Uruguay's agriculture during the past 40–50 years have reflected changes in national policies and political regimes, along with broader developments in the global economy and the markets for agricultural products. Many of these changes will have contributed substantially to changes in agricultural production and productivity, with impacts that are difficult to identify and separate from those attributable to technological innovation derived from investments in research and extension, especially in view of the fact that the roles of innovation and other factors are synergistic.

During the 1970s, and especially after 1978, a process of deregulation of markets and exports took place. A state-owned slaughterhouse was closed and the state monopoly on the Montevideo beef market was ended. Domestic prices of beef and hides were liberalized, and an import tariff of 30% was set for agricultural products. Import tariffs of capital goods and intermediate inputs were eliminated. Export taxes were reduced or eliminated. Subsidies on fertilizers were eliminated. The government-facilitated, industry-funded export promotion by providing institutional support and tax incentives, especially for barley, citrus, rice and dairy.

In 1987 the Forestry Law was passed, which entailed large subsidies and tax exemptions for forestry plantations. The industry developed quickly, with large foreign investments, first in plantations and second, in pulp processing mills (one plant opened in 2007, construction of a second one is about to begin). The diversion of land to forestry production has come mainly at the expense of the grazing industry.

In 1991 the Treaty of Asunción launched the MERCOSUR customs union among Argentina, Brazil, Paraguay and Uruguay. New agricultural policies were set in place: live cattle exports were allowed; government-owned stocks of frozen beef (used for price regulation) were eliminated; the processing industry was deregulated even more, which resulted in increased competition within the industry and a process of modernization of the slaughter plants.

Structure of Agriculture

The number of farms decreased by nearly 25% in the past 30 years, mainly by reducing the number of very small holdings. In 1980, 69% of the farms (i.e., those with less than 100 ha each) occupied 7% of the total area of agricultural land, while in 2010 those farms with less than 100 ha represented 55% of the total number, and occupied 6% of the land (Table 2-2).

[Table 2-2: *Farm Size Distribution in Uruguay*, *1980–2010*

Agricultural exports accounted for around 60–63% of total exports up until 2005. Since then agriculture's share of exports has consistently grown, and in 2010 they accounted for 72% of the national total. The structure of agricultural exports has changed, too. In the early 1980s, wool, meats (particularly beef) and cereals accounted for 82% of all agricultural exports. Wool exports became less important after the severe decline in wool prices in the early 1990s, but exports of timber products, cereals and oilseeds have grown rapidly: in 2009, beef, cereals and oilseeds (particularly soybeans), dairy, and timber products accounted for 84% of agricultural exports (Figure 2-3).

[Figure 2-3: *Changing Structure of Agricultural Exports*, *1980–2009*]

These changes in the balance of export earnings are mirrored in the balance among sources of farm income (Figure 2-4), which reflect a combination of the influence of price changes and changes in production in response to those changes, as illustrated dramatically by changes in the area planted to crops (Figure 2-5). The area planted to crops trended down during the last quarter of the 20th century, but that trend was recently reversed. In the early 2000s, the total area of winter crops increased from 217 thousand hectares to 466 thousand hectares. The area of summer crops increased even more, from 310 thousand hectares to 1,679 thousand hectares. The main summer crop is soybeans with almost 1 million hectares planted in 2010, but we have also seen a large expansion of sorghum, used mostly for silage or direct grazing.

[Figure 2-4: *Changing Structure of Farm Income*, *1980–2009*]

[Figure 2-5: *Changing Structure of Crop Production*, *1980–2010*]

Innovations and Productivity

In the 2000s, several factors contributed to the expansion of rain-fed agriculture, including: (a) large-scale Argentine firms investing in land or renting large areas, and bringing with them capital, management, and technology; (b) the introduction of a new business paradigm based on "planting-pools systems," allowing economies of scale;[1] (c) widespread (almost 100%) adoption of zero tillage techniques and genetically modified crop varieties and production systems for soybeans and corn, (c) increased use of fertilizers, herbicides, and fungicides, encouraged, in the last two cases, by lower relative prices; and (d) increased demand for forage reserves (silage, hay) and grain in beef and dairy production.

The introduction and generalization of zero tillage techniques has had a significant effect on production. It diminished the costs of production (reduced costs of machinery operations), it increased scope for greater convenience and effectiveness of operations (timing), and increased land-

[1] The "planting pools systems" refer to corporate farming structures whereby new farm business were established, typically involving multiple owners with relatively abundant working capital, often renting rather than owning the land they farmed, and operating relative large farming units.

use intensity (double cropping). Consequently, as elsewhere in the world, zero tillage was rapidly adopted by Uruguayan farmers. In 2000, 11.3% of crop producers had already adopted the technique and, of these, 13% were in their fifth year of applying zero tillage practices (MGAP/DIEA, 2001). In 2009, almost 90% of the rain-fed crops area was under zero tillage. Land-use intensity jumped from 1.06 crops per year in 1990 to 1.56 in 2010 (MGAP/DIEA, 2010).

In terms of partial productivity, among the extensive crops, maize and sorghum show the fastest growth in yields, while soybean yields have grown modestly. On average, rain-fed crop yields have grown by 3.5% per year in the past 20 years (Table 2-3). These average figures reflect some significant variation among decades and among crops.

[Table 2-3: *Partial Factor Productivity Growth in Uruguayan Agriculture, 1980-2010*]

In livestock production, sheep-meat has shown more-sustained long-run productivity growth, compared to beef and dairy cattle. Sheep-meat productivity has increased thanks to a change in the production system, which is now more oriented to meat production and less to wool. Today, Uruguay produces 3.4 times more sheep/lamb meat per head than in 1980. Beef productivity has grown more rapidly in the past 10 years, while dairy productivity increased steadily during the past 20 years: in 1980, average productivity was 2,500 liters/cow, in 2009 it was 4,300 liters/cow, 72% higher (Table 2-3). In beef, the rate of off-take (i.e., total slaughtered per head) has trended up in the past two decades, though annual variation is still important. The long-run rate has increased from a typical value of 13-14% in the 1970-80s, to an average of 18% presently. This is even more pronounced for steers than for cows. At the beginning of the 1980s, the off-take rate for steers was 30%, and now is 45%. On average, 20 years ago steers were slaughtered at 4.2 years of age, but nowadays, the average age is 3.5 years. Contrasting trends are seen between finishing operations and cow-calf operations: productivity per hectare among finishing operations, has increased 45% since 1980, while cow-calf operations, are still producing almost the same number of calves per 100 cows as in 1980. At the same time, the area of cultivated pastures has decreased 10% since 1996, and the stocking rate increased 7%.

Role of INIA

The main innovation in the agricultural sector in the past 20 years has been the almost complete adoption of zero-tillage, which has been facilitated by changes in relative prices of herbicides and fungicides, and the availability of machinery. INIA has played various roles in this and other elements of the innovations involved in the transformation of Uruguayan agriculture in the past 20 years. INIA has continued building up the stock of technological knowledge developed by its predecessor (CIAAB), particularly in crop systems and soil management, dairy, wheat and barley breeding, fertilization and plant protection, animal nutrition, and integrated pest management for fruits and vegetables. In dairy systems, the diffusion and adoption of pasture management and livestock nutrition techniques developed initially by CIAAB, has consistently grown during the past 25 years. In rice-beef production systems, INIA has played a key role in facilitating farmers to adjust fertilization techniques, water management, and crop rotation with cultivated pastures. In crop systems and soil management, INIA has sustained a research program that has accumulated 40 years of data and has given support to other research programs. Through the Fund for Agricultural Technology Promotion (FPTA), INIA has contributed with other research institutions, especially the University, by funding research programs in areas where INIA itself has no comparative advantage.

3. Aggregate Inputs, Outputs, and Multifactor Productivity

Multifactor productivity (MFP) in Uruguay's agriculture was estimated using chained Fisher indices of quantities of outputs and inputs used in production. MFP is defined as the ratio of the Fisher index of the aggregate quantity of output to the Fisher index of the aggregate quantity of inputs. This study makes use of relatively detailed data on 39 categories of outputs and 24 categories of inputs over the 30-year period, 1980–2010. Few studies of agricultural production and productivity have had access to such detailed data in long time series. The use of detailed, disaggregated data of this nature, combined with the use of a discrete approximation of a Divisia index, can be expected to minimize index number biases. However, as is always true, the data were incomplete or less than ideal in some aspects, and simplifying assumptions must be made to address such deficiencies. In some cases it was necessary to interpolate between census years to complete series with missing observations. Conventional approaches were used to derive measures of capital and capital service flows and the like. Appendix A provides details on these approaches and procedures adopted to deal with missing observations, and complete tables of the measures of prices and quantities of inputs and outputs and productivity. Table 3-1 summarizes the growth rates of the three series—output, input, and MFP—over the three decades, and Figure 3-1 plots the indexes of quantities of inputs, outputs and productivity.

[Table 3-1: *Growth of Aggregate Output, Input, and Productivity, 1980–2010*]

[Figure 3-1: *Indexes of Aggregate Output, Input, and Productivity, 1980–2010*]

Outputs

Over the 30 years from 1980 to 2010, the index of output from Uruguayan agriculture increased from a base of 100 to 243.8, at an annual average rate of 3.0%. The crop sector (including forestry) grew relatively quickly, by 4.7% per year, reflecting in particular the growth in output of soybeans and forestry products, while the livestock sector grew by 1.7% per year. As a result of these trends, crops as a share of the value of production increased from 35.2% in 1980 to 51.3% in 2010. The 30-year annual averages conceal some variation over time in the growth rates. The decades of the 1980s and 1990s showed a relatively flat production trend, with slower growth in output of both crops and livestock during the 1990s than in the 1980s. Growth of livestock production slowed even more, to 1.3% per year, but crop production grew much more quickly, by 8.1% per year in the most recent decade, such that aggregate output grew by 3.0% per year.

Inputs

The use of inputs also evolved unevenly over time, generally growing less quickly than output, and with some shifts in the balance among input categories. These changes reflect a combination of farmers responding to relative price movements and adopting innovations, particularly technologies that substitute chemicals and machinery for land and labor. Total input use was essentially flat during the 1980s, but began to trend up in the early 1990s, and the rate of growth accelerated during the 2000s. The three categories showed similar patterns of growth rates increasing from decade to decade, but with differences among them reflecting a general substitution of "other" inputs for "capital" and "labor." Specifically, between 1980 and 2010, the index of the quantity of labor used in Uruguayan agriculture grew from 100 to 113.4, but this longer term trend masks a significant reduction in labor use during the 1980s and 1990s that was restored only relatively recently; the index of the quantity of capital (including land and machinery) increased from 100 to 107.2 and the index of the quantity of other inputs (including fuel, fertilizers, chemicals, seeds, and livestock feed) increased from 100 to 221.5, such that the index of the aggregate quantity of inputs increased from 100 to 130.8, implying that the aggregate quantity of inputs increased at an average annual rate of 0.9 percent.

The net effect of all these changes was a decrease in the cost share of labor from 27.9% to 26.4%, a decrease in the cost share of capital from 56.3% to 50.5%, and an increase in the cost share of other inputs from 15.8% to 23.1%. The prices of labor and capital both increased by about 150 percent in nominal terms over the period, whereas the price of other inputs increased by less than 100 percent. The increase in the cost share of other inputs reflects a relative increase in use that much more than compensates for the relative reduction in price.

Multifactor Productivity

Figure 3-1 shows the time path of the aggregate index of output, the aggregate index of input, and the ratio of the two, the index of MFP. The index of MFP grew from 100 in 1980 to 186.4 in 2010, equivalent to an average annual growth rate of 2.1% over the 30-year period. But the pattern of growth was uneven, with a significantly lower rate in the decade in the 1990s (1.6% per year) compared with either the 1980s (2.5% per year) and the 2000s (2.2% per year). These results are similar to those obtained by others who have estimated agricultural productivity growth in South America using FAO data. Fuglie (2010) reported an annual growth of productivity for the Southern Cone countries of 2.15% for 1990–1999, and 2.03% for 2000–2007, with a higher annual rate of 2.8% in Brazil for 1975–2007. Bharati and Fulginiti (2007) used a production function approach to measure agricultural productivity growth during 1972–2002 in each of the countries of South America. Brazil had the highest annual agricultural productivity growth rate (2.62%), while Ecuador had the lowest (0.57%), and Uruguay was in-between (1.86%).

4. Agricultural Research Institutions and Investments

Uruguay's public agricultural research institutions have undergone significant changes during the past half-century, in parallel with changes in agriculture and the broader economy. A brief discussion of the evolving path of these institutions and their investments provides some context for the econometric analysis in which we seek to relate changes in productivity to changes in investments. More discussion of the history can be found in INIA (2009), Beintema et al. (2000) and Stads, Cotro and Allegri (2008).

Early History

The first agricultural research center in Uruguay ("La Estanzuela," in the department of Colonia) was founded in 1919, and for the next forty years this Experiment Station was the predominant form of public agricultural research activity; it emphasized plant breeding. Agricultural research and technology transfer were transformed significantly during the 1960s, through four institutions: the Center for Agricultural Research (CIAAB), the College of Agriculture of the University of the Republic, the "Plan Agropecuario," and the Uruguayan Wool Secretariat.

CIAAB. CIAAB was founded in 1961 as a division of the Ministry of Livestock and Agriculture (MGA). It was originally concentrated in one Experiment Station ("La Estanzuela"). Progressively, over time, it expanded the number of centers and the range of research, and by the mid-1970s, CIAAB had five Experiment Stations throughout the country. However, infrastructure was very limited and it was not possible to develop well-equipped facilities until 1989, with the financial support of the Inter-American Development Bank (IDB).

The College of Agriculture. The main goal of the College of Agriculture of the public University is teaching. Before the early 1960s scientific research was limited, and teaching was based on traditional practices of animal husbandry and soil cultivation. At that time, the College managed four farms in different parts of the country; these farms were used mostly for production and teaching practical knowledge. In 1963, the farm located in department of Paysandú was transformed into an Experiment Station, and applied research began to develop with a group of researchers that focused on original applied research. The process of scientific knowledge accumulation that followed was aborted in 1973 when the military dictatorship occupied the University and almost all the researchers at the Station resigned.

Plan Agropecuario. The "Plan Agropecuario" a public agency funded partly by the World Bank, played a critical role in disseminating the technology of cultivated pastures and grassland improvements, using species of clover imported from New Zealand, and promoting the use of phosphate fertilizers. The Honorary Commission for the Agricultural Plan ("Comisión Honoraria del Plan Agropecuario") was founded within the structure of the MGA in 1957, with the goal of providing technical assistance and overseeing credit to livestock producers to increase productivity. Funds from the World Bank were received first in 1961. Between then and 1980 the World Bank approved eight loans to Uruguay for a total of $95.7 million (World Bank, 1982). The "Plan Agropecuario" managed those funds for transfer of technology and extension, and indirectly for research by transferring part of them to the CIAAB and the College of Agriculture.

Uruguayan Wool Secretariat (SUL). In 1966, another institution was founded: the Uruguayan Wool Secretariat (SUL). The SUL was created specifically to address sheep production technologies, including breeding, husbandry, and flock management. The SUL is funded by a tax on wool exports that was originally set at 0.3% of the FOB value. This levy was increased several times during the following years: to 0.6% in 1969; 1.2% in 1970; 1.8% in 1971; but has been held at 1.6% since the mid-1970s. SUL also obtains part of its funds from selling services to farmers. A large portion of SUL's funds was devoted to promoting Uruguayan wool in international markets.

Recent Developments

From 1973 until 1985, under the military dictatorship, public agricultural research was neglected, and many researchers abandoned their careers. Public investments in agricultural research diminished. In 1986, the new administration changed the organizational structure of the MGAP and created the Directorate of Technology Generation and Transfer (DGTT).[2]

In 1989, the Parliament approved the creation of the National Institute of Agricultural Research (INIA), which began operations in 1990 based on the existing infrastructure of the CIAAB and with a large fraction of its personnel. The legislation established that INIA would be funded by the private sector with a matching amount provided by the government. The industry funds would come from a farm sales tax of 0.4%, applicable on the sales of cattle, wool, unprocessed hides, pigs, grains, milk, poultry, honey, timber, and exports of fresh fruits and vegetables, flowers, and seeds. The private sector would hold two seats on the board of four directors, the other two being appointed by the Ministry of Agriculture, of which one is designated president of the board. It was determined that 10% of the total budget (the collected sales tax plus the government matching funds) had to be allocated to research projects developed by other organizations. This was called the Fund for Agricultural Technology Promotion (FPTA).

In 1988, the government of Uruguay signed a contract with the IDB (Inter-American Development Bank) to execute a project on "Agricultural Technology Generation and Transfer" that would be funded partly by the IDB ($19.3 million) and partly using public funds ($10.4 million). The project would be administered by the DGTT and its main goal was to strengthen the system of agricultural technology generation and transfer in order to improve agricultural productivity and

[2] The Ministry of Livestock and Agriculture (MGA) was renamed as the Ministry of Livestock, Agriculture and Fisheries (MGAP) with the addition of what was at that time the National Institute of Fisheries.

increase market competitiveness and revenues. The strategy was to develop technologies suitable for each region of the country, to develop a methodology for rural extension, and to establish an effective mechanism of technology diffusion (IDB, 1987).

Owing to some initial delays and the fact that the new institution (INIA) was just starting to operate, the IDB project did not start until late in 1989, and the transfer of its rights and liabilities to the newly created INIA occurred in April 1990. By the end of the project, in 1996, more than $20 million had been spent on fixed capital investments (new facilities, new labs); $2.2 million was applied to capacity building, increasing the number of researchers with post-graduate degrees; and $4.3 million was used in other items. A new IDB project was signed in 1998, with the goal of developing new research programs and to acquire new equipment. IDB contributed $6.3 million and Uruguay's government, $3.3 million. Small amounts were allocated to competitive grants open to non-INIA research organizations.

The Uruguayan Wool Secretariat has been negatively affected by the decline of wool exports. The levy has changed several times in the past. It is currently set at 1.6%. The levy applies to rough wool exports. If wool is exported clean or in tops, an adjustment is made to the rate. At the present time, the effective rate is equivalent to 0.8% of the total export FOB value of wool, regardless of type. This is equivalent to approximately 70% of the SUL budget; the total annual budget is about $2.5 million. At present, SUL maintains a small number of researchers (8) and extension staff (21) with a limited budget for research programs.

The University of the Republic, with its Colleges of Agriculture and Veterinary Medicine is the second largest agricultural R&D institution of the country. Although its budget is mostly allocated to teaching activities, it has a large number of full-time professionals that devote between 10 and 50% of their time to research activities. Current annual expenditure by the Colleges of

Agriculture and Veterinary Medicine, including teaching and research activities is $30 million. Of the total expenditure by the Colleges, we estimate that, at different times, between 5 and 25 percent was allocated to agricultural research.

What seems to have been developing during the past 10 years is private research. Data on this segment is not available so it is somehow difficult to assess the importance of private agricultural research within the general framework. Several multinational corporations such as Monsanto, Pioneer and Syngenta, have their own testing fields for new crop varieties. Some new varieties (corn, wheat, soybeans) are released first in Argentina or Brazil, then evaluated in Uruguay. In the past, the main private firm conducting field trials was the brewery FNC ("Fábricas Nacionales de Cerveza"), which played an important role in developing new varieties of barley. Also in the private sector, several organizations have supported research and have done technology transfer.

Research Investments

Appendix Table B-1 contains details on spending on public agricultural research by the main spending agencies and in total. For this we included the CIAAB/INIA, the Plan Agropecuario, and an estimated share of the total expenditures by the Colleges of Agriculture and Veterinary Medicine allocated to research. The Wool Secretariat was not included because it was not possible to quantify the amount of funds used annually for research. Figure 4-1 shows the pattern of total (deflated) spending and its distribution among agencies over time. Annual spending on public agricultural research in Uruguay has increased from the equivalent of US$1.1 million in 1961 to $38.5 million in 2010. In domestic currency terms, after adjusting for currency reforms and inflation, the total grew by a factor of four, from 131.5 million pesos in 1961 to 550.3 million pesos in 2010 (constant 2005 values). But the growth was not uniform over time, and the balance among spending agencies varied significantly.

[Figure 4-1: *Spending on Agricultural Research and Extension by Spending Agency, 1961–2010*]

Total spending fluctuated around a rising trend through the 1960s and early 1970s until it dropped precipitously, from 272.2 million pesos in 1976 to 105.8 million pesos in 1987 (constant 2005 values). Beginning in the early 1990s, however, total expenditure was revitalized: it grew in real terms during the 1990s by 6.3 percent per year and in the 2000s by 4.8 percent per year. The lion's share of that growth has been in the expenditure by INIA (formerly CIAAB) and the University (Colleges of Agriculture and Veterinary Medicine). From the mid-1960s, the share of the Plan Agropecuario increased significantly, while the University share decreased from 20% to a minimum of 2% in 1974/75. Conversely, after 1990, the share of the Plan decreased to its current 3.6%, while the University increased to reach almost 20% of the total. Since its foundation, INIA has accounted for between 74% and 82% of the total public expenditures on agricultural R&D.

International comparisons are also informative. Table 4-1, taken from Byerlee (2011) includes a number of measures of performance of the public agricultural R&D system in Uruguay compared with three neighbors: Argentina, Brazil, and Chile. The comparison may be distorted by the fact that Uruguay is much smaller, compared with these three agricultural powerhouses, and there may be significant economies of size, scale, and scope in agricultural R&D, such that smaller countries have to invest more intensively than their larger counterparts, everything else equal. Nevertheless it can be seen that compared with these other countries, Uruguay has a higher agricultural research intensity (by several measures) and a faster growth rate of spending during the relevant period, 1990—2006. On balance, the evidence would suggest that the institutional reform in 1990, to create INIA, was effective in revitalizing the total funding available for public agricultural research and extension in Uruguay, enhancing spending both within INIA itself and in the University. The real growth in spending during the recent decade is more particularly remarkable when compared with the generally sluggish public agricultural research spending performance by most countries in recent times (e.g., see Pardey and Alston, 2010). What remains to be seen is whether that investment has yielded a favorable return. We turn to that question next, but with two cautions in mind: first, given long research lags, it may be too early to expect to have seen much impact from investments undertaken since the INIA initiative; second, given the potential roles of spillovers from other countries, it may be difficult to identify contributions by INIA or other public sector entities in Uruguay, let alone separately identify a contribution by INIA.

[Table 4-1: *Comparative Indicators of Research Spending, Uruguay and its Neighbors*]

5. Modeling Agricultural Research and Productivity

In 2010, Uruguayan agriculture produced 2.44 times the quantity of output produced in 1980, using only 1.31 times the 1980 quantity of aggregate inputs, so MFP approximately doubled. This total growth in MFP reflects varying growth rates in productivity over the 30-year period, which we model as a function of investments in agricultural research and extension, which also evolved over the period of our analysis.

Model Structure

Our model of productivity growth as a function of investments in agricultural research and extension is based that of Alston, Andersen, James, and Pardey (2010, 2011), which itself builds on foundations laid by Griliches (1964 and 1979) and Evenson (1967) among others. In our model, agricultural productivity in year t is a function of a stock of agricultural knowledge from public research and extension investments, K_t, a stock of agricultural knowledge from private research, PR_t, weather, C_t, and random factors, ε_t.

Public agricultural knowledge stocks are based on data on total expenditures on public agricultural research and extension over the years 1961–2010, which include research expenditures by CIAAB/INIA and the "Plan Agropecuario," and a share of total expenditures by the Colleges of Veterinary Medicine and Agriculture of the Public University, which we use as an estimate of their agricultural research expenditures. There are no official data on research expenditures by these two Colleges. Our estimates are based on various reports, such as Beintema et al. (2000), Stads, Cotro and Allegri (2008), and Berretta, Condón and Rivas (2010). Reported research spending as a share of total spending varies from 10 to 30%, depending on the source and the time. We know that from the mid-1970s until the mid-1980s, under the military intervention, research funding was minimal, and consequently we set a 5% share for that period. Then we allowed for successive increments to reach a maximum of 25% share in the 2000s. The data are included in Appendix Table B-1 (including details on the research shares of the University budgets) and plotted in Figure 4-1.

To transform the data on annual investments into a measure of the knowledge stock we adopt the gamma lag distribution model used by Alston, Andersen, James, and Pardey (2010, 2011). Specifically, we assume:

(2) $$K_t = \sum_{k=0}^{L_R} b_k R_{t-k}, \text{ where } \sum_{k=0}^{L_R} b_k = 1,$$

L_R is the total lag length, and the b_k parameters are lag weights applied to research expenditures k years previously, R_{t-k}. The research lag weights (b_k) implied by the gamma distribution (assuming no gestation lag, as in Alston, Andersen, James, and Pardey 2010) are:

(3) $$b_k = \frac{(k+1)^{\left(\delta/_{1-\delta}\right)} \lambda^{(k)}}{\sum_{k=0}^{L_R} \left[(k+1)^{\left(\delta/_{1-\delta}\right)} \lambda^{(k)} \right]} \text{ for } L_R \geq k; \text{ otherwise } b_k = 0;$$

where δ and λ are parameters that define the shape of the distribution ($0 \leq \delta < 1$ and $0 \leq \lambda < 1$). Given data limitations, and in view of the relatively applied nature of agricultural R&D in Uruguay, we allow for L_R = 25 years, which is longer than allowed in most studies of agricultural R&D. The resulting lag distribution allows for positive contributions to the current stock from up to 25 years of past expenditures on research and extension, but particular values of λ and δ can correspond to a pattern of very low b_k parameters, after a time, that imply a much shorter effective maximum lag.

As a proxy variable to represent the effects of knowledge stocks resulting from private research, *PR*, we used the number of private cultivars that are included each year in the National Registry; we used the number of varieties of oats, wheat, barley, forage sorghum, corn, sunflower and soybeans. The data were provided by the National Institute of Seeds (INASE), and are included in

Appendix Table B-2. We also included a time-trend variable, to capture the effect of other factors that may have contributed to productivity growth, such as infrastructure improvements, economies of size and scale not associated with innovation or other sources of efficiency gains, technology spillovers from other countries, or private-sector activities not captured by the proxy for private research, *PR*.

The weather variable (*C*) was defined as the squared difference between the annual observation of precipitation during September to December, and the 30-year average of annual precipitation during September to December (i.e., over the years 1980–2010). We accounted only for precipitation during September to December, since that seems to be the period during the cropping season when precipitation matters most. Low precipitation during those months may result in little water accumulated in the soil, which implies a water deficit for the coming summer crops, and loss of cultivated pastures. Excess of water during that period increases the probability of diseases in winter crops and delays harvest, with negative consequences for yields. It may also delay the sowing of summer crops, which in turn, would affect yields because later harvest periods have increased risk of frost damage. The data used come from the precipitation records of INIA in three of its Experiment Stations. The expected sign of the coefficient would be negative, as a larger value of the variable means that year is either too wet or too dry.

In short, assuming the model is linear in logarithms of the variables, we can express it as

$$(1)\quad \ln MFP_t = \beta_0 + \beta_K \ln K_t + \beta_{PR} \ln PR_t + \beta_T T_t + \beta_C \ln C_t + \varepsilon_t,$$

where MFP_t is a Fisher ideal index (i.e., a discrete approximation to a Divisia index) of multifactor agricultural productivity in year *t*; K_t is the stock of knowledge in year *t* from publicly performed agricultural research and extension over the previous 25 years, in real terms, with lag weights defined using a gamma distribution; PR_t is the stock of knowledge in year t from private agricultural research and extension, proxied by the number of private cultivars that are included each year in the National Registry; T_t is a linear time-trend variable; C_t is a weather index, defined as the squared difference between the annual observation of precipitation during September to December and the 30-year average; and ε_t is a residual, with an i.i.d. structure. Simple summary statistics are presented in Table 5-1.

[Table 5-1. *Simple Summary Statistics, Data for the Productivity Model*]

Estimation Results

The models were estimated using STATA 11.2. Given a maximum lag length of 25 years, and research spending data beginning in 1961, we were able to fit models to data on MFP for the years 1986–2010. We used a type of grid-search procedure, in which we assigned values for the parameters of the gamma lag distribution (λ and δ), constructed the knowledge stock variables using these parameters along with the expenditures on R&D, and then estimated the model using these constructed stocks.[3] By repeating this procedure using different values for λ and δ, we were able to search for the values of these parameters that, jointly with the estimated values for the other parameters, would best fit the data. Combining the following seven possible values for both λ and δ (0.60, 0.65, 0.70, 0.75, 0.80, 0.85, and 0.90) with a fixed maximum lag (25 years) yields a total of 49 possible combinations, which encompass a very wide range of shapes and effective lag lengths (see Alston et al., 2010, pp. 280–281).

[3] This approach of estimating productivity models with pre-constructed research knowledge stocks is standard in much of the relevant previous work, but unlike most previous work, and like Alston, Andersen, James, and Pardey (2010), here we search across the range of possibilities for the lag distribution used to construct that stock, and test amongst them, rather than simply impose one.

Table 5-2 summarizes the results from the 49 lag distribution models, in terms of their goodness of fit (measured by SSE and R^2), the elasticity of *MFP* with respect to the public knowledge stock (K) and its approximate standard error, and the peak lag (i.e., the length of the lag in years, k, at which the research lag weight, b_k, is greatest, given the values for λ and δ). The best-fitting model was obtained with values for $\lambda = 0.70$ and $\delta = 0.90$ implying a peak lag weight at year 24, as seen in Figure 5-1. This is identical to the best-fitting lag distribution found by Alston et al. (2010) for the United States, except that here we have truncated the lag at 25 years, whereas they had an overall lag length of 50 years. Several other models with a similar lag length and shape yielded similar results; but for many of the other models, all of which did not fit the data so well, the implied elasticity of *MFP* with respect to the public knowledge stock is negative, an implausible result. We discuss possible reasons for this pattern of results later, in the context of sensitivity analysis. Fortunately, the best-fitting models have plausible values for all of the model parameters, and good statistical properties.

[Table 5-2. *Summary of Results for the Base Model, Alternative Lag Distributions*]

[Figure 5-1. *Gamma Lag Distributions*]

Table 5-3 summarizes the main results for the highest-ranked four models, arranged in rank order according to goodness-of-fit (SSE) criteria, highest to lowest from left to right. In all four models, the coefficients on the public and private knowledge stock variables, K and PR, and the time-trend variable, T, are statistically significantly different from zero, but the coefficient on the weather variable, C, is not. The elasticity of *MFP* with respect to the public knowledge stock is relatively large, at around 0.57 in the preferred specification, compared with previous studies that more often reported elasticities closer to 0.2 or 0.3 (for instance, Alston et al., 2010; Sheng et al., 2011). The peak lag length at 24 years, while comparable to that of Alston et al. (2010) for the United States, is longer than we anticipated for Uruguay given its relatively applied research and extension emphasis.

[Table 5-3. *Summary of Results for the Base Model, Four Top-Ranked Models*]

We tested the models for unit roots using the Augmented Dickey-Fuller test, specifically examining the natural logarithms of multi-factor productivity, private investment, and capital stock. We also tested for cointegration using the Johansen test. The results indicated that the data are non-stationary and cointegrated, lending support to the view that the estimates are not spurious because of time-series data problems. We tested for autocorrelation using the Durbin-Watson statistic, and comparing this to critical values at the 95% confidence level. While autocorrelation was not a problem in the preferred, baseline model, it was significant in several of the alternatives we tried in examining the sensitivity of findings to specification choices. To correct the estimates in those models that exhibited autocorrelation, we used the Cochrane-Orcutt procedure. Additionally, we tested for heteroskedasticity using the White test, and failed to reject the null hypothesis of homoskedasticity.

[Table 5-4. *Statistical tests*]

Sensitivity Analysis

We tried several alternative specifications with variations in two dimensions. First, we tried alternative assumptions about the fraction of expenditure by the University (Colleges of Agriculture and Veterinary Medicine) to apportion to research. Second, we tried dropping the proxy for the private knowledge stock, *PR* and the time trend variable, *T*, or both to see how such omissions would affect the overall performance of the model and the estimated impact of public research.

University Budget Share. In the baseline model we applied specific estimates of research spending as a fraction of total spending by the two Colleges, ranging from 5% to 25% in particular years. In the sensitivity analysis we tried assuming either all or none of the spending by the two Colleges should be counted as contributing to the public agricultural knowledge stock, *K*. Compared with the baseline, the results for the two alternative model structures were less reliable. Treating the entire expenditures for the two Colleges as counting towards public research almost always resulted in implausible, negative estimated elasticities of *MFP* with respect to *K*, and autocorrelation problems. Omitting University expenditures entirely yielded models that were generally similar to those for the baseline model. Detailed results for these models are included in the Appendix C.

Private Research Roles. Table 5-5 reports the results for four alternative specifications of the model, with the baseline treatment of University expenditures. The model in column 1 is the baseline model; the model in column 2 omits private research, *PR*, but retains the time trend, *T*; the model in column 3 retains private research but omits the time trend; and the model in column 4 omits both private research and the time trend, *T*. These alternative treatments have interesting implications for the explanatory power of the model, the evidence of autocorrelation in the residuals, and the estimated elasticity of *MFP* with respect to the private knowledge stock and the lag distribution shape. They indicate some significant correlation among the three variables in question, *K*, *T*, and *PR*, as they relate to the dependent variable, *MFP*, such that omitting any or all of them has significant implications for findings with respect to the roles of the others. Knowing what is best to do, and how to interpret the results, can be challenging in such a setting.

Comparing models 1 and 2 (or models 3 and 4) the effect of omitting *PR* is to increase the estimated elasticity of *MFP* with respect to the public agricultural knowledge stock (omitted variables bias from leaving out private research, as suggested by Alston and Pardey 2001 for example, results in an overestimate of the effect of public research on productivity). However, the best-fitting lag distribution shape for the public agricultural knowledge stock, *K* is not much affected by the omission of *PR*. In contrast, comparing models 1 and 3 (or models 2 and 4), omitting the time trend variable has a profound effect on the best-fitting lag distribution shape and thus for the public agricultural knowledge stock, *K*, and the estimated elasticity of *MFP* with respect to that stock. In the models that omit the time trend the best-fitting lag distribution models peak at a lag of two years, an implausibly short lag for anything other than the most applied research and extension. These models also exhibit evidence of significant autocorrelation and much reduced explanatory power, compared with the baseline model. The implied elasticities of *MFP* with respect to the knowledge stock are much smaller, too. In the next section we explore the implications of these alternative specifications for benefit-cost ratios and estimated rates of return to research.

[Table 5-5. *Summary of Results for Alternatives to the Baseline Model*]

6. Returns to Research

We used the estimated productivity model to compute the *marginal* benefit associated with various hypothetical (counterfactual) changes in research investments. The gross annual research benefits (*GARB*) in year *t* were computed using the following approximation:

$$(2) \qquad GARB_t = \Delta \ln MFP_t V_t$$

where V_t is the real, deflated value (in year 2010 pesos) of agricultural production in year *t*, and $\Delta \ln MFP_t$ is the proportional change in agricultural productivity in year *t*, associated with a simulated increase in public agricultural research spending.[4] Since the variables are in logarithms, the simulated proportional change in *MFP* is simply equal to $\Delta \ln MFP = \ln MFP^1 - \ln MFP^0$, where the superscript 0 denotes the predicted ln *MFP* given the actual research expenditure and the 1 denotes the predicted ln *MFP* with the increased (counterfactual) expenditure. Then, the present value in the year 2010 of accrued benefits (*PVB*) was computed using a (correspondingly real) discount rate of $r = 5\%$ per year (we also tried values of $r = 3\%$ per year and $r = 10\%$ per year, for comparison).

$$(3) \qquad PVB = \sum_{t=1961}^{2010} GARB_t \cdot (1+r)^{2010-t} = \sum_{t=1961}^{2010} \Delta \ln MFP_t \cdot V_t \cdot (1+r)^{2010-t}$$

Using our preferred baseline model, we computed *PVB* = 163 million pesos in 2010 for an increase by 1 million pesos in public research spending in 1985. The benefit-cost ratio is given by dividing the present value of the corresponding simulated benefits by the present value of the costs—*PVC* = 1 million times $(1+r)^{25}$ (= 3.4 million pesos for $r = 0.05$). Hence, the marginal benefit-cost ratio is given by $B/C = PVB/PVC = 163/3.4 = 48.2$. We also computed the corresponding conventional internal rate of return and a modified internal rate of return (assuming that flows of benefits would be

[4] This approximation is likely to be reasonably valid as a measure of the total benefits for a small research-induced change in production, as a result of a comparatively small change in the research investment.

reinvested at a real interest rate of 5% per annum), following Alston, Andersen, James, and Pardey (2011). Consider an investment of I_t dollars in time t that will yield a flow of benefits, B_{t+n} over the following N years. The modified internal rate of return, m solves the problem:

$$(4) \qquad \sum_{n=0}^{N} B_{t+n}(1+r)^{N-n} - I_t(1+m)^N = 0.$$

Intuitively, m is the rate at which one could afford to borrow the amount to be invested, I_t, given that it would generate the flow of benefits, B_{t+n}, which would be reinvested at the external rate, r. Using our preferred, baseline model, we estimated the modified internal rate of return was 24% per annum for a marginal increase in research spending in 1985. This is somewhat smaller than the conventional internal rate of return, 30% per annum, which itself is lower than many estimates in the literature (e.g., see Alston et al. 2000), a result that we ascribe substantially to the comparatively long lag in the present case.

Table 6-1 reports estimates of the marginal benefit-cost ratio, conventional internal rate of return and modified internal rate of return for a marginal increase in spending in 1985 for our referred baseline model and the three alternative models that differ in their treatment of the proxy for private research, *PR*, and the time trend, *T*. The conventional internal rate of return is very sensitive to specification choices: In the models that exclude the time trend (models 3 and 4), with their very short lag distribution, the conventional internal rate of return is not well defined; in the models that do include the time trend, it is sensitive to the omission of private research. In contrast, the modified internal rate of return is much more stable across specifications, ranging between 24% and 27% with a reinvestment rate of 5% per year, and varies in an expected fashion as the reinvestment rate is varied. The benefit-cost ratio also varies in a somewhat predictable fashion across specifications. The models that exclude the time trend have a shorter lag (implying a higher benefit-cost ratio) but a much smaller elasticity of *MFP* with respect to *K* (implying a larger benefit-cost ratio); the net effect is mixed, depending on the treatment of private research. Leaving out private research increases the estimated benefit-cost ratio for public research by about 25 percent.

[Table 6-1. *Benefit-Cost Ratios and Rates of Return for the Baseline Model and Alternatives*]

7. Credibility of Results

Over the period 1980–2010, our index of MFP increased from 100 in 1980 to about 186 in 2010, and if aggregate input had been held constant at the 1980 quantities, output would have increased by a factor of 1.86:1. Of Uruguay's actual agricultural output in 2010, only 54 percent (i.e., 100/186 = 0.54) could be accounted for by conventional inputs using 1980 technology, holding productivity constant. The remaining 46 percent is accounted for by economies of scale along with improvements in infrastructure, inputs, and other technological changes. Hence, of the total production value, worth US$4.9 billion in 2010, only 54 percent or $2.7 billion could be accounted for by conventional inputs using 1980 technology, and the remaining $2.2 billion is attributable to the factors that gave rise to improved productivity. Among these factors is new technology, developed and adopted as a result of public agricultural research and extension.

The actual value of agricultural output (AV_t) can be divided into two parts: (a) one representing what the value of output would have been, given the actual input quantities, if productivity had not grown since 1980—i.e., hypothetical value, $HV_t = AV_t * (100 / MFP_t)$; and (b) the other, a residual representing the value of additional output that is attributable to productivity growth—i.e., residual value, $RV_t = AV_t - HV_t = AV_t * (MFP_t - 100) / MFP_t$. As productivity increases over time, the share of the value of production that is attributable to productivity growth increases, as can be seen in Figure 7-1, which shows the value of agricultural production, AV_t in Uruguay over the years 1980 through 2010 partitioned between the part attributable to conventional inputs holding productivity constant, and the residual value, RV_t attributable to productivity growth since 1980, all expressed in constant (2005) pesos. The deflated values were compounded at a real interest rate of 5% per annum and evaluated in the year 2010. The resulting stream of values of agricultural output attributable to productivity improvements is equivalent to a one-time payment of more than $31 billion in 2010, an enormous benefit from improved agricultural productivity in Uruguay since 1980.

[Figure 7-1: *Residual Value Attributable to Productivity Growth Since 1980*]

We compared the value of productivity gains since 1980 compounded forward over 30 years to 2010, against the expenditures on agricultural research and extension, also over 30 years, from 1961–1991, compounded forward to 2010. Both costs and benefits were converted into real terms using the GDP price deflator and accumulated forward to 2010 using a real discount rate of 5% per annum. The result is a benefit-cost ratio of over 19:1.

This simple ratio of approximate benefits over 1980–2010 (compounded forward to 2010) to approximate costs 1961–1991 (also compounded forward to 2010) is a biased estimate of the true benefit-cost ratios for several reasons. First, the existence of long R&D lags mean that we have left out some of the relevant costs (research expenditures prior to 1961 will have contributed to productivity growth between 1980 and 2010) and some of the relevant benefits (research expenditures between 1991 and 2010 will generate benefits between 1991 and 2010 and for many years after 2010). Depending on the pattern of benefits and costs over time and the effects of discounting, these two sources of bias could be offsetting. However, given the generally rising pattern of research expenditures and the annual flows of benefits from productivity gains, we would expect the effect of the understatement of benefits to outweigh the effect of the understatement of costs, biasing the benefit-cost ratios down on balance. Second, a significant share of the total benefits may be attributable to private and rest-of-world research.

Table 7-1 reports approximate benefit-cost ratios for a range of assumptions about the attribution of benefits between public research in Uruguay and other sources, about the timing of the flows of benefits and costs to be compared, and the appropriate rate of discount. Holding other aspects constant, the effect of the attribution rate assumption is direct: the benefit cost ratio is proportional to the attribution rate. Under the most optimistic scenario (100% attribution) and the most favorable discount rate (3% per annum) the benefit-cost ratio ranges from 24:1 to 55:1, as the period of included costs varies from 40 years, 1961–2001 to 20 years 1975–1995. This pattern of the effect of changing assumptions about costs is comparable under alternative assumptions about attribution and the discount rate. Varying the discount rate has a very substantial effect on the benefit-cost ratio, and in ways that vary depending on assumptions about the comparable stream of costs. Attributing 50% or more of the benefits over 30 years (1980–2010) to public agricultural R&D in Uruguay over 20 years (1971–1991 or 1975–1995, the last two rows of table 6-1) with a 5% per annum discount rate, the approximate benefit-cost ratio ranges from 21:1 to 42:1—substantially lower but of a comparable magnitude to the econometrics-based estimate of 48:1.

[Table 7-1. *Approximate Benefit-Cost Ratios*]

8. Conclusion

Governments around the world are exploring alternative models for financing agricultural R&D, including private-public partnerships whereby commodity levies are used to finance commodity collective goods elements of applied agricultural R&D. The INIA model was partly inspired by and based on the Australian Research and Development Corporation (RDC) model, whereby the government provides dollar-for dollar matching support for funds raised by commodity levies, and the funds are administered by boards with representatives of industry and the government. Australia has some 15 separate RDCs for different commodities (http://www.ruralrdc.com.au/), Uruguay has just one counterpart, INIA which has a much broader mandate. A recent review of the first 20 years of INIA provided the means and opportunity for the present work, which sought to quantify the productivity performance of agriculture in Uruguay and evaluate the contribution of public agricultural research and the INIA initiative to that performance.

INIA was created in a conjunction with other economic policy reforms in Uruguay that served to stimulate the agricultural sector, including forestry, and its effects on the sector are difficult to isolate from the effects of the other policies and influences, as well as other sources of agricultural innovations. While definitive specific conclusions about the role of INIA are not possible, the evidence is broadly favorable. First, agricultural research investments have been revitalized in the post-INIA period, going from a period of essentially flat or declining real spending, and a shrinking share of CIAAB (the precursor to INIA), to a 20-year period of sustained and fairly steady growth in real spending—an almost four-fold increase since 1989, with the lion's share of the growth being in spending by INIA.

Second, agricultural productivity growth in Uruguay has been relatively strong over the past 30 years, averaging 2.1 percent per annum, and has been sustained in the most recent decade of the

2000s. Many countries have experienced a recent slowdown in agricultural productivity. The fact that Uruguay has not experienced a slowdown may be attributable in part, or even significantly, to INIA. However, we do know that other influences were present, such as innovations within farming systems introduced from Argentina.

Third, our econometric analysis attributes a significant portion of multifactor agricultural productivity growth in Uruguay to a public agricultural knowledge stock in a model that includes a measure of private research knowledge (seed varieties) and a time trend variable to capture the effect of private research and other sources of productivity growth, including international spillovers. This analysis uses a state-of-the-art model, of a type that has previously been applied only in higher-income countries such as the United States (Alston et al. 2010) and Australia (Sheng et al. 2011) with comparatively extensive data resources available. In the present application, the preferred specification entailed a lag distribution model with a peak lag weight at year 24, a gamma lag distribution with the same shape as found by Alston et al. (2010) in their application a panel of data on 48 U.S. states, but truncated at 25 years rather than 50 years. We expected to find a lag distribution with a much earlier peak for Uruguay, given its comparatively applied research focus. This aspect of our model was sensitive to the inclusion of the other variables that had strong time trends, but none of the specifications we tried resulted in a more-plausible lag distribution model combined other desirable characteristics, and our preferred model statistically dominated the alternatives. As noted by many before us (e.g., Griliches 1964, 1979), it may be asking too much of the data to attempt to estimate the structure of the knowledge stock jointly with the other model parameters, especially when we have only a single, short time series of data to work with.

Fourth, the investment appears to have been very profitable. In view of the potential fragility of the econometric estimates, we estimated summary measures of marginal payoffs to research investments based on several alternative specifications as well as our preferred model. The results illustrated that the implied benefit-cost ratios were remarkably similar across four models that had very different specifications of other included variables and thus the lag distribution underlying the public agricultural knowledge stock, and correspondingly different elasticities of productivity with respect to that stock. The preferred model had a benefit-cost ratio of 48:1 computed using a discount rate of 5% per annum, and the three alternative (mis-specified) models had benefit-cost ratios ranging from 46:1 to 90:1. The corresponding measures of the modified internal rate of return were almost identical across all the models, ranging from 23% per annum to 27% per annum with a reinvestment rate of 5% per annum.

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List of Acronyms

ACA	Asociación de Cultivadores de Arroz *Rice Growers Association*
CIAAB	Centro de Investigaciones Agrícolas "Alberto Boerger" *Agricultural Research Center "Alberto Boerger"*
COMTRADE	Commodity Trade Statistics (United Nations)
DICOSE	Dirección de Contralor de Semovientes (MGAP) *Directorate of Livestock Control*
DGSA	Dirección General de Servicios Agrícolas (MGAP) *Directorate of Agricultural Services*
DIEA	Dirección de Estadísticas Agropecuarias (MGAP) *Directorate of Agricultural Statistics*
ECLAC	Economic Commission for Latin America and the Caribbean (United Nations)
FAO	Food and Agriculture Organization (United Nations)
IDB	Inter-American Development Bank
INAC	Instituto Nacional de Carnes *National Institute of Meats*
INASE	Instituto Nacional de Semillas *National Institute of Seeds*
INAVI	Instituto Nacional de Vitivinicultura *National Institute of Viticulture*
INC	Instituto Nacional de Colonización *National Institute of Rural Settlements*
INE	Instituto Nacional de Estadísticas *National Institute of Statistics*
INIA	Instituto Nacional de Investigación Agropecuaria *National Institute for Agricultural Research*
MGAP	Ministerio de Ganadería Agricultura y Pesca *Ministry of Livestock, Agriculture and Fisheries*

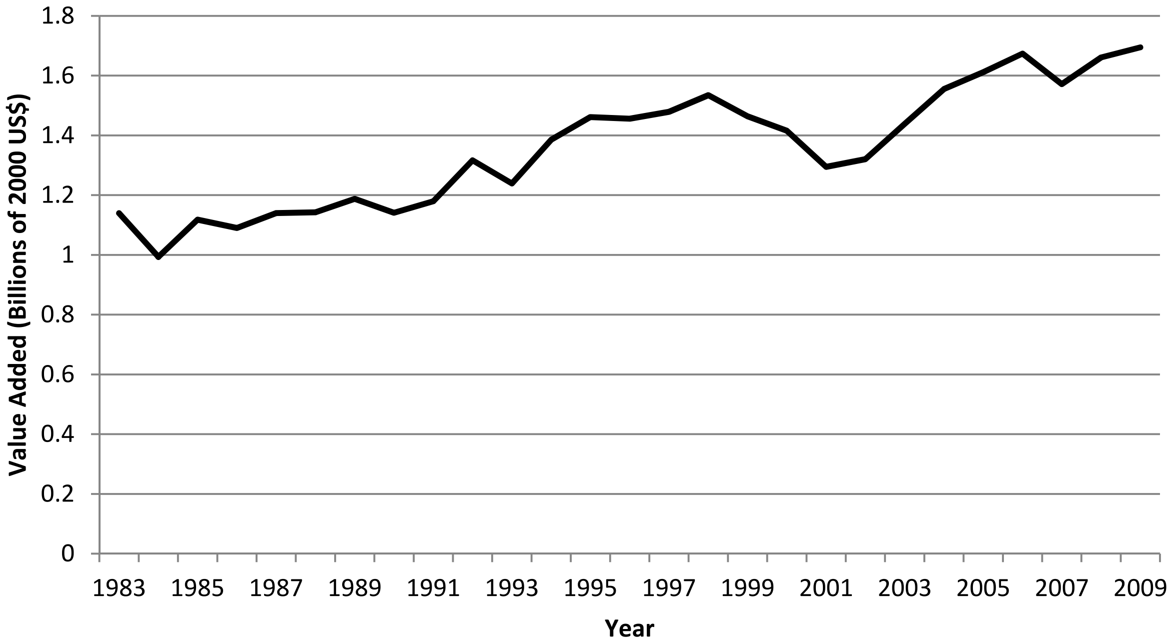
OPYPA	Oficina de Programación y Políticas Agropecuarias (MGAP) *Agricultural Policy and Programming Office*
RENARE	Recursos Naturales Renovables (MGAP) *Renovable Natural Resources*
SUL	Secretariado Uruguayo de la Lana *Uruguayan Wool Secretariat*

Table 2-1: *Uruguay's Agriculture in Brief (2010)*

Number of farms	51,675
	Full-time equivalents
Farm labor force	192,000
Land in farms	*'000 Hectares*
Total	15,417
Cultivated pastures	993
Improved pastures	855
Natural grasslands	10,600
Winter crops	1,181
Orchards, vineyards and vegetable crops	66
Natural forests	769
Plantation forests	953
Livestock Numbers	*'000 Head*
Beef cattle	10,327
Dairy cattle	765
Sheep	7,710
Pigs	155

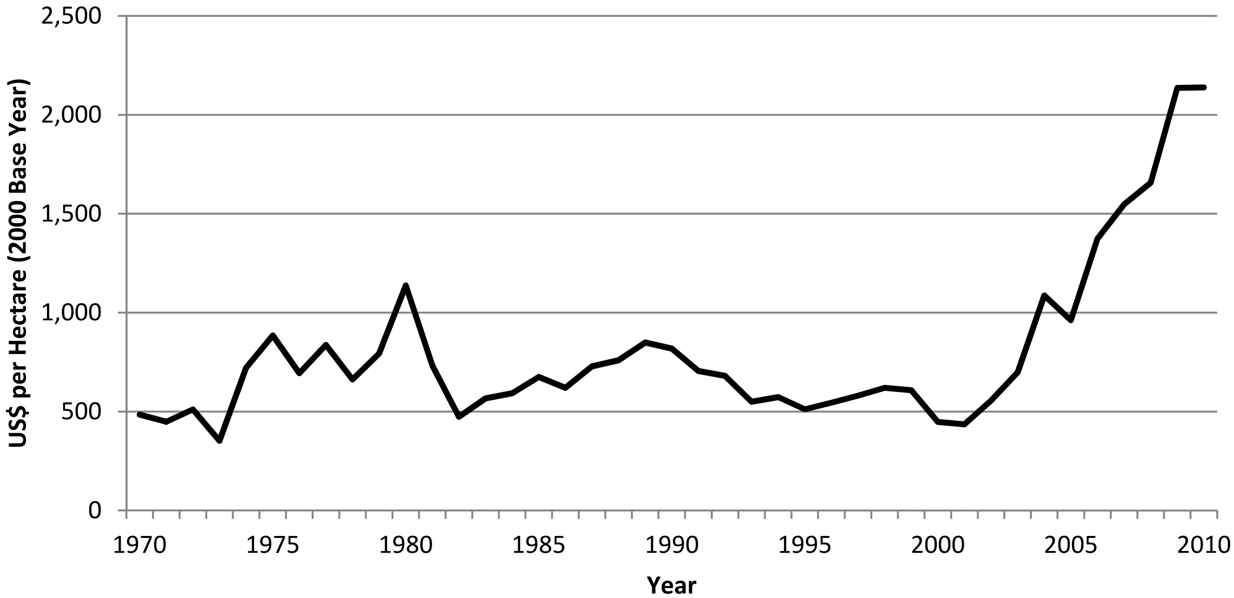
Notes: Data were taken from MGAP/DICOSE; MGAP/Dirección Forestal. Summer crops are not accounted for because DICOSE collects the data from farms during the winter season. A fraction of the summer crops area is on a double-cropping system.

Figure 2-1: *Growth in Real Agricultural Value Added, 1983–2010*



Source: Based on World Bank data (http://data.worldbank.org/).

Figure 2-2: *Real Farmland Values in Uruguay*, *1970–2010*



Source: Based on INC (1970-79), Seragro (1980-99), MGAP/DIEA (2000-2010)

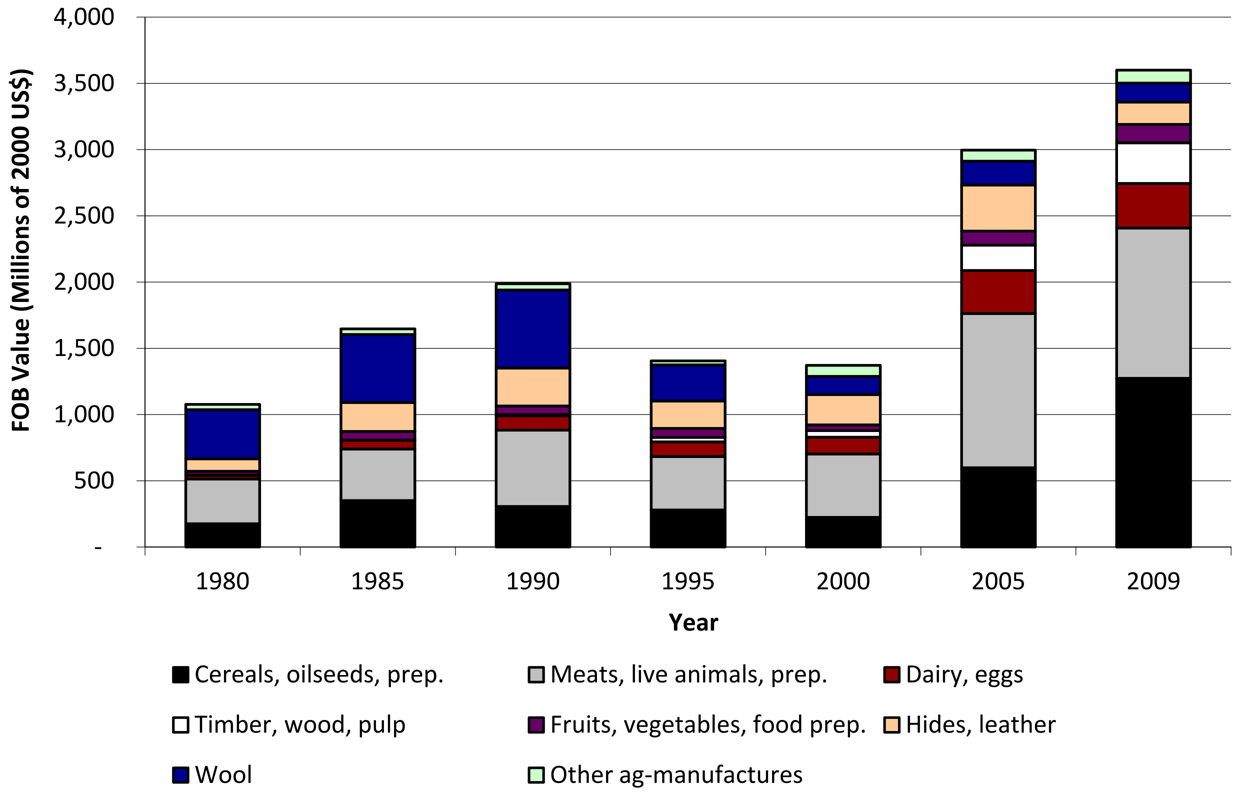
Notes: INC stands for National Institute of Settlements (Colonies); Seragro is a private consultant firm

Table 2-2: *Farm Size Distribution in Uruguay, 1980–2010*

	1980		1990		2010	
Size Range	Number of Farms	Area	Number of Farms	Area	Number of Farms	Area
Hectares		*'000 Hectares*		*'000 Hectares*		*'000 Hectares*
< 100	46,935	1,114.9	33,811	908.9	28,519	924.3
100–499	13,740	3,157.2	13,088	3,066.2	15,262	3,586.3
500–999	3,792	2,681.9	3,887	2,754.8	4,280	3,019.4
1,000–2499	2,810	4,331.5	2,931	4,492.7	2,753	4,090.0
> 2,500	1,085	4,739.1	1,099	4,581.2	861	3,783.5
Total	**68,362**	**16,024.7**	**54,816**	**15,803.8**	**51,675**	**15,403.6**

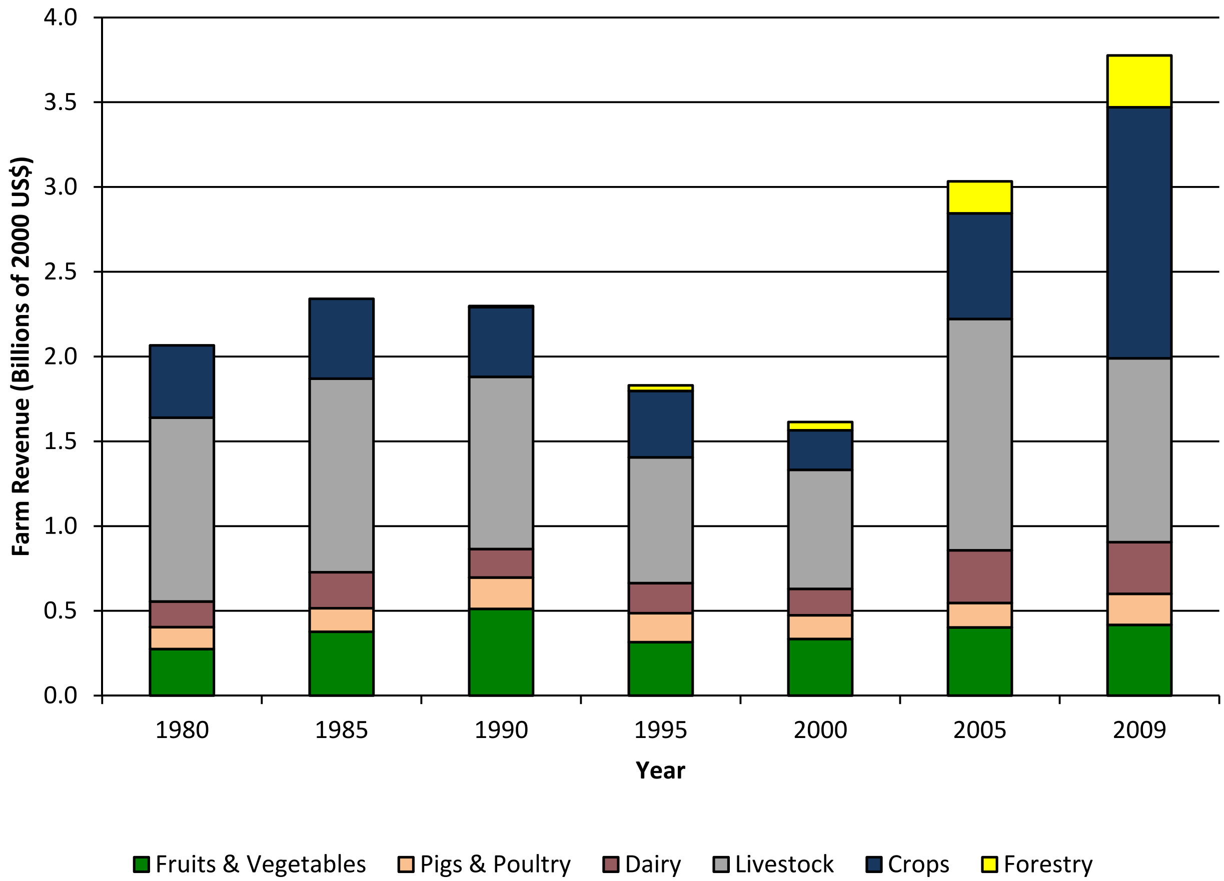
Notes: Data taken from MGAP/DIEA, Censos Agropecuarios (1980, 1990); DICOSE (2010). Total land in farms in 2010 differs from Table 1 because of some differences between reporting agencies.

Figure 2-3: *Changing Structure of Agricultural Exports*, *1980–20*



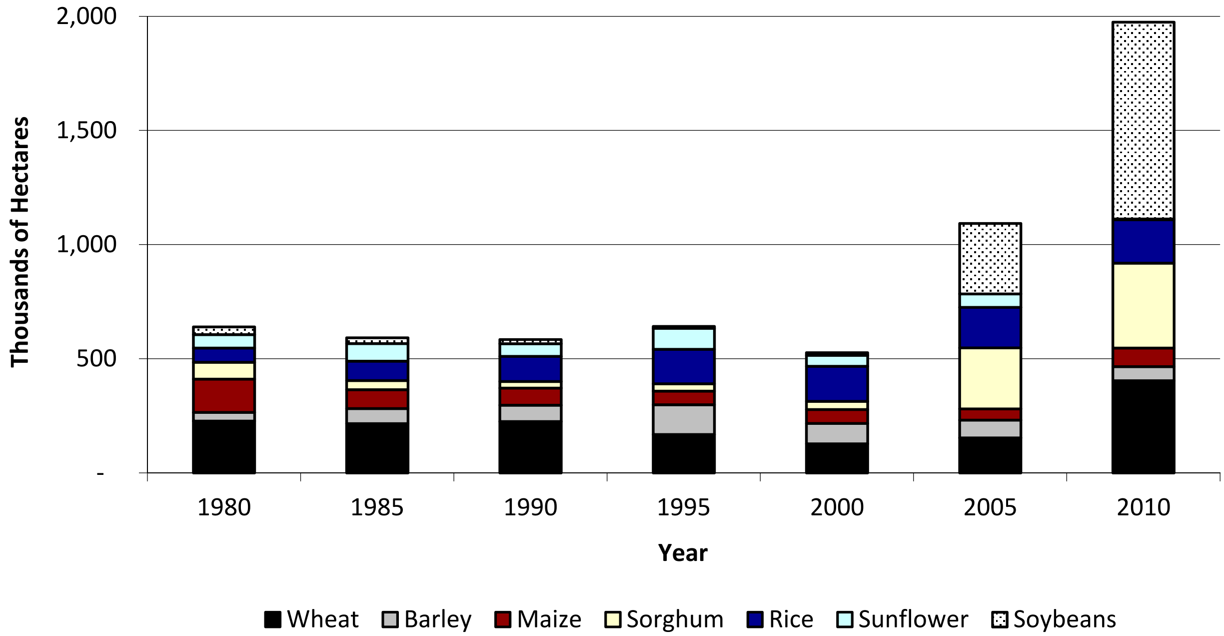
Source: based on ECLAC data (UN-Economic Commission for Latin America and the Caribbean), (http://www.eclac.org/estadisticas/)

Figure 2-4: *Changing Structure of Farm Income, 1980–2009*



Source: own calculations based on several local sources (MGAP, INAC, INASE, ACA)

Figure 2-5: *Changing Structure of Crop Production, 1980–2010*



Source: Based on data published by MGAP/DIEA, and own estimates based on INASE data.

Notes: The official MGAP/DIEA data do not include summer fodder crops. They only report on crops for grain production. Acreage of corn and sorghum, as shown here, is estimated based on the quantity of seed used.

Table 2-3: *Partial Factor Productivity Growth in Uruguayan Agriculture*, *1980–2010*

Crops (annual rate based on 3-year moving average)

	1980s	1990s	2000s
Wheat	3.4	-0.2	5.7
Barley	1.8	-1.2	6.8
Rice	-1.4	2.6	2.0
Sorghum	2.1	-0.4	4.4
Corn	4.2	5.7	3.8
Soybeans	-0.3	1.4	0.9

Source: Own calculations, based on MGAP-DIEA data. Corn and sorghum: grain yields only.

Livestock (annual rate based on 3-year moving average)

	1980s	1990s	2000s
Beef*	1.32	0.09	3.13
Sheep/Lamb*	3.41	4.97	5.70
Equivalent meat/ha	0.18	0.87	3.45
Milk/cow**	-0.13	3.40	2.45

Source: Own calculations, based on MGAP-DICOSE, DIEA data.
(*): Kilogram of meat per cattle unit-equivalent
(**): Milking and dried cows

Table 3-1: *Indexes of Output, Input, and Multifactor Productivity, 1980–2010*

Year	Output Quantity			Input Quantity				Multifactor Productivity
	Crops	Livestock	Total	Labor	Capital	Other	Total	
1980	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.00
1981	115.6	111.9	113.3	100.0	100.5	101.0	100.4	112.79
1982	105.3	116.0	111.8	100.0	98.9	96.5	98.7	113.28
1983	110.6	119.8	116.2	99.9	96.1	97.1	97.5	119.21
1984	120.4	96.6	104.9	99.9	96.3	102.8	99.1	105.82
1985	115.4	107.9	110.4	99.9	96.9	102.2	99.2	111.27
1986	106.2	114.9	111.6	98.7	96.4	101.1	98.4	113.39
1987	122.9	103.5	109.6	97.5	97.2	104.2	99.2	110.49
1988	136.4	107.6	116.7	96.2	97.1	110.2	100.2	116.52
1989	130.3	123.8	125.7	95.0	95.5	111.2	99.3	126.59
1990	137.8	122.1	127.4	93.8	96.4	111.4	99.5	128.01
1991	143.4	113.6	124.1	92.6	97.5	110.7	99.7	124.54
1992	159.5	121.0	134.4	91.4	98.6	118.9	101.4	132.54
1993	154.6	119.7	131.9	90.2	99.0	122.0	101.8	129.55
1994	165.5	128.3	141.2	89.0	101.2	131.1	104.2	135.59
1995	180.2	123.7	142.8	87.8	101.9	137.2	105.3	135.71
1996	203.3	140.4	161.8	86.6	101.9	153.1	108.0	149.81
1997	187.0	148.6	161.7	88.0	100.1	158.1	108.3	149.32
1998	218.5	146.3	170.1	89.4	100.6	162.3	109.6	155.13
1999	189.6	144.7	160.3	88.2	100.4	159.4	108.8	147.34
2000	182.2	145.1	158.3	84.8	100.2	143.5	105.1	150.64
2001	177.3	126.0	143.5	86.1	101.2	155.3	108.1	132.76
2002	183.2	133.5	150.6	95.0	102.1	148.4	109.7	137.26
2003	239.9	130.6	166.7	99.1	103.1	170.7	115.4	144.39
2004	258.4	151.5	187.6	100.8	105.6	192.8	121.7	154.20
2005	266.3	169.4	203.3	104.9	105.1	196.3	123.0	165.25
2006	285.3	182.6	218.6	112.0	104.3	197.1	124.6	175.46
2007	298.3	161.5	207.8	112.7	106.8	226.3	131.2	158.40
2008	345.5	172.3	230.8	115.2	108.4	219.6	131.5	175.45
2009	416.1	171.5	254.3	113.0	110.1	231.1	133.8	190.10
2010	395.9	165.7	243.8	113.4	107.2	221.5	130.8	186.42
Average annual percentage growth rate								
1980-1990	3.3	2.0	2.4	-0.6	-0.4	1.1	-0.1	2.5
1990-2000	2.8	1.7	2.2	-1.0	0.4	2.6	0.5	1.6
2000-2010	8.1	1.3	4.4	3.0	0.7	4.4	2.2	2.2
1980-2010	4.7	1.7	3.0	0.4	0.2	2.7	0.9	2.1

Notes: See notes to Appendix Tables A-1 and A-2.

Figure 3-1: Growth in Inputs, Outputs, and Multifactor Productivity, 1980–2010

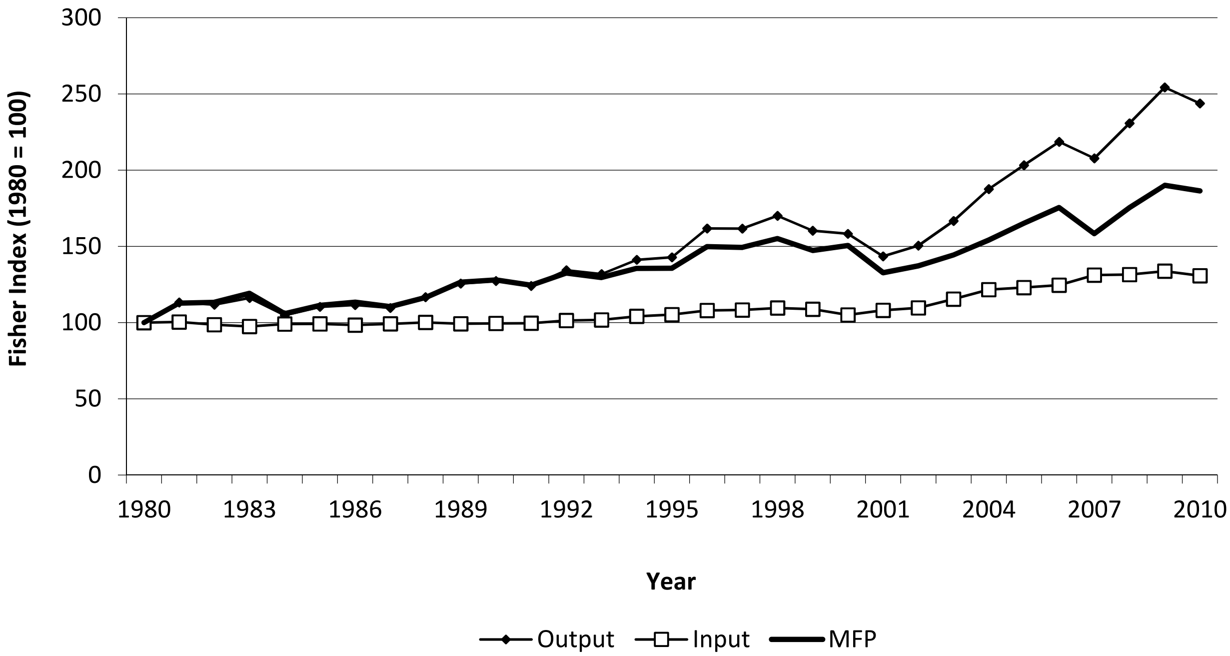
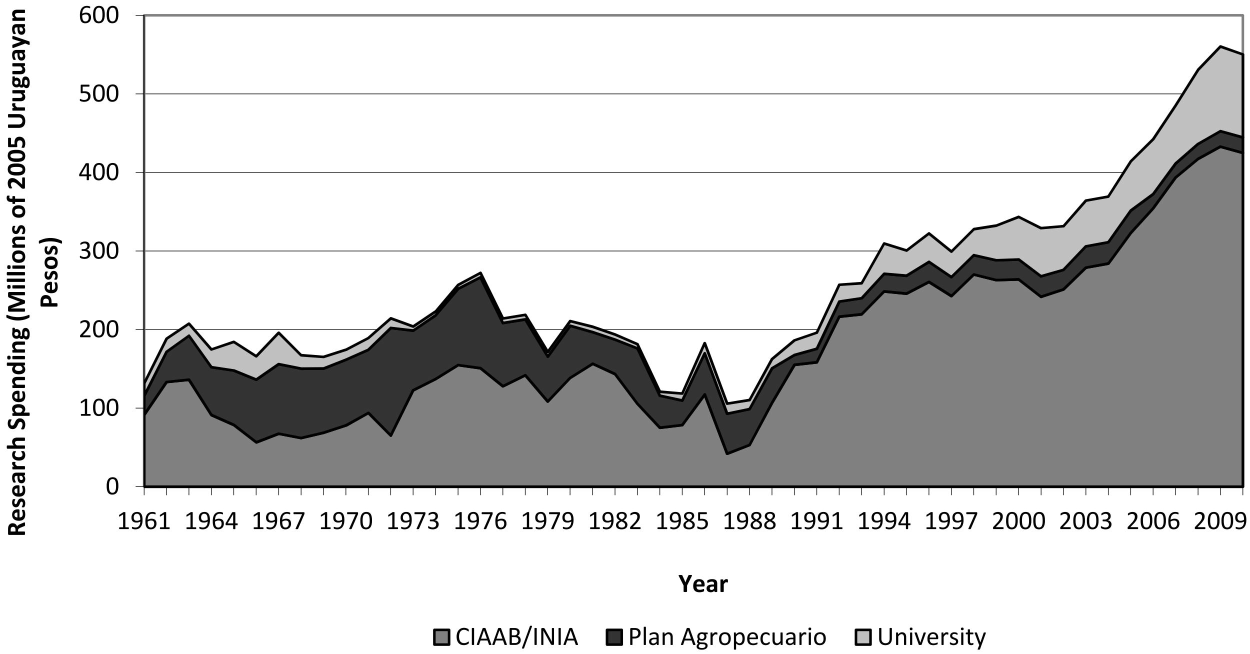


Figure 4-1: *Spending on Agricultural Research and Extension by Spending Agency, 1961–2010*



Source: Table B-1.

Notes: "University" expenditures are the estimated shares of the College of Agriculture and the College of Veterinary Medicine budget allocated to research activities.

Table 4-1: *Comparative Indicators of Research Spending, Uruguay and its Neighbors*

Indicator	Uruguay	Argentina	Brazil	Chile
R&D spending as a share of AgGDP, 2006 (%)	1.99	1.27	1.68	1.22
INIA budget as share of AgGDP, 2006 (%)	1.19	na	0.96	na
Per capita R&D, 2006 (2000 PPP dollars)	15.61	7.61	6.81	6.45
Annual growth of government R&D spending, 1990-2006 (%)	3.65	2.61	-0.74	1.92
INIA operating budget as share of total budget, 2006 (%)	52	20	na	40
Spending per FTE researcher, 2006 (2000 PPP dollars)	206	130	241	152
Share of INIA scientists with a postgraduate degree (%)	77	13	99	60
Share of INIA scientists with PhD degree (%)	32	na	77	na

Source: Byerlee (2011)

Table 5-1: *Simple Summary Statistics, Data for the Productivity Model,* 1985–2010

Symbol	Variable Name	Definition	Value Description	Value
$MFP_{,t}$	Multifactor agricultural productivity	Fisher ideal index of agricultural output divided by Fisher ideal index of agricultural output in year *t*	Minimum Maximum Average across years	100.0 186.4 138.3
$K_{,t}$	Stock of public agricultural knowledge	Constructed using 25 years of lagged government spending on agricultural research and extension (in real 2005 pesos) and a gamma lag distribution (λ = 0.70, δ = 0.90)	Minimum Maximum Average across years	165:9 208:5 187:1
$PR_{,t}$	Stock of private agricultural knowledge	Proxied using the number of cultivars of oats, wheat, barely, forage sorghum, corn, sunflowers, and soybeans in the National Registry	Minimum Maximum Average across years	105 363 188
C_t	Weather	Measured as the squared difference between September to December precipitation, and its 30-year average (i.e., over the years 1980–2010)	Minimum Maximum Average across years	181.6 91,661.8 18,594.2

Table 5-2: *Summary of Results for the Preferred Model, Alternative Lag Distributions*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.844	0.849	0.861	0.878	0.894	0.883	0.868
	SSE	0.068	0.066	0.061	0.053	0.046	0.051	0.058
	ln K	-0.001	-0.103	-0.176	-0.221^{*}	-0.255^{**}	-0.274^{*}	0.347^{+}
	s.e. K	(0.150)	(0.133)	(0.112)	(0.093)	(0.084)	(0.106)	(0.182)
	Peak Lag	2	3	4	5	7	10	17
	Rank	49	45	34	20	7	15	30
0.65	Adj. R^2	0.850	0.860	0.874	0.887	0.891	0.859	0.903
	SSE	0.066	0.061	0.055	0.049	0.047	0.062	0.042
	ln K	-0.121	-0.186	-0.228^{*}	-0.259^{*}	-0.289^{**}	-0.226	0.571^{**}
	s.e. K	(0.141)	(0.122)	(0.105)	(0.093)	(0.098)	(0.158)	(0.163)
	Peak Lag	2	3	4	6	8	12	20
	Rank	43	35	24	12	10	36	4
0.70	Adj. R^2	0.862	0.873	0.883	0.889	0.877	0.845	0.908
	SSE	0.060	0.056	0.051	0.049	0.053	0.068	0.040
	ln K	-0.207	-0.244^{*}	-0.272^{*}	-0.299^{*}	-0.313^{*}	0.054	0.565^{**}
	s.e. K	(0.130)	(0.115)	(0.105)	(0.106)	(0.134)	(0.229)	(0.152)
	Peak Lag	3	4	6	7	10	15	24
	Rank	32	27	16	11	22	48	1
0.75	Adj. R^2	0.873	0.880	0.884	0.879	0.853	0.878	0.892
	SSE	0.056	0.052	0.050	0.053	0.064	0.053	0.047
	ln K	-0.268^{*}	-0.293^{*}	-0.318^{*}	-0.338^{*}	-0.234	0.562^{*}	0.447^{**}
	s.e. K	(0.127)	(0.120)	(0.121)	(0.141)	(0.211)	(0.240)	(0.150)
	Peak Lag	4	5	7	9	13	19	30
	Rank	28	17	14	18	39	21	8
0.80	Adj. R^2	0.877	0.879	0.874	0.857	0.849	0.908	0.874
	SSE	0.054	0.053	0.055	0.062	0.066	0.040	0.055
	ln K	-0.322^{*}	-0.345^{*}	-0.362^{*}	-0.302	0.255	0.724^{**}	0.319^{*}
	s.e. K	(0.139)	(0.144)	(0.164)	(0.222)	(0.303)	(0.195)	(0.147)
	Peak Lag	6	7	9	12	17	24	39
	Rank	23	19	25	37	43	2	26
0.85	Adj. R^2	0.871	0.866	0.853	0.847	0.895	0.901	0.861
	SSE	0.056	0.059	0.064	0.067	0.046	0.043	0.061
	ln K	-0.374^{+}	-0.377^{+}	-0.290	0.192	0.822^{**}	0.588^{**}	0.220
	s.e. K	(0.182)	(0.210)	(0.270)	(0.347)	(0.265)	(0.174)	(0.140)
	Peak Lag	8	10	13	17	24	34	54
	Rank	29	31	40	46	6	5	33
0.90	Adj. R^2	0.853	0.845	0.853	0.892	0.905	0.884	0.853
	SSE	0.064	0.068	0.064	0.047	0.041	0.051	0.064
	ln K	-0.326	-0.120	0.446	0.919^{**}	0.740^{**}	0.424^{*}	0.149
	s.e. K	(0.295)	(0.361)	(0.402)	(0.307)	(0.207)	(0.163)	(0.133)
	Peak Lag	13	17	21	27	37	53	84
	Rank	41	47	38	9	3	13	42

Notes: Standard errors in parentheses; ** significant at 1%, * significant at 5%, and + significant at 10%.
Adj R^2 is defined as the Adjusted R^2; SSE is defined as the Sum of Squared Errors.
ln K is defined as the natural logarithm of capital stock and. s.e. K is defined as the standard error of ln K.
Peak lag is defined as years until the maximum impact of research funds are reached.
Rank refers to ranking of the model according to goodness of fit, measured by SSE and adjusted R^2.
Shaded values represent results with a negative capital stock coefficient.

Figure 5-1: Gamma Lag Distribution

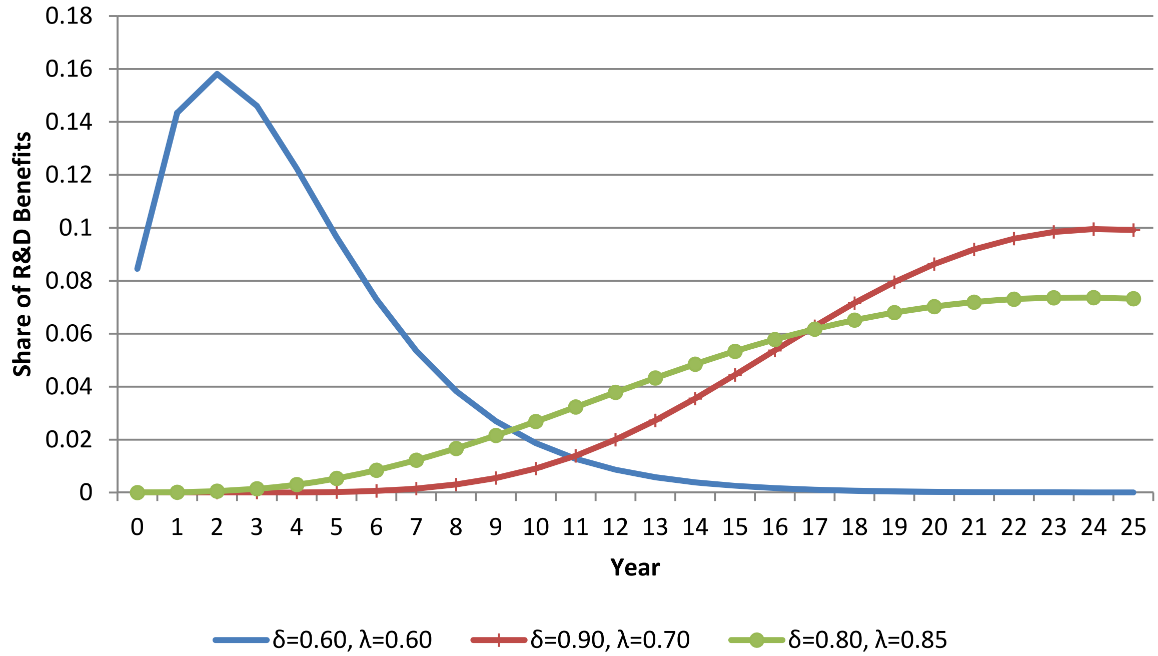


Table 5-3: *Summary of Results for the Base Model, Four Top-Ranked Models*

Model Details	**Model Results**			
Model Rank by SSE	1	2	3	4
Adjusted R^2	0.908	0.908	0.905	0.903
Lag Distribution Characteristics				
λ	0.70	0.80	0.90	0.65
δ	0.90	0.85	0.80	0.90
Peak Lag Year	24	24	37	20
Elasticities With Respect to				
Public Knowledge Stock (*K*)	0.565**	0.724**	0.740**	0.571**
	(0.152)	(0.195)	(0.207)	(0.163)
Private Knowledge Stock (*PR)*	0.155**	0.010*	0.145**	0.066
	(0.045)	(0.042)	(0.044)	(0.044)
Weather Index (*C*)	-0.002	-0.004	-0.002	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)
Trend (*T*)	0.017**	0.018**	0.017**	0.019**
	(0.002)	(0.002)	(0.002)	(0.002)

Notes:
Standard errors in parentheses.
** Significant at 1%, * significant at 5%, and + significant at 10%.
SSE is defined as the Sum of Squared Errors. Models are arranged by SSE and Adjusted R^2.
Peak lag is the number of years until the current investment has the maximum impact on the knowledge stock.
All explanatory variables enter in natural logarithms.

Table 5-4: *Statistical Tests Applied to Preferred Models*

λ=0.70, δ=0.90					
Augmented Dickey-Fuller Test[1]	MFP	K	PR		
Test Statistic	-0.87	-2.48	-0.75		
MacKinnon approximate p-value	0.80	0.12	0.83		
Johansen Test for Integration[2]					5% Critical
Max Rank	Parms	LL	Eigen Value	Trace Stat	Value
0	20	72.73	.	44.75*	47.21
1	27	82.69	0.58	24.83	29.68
2	32	88.69	0.41	12.84	15.41
3	35	93.49	0.34	3.24	3.76
4	36	95.11	0.13		
Durbin Watson Statistic[3]	2.07				
White's Test Statistic (p-value in parenthesis)[4]	10.27	(0.74)			
λ=0.80, δ=0.85					
Augmented Dickey-Fuller Test[1]	MFP	K	PR		
Test Statistic	-0.87	-2.01	-0.75		
MacKinnon approximate p-value	0.80	0.28	0.83		
Johansen Test for Integration[2]					5% Critical
Max Rank	Parms	LL	Eigen Value	Trace Stat	Value
0	20	76.02	.	46.54*	47.21
1	27	87.22	0.62	24.13	29.68
2	32	93.60	0.43	11.38	15.41
3	35	97.93	0.31	2.71	3.76
4	36	99.29	0.11		
Durbin Watson Statistic[3]	2.00				
White's Test Statistic (p-value in parenthesis)[4]	12.67	(0.55)			
λ=0.90, δ=0.80					
Augmented Dickey-Fuller Test[1]	MFP	K	PR		
Test Statistic	-0.87	-1.93	-0.75		
MacKinnon approximate p-value	0.80	0.32	0.83		
Johansen Test for Integration[2]					5% Critical
Max Rank	Parms	LL	Eigen Value	Trace Stat	Value
0	20	72.93	.	42.37*	47.21
1	27	82.72	0.57	22.81	29.68
2	32	88.65	0.40	10.93	15.41
3	35	92.41	0.28	3.42	3.76
4	36	94.12	0.14		
Durbin Watson Statistic[3]	2.05				
White's Test Statistic (p-value in parenthesis)[4]	11.05	(0.68)			
λ=0.65, δ=0.90					
Augmented Dickey-Fuller Test[1]	MFP	K	PR		
Test Statistic	-0.87	-2.75	-0.75		
MacKinnon approximate p-value	0.80	0.07	0.83		
Johansen Test for Integration[2]					5% Critical
Max Rank	Parms	LL	Eigen Value	Trace Stat	Value
0	20	80.01	.	51.52	47.21
1	27	92.07	0.65	27.40*	29.68
2	32	99.49	0.48	12.55	15.41
3	35	104.65	0.36	2.24	3.76
4	36	105.77	0.09		
Durbin Watson Statistic[3]	1.83				
White's Test Statistic (p-value in parenthesis)[4]	16.03	(0.31)			

Notes:

[1]Augmented Dickey-Fuller Null Hypothesis: H_o = Unit Roots

[2]Johansen's Integration Null Hypothesis: H_o = No Cointegration

[3]Durbin-Watson Critical Values {1.04, 1.77}

[4]White's Heteroskedasticity Test Null Hypothesis: H_o = Homoskedasticity,

Table 5-5. *Summary of Results for Alternatives to the Baseline Model*

Model Details	Model Results			
Model Rank by SSE	1	2	3	4
Adjusted R^2	0.908	0.896	0.457	0.631
Lag Distribution Characteristics				
λ	0.70	0.85	0.60	0.60
δ	0.90	0.80	0.60	0.60
Peak Lag Year	24	24	2	2
Elasticities With Respect to				
Public Knowledge Stock (*K*)	0.565**	0.910**	0.259**	0.323**
	(0.152)	(0.242)	(0.066)	(0.070)
Private Knowledge Stock (*PR)*	0.155**		0.120+	
	(0.045)		(0.066)	
Weather Index (*C*)	-0.002	-0.008	-0.003	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)
Trend (*T*)	0.017**	0.020**		
	(0.002)	(0.001)		
Durbin-Watson Statistic (Original)	2.07	1.72	1.04	0.75
Durbin-Watson Statistic (Transformed)			2.06	1.86

Notes:
Standard errors in parentheses.
** Significant at 1%, * significant at 5%, and + significant at 10%.
SSE is defined as the Sum of Squared Errors. Models are arranged by SSE and Adjusted R^2.
Peak lag is the number of years until the current investment has the maximum impact on the knowledge stock.
All explanatory variables enter in natural logarithms.
Models 3 and 4 were corrected for autocorrelation using the Cochrane-Orcutt procedure.

Table 6-1: *Benefit-Cost Ratios and Internal Rates of Return*

	Model			
	1	2	3	4
Model Characteristics				
Peak Lag Year	24	24	2	2
Elasticity with respect to K	0.565	0.910	0.259	0.323
Discount rate	Benefit-Cost Ratio			
3% p.a.	71.0	130.6	50.4	62.8
5% p.a.	48.2	90.9	46.4	57.9
10% p.a.	19.3	39.3	38.5	48.0
Reinvestment rate	Modified Internal Rate of Return			
3% p.a.	23.2	26.3	21.4	22.6
5% p.a.	23.7	27.0	23.5	24.6
10% p.a.				
	Conventional Internal Rate of Return			
	29.7	46.0	620	760

Notes: For each model the analysis is based on an extra 1 million pesos of R&D expenditures in 1985.

Figure 7-1: *Agricultural output value attributable to productivity growth, 1980-2010*

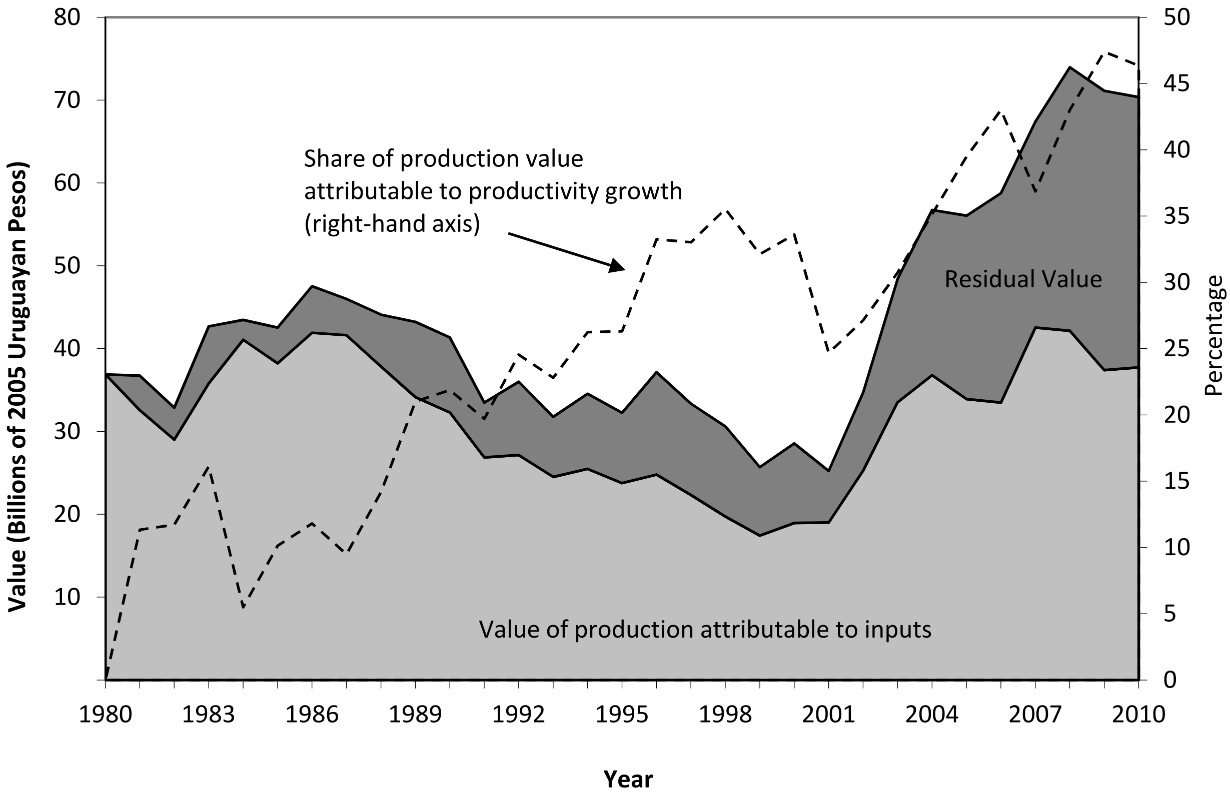


Table 7-1: *Benefit-Cost Ratios – Approximations versus Econometric Estimates*

Period of Costs	Discount Rate	Share of Benefits over 1980–2010 Attributed to Public Agricultural R&D 100%	75%	50%	25%
	% per Year	*Approximate Benefit-Cost Ratio*			
	3	24	18	12	6
Costs over 1961–2001	5	16	12	8	4
	10	6	4	3	1
	3	31	23	15	8
Costs over 1961–1991	5	19	14	9	5
	10	6	5	3	2
	3	33	25	16	8
Costs over 1965–1995	5	22	17	11	6
	10	9	7	4	2
	3	52	39	26	13
Costs over 1971–1991	5	36	27	18	9
	10	16	12	8	4
	3	55	42	28	14
Costs over 1975–1995	5	42	32	21	11
	10	23	17	11	6

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Appendices

Appendix A. Data and Measures of Outputs, Inputs, and Multifactor Productivity

The Fisher indexes of inputs and outputs used in this study were based on data for 39 categories of outputs and 24 categories of inputs used in production, as listed in table A-1. By and large, unless stated otherwise, prices are given in current (i.e., nominal) U.S. dollars and quantities are in metric tons.

A-1.   Output Data

Crops:

Prices and quantities are from the Statistics Division of the Ministry of Agriculture (MGAP/DIEA),[5] except for the case of rice, where data were taken from the Rice Growers Association (ACA).[6] Data on quantities of vegetables and fruits produced are not available for all years. For vegetables we used Census data and linear interpolation to fill in missing observations.[7] For deciduous fruits, potatoes, and strawberries we combined Census data with FAO data. The price of wine grapes is an estimate based on the winegrape prices published by the National Wine Institute (INAVI) [8] and the wine index published by the National Institute of Statistics (INE).[9] Other prices for fruits and vegetables were taken from two sources: MGAP/DIEA and the Montevideo Fresh Produce Central Market ("Mercado Modelo").[10]

Beef and sheep meat:

Quantities are estimated as the number of animals slaughtered in inspected facilities, as reported by the National Institute of Meats (INAC),[11] times average weight. This excludes on-farm consumption and local (small) slaughterhouses. The annual price is a weighted average based on monthly numbers of animals slaughtered and average weight by category (steers, cows, etc). Prices for 1980 and 1981 were missing. We estimated them using as reference the price of steers in 1981 (0.63 U$S/kg) and knowing from other sources that the 1980 price was 28% higher than the 1981 price. For those years prices of cows, calves, and bulls were estimated using a constant ratio to the price of steers. Prices of sheep, ewes, and lambs are fixed per head from 1980 to 1994, and afterwards we used data from INAC.

Pigs and poultry:

The pig meat price is a simple average of the prices of fat pigs and piglets, also from INAC. Eggs are given in units of 30-dozen boxes.

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[5] http://www.mgap.gub.uy/portal/hgxpp001.aspx?7,5,27,O,S,0,MNU;E;2;16;10;6;MNU;,
[6] http://www.aca.com.uy/
[7] 1970, 1980, 1990, and 2000 Agricultural Census. The 2010 Census was not available because it was postponed until the spring of 2011.
[8] http://www.inavi.com.uy/sitio/home/home/index.php?t=index&secc=1
[9] http://www.ine.gub.uy/preciosysalarios/ipc2008.asp?Indicador=ipc
[10] http://www.mercadomodelo.net/index.php
[11] http://www.inac.gub.uy/

Wood:

Data for years before 2002 are scarce and there are not any official records. The MGAP did not collect data because the industry was marginal, and all wood was used as fuel. In the mid-1990s, after major changes in policy, the industry began to develop and the area planted with trees (mostly Eucalyptus) increased rapidly. The Timber Producers Association does not have records on production or prices before 2000. Quantities finally used correspond only to bulk wood processed for paper and pulp, and for construction, in thousands of cubic meters. Wood used as fuel was not included. Prices are derived from export values from 1988 to 1994 (UN-Comtrade database) [12] and from tax records from 1995 on.

A-2. Input Data

Energy (diesel-oil)

There is no official record of diesel-oil consumption by the agricultural sector. For this study, we estimated the quantities consumed using standard information on costs of production of the main farm activities. All diesel-oil is sold by a single State Company (ANCAP), which means the price is uniform, officially set for the whole country.

Fertilizers.

Volumes of all types of imported fertilizers and raw materials used for domestic production were taken from the Natural Resources (Soils and Water) Division of the Ministry of Agriculture (MGAP/RENARE)[13]. For the years before 1984, the data come from the Honorary Commission of the Agricultural Development Plan (MGAP). The price is a weighted average of the CIF price for all types of fertilizers and raw materials, except for the period 1984–88, where the CIF price was not available, and an adjusted domestic market price was used instead, according to MGAP/DIEA published prices.

Herbicides, fungicides, insecticides:

The volume of all types of herbicides, fungicides and insecticides is expressed in tons of active ingredient. We used CIF prices. The source is the Division of Agricultural Services of the Ministry (MGAP/DGSA)[14] for the period following 1987 and the INIA/BID (1991) project for the previous years.

Seeds:

[12] http://comtrade.un.org/db/
[13] http://www.cebra.com.uy/renare/
[14] http://www.mgap.gub.uy/DGSSAA/index.htm

Official records of seeds used, kept by the National Seeds Institute (INASE)[15] are reliable only for the very recent past. For most years we had to estimate the use of seeds based on the area planted of each of the main crops and a standard sowing density (rate kg/ha). We computed the quantities and price of seeds of the main crops cereals and oilseeds. Data are very limited with respect to forages and vegetables.

Irrigation water:

According to the Agricultural Census rice cultivation accounts for 72–80% of the total irrigated area of the country. The rest of the irrigated crop area corresponds to a number of different crops in small areas (fruits, vegetables), but there is no available record on the specific volumes used. The volume of water used for rice cultivation most likely accounts for more than 90% of the total. On this basis we estimated the use of irrigation water in rice production and applied the price paid by rice growers. It has been a standard arrangement, between rice producers and landowners (who own water rights) that the price of irrigation water is equivalent to 1 ton of rice, per hectare (20 sacks of 50 kg each), and we assume one meter of water is applied.

Labor:

The numbers of farmers and rural workers are taken from the National Census of Population and Housing, with linear interpolation in between Censuses (the last Census was in 1996). Since 1999, the numbers of farmers and rural workers are taken from the Social Security Administration, that publishes annual data on workers per sector of the economy. These two sources organize the data in different ways. So it is necessary to adjust the criteria for estimating the annual cost of labor. The basis for the estimates is the official minimum wage, published by the MGAP/DIEA. Up to 1999 the cost of labor was defined as follows: a farmer's labor is equivalent to five times the minimum wage of a foreman; a contractors is equivalent to a foreman's minimum wage; unpaid family labor is equivalent to a specialized field worker; and paid workers are paid the equivalent of the minimum wage of a field worker. From 1999 on, because the data-base changed, the procedure to estimate the annual cost of labor also changed. The Social Security database gives only two types of labor: farmers (operators) and paid workers. We applied two times the wage rate of a foreman to all farmers, and the wage rate of a field worker to all the paid workers. In all cases the monthly wage was multiplied by 14 in order to get the annual cost of labor, so as to reflect current labor laws that apply to all labor force in the country. The annual cost of labor, which is given in local currency, was divided by the annual average exchange rate to get the equivalent in US dollars.

Machinery:

We took into account only the numbers of tractors, seeder/fertilizers, combine harvesters, and balers. Data on quantities in stock were taken from the Agricultural Census and prices from MGAP/DIEA with some adjustments. For the MFP calculations we estimated the annual cost of the

[15] http://www.inase.org.uy/

service, based on the average age of the machinery in stock, a depreciation factor, and an interest factor.

We began by taking the number of units in stock according to the 1970, 1980, 1990 and 2000 Agricultural Censuses. Linear interpolations were applied for the periods in between. Data on sales of new machinery were obtained from the Agricultural Machinery Chamber and also from Customs and the UN-Comtrade database.

The stock at time t equals the stock at t-1 plus the value of new machinery purchased (I) minus the value of machinery that is discarded (D):

$$S_t = S_{t-1} + I - D$$

Then we can estimate the number of tractors or other units that must be discarded every year, such that the estimate of the stock is equal to that observed in each Census. As it turned out, the rate at which machinery is disposed is lower than we initially expected. For instance, it is customary to take the life span of a tractor to be around 15 years. That would imply a replacement rate of about 7% to keep the stock constant. Census data suggest that the replacement rate is closer to 2% per year in the long run. That means that the stock of machinery includes an important number of relatively old units and that the average age of the machinery is relatively high. It is also a fact that about 25% of the imported tractors and harvesters are bought used, mostly from Argentina and the United States (although for estimation purposes they were treated as new). The number of tractors was furthermore adjusted according to size, in terms of horse-power. In 1980 average power was 51HP, and for 2010 it was estimated as 75HP.

In some particular years we do not observe prices for some types of machinery. In those cases we applied fixed price ratios with respect to the price of tractors.

The depreciated value of a piece of equipment in time t is equal to

$$V_t = V_n\,(1 - d)^t$$

where V_n is the purchase price fore a new item and d is the annual depreciation rate (2%). Additionally, we consider a 2% rate of maintenance and repairs and a 4% annual interest rate charged over the depreciated value V_t.

Land:

Five different types of land were identified: non-irrigated cropland; irrigated rice land; the dairy basin; livestock grasslands; and forests. The average rental price of land is a weighted average of the annual rent paid to landlords for each type of land. Between 1980 and 1999 data on rental contracts are not available. We estimated the rental rate using the ratio of paid rent to the sales value of the land observed in 2000 and applied this ratio, which varies from 6.0% to 6.6% depending on the type of land, to the entire period 1980–99. The value of land is given for each “departmento” by the

MGAP/DIEA.[16] Three groups of "departamentos" were put together to account for three different types of land (rain fed cropland, extensive cattle grasslands, and the dairy basin). For forest land, we applied the same rent as for grasslands until 2000, and twice the average rent paid in the "departamento" Rivera after that. In the case of rice, irrigated land, we took what is standard in rice rental contracts, which is equal to the value of half a ton of rice (10 sacks of 50kg per hectare).

A-3. Outputs, Inputs, and Productivity

Table A-2 shows the annual values of the indexes of quantities and prices of outputs by major category and in aggregate, the value shares, and the growth rates for sub-periods as well as the total period, 1980– 2010. Table A-3 shows the corresponding indexes and cost shares for the three major categories of inputs. Table A-4 includes the quantity indexes for inputs and outputs and the implied indexes of multifactor productivity. Growth rates were computed as the average of year-to year proportionate changes (or logarithmic differences).

[16] The "departamento" of Montevideo is normally excluded from the statistics. Only some vineyards, fruit orchards and small vegetables plots are to be found in the metropoliotan area.

Appendix Table A-1: *Categories of Outputs and Inputs*

Category (# of elements)	Elements
Crops (26)	• Winter crops: wheat, barley, oats • Summer crops: rice, corn, sorghum, soybeans, sunflower • Sugar cane • Vegetables: potatoes, sweet potatoes, onions, carrots, peppers, tomatoes, strawberries • Deciduous fruits: wine-grapes, apples, peaches, plums, pears • Citrus: oranges, mandarins, grapefruit, lemons • Forestry: wood (bulk)
Animal products (13)	• Beef: slaughter of steers, cows, bulls and calves • Sheep meat: slaughter of ewes, sheep, lambs, and hoggets • Dairy • Wool • Pig meat • Poultry • Eggs
Other inputs (9)	• Energy (diesel-oil) • Seeds • Fertilizers • Herbicides, fungicides, insecticides • Irrigation water • Dairy feedstuffs • Poultry feedstuffs
Labor (4)	• Farmer • Family labor (unpaid) • Paid labor • Contractors
Capital (11)	• Land (5 types) • Machinery: tractors, seeders, combine-harvesters, balers • Cattle: cows and bulls

Appendix Table A-2: *Output Prices, Quantities and Value Shares, 1980–2010*

	Price Index			Quantity Index			Output Value Shares	
Year	Crops	Livestock	Total	Crops	Livestock	Total	Crops	Livestock
1980	100.0	100.0	100.0	100.0	100.0	100.0	35.2	64.8
1981	100.8	90.6	94.2	115.6	111.9	113.3	38.4	61.6
1982	91.1	71.9	78.6	105.3	116.0	111.8	38.4	61.6
1983	64.1	58.9	60.8	110.6	119.8	116.2	35.3	64.7
1984	65.9	65.9	66.0	120.4	96.6	104.9	40.3	59.7
1985	59.8	58.4	59.0	115.4	107.9	110.4	37.3	62.7
1986	75.4	73.7	74.4	106.2	114.9	111.6	33.9	66.1
1987	77.4	89.2	85.1	122.9	103.5	109.6	35.9	64.1
1988	73.2	90.5	84.2	136.4	107.6	116.7	35.7	64.3
1989	75.9	78.6	77.9	130.3	123.8	125.7	35.6	64.4
1990	88.2	75.8	80.7	137.8	122.1	127.4	41.6	58.4
1991	74.3	80.7	78.1	143.4	113.6	124.1	38.7	61.3
1992	77.9	85.7	82.5	159.5	121.0	134.4	39.4	60.6
1993	84.3	84.1	84.3	154.6	119.7	131.9	41.3	58.7
1994	87.5	96.5	92.9	165.5	128.3	141.2	38.8	61.2
1995	85.9	103.3	96.1	180.2	123.7	142.8	39.7	60.3
1996	94.9	100.3	98.4	203.3	140.4	161.8	42.7	57.3
1997	92.2	102.1	98.3	187.0	148.6	161.7	38.2	61.8
1998	72.1	97.4	86.9	218.5	146.3	170.1	37.5	62.5
1999	65.0	82.4	75.2	189.6	144.7	160.3	36.0	64.0
2000	73.6	87.5	81.8	182.2	145.1	158.3	36.4	63.6
2001	66.8	81.7	75.6	177.3	126.0	143.5	38.4	61.6
2002	65.8	68.7	67.7	183.2	133.5	150.6	41.7	58.3
2003	64.1	83.5	74.9	239.9	130.6	166.7	43.4	56.6
2004	67.3	98.8	84.4	258.4	151.5	187.6	38.7	61.3
2005	76.2	103.0	90.8	266.3	169.4	203.3	38.7	61.3
2006	81.0	110.0	96.8	285.3	182.6	218.6	38.4	61.6
2007	125.3	134.7	131.2	298.3	161.5	207.8	48.3	51.7
2008	145.5	163.6	155.8	345.5	172.3	230.8	49.2	50.8
2009	133.1	129.4	133.2	416.1	171.5	254.3	57.5	42.5
2010	146.3	180.1	162.9	395.9	165.7	243.8	51.3	48.7
Average annual growth rates (percentage)								
1980-1990	-1.2	-2.7	-2.1	3.3	2.0	2.4	1.7	-1.0
1990-2000	-1.8	1.4	0.1	2.8	1.7	2.2	-1.3	0.9
2000-2010	7.1	7.5	7.1	8.1	1.3	4.4	3.5	-2.6
1980-2010	**1.3**	**2.0**	**1.6**	**4.7**	**1.7**	**3.0**	**1.3**	**-0.9**

Notes: A list of outputs included in each category is provided in Appendix Table A-1. Prices are current U.S. dollars.

Appendix Table A-3: *Input Prices, Quantities, and Value Shares, 1980–2010*

Year	Price Index				Quantity Index				Input Cost Shares		
	Labor	Capital	Other	Total	Labor	Capital	Other	Total	Labor	Capital	Other
1980	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	27.9	56.3	15.8
1981	84.0	76.1	103.8	82.7	100.0	100.5	101.0	100.4	28.2	51.9	20.0
1982	71.9	50.0	95.9	63.4	100.0	98.9	96.5	98.7	32.1	44.5	23.4
1983	35.0	43.6	76.3	46.2	99.9	96.1	97.1	97.5	21.7	52.4	26.0
1984	35.6	41.7	82.1	46.3	99.9	96.3	102.8	99.1	21.6	49.3	29.1
1985	39.0	39.5	85.8	46.7	99.9	96.9	102.2	99.2	23.5	46.6	29.9
1986	49.9	42.7	80.8	50.7	98.7	96.4	101.1	98.4	27.5	46.6	25.9
1987	52.5	56.8	84.9	59.8	97.5	97.2	104.2	99.2	24.0	52.4	23.6
1988	52.0	57.5	81.8	59.5	96.2	97.1	110.2	100.2	23.4	52.7	23.9
1989	55.4	61.2	84.3	62.9	95.0	95.5	111.2	99.3	23.5	52.8	23.7
1990	62.6	71.7	92.4	71.9	93.8	96.4	111.4	99.5	22.9	54.4	22.7
1991	81.0	74.8	92.2	78.4	92.6	97.5	110.7	99.7	26.8	52.6	20.7
1992	81.5	76.1	91.9	79.2	91.4	98.6	118.9	101.4	25.9	52.6	21.5
1993	91.9	69.5	87.9	77.4	90.2	99.0	122.0	101.8	29.3	49.2	21.5
1994	91.5	75.8	93.2	81.8	89.0	101.2	131.1	104.2	26.6	50.7	22.7
1995	95.6	79.4	102.3	86.6	87.8	101.9	137.2	105.3	25.7	50.0	24.4
1996	92.8	81.7	112.8	89.4	86.6	101.9	153.1	108.0	23.2	48.5	28.3
1997	83.8	99.5	108.9	95.9	88.0	100.1	158.1	108.3	19.8	54.0	26.2
1998	82.6	105.5	94.1	95.3	89.4	100.6	162.3	109.6	19.7	57.2	23.1
1999	100.7	98.6	84.2	93.5	88.2	100.4	159.4	108.8	24.3	54.8	20.9
2000	96.5	73.9	89.3	80.7	84.8	100.2	143.5	105.1	26.9	49.2	23.9
2001	89.9	78.7	88.5	81.6	86.1	101.2	155.3	108.1	24.5	50.9	24.7
2002	55.1	77.0	83.9	71.6	95.0	102.1	148.4	109.7	18.6	56.3	25.1
2003	45.0	76.0	88.9	69.8	99.1	103.1	170.7	115.4	15.4	54.8	29.8
2004	53.5	89.8	104.1	82.3	100.8	105.6	192.8	121.7	15.0	53.3	31.7
2005	83.5	94.0	117.8	94.8	104.9	105.1	196.3	123.0	20.9	47.7	31.3
2006	134.2	130.3	132.2	128.1	112.0	104.3	197.1	124.6	26.2	48.0	25.8
2007	152.2	137.0	167.1	144.8	112.7	106.8	226.3	131.2	25.2	43.4	31.5
2008	189.9	223.7	251.8	216.6	115.2	108.4	219.6	131.5	21.4	47.9	30.7
2009	206.4	207.8	174.2	192.4	113.0	110.1	231.1	133.8	25.2	50.0	24.7
2010	251.0	251.1	197.6	229.5	113.4	107.2	221.5	130.8	26.4	50.5	23.1
Average annual growth rates (percentage)											
1980-1990	-4.6	-3.3	-0.8	-3.2	-0.6	-0.4	1.1	-0.1	-2.0	-0.3	3.7
1990-2000	4.4	0.3	-0.3	1.2	-1.0	0.4	2.6	0.5	1.6	-1.0	0.5
2000-2010	10.0	13.0	8.3	11.0	3.0	0.7	4.4	2.2	-0.2	0.3	-0.4
1980-2010	**3.1**	**3.1**	**2.3**	**2.8**	**0.4**	**0.2**	**2.7**	**0.9**	**-0.2**	**-0.4**	**1.3**

Notes: A list of inputs included in each category is provided in Appendix Table A-1. Prices are current U.S. dollars.

Appendix B. Data and Measures of Research Investments

Data on research investments were compiled from various sources. Appendix Table B-1 includes the data on spending, by major spending agency and in total, all expressed in nominal U.S. dollars and constant pesos. Detailed sources are noted at the bottom of the table.

Appendix Table B-1: *Spending on Research and Extension by Spending Agency, 1960–2010*

			Colleges Agric + VetMed							
Year	CIAAB / INIA	Plan Agro-pecuario	Total Exp.	Research share %	Research Exp.	Total Research Exp.	CIAAB / INIA	Plan Agro-pecuario	Colleges Agric + VetMed Research Expend	Total Research Exp.
	2005 pesos, million						*Current dollars, thousand*			
1961	91.3	24.5	314.7	5.0	15.7	131.5	729.9	195.8	125.8	1,051.5
1962	133.2	38.6	331.6	5.0	16.6	188.4	1,189.2	344.5	148.0	1,681.8
1963	136.2	56.1	306.3	5.0	15.3	207.6	1,097.2	451.6	123.4	1,672.2
1964	91.3	60.8	300.6	7.5	22.5	174.7	918.1	611.8	226.6	1,756.5
1965	78.7	69.2	485.1	7.5	36.4	184.3	726.5	639.0	335.8	1,701.3
1966	56.5	79.8	396.3	7.5	29.7	166.1	484.6	684.2	254.8	1,423.6
1967	67.5	88.6	533.2	7.5	40.0	196.0	530.2	696.2	314.3	1,540.7
1968	62.0	88.3	227.7	7.5	17.1	167.4	476.2	677.8	131.1	1,285.1
1969	68.8	81.6	197.9	7.5	14.8	165.3	629.6	747.2	135.9	1,512.7
1970	78.0	83.6	169.5	7.5	12.7	174.4	742.3	796.0	121.0	1,659.3
1971	93.9	80.4	199.4	7.5	15.0	189.3	1,168.6	1,000.0	186.0	2,354.6
1972	65.2	137.0	162.1	7.5	12.2	214.3	634.7	1,334.0	118.4	2,087.1
1973	122.9	75.9	69.2	7.5	5.2	203.9	2,160.9	1,334.0	91.3	3,586.2
1974	137.2	81.1	95.6	5.0	4.8	223.0	2,251.6	1,331.2	78.5	3,661.2
1975	154.9	97.0	97.1	5.0	4.9	256.8	2,231.4	1,398.0	69.9	3,699.3
1976	150.9	115.7	111.8	5.0	5.6	272.2	2,164.5	1,660.0	80.2	3,904.7
1977	127.9	80.5	115.9	5.0	5.8	214.2	2,033.5	1,280.0	92.1	3,405.6
1978	141.9	71.1	116.6	5.0	5.8	218.8	2,554.3	1,280.0	104.9	3,939.2
1979	108.5	57.1	120.4	5.0	6.0	171.6	2,708.6	1,424.5	150.3	4,283.4
1980	138.6	66.2	119.6	5.0	6.0	210.8	4,662.0	2,226.9	201.1	7,090.0
1981	156.5	40.2	137.9	5.0	6.9	203.6	5,638.3	1,448.0	248.3	7,334.7
1982	143.5	43.9	128.8	5.0	6.4	193.7	4,737.1	1,448.0	212.7	6,397.8
1983	105.7	70.5	105.6	5.0	5.3	181.4	2,170.0	1,448.0	108.4	3,726.4
1984	75.1	40.8	100.4	5.0	5.0	120.9	1,482.8	805.0	99.1	2,386.9
1985	78.5	31.2	118.8	7.5	8.9	118.6	1,489.7	593.1	169.1	2,252.0
1986	117.4	52.4	172.8	7.5	13.0	182.8	2,546.0	1,135.8	280.9	3,962.7

1987	42.1	50.9	171.1	7.5	12.8	105.8	1,057.9	1,280.5	322.8	2,661.2
1988	53.1	45.8	152.7	7.5	11.5	110.4	1,468.0	1,264.7	316.5	3,049.2
1989	106.7	44.1	156.6	7.5	11.7	162.6	2,997.1	1,237.5	329.7	4,564.3
1990	155.1	12.6	155.1	12.0	18.6	186.3	4,785.6	388.3	574.1	5,748.0
1991	158.4	17.3	170.5	12.0	20.5	196.1	5,686.8	619.5	734.5	7,040.9
1992	216.4	19.2	178.3	12.0	21.4	257.1	8,273.9	735.8	818.0	9,827.8
1993	219.5	20.4	159.1	12.0	19.1	259.1	9,523.4	887.0	828.2	11,238.6
1994	248.7	22.4	192.8	20.0	38.6	309.6	11,712.3	1,053.4	1,816.7	14,582.3
1995	245.8	22.8	159.7	20.0	31.9	300.6	12,976.2	1,203.9	1,686.3	15,866.4
1996	260.6	25.6	180.6	20.0	36.1	322.4	13,852.9	1,362.2	1,920.0	17,135.1
1997	242.7	24.2	161.8	20.0	32.4	299.3	14,348.4	1,429.4	1,912.7	17,690.5
1998	270.1	24.6	165.6	20.0	33.1	327.8	16,174.1	1,475.7	1,982.9	19,632.7
1999	263.0	25.2	220.3	20.0	44.1	332.3	15,318.1	1,469.7	2,566.3	19,354.1
2000	263.9	25.4	216.6	25.0	54.1	343.4	14,836.4	1,430.8	3,044.3	19,311.6
2001	241.8	26.0	245.4	25.0	61.3	329.2	12,884.6	1,388.0	3,269.4	17,542.0
2002	251.3	24.9	221.9	25.0	55.5	331.6	9,149.4	905.8	2,020.1	12,075.2
2003	278.9	27.1	233.0	25.0	58.2	364.3	8,918.4	868.1	1,862.6	11,649.1
2004	284.1	27.3	232.0	25.0	58.0	369.3	9,829.5	943.0	2,006.7	12,779.2
2005	323.0	28.6	250.3	25.0	62.6	414.2	13,195.0	1,168.6	2,556.5	16,920.1
2006	354.4	18.2	279.2	25.0	69.8	442.4	15,829.2	810.8	3,117.3	19,757.3
2007	393.7	17.7	295.4	25.0	73.9	485.2	19,750.5	888.2	3,705.2	24,343.8
2008	417.3	19.0	376.8	25.0	94.2	530.5	25,173.8	1,148.1	5,682.4	32,004.3
2009	432.9	19.7	430.8	25.0	107.7	560.3	25,576.6	1,163.9	6,362.8	33,103.3
2010	424.9	19.8	422.3	25.0	105.6	550.3	29,747.1	1,388.7	7,392.5	38,528.3
Average annual percentage growth rates										
1961-1971	0.30	12.60	-4.50		-0.50	3.70	4.80	17.70	4.00	8.40
1970-1980	5.90	-2.30	-3.40		-7.30	1.90	20.20	10.80	5.20	15.60
1980-1990	1.10	-15.30	2.60		12.00	-1.20	0.30	-16.00	11.10	-2.10
1990-2000	5.50	7.30	3.40		11.30	6.30	12.00	13.90	18.20	12.90
2000-2010	4.90	-2.50	6.90		6.90	4.80	7.20	-0.30	9.30	7.20

Notes: The CIAAB was transformed into INIA in 1989. University (Universidad de la República) comprises only the Faculties (Colleges) of Agriculture and Veterinary Medicine, within which research expenditures were estimated as a share of the total. Plan Agropecuario is mostly dedicated to technology transfer. Local currency GDP deflator was used to obtain constant pesos. GDP deflator is from World Bank dataset (http://data.worldbank.org/country/Uruguay).

Sources: authors compilation based on several sources: Uruguay's Government General Accounting Office (http://www.cgn.gub.uy/); Uruguay's Parliament Registry of Laws (http://www0.parlamento.gub.uy/palacio3/index1280.asp?e=0&w=1366); Astori et al. (1979); MGAP/OPYPA; MGAP/DIEA; INIA (http://www.inia.org.uy/online/site/); University of the Republic, Division of Planning; World Bank reports; IDB reports; Jarvis and Seré (1991); Beintema et al. (2000).

Appendix Table B-2: *Number of Private Cultivars Included in the National Registry*

Year	Number of Cultivars
1980	105
1981	110
1982	115
1983	120
1984	120
1985	135
1986	129
1987	150
1988	159
1989	195
1990	217
1991	198
1992	123
1993	144
1994	152
1995	134
1996	157
1997	163
1998	191
1999	185
2000	181
2001	159
2002	143
2003	179
2004	216
2005	243
2006	290
2007	331
2008	359
2009	361
2010	363

Source: INASE. Species included are wheat, barley, oats, forage sorghum, corn, sunflower, and soybeans

Appendix C. Regression Results

Table C-1 presents the results from twelve regression models. The table is divided into three blocks of four models. Each block of four was estimated with a different assumption about the percentage of spending by the Colleges of Agriculture and Veterinary Medicine to treat as agricultural research spending: model K1 includes 100% of expenditures; model K2 is the baseline model, where research expenditures by the Colleges are estimated as percentages of annual expenditure that vary between 5% and 25% over the data; model K3 excludes expenditures by the two Colleges altogether. Within each block, models vary in terms of whether they include the variable to represent the private knowledge stock (*PR*) and the time trend (*T*).

In each case in Table C-1, the reported model is the best fitting among the 49 alternative gamma lag distributions (defined by combinations of the δ and λ parameters) given the other details of the specification. Tables C-2 through C-13 show the R^2, the estimated coefficient for the public knowledge stock variable and its standard error, and the peak lag for each of the 49 combinations of δ and λ. Each of these 12 tables corresponds to the specification in one of the columns of Table C-1.

Appendix Table C-1: *Regressions of Multi-Factor Productivity; Best Fitting Models, Corrected for Autocorrelation, 1986-2010*

	K1				K2				K3			
δ	0.8	0.75	0.9	0.6	0.9	0.8	0.6	0.6	0.85	0.85	0.6	0.6
λ	0.6	0.6	0.9	0.6	0.7	0.85	0.6	0.6	0.8	0.75	0.6	0.6
Peak Lag	8	5	84	2	24	24	2	2	24	19	2	2
Model	1	2	3	4	5	6	7	8	9	10	11	12
Regressor												
Constant	6.043**	7.012*	6.573**	2.293**	1.012	0.028	2.941**	3.255**	0.887	1.162	2.824**	3.150**
	(0.713)	(2.783)	(0.513)	(0.458)	(0.903)	(1.271)	(0.327)	(0.390)	(0.897)	(0.976)	(0.342)	(0.428)
T	0.022**	0.033+			0.017**	0.020**			0.0152**	0.020**		
	(0.003)	(0.018)			(0.002)	(0.001)			(0.002)	(0.001)		
ln *PR*	0.177**		0.197**		0.155**		0.120+		0.154**		0.125+	
	(0.055)		(0.037)		(0.045)		(0.066)		(0.044)		(0.065)	
ln *W*	0.003	-0.006	-0.001	-0.006	-0.002	-0.008	-0.003	-0.006	-0.002	-0.008	-0.002	-0.006
	(0.008)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
ln *K*	-0.390*	-0.404	-0.451**	0.457**	0.565**	0.910**	0.259**	0.323**	0.599**	0.702**	0.281**	0.350**
	(0.147)	(0.507)	(0.061)	(0.077)	(0.152)	(0.242)	(0.066)	(0.070)	(0.154)	(0.188)	(0.072)	(0.079)
Adjusted R^2	0.89	0.60	0.89	0.60	0.91	0.90	0.46	0.63	0.91	0.90	0.63	0.44
D-W (Original)	1.72	1.04	1.85	0.95	2.07	1.72	1.04	0.75	2.15	1.65	1.03	0.72
D-W(Transformed.)	-	1.81	-	1.85	-	-	2.06	1.86	-	-	2.08	1.86

Notes: Model K1 includes 100% of the expenditures by the Colleges of Agriculture and Veterinary Medicine; K2 is the baseline model; K3 does not include the University's expenditures

Standard errors in parentheses.

** Significant at 1%, * significant at 5%, and + significant at 10%

25 Observations

Appendix Table C-2: *Model K1 Regression Results without "Trend," without "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.824	0.804	0.772	0.717	0.617	0.383	0.004
	SSE	0.084	0.094	0.109	0.136	0.184	0.296	0.478
	ln K	0.483**	0.498**	0.519**	0.551**	0.602**	0.667**	-0.386
	s.e. K	(0.046)	(0.050)	(0.058)	(0.071)	(0.096)	(0.166)	(0.305)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.804	0.778	0.736	0.665	0.526	0.149	0.305
	SSE	0.094	0.106	0.126	0.161	0.227	0.408	0.333
	ln K	0.508**	0.529**	0.558**	0.603**	0.670**	0.594*	-0.748**
	s.e. K	(0.051)	(0.058)	(0.068)	(0.087)	(0.128)	(0.250)	(0.217)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.777	0.742	0.685	0.582	0.351	-0.067	0.524
	SSE	0.107	0.124	0.151	0.200	0.311	0.511	0.228
	ln K	0.547**	0.577**	0.620**	0.681**	0.719**	0.070	-0.781**
	s.e. K	(0.060)	(0.069)	(0.085)	(0.116)	(0.190)	(0.334)	(0.149)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.736	0.684	0.595	0.416	0.055	0.108	0.638
	SSE	0.127	0.151	0.194	0.280	0.453	0.428	0.174
	ln K	0.610**	0.655**	0.712**	0.758**	0.509	-0.599*	-0.738**
	s.e. K	(0.075)	(0.090)	(0.119)	(0.177)	(0.299)	(0.287)	(0.113)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.660	0.569	0.400	0.104	-0.044	0.393	0.697
	SSE	0.163	0.207	0.287	0.430	0.501	0.291	0.145
	ln K	0.714**	0.768**	0.796**	0.604+	-0.248	-0.801**	-0.694**
	s.e. K	(0.104)	(0.135)	(0.192)	(0.293)	(0.344)	(0.196)	(0.093)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.486	0.303	0.048	-0.056	0.240	0.564	0.727
	SSE	0.247	0.334	0.456	0.506	0.364	0.209	0.131
	ln K	0.841**	0.811**	0.534	-0.183	-0.753**	-0.786**	-0.658**
	s.e. K	(0.173)	(0.236)	(0.325)	(0.358)	(0.252)	(0.139)	(0.082)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.109	-0.052	-0.016	0.225	0.479	0.652	0.742
	SSE	0.427	0.504	0.487	0.372	0.250	0.167	0.124
	ln K	0.668*	0.224	-0.378	-0.757**	-0.819**	-0.737**	-0.632**
	s.e. K	(0.319)	(0.373)	(0.354)	(0.262)	(0.170)	(0.109)	(0.076)
	Peak Lag	13	17	21	27	37	53	84

Notes:
Standard errors in parentheses.
** Significant at 1%, * significant at 5%, and + significant at 10%.
Adj R^2 defined as the Adjusted R^2.
SSE defined as the Sum of Squared Errors.
Ln K defined as the natural logarithm of capital stock.
S.e. K defined as the standard error of the natural logarithm of capital stock.
Peak lag defined as years until the maximum impact of research funds are reached.
Shaded values represent results with a negative capital stock coefficient.

Appendix Table C-3: *Model K1 Regression Results without "Trend," with "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.847	0.828	0.796	0.743	0.659	0.591	0.802
	SSE	0.070	0.079	0.093	0.117	0.156	0.187	0.091
	ln K	0.384^{**}	0.389^{**}	0.395^{**}	0.393^{**}	0.341^{*}	-0.119	-0.664^{**}
	s.e. K	(0.064)	(0.072)	(0.085)	(0.110)	(0.162)	(0.263)	(0.139)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.824	0.798	0.757	0.693	0.605	0.673	0.837
	SSE	0.080	0.092	0.111	0.140	0.181	0.150	0.075
	ln K	0.400^{**}	0.408^{**}	0.412^{**}	0.394^{*}	0.220	-0.585^{*}	-0.604^{**}
	s.e. K	(0.075)	(0.087)	(0.107)	(0.146)	(0.225)	(0.250)	(0.107)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.793	0.759	0.706	0.631	0.597	0.776	0.859
	SSE	0.095	0.110	0.134	0.169	0.184	0.102	0.065
	ln K	0.426^{**}	0.433^{**}	0.425^{**}	0.328	-0.203	-0.746^{**}	-0.553^{**}
	s.e. K	(0.093)	(0.112)	(0.146)	(0.209)	(0.286)	(0.177)	(0.087)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.749	0.702	0.636	0.588	0.710	0.829	0.873
	SSE	0.115	0.136	0.166	0.189	0.133	0.078	0.058
	ln K	0.461^{**}	0.452^{**}	0.364	-0.0386	-0.709^{**}	-0.687^{**}	-0.516^{**}
	s.e. K	(0.125)	(0.159)	(0.217)	(0.291)	(0.239)	(0.126)	(0.075)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.679	0.620	0.589	0.686	0.807	0.855	0.881
	SSE	0.147	0.174	0.188	0.144	0.088	0.066	0.055
	ln K	0.468^{*}	0.337	-0.081	-0.676^{*}	-0.768^{**}	-0.611^{**}	-0.488^{**}
	s.e. K	(0.191)	(0.249)	(0.308)	(0.263)	(0.157)	(0.098)	(0.068)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.592	0.608	0.708	0.803	0.848	0.869	0.885
	SSE	0.187	0.180	0.133	0.090	0.070	0.060	0.053
	ln K	0.152	-0.335	-0.752^{**}	-0.801^{**}	-0.677^{**}	-0.556^{**}	-0.467^{**}
	s.e. K	(0.306)	(0.323)	(0.255)	(0.167)	(0.113)	(0.083)	(0.064)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.679	0.761	0.819	0.850	0.866	0.878	0.886
	SSE	0.147	0.109	0.083	0.069	0.061	0.056	0.052
	ln K	-0.708^{*}	-0.844^{**}	-0.803^{**}	-0.701^{**}	-0.599^{**}	-0.517^{**}	-0.451^{**}
	s.e. K	(0.290)	(0.216)	(0.155)	(0.116)	(0.091)	(0.073)	(0.061)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-4: *Model K1 Regression Results with "Trend", without "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.827	0.827	0.831	0.835	0.834	0.827	0.831
	SSE	0.079	0.079	0.077	0.076	0.076	0.079	0.078
	ln K	0.110	-0.068	-0.182	-0.199	-0.145	-0.0422	0.096
	s.e. K	(0.317)	(0.292)	(0.243)	(0.191)	(0.151)	(0.128)	(0.134)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.827	0.830	0.833	0.833	0.829	0.827	0.830
	SSE	0.079	0.078	0.077	0.076	0.078	0.079	0.078
	ln K	-0.066	-0.160	-0.184	-0.153	-0.085	0.011	0.104
	s.e. K	(0.295)	(0.254)	(0.208)	(0.169)	(0.142)	(0.129)	(0.148)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.829	0.831	0.831	0.851	0.827	0.828	0.829
	SSE	0.078	0.077	0.077	0.078	0.079	0.079	0.078
	ln K	-0.139	-0.158	-0.138	-0.930	-0.028	0.0517	0.081
	s.e. K	(0.253)	(0.215)	(0.180)	(0.154)	(0.137)	(0.134)	(0.163)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.829	0.829	0.828	0.827	0.827	0.829	0.827
	SSE	0.078	0.078	0.079	0.080	0.080	0.078	0.080
	ln K	-0.123	-0.110	-0.080	-0.037	0.018	0.074	0.033
	s.e. K	(0.212)	(0.185)	(0.162)	(0.145)	(0.137)	(0.143)	(0.173)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.828	0.827	0.827	0.826	0.827	0.828	0.827
	SSE	0.079	0.079	0.079	0.079	0.079	0.079	0.079
	ln K	-0.075	-0.055	-0.027	0.008	0.048	0.073	-0.021
	s.e. K	(0.182)	(0.165)	(0.151)	(0.143)	(0.143)	(0.156)	(0.176)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.827	0.826	0.827	0.827	0.828	0.827	0.828
	SSE	0.079	0.079	0.080	0.079	0.079	0.079	0.079
	ln K	-0.027	-0.010	0.012	0.038	0.060	0.049	-0.066
	s.e. K	(0.164)	(0.155)	(0.148)	(0.146)	(0.152)	(0.167)	(0.172)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.826	0.827	0.827	0.827	0.827	0.826	0.829
	SSE	0.079	0.079	0.079	0.079	0.079	0.079	0.078
	ln K	0.008	0.021	0.036	0.049	0.051	0.009	-0.096
	s.e. K	(0.157)	(0.153)	(0.151)	(0.154)	(0.162)	(0.173)	(0.166)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-5: *Model K1 Regression Results with "Trend," with "Private Research"*

λ		δ = 0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.845	0.845	0.855	0.870	0.885	0.882	0.853
	SSE	0.067	0.068	0.063	0.057	0.050	0.052	0.064
	ln K	0.124	-0.103	-0.278	-0.364$^+$	-0.390*	-0.366*	-0.215
	s.e. K	(0.300)	(0.276)	(0.230)	(0.181)	(0.147)	(0.145)	(0.197)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.846	0.854	0.867	0.879	0.884	0.870	0.854
	SSE	0.067	0.063	0.058	0.053	0.051	0.057	0.064
	ln K	-0.143	-0.288	-0.367$^+$	-0.395*	-0.390*	-0.329$^+$	-0.247
	s.e. K	(0.281)	(0.242)	(0.199)	(0.165)	(0.149)	(0.164)	(0.218)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.856	0.866	0.875	0.881	0.877	0.862	0.859
	SSE	0.063	0.059	0.055	0.052	0.054	0.060	0.061
	ln K	-0.315	-0.376$^+$	-0.399*	-0.397*	-0.369*	-0.295	-0.335
	s.e. K	(0.245)	(0.210)	(0.180)	(0.161)	(0.160)	(0.184)	(0.230)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.866	0.873	0.877	0.876	0.869	0.859	0.868
	SSE	0.058	0.055	0.054	0.054	0.057	0.062	0.058
	ln K	-0.387$^+$	-0.402*	-0.399*	-0.380*	-0.341$^+$	-0.295	-0.424$^+$
	s.e. K	(0.213)	(0.189)	(0.172)	(0.166)	(0.175)	(0.204)	(0.226)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.871	0.874	0.874	0.870	0.864	0.861	0.875
	SSE	0.056	0.055	0.055	0.057	0.059	0.061	0.055
	ln K	-0.400$^+$	-0.396*	-0.382*	-0.358$^+$	-0.328	-0.339	-0.463*
	s.e. K	(0.195)	(0.182)	(0.176)	(0.179)	(0.194)	(0.221)	(0.209)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.871	0.871	0.869	0.866	0.863	0.866	0.879
	SSE	0.056	0.056	0.057	0.059	0.060	0.058	0.053
	ln K	-0.389$^+$	-0.380$^+$	-0.365$^+$	-0.350$^+$	-0.348	-0.408$^+$	-0.455*
	s.e. K	(0.190)	(0.185)	(0.186)	(0.195)	(0.211)	(0.226)	(0.190)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.869	0.868	0.867	0.865	0.866	0.872	0.880
	SSE	0.057	0.057	0.058	0.059	0.059	0.056	0.052
	ln K	-0.379$^+$	-0.373$^+$	-0.367$^+$	-0.370$^+$	-0.399$^+$	-0.459*	-0.424*
	s.e. K	(0.194)	(0.195)	(0.200)	(0.210)	(0.222)	(0.218)	(0.174)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-6: *Model K2 Regression Results without "Trend," without "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.767	0.737	0.690	0.615	0.496	0.309	-0.050
	SSE	0.112	0.126	0.149	0.185	0.242	0.331	0.503
	ln K	0.351^{**}	0.360^{**}	0.371^{**}	0.386^{**}	0.411^{**}	0.463^{**}	0.245
	s.e. K	(0.040)	(0.044)	(0.051)	(0.062)	(0.083)	(0.133)	(0.385)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.743	0.706	0.650	0.564	0.436	0.230	-0.026
	SSE	0.123	0.141	0.168	0.209	0.270	0.369	0.492
	ln K	0.370^{**}	0.382^{**}	0.399^{**}	0.424^{**}	0.468^{**}	0.564^{**}	-0.442
	s.e. K	(0.044)	(0.050)	(0.060)	(0.075)	(0.106)	(0.193)	(0.459)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.714	0.669	0.604	0.510	0.372	0.115	0.090
	SSE	0.137	0.159	0.190	0.235	0.301	0.424	0.436
	ln K	0.400^{**}	0.419^{**}	0.446^{**}	0.490^{**}	0.574^{**}	0.685^{*}	-0.724^{+}
	s.e. K	(0.052)	(0.060)	(0.073)	(0.096)	(0.146)	(0.321)	(0.370)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.679	0.627	0.555	0.453	0.292	-0.051	0.121
	SSE	0.154	0.179	0.213	0.262	0.339	0.504	0.422
	ln K	0.450^{**}	0.481^{**}	0.529^{**}	0.612^{**}	0.770^{**}	0.344	-0.645^{*}
	s.e. K	(0.063)	(0.075)	(0.095)	(0.134)	(0.230)	(0.559)	(0.296)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.640	0.583	0.504	0.388	0.149	0.008	0.114
	SSE	0.173	0.200	0.238	0.293	0.408	0.476	0.425
	ln K	0.539^{**}	0.596^{**}	0.689^{**}	0.857^{**}	1.038^{*}	-0.718	-0.546^{*}
	s.e. K	(0.082)	(0.102)	(0.137)	(0.211)	(0.438)	(0.550)	(0.256)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.602	0.540	0.451	0.275	-0.068	0.102	0.099
	SSE	0.191	0.221	0.263	0.348	0.512	0.430	0.432
	ln K	0.714^{**}	0.833^{**}	1.036^{**}	1.342^{**}	0.0954	-0.797^{+}	-0.472^{+}
	s.e. K	(0.117)	(0.154)	(0.227)	(0.416)	(0.756)	(0.389)	(0.233)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.573	0.499	0.336	-0.042	0.051	0.117	0.083
	SSE	0.205	0.240	0.318	0.500	0.455	0.423	0.440
	ln K	1.110^{**}	1.400^{**}	1.805^{**}	0.651	-0.888	-0.656^{*}	-0.419^{+}
	s.e. K	(0.193)	(0.280)	(0.493)	(0.869)	(0.533)	(0.305)	(0.219)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-7: *Model K2 Regression Results without "Trend," with "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.828	0.797	0.751	0.684	0.606	0.618	0.621
	SSE	0.079	0.093	0.114	0.145	0.180	0.175	0.174
	ln K	0.255**	0.254**	0.247**	0.223*	0.128	-0.249	-0.338
	s.e. K	(0.047)	(0.055)	(0.067)	(0.088)	(0.128)	(0.192)	(0.249)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.796	0.758	0.706	0.638	0.588	0.656	0.588
	SSE	0.093	0.111	0.135	0.166	0.189	0.157	0.188
	ln K	0.264**	0.261**	0.248**	0.201	0.019	-0.482+	-0.061
	s.e. K	(0.057)	(0.068)	(0.086)	(0.117)	(0.174)	(0.235)	(0.298)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.758	0.714	0.659	0.602	0.601	0.650	0.605
	SSE	0.111	0.131	0.156	0.182	0.183	0.160	0.181
	ln K	0.278**	0.271**	0.244*	0.144	-0.204	-0.568+	0.293
	s.e. K	(0.072)	(0.089)	(0.116)	(0.165)	(0.241)	(0.293)	(0.307)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.714	0.668	0.617	0.587	0.632	0.605	0.642
	SSE	0.131	0.152	0.175	0.189	0.168	0.181	0.164
	ln K	0.299**	0.282*	0.218	-0.006	-0.517	-0.345	0.488+
	s.e. K	(0.098)	(0.125)	(0.170)	(0.245)	(0.324)	(0.361)	(0.273)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.670	0.626	0.591	0.602	0.622	0.589	0.662
	SSE	0.151	0.171	0.187	0.182	0.173	0.188	0.155
	ln K	0.330*	0.283	0.119	-0.321	-0.580	0.115	0.506*
	s.e. K	(0.144)	(0.192)	(0.269)	(0.371)	(0.421)	(0.383)	(0.235)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.631	0.598	0.589	0.606	0.588	0.620	0.666
	SSE	0.169	0.184	0.188	0.180	0.188	0.174	0.153
	ln K	0.371	0.238	-0.134	-0.517	-0.102	0.454	0.460*
	s.e. K	(0.236)	(0.326)	(0.448)	(0.521)	(0.470)	(0.339)	(0.207)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.606	0.589	0.589	0.587	0.605	0.650	0.663
	SSE	0.180	0.188	0.188	0.189	0.181	0.160	0.154
	ln K	0.439	0.136	-0.188	0.025	0.402	0.542+	0.407*
	s.e. K	(0.436)	(0.584)	(0.651)	(0.557)	(0.413)	(0.280)	(0.188)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-8: *Model K2 Regression Results with "Trend," without "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.829	0.834	0.840	0.843	0.837	0.827	0.874
	SSE	0.078	0.076	0.073	0.072	0.075	0.079	0.058
	ln K	-0.085	-0.139	-0.163	-0.150	-0.105	-0.017	0.377^{*}
	s.e. K	(0.149)	(0.138)	(0.120)	(0.101)	(0.089)	(0.089)	(0.134)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.834	0.839	0.841	0.838	0.830	0.829	0.898
	SSE	0.076	0.074	0.073	0.074	0.078	0.078	0.047
	ln K	-0.147	-0.167	-0.156	-0.120	-0.063	0.061	0.626^{**}
	s.e. K	(0.147)	(0.131)	(0.113)	(0.100)	(0.094)	(0.107)	(0.163)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.837	0.838	0.836	0.831	0.826	0.845	0.859
	SSE	0.074	0.074	0.075	0.077	0.079	0.071	0.064
	ln K	-0.166	-0.153	-0.123	-0.078	-0.003	0.225	0.393^{*}
	s.e. K	(0.140)	(0.124)	(0.111)	(0.104)	(0.108)	(0.141)	(0.177)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.835	0.833	0.830	0.827	0.831	0.883	0.833
	SSE	0.075	0.076	0.078	0.079	0.077	0.053	0.076
	ln K	-0.141	-0.114	-0.076	-0.018	0.107	0.598^{**}	0.140
	s.e. K	(0.134)	(0.123)	(0.116)	(0.118)	(0.137)	(0.187)	(0.152)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.830	0.828	0.826	0.829	0.854	0.887	0.827
	SSE	0.078	0.079	0.079	0.078	0.067	0.052	0.079
	ln K	-0.091	-0.057	-0.007	0.092	0.385^{+}	0.727^{**}	0.028
	s.e. K	(0.137)	(0.132)	(0.135)	(0.150)	(0.192)	(0.215)	(0.128)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.827	0.827	0.831	0.850	0.896	0.845	0.827
	SSE	0.079	0.079	0.077	0.069	0.048	0.071	0.079
	ln K	-0.017	0.036	0.137	0.390^{+}	0.910^{**}	0.307	-0.024
	s.e. K	(0.155)	(0.161)	(0.178)	(0.215)	(0.242)	(0.194)	(0.112)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.830	0.838	0.859	0.894	0.862	0.830	0.829
	SSE	0.078	0.074	0.065	0.048	0.063	0.078	0.079
	ln K	0.139	0.277	0.579^{*}	1.020^{**}	0.555^{*}	0.096	-0.051
	s.e. K	(0.205)	(0.229)	(0.264)	(0.278)	(0.240)	(0.155)	(0.102)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-9: *Model K2 Regression Results with "Trend," with "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.844	0.849	0.861	0.878	0.894	0.883	0.868
	SSE	0.068	0.066	0.061	0.053	0.046	0.051	0.058
	ln K	-0.001	-0.103	-0.176	-0.221^{*}	-0.255^{**}	-0.274^{*}	0.347^{+}
	s.e. K	(0.150)	(0.133)	(0.112)	(0.093)	(0.084)	(0.106)	(0.182)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.850	0.860	0.874	0.887	0.891	0.859	0.903
	SSE	0.066	0.061	0.055	0.049	0.047	0.062	0.042
	ln K	-0.121	-0.186	-0.228^{*}	-0.259^{*}	-0.289^{**}	-0.226	0.571^{**}
	s.e. K	(0.141)	(0.122)	(0.105)	(0.093)	(0.098)	(0.158)	(0.163)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.862	0.873	0.883	0.889	0.877	0.845	0.908
	SSE	0.060	0.056	0.051	0.049	0.053	0.068	0.040
	ln K	-0.207	-0.244^{*}	-0.272^{*}	-0.299^{*}	-0.313^{*}	0.054	0.565^{**}
	s.e. K	(0.130)	(0.115)	(0.105)	(0.106)	(0.134)	(0.229)	(0.152)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.873	0.880	0.884	0.879	0.853	0.878	0.892
	SSE	0.056	0.052	0.050	0.053	0.064	0.053	0.047
	ln K	-0.268^{*}	-0.293^{*}	-0.318^{*}	-0.338^{*}	-0.234	0.562^{*}	0.447^{**}
	s.e. K	(0.127)	(0.120)	(0.121)	(0.141)	(0.211)	(0.240)	(0.150)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.877	0.879	0.874	0.857	0.849	0.908	0.874
	SSE	0.054	0.053	0.055	0.062	0.066	0.040	0.055
	ln K	-0.322^{*}	-0.345^{*}	-0.362^{*}	-0.302	0.255	0.724^{**}	0.319^{*}
	s.e. K	(0.139)	(0.144)	(0.164)	(0.222)	(0.303)	(0.195)	(0.147)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.871	0.866	0.853	0.847	0.895	0.901	0.861
	SSE	0.056	0.059	0.064	0.067	0.046	0.043	0.061
	ln K	-0.374^{+}	-0.377^{+}	-0.290	0.192	0.822^{**}	0.588^{**}	0.220
	s.e. K	(0.182)	(0.210)	(0.270)	(0.347)	(0.265)	(0.174)	(0.140)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.853	0.845	0.853	0.892	0.905	0.884	0.853
	SSE	0.064	0.068	0.064	0.047	0.041	0.051	0.064
	ln K	-0.326	-0.120	0.446	0.919^{**}	0.740^{**}	0.424^{*}	0.149
	s.e. K	(0.295)	(0.361)	(0.402)	(0.307)	(0.207)	(0.163)	(0.133)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-10: *Model K3 Regression Results without "Trend," without "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.751	0.714	0.655	0.561	0.417	0.212	-0.066
	SSE	0.119	0.137	0.166	0.211	0.280	0.378	0.511
	ln K	0.387**	0.397**	0.408**	0.421**	0.434**	0.456*	0.105
	s.e. K	(0.046)	(0.051)	(0.060)	(0.075)	(0.101)	(0.163)	(0.407)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.722	0.676	0.605	0.500	0.351	0.142	-0.042
	SSE	0.133	0.155	0.189	0.239	0.311	0.411	0.500
	ln K	0.410**	0.423**	0.439**	0.460**	0.492**	0.553*	-0.309
	s.e. K	(0.052)	(0.0596)	(0.072)	(0.092)	(0.131)	(0.238)	(0.413)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.687	0.631	0.551	0.440	0.288	0.050	-0.012
	SSE	0.150	0.177	0.215	0.269	0.341	0.455	0.485
	ln K	0.446**	0.465**	0.492**	0.532**	0.608**	0.656	-0.361
	s.e. K	(0.0612)	(0.0721)	(0.0892)	(0.119)	(0.183)	(0.396)	(0.326)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.645	0.582	0.497	0.385	0.227	-0.064	-0.013
	SSE	0.170	0.200	0.241	0.295	0.371	0.510	0.485
	ln K	0.504**	0.538**	0.588**	0.677**	0.854**	0.190	-0.294
	s.e. K	(0.0758)	(0.0919)	(0.118)	(0.168)	(0.295)	(0.590)	(0.265)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.603	0.538	0.455	0.345	0.108	-0.040	-0.021
	SSE	0.190	0.221	0.261	0.314	0.428	0.499	0.489
	ln K	0.612**	0.679**	0.793**	1.016**	1.186*	-0.363	-0.234
	s.e. K	(0.100)	(0.126)	(0.172)	(0.272)	(0.569)	(0.467)	(0.231)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.576	0.519	0.447	0.277	-0.069	-0.019	-0.030
	SSE	0.203	0.230	0.265	0.346	0.512	0.489	0.494
	ln K	0.840**	1.005**	1.320**	1.802**	0.051	-0.349	-0.191
	s.e. K	(0.145)	(0.194)	(0.291)	(0.555)	(0.684)	(0.337)	(0.210)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.603	0.565	0.383	-0.053	-0.038	-0.020	-0.038
	SSE	0.190	0.209	0.296	0.505	0.497	0.489	0.498
	ln K	1.443**	1.973**	2.578**	0.451	-0.356	-0.279	-0.160
	s.e. K	(0.236)	(0.349)	(0.642)	(0.784)	(0.437)	(0.271)	(0.197)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-11: *Model K3 Regression Results without "Trend," with "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.824	0.787	0.733	0.659	0.591	0.658	0.598
	SSE	0.081	0.097	0.122	0.156	0.187	0.156	0.184
	ln K	0.276^{**}	0.272^{**}	0.258^{**}	0.213^{*}	0.062	-0.396^{*}	-0.188
	s.e. K	(0.052)	(0.061)	(0.076)	(0.101)	(0.144)	(0.190)	(0.255)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.787	0.743	0.683	0.615	0.594	0.687	0.605
	SSE	0.098	0.118	0.145	0.176	0.186	0.143	0.181
	ln K	0.285^{**}	0.276^{**}	0.249^{*}	0.164	-0.108	-0.602^{*}	0.264
	s.e. K	(0.064)	(0.078)	(0.099)	(0.135)	(0.190)	(0.234)	(0.271)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.743	0.693	0.634	0.589	0.631	0.636	0.684
	SSE	0.118	0.140	0.167	0.188	0.169	0.166	0.145
	ln K	0.296^{**}	0.278^{*}	0.223	0.055	-0.399	-0.528	0.569^{*}
	s.e. K	(0.083)	(0.103)	(0.136)	(0.189)	(0.254)	(0.314)	(0.225)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.694	0.645	0.599	0.595	0.650	0.588	0.735
	SSE	0.140	0.163	0.184	0.185	0.160	0.189	0.121
	ln K	0.311^{*}	0.271^{+}	0.154	-0.179	-0.683^{+}	0.041	0.603^{**}
	s.e. K	(0.115)	(0.147)	(0.200)	(0.278)	(0.354)	(0.368)	(0.177)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.649	0.608	0.587	0.614	0.595	0.648	0.747
	SSE	0.161	0.179	0.189	0.176	0.185	0.161	0.116
	ln K	0.330^{+}	0.241	-0.011	-0.526	-0.297	0.585^{+}	0.540^{**}
	s.e. K	(0.172)	(0.229)	(0.321)	(0.435)	(0.476)	(0.307)	(0.149)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.618	0.592	0.589	0.588	0.622	0.717	0.741
	SSE	0.175	0.187	0.188	0.189	0.173	0.130	0.118
	ln K	0.374	0.201	-0.174	-0.081	0.579	0.693^{**}	0.470^{**}
	s.e. K	(0.288)	(0.404)	(0.567)	(0.615)	(0.415)	(0.224)	(0.133)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.621	0.608	0.614	0.647	0.701	0.743	0.731
	SSE	0.174	0.179	0.177	0.162	0.137	0.118	0.123
	ln K	0.741	0.767	0.825	0.860^{+}	0.793^{*}	0.625^{**}	0.414^{**}
	s.e. K	(0.546)	(0.731)	(0.689)	(0.458)	(0.281)	(0.176)	(0.123)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-12: *Model K3 Regression Results with "Trend," without "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.828	0.833	0.840	0.844	0.838	0.827	0.886
	SSE	0.079	0.076	0.073	0.072	0.074	0.079	0.052
	ln K	-0.063	-0.123	-0.157	-0.152	-0.111	-0.018	0.451^{**}
	s.e. K	(0.142)	(0.133)	(0.117)	(0.100)	(0.089)	(0.093)	(0.135)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.833	0.838	0.841	0.839	0.831	0.830	0.883
	SSE	0.076	0.074	0.073	0.074	0.078	0.078	0.054
	ln K	-0.131	-0.160	-0.158	-0.128	-0.069	0.080	0.479^{**}
	s.e. K	(0.143)	(0.128)	(0.112)	(0.100)	(0.097)	(0.117)	(0.151)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.837	0.839	0.837	0.832	0.826	0.854	0.844
	SSE	0.075	0.074	0.075	0.077	0.079	0.067	0.071
	ln K	-0.161	-0.157	-0.132	-0.087	-0.001	0.317^{+}	0.213
	s.e. K	(0.139)	(0.124)	(0.113)	(0.108)	(0.116)	(0.158)	(0.138)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.836	0.834	0.830	0.827	0.834	0.896	0.828
	SSE	0.075	0.076	0.078	0.079	0.076	0.048	0.079
	ln K	-0.147	-0.124	-0.086	-0.020	0.152	0.702^{**}	-0.067
	s.e. K	(0.137)	(0.127)	(0.122)	(0.128)	(0.157)	(0.188)	(0.143)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.826	0.831	0.872	0.862	0.826	0.827	0.827
	SSE	0.079	0.077	0.058	0.063	0.079	0.079	0.079
	ln K	-0.005	0.137	0.607^{*}	0.426^{*}	0.005	-0.018	0.056
	s.e. K	(0.151)	(0.176)	(0.221)	(0.182)	(0.098)	(0.176)	(0.189)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.835	0.869	0.885	0.835	0.827	0.833	0.849
	SSE	0.076	0.060	0.053	0.076	0.079	0.076	0.069
	ln K	0.224	0.683^{*}	0.752^{**}	0.149	-0.027	0.245	0.535^{+}
	s.e. K	(0.220)	(0.262)	(0.230)	(0.143)	(0.088)	(0.263)	(0.301)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.886	0.882	0.843	0.827	0.829	0.829	0.830
	SSE	0.052	0.054	0.072	0.079	0.078	0.078	0.078
	ln K	1.049^{**}	0.829^{**}	0.263	0.041	-0.045	0.069	-0.102
	s.e. K	(0.316)	(0.264)	(0.179)	(0.116)	(0.081)	(0.114)	(0.145)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.

Appendix Table C-13: *Model K3 Regression Results with "Trend," with "Private Research"*

		δ						
λ		0.60	0.65	0.70	0.75	0.80	0.85	0.90
0.60	Adj. R^2	0.844	0.848	0.860	0.878	0.895	0.884	0.882
	SSE	0.068	0.066	0.061	0.053	0.046	0.051	0.051
	ln K	0.017	-0.088	-0.166	-0.218*	-0.260**	-0.292*	0.410*
	s.e. K	(0.142)	(0.129)	(0.110)	(0.092)	(0.083)	(0.112)	(0.161)
	Peak Lag	2	3	4	5	7	10	17
0.65	Adj. R^2	0.848	0.859	0.874	0.888	0.894	0.855	0.910
	SSE	0.066	0.061	0.055	0.049	0.046	0.063	0.039
	ln K	-0.104	-0.175	-0.225*	-0.263*	-0.306**	-0.219	0.508**
	s.e. K	(0.137)	(0.120)	(0.104)	(0.094)	(0.101)	(0.176)	(0.132)
	Peak Lag	2	3	4	6	8	12	20
0.70	Adj. R^2	0.860	0.872	0.884	0.891	0.878	0.850	0.907
	SSE	0.061	0.056	0.051	0.048	0.053	0.066	0.040
	ln K	-0.197	-0.242*	-0.278*	-0.317**	-0.344*	0.209	0.453**
	s.e. K	(0.130)	(0.116)	(0.106)	(0.109)	(0.147)	(0.241)	(0.123)
	Peak Lag	3	4	6	7	10	15	24
0.75	Adj. R^2	0.872	0.881	0.886	0.880	0.849	0.896	0.891
	SSE	0.056	0.052	0.050	0.052	0.066	0.045	0.048
	ln K	-0.269^{+}	-0.303*	-0.341*	-0.378*	-0.198	0.631**	0.357**
	s.e. K	(0.129)	(0.123)	(0.126)	(0.154)	(0.249)	(0.199)	(0.122)
	Peak Lag	4	5	7	9	13	19	30
0.80	Adj. R^2	0.877	0.880	0.875	0.853	0.867	0.911	0.875
	SSE	0.054	0.052	0.055	0.064	0.058	0.039	0.055
	ln K	-0.341*	-0.378*	-0.411*	-0.300	0.553^{+}	0.599**	0.264*
	s.e. K	(0.147)	(0.155)	(0.186)	(0.271)	(0.302)	(0.154)	(0.120)
	Peak Lag	6	7	9	12	17	24	39
0.85	Adj. R^2	0.871	0.864	0.848	0.863	0.909	0.900	0.863
	SSE	0.056	0.059	0.066	0.060	0.040	0.044	0.060
	ln K	-0.422^{+}	-0.430	-0.234	0.612	0.775**	0.461**	0.190
	s.e. K	(0.208)	(0.252)	(0.346)	(0.370)	(0.205)	(0.138)	(0.116)
	Peak Lag	8	10	13	17	24	34	54
0.90	Adj. R^2	0.848	0.846	0.882	0.909	0.905	0.884	0.855
	SSE	0.066	0.067	0.052	0.040	0.041	0.051	0.063
	ln K	-0.269	0.254	0.962*	0.879**	0.579**	0.340*	0.134
	s.e. K	(0.389)	(0.466)	(0.382)	(0.232)	(0.161)	(0.131)	(0.111)
	Peak Lag	13	17	21	27	37	53	84

Notes:
See notes to Appendix Table C-2.