# SOURCES OF ECONOMIC GROWTH AND PRODUCTIVITY INDUCED INNOVATION AND TECHNOLOGICAL CHANGE BIASES IN THE AGRICULTURAL SECTOR.

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## 1. ARGENTINE AGRICULTURE.

Agriculture is a key sector in the Argentine economy.

The agricultural sector has always been the greatest earner of foreign exchange of the Argentine economy and remains so to this day.

Historically, export earnings from agricultural and agroindustrial products have been the 70-80 percent of total export earnings.

Though this percentage has fallen somewhat in recent years (to 67,2 percent for 1990-92), the capacity of the agricultural sector to generate export earnings, exceeds that of any other sector.

Nevertheless, the relative importance of agriculture in Argentina has been declining. In 1950-54, Argentine agriculture generated 18,8 percent of GDP (at factor cost and at 1960 prices) and employed 21,0 percent of the labor force. By 1990-92, these percentages had declined to 8,4 percent for GDP (at market prices and at 1986 prices) and 8,4 percent for employment.

The agricultural sector has made good progress in increasing its land productivity.

This progress was achieved mainly in the crop sector, rather than in the livestock sector. This is reflected in the different growth rates of the two subsectors.

Between 1950-52/1990-92, the production of main crops (wheat, corn, sorghum, sunflowers and soybeans) grew at about 3,7 percent a year. In contrast, the size of cattle herds only grew 0.6 percent a year, in the same time.

The increased share of crop in total agricultural output was due to a number of factors, such as the introduction of improved crop varieties and technologies which increased the relative profitability of crops, and the important cyclical fluctuations in beef prices which discouraged development in the livestock sector.

Nevertheless, while overall crop output growth has been high in recent years, there are important differences from crop to crop. The growth rate of soybean production has been particularly outstanding, supported by a simultaneus increase in the area planted and in average yields per hectarea.

Agricultural production in Argentina comes from two natural regions that differ in ecological characteristics: the "pampas" and the "rest of the country" (an aggregate of areas highly specialized in producing particular commodities).

The pampean region, which covers 45 million hectares in the East-Central part of the country, has specialized in products

TABLE 1.

ARGENTINA AND THE UNITED STATES. OUTPUT AND PARTIAL PRODUCTIVITY.

ANNUAL AVERAGE COMPOUND GROWTH RATES.

| | Y | Y/L | A/L | Y/A |
|---|---|---|---|---|
| | | (Percentages) | | |
| ARGENTINA. | | | | |
| 1950-1970 | 2,25 | 3,23 | 1,33 | 1,88 |
| 1970-1990 | 1,81 | 2,75 | 0,14 | 2,61 |
| 1950-1990 | 2,03 | 2,99 | 0,73 | 2,24 |
| 1950-1992 | 2,03 | 2,98 | 0,68 | 2,29 |
| UNITED STATES. | | | | |
| 1950-1970 | 1,43 | 5,88 | 3,55 | 2,26 |
| 1970-1990 | 1,85 | 3,58 | 2,18 | 1,37 |
| 1950-1990 | 1,64 | 4,72 | 2,86 | 1,81 |

which constitute the main source of export earnings. More than 80 percent of the grains and oilseeds and about 90 percent of the livestock originate in this region.

The system of production in the pampean region is charaterized by the rotation of crops and livestock, double cropping and by the transfer from forage crops to oilseeds and to wheat.

The other agricultural regions of Argentina are: i- Northeast: specialized in citrus, cotton, rice, tobacco, tea and livestock, ii- Northwest: produces tobacco, sugarcane, citrus and vegetables, iii- Cuyo: specialized in grapes and fruits and iv- Patagonia: where sheep production is the main activity.

These regions sell its production mainly towards the domestic market.

More than 80 percent of the industrial crops and more than half of fruits and vegetables are produced in non-pampean regions.

## 2. RESOURCE ENDOWMENT AND RELATIVE PRICES, OUTPUT AND PARTIAL PRODUCTIVITY GROWTH IN ARGENTINA. COMPARISON WITH THE UNITED STATES.

### 2.1. RESOURCE ENDOWMENTS AND RELATIVE PRICES.

Argentina and the United States don't present extreme differences in relative endowments of land and labor in the agricultural sector.

Nevertheless, land-labor ratios in both countries have changed over time.

In 1950, land-labor ratio was larger in Argentina than in the United States. In 1990, in contrast, this ratio was larger in the United States than in Argentina.

Argentina is characterized by a low use of fertilizer per hectare of land and by a low ratio of machinery per worker, in comparison with the United States.

The relative prices of labor and other inputs also differ in the two countries. The rural wages are lower in Argentina than in the United States and the prices of fertilizers and machinery are higher in Argentina than in the United States.

### 2.2. OUTPUT, INPUTS AND PARTIAL PRODUCTIVITY GROWTH.

In Argentina, agricultural output grew at 2,03 percent per year between 1950 and 1990 (and at the same rate during 1950-92), Table 1.

Over the whole period, land and labor declined, livestock grew and machinery and fertilizers increased at approximately the annual compound growth rate of 6,0 percent.

Between 1950 and 1990, output per hectare (2,24 percent per year) rose more rapidly than total output and output per worker (2,99 percent per year) rose more rapidly than total output and than output per hectare.

Increases in output per hectare became a more important source of growth in output per worker during 1950-90 (92) period.

In the United States, the agricultural output grew at 1.64 percent per year during 1950-90. Labor declined at the annual compound growth rate of 2,9 percent, the fertilizer consumption growth at 4,8 percent per year and land and machinery stayed nearly constant (1).

Output per worker (4,72 percent per year) rose more rapidly than output per hectare (1,81 percent per year) and both rose more rapidly than total output.

There were two important subperiods from the point of view of performance in agriculture during 1950-90 period: i- 1950-70 and ii- 1970-90.

Argentine agricultural output grew more in the first subperiod (2,25 percent per year) than in the second one (1,81 percent per year), while the american agricultural output grew more in 1970-90 subperiod (1,85 percent per year) compared with 1950-70 subperiod (1,43 percent per year).

In Argentina, the output per land grew more in the second subperiod than in 1950-70 subperiod, while the output per worker grew more in the first subperiod than in 1970-90.

In change, in the United States agriculture, the output per worker and the output per land grew more in 1950-70 subperiod.

In conclusion, between 1950 and 1990, the rates of growth of total output and of output per land were higher in Argentina than in the United States.

In the same period, in contrast, output per worker grew more in the United States than in Argentina.

## 3. THE HAYAMI AND RUTTAN FRAMEWORK.

### 3.1. SOURCES OF AGRICULTURAL GROWTH IN ARGENTINA DURING 1950-1992.

#### 3.1.1. DATA AND FUNCTIONAL FORM SPECIFICATION.

TABLE 2.

ARGENTINA. AGRICULTURAL PRODUCTION FUNCTIONS. 1950-92.

| | Estimations #. | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Dependent Variable: Y | | | | |
| Independent Variables: | | | | |
| L | 0,239 (1,538)* | 0,276 (1,473)* | 0,202 (1,905) | 0,258 (2,727) |
| A | -0,020 (-0,113)* | | | |
| S | 0,652 (4,954) | | | |
| Z1 | | 0,541 (2,663) | | |
| Z2 | | | 0,669 (5,449) | 0,619 (5,367) |
| M | 0,057 (1,900) | 0.098 (2,867) | 0.053 (1,955) | 0,074 (3,552) |
| F | 0,031 (1,044)* | 0,015 (0,433)* | 0,033 (1,158)* | |
| T | 0,017 (6,884) | 0,022 (8,654) | 0,017 (7,153) | 0,019 (16,860) |
| $\bar{R}^2$ | 0,96 | 0,94 | 0,96 | 0,96 |
| D.W. | 1,99 | 1,73 | 2,05 | 2,02 |
| F-S | 197,1 | 164,7 | 252,0 | 332,7 |

Z1 = log (0,8*A + 0,2*S)
Z2 = log (0,05*A + 0,95*S)

* denotes: it is not significantly different from zero at the standard level of significance.
# Annual data and log form.

The data used in this study include annual observations for Argentina from 1950 to 1992.

The basic approach consists of estimating an unrestricted production function of the Cobb-Douglas type, using separate variables for each of the five major input categories.

In this study, agricultural output (Y, dependent variable) includes not only crops, but also animal husbandry, fishery and forestry. Output here refers to value added.

The independent variables used in the study include labor (L), land (A), machinery (M), livestock (S) and chemical fertilizers (F).

Land refers to cultivated land. It includes all land under cultivation but excludes natural pasture land.

Labor refers to the number of workers in the agriculture sector.

Machinery includes stock of tractors for farm purposes measured in equivalent horsepower units.

Chemical fertilizers refer to the sum of nitrogenous (N), phosphate (P) and potash fertilizers (K) consumed in each year. Fertilizers are measured in terms of nutrients.

Livestock refers to the stock of cattle to June of each year.

Moreover, we include a time trend variable, with 0 from 1950 to 1963 and 1, 2, 3,..., respectively, in the other years, to capture the trend in technological change in the agricultural sector in Argentina.

The total number of observations for each variable is 43.

The equations estimated are linear in the logarithms of the variables, except for the trend variable.

3.1.2. RESULTS.

Production functions were estimated for 1950-1992 period.

Table 2 presents the estimates of the unrestricted Cobb-Douglas production functions.

Each column reports the results of a regression of agricultural output on a different set of inputs in the log linear form, including estimates of the production elasticities, D.W., t of Student and the coefficients of determination adjusted for the degrees of freedom.

Estimates for the agricultural sector of Argentina (1950-1992) yield the following contributions of inputs to total output (eq. 4): labor 0,258, land and livestock 0,619 and machinery 0,074.

In other estimation, we obtained aggregate production elasticities of around 0,202 for labor, 0,669 for land and livestock, 0.053 for machinery and 0.033 for fertilizer consumption (though the coefficient for fertilizer was not significant at commonly accepted levels) (eq. 3).

Technical change has taken place at an approximate rate of 1,9 percent per year between 1964 and 1992.

It is of some interest to compare these results with those obtained by Ballesteros (Ballesteros M., 1958. "Argentine Agriculture 1908-1954: a Study in Growth and Decline". Ph.D. diss. Un. of Chicago.) in his study of Argentine agriculture. In the Ballesteros study the labor and land coefficients were 0,46 and 0,36, respectively.

Results of other study (Reca L. and Verstraeten J. 1977. "La formación del producto agropecuario argentino. Antecedentes y posibilidades. CONICET) also show a high share of land in the Argentine agriculture (0,38).

In the present study, a combination of land and livestock contributed to 0,619 of total output, but livestock is much more important than land in the estimation.

In this study, labor (0,258) is lower than in Ballesteros (0,46) but is higher than in the Reca and Verstraeten estimation (0,24).

As in Ballesteros and in Reca and Verstraeten, in this study, machinery use and fertilizer consumption present a low share in the total output of the agricultural sector. Nevertheless, the intermediate inputs, as fertilizers, included in the functions fitted should correspond to a gross-output function rather than to a value-added function.

## 3.2. ACCOUNTING FOR PRODUCTIVITY DIFFERENCES AMONG UNITED STATES AND ARGENTINA.

The sources of differences in labor productivity in agriculture between the United States and Argentina, in 1990, are presented in Tables 3 and 4.

The column (2) in Table 4 (1990) compares the percentage differences in agricultural output per worker, between the United States and Argentina, with the linear combinations of percentage differences in input variables (land, fertilizers, machinery and livestock) weighted by the specified production elasticities (2).

We used the following formula in the estimation:

TABLE 3.

OUTPUT, INPUTS AND RESOURCE ENDOWMENTS.

| | ARGENTINA | | UNITED STATES | |
|---|---|---|---|---|
| | 1950 | 1990 | 1950 | 1990 |
| Y (000 Wheat Units) | 39.038 | 87.200 | 319.469 | 611.740 |
| L (000's) | 1.480 | 1.017 | 9.926 | 2.869 |
| Y/L | 26,377 | 85,742 | 32,185 | 213,224 |
| A (000 Hectares) | 26.063 | 23.984 | 139.622 | 130.313 |
| A/L | 17,610 | 23,583 | 14,066 | 45,421 |
| S (000 Units) | 40.900 | 49.600 | 81.706 | 137.732 |
| S/L | 27,635 | 48,771 | 8,232 | 48,007 |
| M (000 Horsepower) | 404 | 5.256 | 119.401 | 117.743 |
| M/L | 0,273 | 5,168 | 12,029 | 41,040 |
| F (000 Tons Nutrients. Consumption) | 15.7 | 165.5 | 2.870 | 18.429 |
| F/L | 0,011 | 0,163 | 0,289 | 6,423 |

TABLE 4.

ACCOUNTING FOR DIFFERENCE IN LABOR PRODUCTIVITY IN AGRICULTURE BETWEEN THE UNITED STATES AND ARGENTINA.

| | 1950 (1) | 1990 (2) |
|---|---|---|
| | (percentages) | |
| Difference in output per worker: | 18.0(100) | 59.8(100) |
| Land/Labor | 0.5(2.8)* | 1.0(1.7) |
| Livestock/Labor | 58.9(327.2)* | 0.4(0.7)* |
| Machinery/Labor | 12.7(70.6) | 11.4(19.1) |
| Fertilizer/Labor | 24.0(133.3) | 24.4(40.8) |
| Percent of difference explained for the four variables: | 22.7(126.1)* | 36.4(60.9) |

Note: * it indicates relation in favour of Argentina.

$$y1 - y3 / y1 = 0{,}02 (a1 - a3 / a1) + 0{,}25 (s1 - s3 / s1) + 0{,}25 (f1 - f3 / f1) + 0{,}13 (m1 - m3 / m1).$$

Where: 1: denotes United States, and

3: denotes Argentina.

Here, y, a, s, f, and m are, respectively, output, land, livestock, fertilizer consumption and machinery use per worker.

The index with the output per worker difference set equal to 100 is shown in parentheses.

The difference in agricultural output per worker between the United States and Argentina was 59,8 percent in 1990.

The four conventional variables included in the production function accounted for 60,9 percent of the difference in agricultural output per worker between the United States and Argentina.

The differences in fertilizer and machinery per worker account for most of the differences (conventional inputs) in output per worker between these two countries.

Moreover, the investment in technical education and research would explain a part of the remain difference in agricultural output per worker between the United States and Argentina.

On the other hand, output per worker rose more rapidly in the United States than in Argentina, between 1950 and 1990, since the difference in labor productivity between these two countries was lower in 1950 than in 1990.

Thus, the increasing gap in labor productivity in agriculture between the United States and Argentina resulted not only from the difference in endowment of machinery per worker and from the increasing difference in land and fertilizers per worker, but also from the difference in the rates of growth in scientific research and in development of more efficient technologies (percent of difference not explained by the four conventional variables).

## 3.3. THE INDUCED INNOVATION HYPOTHESIS.

The induced innovation hypothesis, most closely associated with the work of Hayami and Ruttan (Hayami Y. and Ruttan V. 1985. "Agricultural Development: an International Perspective". Johns Hopkins University Press) argues that successful economies develop technologies in accordance with market price signals to loosen constraints on growth imposed by factor scarcities (Olmstead A. and Rhode P., 1993. "Induced Innovation in American Agriculture: a Reconsideration". Journal of Political Economy).

A useful entry point into their analysis is the decomposition of changes in output per worker, into changes in output per land and changes in land area per worker, as in the following identity:

$$Y/L = A/L * Y/A \qquad (3)$$

where: Y: output.

L: labor.

A: land area.

Y/L: output per worker, or labor productivity.

A/L: land area per worker.

Y/A: output per land area, or land productivity.

Hayami and Ruttan, as Griliches, argue that growth in land area per worker (A/L) and growth in output per land area (Y/A) are somewhat independent, at least over a certain range.

In Hayami and Ruttan model, separability of the production function is assumed, so that within a range the forces determining the productivity of land can be viewed as relatively independent of the forces determining the productivity of labor. The two partial productivity measures are linked through the ratio of land area per worker (A/L).

Changes in land per worker and changes in output per land are associated with two alternative development paths: one typified by the United States experience (1880-1980), in which progress in mechanical technology facilitated the substitution of other sources of power for human labor, and the other typified by the Japanese experience, in which progress in biological technology increased the productivity of land (Hayami and Ruttan).

Thus, the land-abundant, labor-scarce U.S. developed labor-saving techniques; and Japan, a land-constrained, labor-abundant economy, developed land-saving methods (Olmstead and Rhode, 1993).

In the United States case, the technology which permits an expansion in land area per worker is generally associated with higher mechanical power inputs per worker. This would implicate a complementary relationship between land and machinery power.

In the Japanese case, is hypothesized the complementary relationship between biological technologies and fertilizer use.

In the induced innovation hypothesis, the differences in factor-price movements influence the process of technical change and the choice of inputs in the countries.

The theory of induced innovation implies that a rise in the price of one factor relative to that of other factors induces a sequence of technical changes that reduces the use of that factor relative to the use of other factor inputs. As a result, the constraints on economic growth imposed by resource scarcity are released by technical advanced that facilitate the substitution of relatively abundant factors for relatively scarce factors (Hicks).

We have referred to agricultural technologies which substitute machinery for labor as mechanical technology and to agricultural technologies which increase output per land area as biological technology. In the first case, increases in output per worker can be achieved through advances in technology which enable the land area per worker to rise. In the second case, increases in output per worker are achieved through increases in land productivity.

In the United States, land area per worker (A/L) rose much more rapidly than in Japan (Hayami and Ruttan).

In Japan, land productivity (Y/A) rose much more rapidly than in the United States.

Thirtle (Thirtle C., 1982. "Induced Innovation in the United States Field Crops, 1939-78". Ph.D. diss.. Columbia University. U.S.) criticizes the Hayami and Ruttan model. He shows that even though the mechanical and biological technical changes are constrained to be Hicks-neutral, their effect on the land-labor ratio will be non-neutral unless the two changes are equal. Thus, allowing for the interaction of the two types of technological change permits changes in the land-labor ratio even at constant factor prices. This possibility does not exist in the Hayami and Ruttan model and is not allowed for in their land- labor ratio tests. In the Hayami and Ruttan model changes in the land-labor ratio caused by the substitution of fertilizer for land are ignored.

## 4. THE MEASUREMENT OF TECHNICAL CHANGE BIASES WITH MANY FACTORS OF PRODUCTION.

Within the framework of Hayami and Ruttan model, the tests of induced innovation assume that innovation possibilities are neutral and that all biases are caused by factor price changes.

In this section, we intend to separate observed factor-share changes into a component that results from ordinary factor

TABLE 5.

ARGENTINA. FACTOR SHARES (Si) AND FACTOR PRICES RELATIVE TO AGRICULTURAL OUTPUT PRICES.

| | Sl | Sf | Sm | Sa |
|---|---|---|---|---|
| 1950-54 | 0,762 | 0,103 | 0,036 | 0,099 |
| 1955-59 | 0,620 | 0,134 | 0,106 | 0,141 |
| 1960-64 | 0,467 | 0,207 | 0,173 | 0,153 |
| 1965-69 | 0,457 | 0,247 | 0,165 | 0,130 |
| 1970-74 | 0,494 | 0,218 | 0,167 | 0,121 |
| 1975-79 | 0,289 | 0,268 | 0,245 | 0,198 |
| 1980-84 | 0,300 | 0,336 | 0,215 | 0,148 |
| 1985-89 | 0,309 | 0,398 | 0,135 | 0,157 |
| 1990-92 | 0,459 | 0,282 | 0,113 | 0,145 |
| Mean: | 0,462 | 0,242 | 0,152 | 0,143 |

| | W/Pag | Pf/Pag | Pm*/Pag | Pa/Pag |
|---|---|---|---|---|
| | | (1977=100) | | |
| 1950-54 | 190,2 | 143,3 | 120,4 | 32,4 |
| 1955-59 | 164,3 | 168,0 | 106,4 | 38,1 |
| 1960-64 | 126,0 | 180,2 | 90,6 | 43,3 |
| 1965-69 | 178,1 | 143,9 | 97,2 | 54,3 |
| 1970-74 | 197,2 | 82,0 | 84,3 | 52,9 |
| 1975-79 | 132,5 | 102,2 | 108,1 | 89,9 |
| 1980-84 | 165,1 | 114,7 | 130,9 | 83,7 |
| 1985-89 | 146,4 | 83,7 | 71,5 | 82,6 |
| 1990-92 | 221,8 | 53,9 | 60,2 | 73,0 |

TABLE 6.

UNITED STATES. FACTOR SHARES (Si) AND FACTOR PRICES RELATIVE TO PRICES RECEIVED BY FARMERS.

| | Sl | Sf | Sm | Sa |
|---|---|---|---|---|
| 1950-54 | 0,508 | 0,108 | 0,242 | 0,142 |
| 1955-59 | 0,453 | 0,127 | 0,265 | 0,155 |
| 1960-64 | 0,400 | 0,160 | 0,274 | 0,166 |
| 1965-69 | 0,339 | 0,196 | 0,284 | 0,180 |
| 1970-74 | 0,309 | 0,214 | 0,285 | 0,192 |
| 1975-79 | 0,248 | 0,263 | 0,251 | 0,238 |
| 1980-84 | 0,223 | 0,275 | 0,250 | 0,252 |
| 1985-89 | 0,235 | 0,256 | 0,324 | 0,185 |
| 1990 | 0,245 | 0,257 | 0,330 | 0,168 |
| Mean: | 0,337 | 0,201 | 0,273 | 0,188 |

| | W/PRF | Pf/PRF | idr/PRF | Pa/PRF |
|---|---|---|---|---|
| | | (1977=100) | | |
| 1950-54 | 43,3 | 98,2 | 62,0 | 28,6 |
| 1955-59 | 56,1 | 110,9 | 78,0 | 40,0 |
| 1960-64 | 65,0 | 109,1 | 89,8 | 49,8 |
| 1965-69 | 79,3 | 95,3 | 101,9 | 62,7 |
| 1970-74 | 85,4 | 76,1 | 98,6 | 64,9 |
| 1975-79 | 91,4 | 97,5 | 93,0 | 89,6 |
| 1980-84 | 103,7 | 102,8 | 121,0 | 110,5 |
| 1985-89 | 125,8 | 95,1 | 180,5 | 84,8 |
| 1990-91 | 133,0 | 89,9 | 201,6 | 77,0 |

substitution along the isoquant of the production process and a component that derives from nonneutral shifts in the isoquant. This can be done by measuring biases of technical change.

In this paper, we employed a translog cost function approach with four factors of production (land, labor, fertilizers and machinery) to explain the technical progress in the agricultural sector of Argentina and the United States.

## 4.1. THE TRANSLOG COST FUNCTION.

In order to estimate the underlying structure of production in Argentine and in the U.S. agricultural sector, a cost-function model is utilized. The cost model utilizes four-input cost function (L, M, A, F).

It is possible to think in two forms of cost functions:

-1- $C1 = F1 (P1, P2, \ldots, Pn, Y)$

-2- $C2 = F2 (P1, P2, \ldots, Pn, Y, T)$, where:

C: the minimizing cost.

Pi: prices of n production factors.

Y: output

T: technical index

Equation -1- corresponds to the meta-production function of Hayami and Ruttan. In this equation, the price variables are expected to remove the substitution effect and price-induced technical biases.

In equation -2- , the price variables identify the substitution effect and the technical index captures both price-induced and nonprice-induced technical biases.

In this paper, we assume that the biases of technical change are constant. If this is done, biased technical change at constant exogenous rate can be introduced in the translog cost function:

$$\ln C = \ln Vo + Vy \ln Y + Vt \ln T + \sum_i Vi \ln Pi +$$

$$+ 1/2 \sum_i \sum_j Vij \ln Pi \ln Pj + \text{remainder.}$$

Upon differentiation the share equation become:

$$\partial \ln C / \partial \ln Pi = Si = Vi + \sum_j Vij \ln Pj + Vit \ln T$$

$(i=1,..,n)$

where Vit is the constant exogenous rate of the bias of factor i. Technical change will be factor i using, neutral or saving according to the sign plus, zero or minus of the coefficient Vit.

For the data, we used the following equations estimated with the seemingly unrelated regressions method of Zellner:

$$Si = Vi + \sum_j Vij \ln Pjt + Vit \ln T + ut$$

with constraints:

$Vij = Vji, \quad \forall i,j \quad ; \quad i \neq j$ (symmetry constraint)

$\sum_i Vij = 0, \sum_j Vij = 0 \quad , \forall i,j$ (homogeneity constraint)

$\sum_i Vit = 0$

$\sum_i Vi = 1$

where:

i,j = 1,..,4 are the indices for the factors of production.

t = 1,...,43 denotes the time periods.

Si: Cost share, $Si = Pi * Xi / C$.

C: total cost. $C = \sum_i Pi * Xi$, (i = L, M, F, A).

Pi: price of factor i/ index of agricultural output prices.

Xi: quantity of factor i.

The cost share of input i in the total cost of production, Si, was obtained by dividing the expenditure on each category of factor (Pi * Xi) by the total cost C. The total cost, C, was defined as the sum of the expenditures on these four categories of factor.

The estimates of the coefficients Vij can be converted into point estimates of Allen partial elasticites of substitution ($\sigma ij$) and of elasticities of factor demand (nii) according to the following equations (Binswanger H. and Ruttan V., 1978. "Induced Innovation, Technology, Institutions and Development". The Johns Hopkins University Press):

TABLE 7.

ARGENTINA AND THE UNITED STATES. OWN-PRICE ELASTICITIES AND ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION (AVERAGES FOR 1950-92 (90)).

ARGENTINA.

| | | L | F | A | M |
|---|---|---|---|---|---|
| Own-price Elasticities: | | -0,065<br>(0,039) | -0,290<br>(0,099) | 0,010<br>(0,066) | 0,041 |
| Allen Partial El. of Subst. | L | -0,140<br>(0,039) | 0,286 | 0,148<br>(0,100) | -0,175<br>(0,272) |
| | F | | -1,197<br>(0,099) | 0,296 | 0,752<br>(0,589) |
| | A | | | 0,073<br>(0,066) | -0,997 |
| | M | | | | 0,268 |

UNITED STATES.

| | | L | F | A | M |
|---|---|---|---|---|---|
| Own-price Elasticities: | | -0,655<br>(0,074) | -0,576<br>(0,068) | -0,079<br>(0,035) | -0,351 |
| Allen Partial El. of Subst. | L | -1,943<br>(0,074) | 1,637 | -0,540<br>(0,182) | 1,561<br>(0,182) |
| | F | | -2,866<br>(0,068) | 1,343 | -0,840<br>(0,164) |
| | A | | | -0,419<br>(0,035) | -0,037 |
| | M | | | | -1,287 |

Note: Standard Errors in parentheses are computed as follows: SE(nii) = SE(Vii)/Si. SE(σij) = SE(Vij)/(Si*Sj). The estimates without SE were computed by making use of the linear homogeneity restrictions.

$$\sigma ij = Vij / (Si*Sj) + 1 \quad , \forall i \neq j$$

$$\sigma ii = 1/Si^2 * (Vii + Si^2 - Si) \quad , \forall i$$

$$nii = Vii/Si + Si - 1 \quad , \forall i$$

In the Argentine case, the price of machinery, Pm*, includes the nonrural wholesale prices from 1950 to 1977 and the nominal lending rate of interest from 1978 to 1992, since between 1950 and 1977 interest rate was regulated by the monetary authority. In the U.S. case, Pm includes the discount rate of interest of Federal Reserve Bank of New York.

## 4.2. RESULTS.

The coefficients estimated (Vij), with the translog cost functions resulted significant at the 0,5 level, except Vfm (Vmf), in Argentine case, and Vll in the U.S. case.

The coefficients of the time variable are significant, at the 0,5 level, in the four equations. Technical change was labor-saving , machinery-using, land-saving and fertilizer-using in Argentina, and land-using, fertilizer-using, labor-saving and machinery-saving in the United States.

The Vij coefficients have little economic meaning. They are better evaluated by the values which they imply for elasticities of factor demand and elasticities of substitution (Table 7). The values are computed for the simple average of factor shares, between 1950 and 1992 (90).

In Argentina, the values of labor and fertilizer demand elasticities have the correct sign and labor demand seems to be very inelastic.

Elasticities of substitution should be positive for substitutes and negative for complements. In accordance with the results (Argentine case), substitutability seems to exist between fertilizer and land and between fertilizer and labor. On the other hand, it is observe complementarity between machinery and land. Finally, complementarity between machinery and labor is inconsistent with the Hayami and Ruttan framework.

In the U.S. case, the direct price elasticities of demand are -0,655 for labor, -0,576 for fertilizer, -0,079 for land and -0,351 for machinery.

In the estimation (U.S. case), fertilizer was a substitute for land and labor. Machinery was a substitute for labor and a complement to the land. Finally, fertilizer and machinery were complements for each other. The negative elasticity of substitution between fertilizer and machinery is consistent with the fact that these two categories of technology exist side by side in the United States.

The bias of technical change towards saving labor in the U.S. (using machinery in Argentina) and using fertilizers in both countries likely is associated, respectively, with the rising trend of the prices of labor relative to the agricultural output prices (declines in the prices of machinery in Argentina) and declines in the prices of fertilizers relative to the agricultural output prices. In this sense, the bias of technical change with respect to these factors is constistent with the induced innovation hypothesis.

## CONCLUDING REMARKS.

In this study, we show the differences in output and in output per worker between Argentina and the United States between 1950 and 1990 (1992).

In accordance with the labor productivity identity (Y/L = A/L * Y/A), a higher level of labor productivity can be achieved through either an increasing of the land-labor ratio, higher land productivity, or both.

In spite of land and labor relative endowment has been similar in Argentina and in the United States, Argentina has achieved higher labor productivity through higher land productivity.

In contrast, the United States has achieved higher labor productivity principally by increasing their land-labor ratio. In this country, the land-labor ratio increased between 1950 and 1990 due to rapid labor absorption by the nonagricultural sectors.

In change, Argentina experienced a low increase in the land-labor ratio, during the past four decades. This ocurred, partly because of insufficient labor absorption by nonagricultural sector and partly because of the low wages paid in Argentine agriculture.

Nevertheless, the translog cost function (TCF) with four factor of production (land, labor, machinery and fertilizers) estimated in this paper shows labor-saving bias and machinery-using bias in Argentine case and labor-saving bias in the U.S. case. The TCF also presents fertilizer-using biases in both countries.

Finally, the biases of technical change (machinery-using and fertilizer-using in Argentina and fertilizer-using and labor-saving in the U.S.) are consistent with the induced innovation hypothesis.

## NOTES

(1). The United States farm production sector employed 11,5 percent of the total civilian labor force, by 1950.

Forty years later (1990), it employed 2,6 percent of the total civilian labor force.

The farm sector's contribution to GDP (in 1987 dollars), while varying from year to year, is declining. It dropped from 2,4 percent of GDP in 1960 to 1,5 percent in 1990.

(2). The coefficients of this equation were obtained from Yamada and Ruttan (1980).

(3). The estimations of this identity, for Argentina and the United States, presented the following results:

Argentina: 1950-1992 period.

$$\ln Y/L = \underset{(-0,225)^{*}}{-0,010} \ln A/L + \underset{(21,117)}{0,992} \ln Y/A$$

$\bar{R}^2 = 0,93$
DW = 0,34

United States: 1950-1990 period.

$$\ln Y/L = \underset{(14,335)}{1,358} \ln A/L + \underset{(-3,797)}{-0,337} \ln Y/A$$

$\bar{R}^2 = 0,91$
DW = 0,32

## DATA SOURCES

### ARGENTINA.

#### OUTPUT (Y).

It includes not only crops, but also animal husbandry, fishery and forestry. Output here refers to value added.

Sources. 1950-92. Cuentas del Producto e Ingreso Nacional.

#### LABOR (L).

It refers to the number of workers in the agricultural sector.

Sources. 1950-84. Fundación Mediterránea. IEERAL. (1986) Estadísticas de la evolución económica de la Argentina. Estudios no 39.
1988. Censo Agropecuario.

#### LAND (A).

It includes all land under cultivation (crops and pastures), but excludes natural pasture land.

Sources. 1950-92. Bolsa de Cereales.

#### MACHINERY (M).

It includes stock of tractors measured in equivalent horsepower units.

Sources. 1950-73. Reca L. and Verstraeten J. (1977).
1974-81. Elías V. (1985). "Government Expenditures on Agriculture and Agricultural Growth in Latin America". IFPRI. Research Report no 50.
1982-90. Secretaría de Programación Económica. Ministerio de Economía.
1991-92. Cuentas del Producto e Ingreso Nacional.

#### FERTILIZER (F).

Sum of N, P, and K fertilizers consumed in each year. Fertilizers are measured in terms of nutrients.

Sources. 1950-55. Cuentas del Producto e Ingreso Nacional.

1956-90. World Fertilizer Consumption Statistics. International Fertilizer Industry Association.
1991-92. Tendencias Económicas.

LIVESTOCK (S).

Stock of cattle to June of each year.

Sources. 1950-67. Jarvis L. (1969) "Supply Response in the Cattle Industry: the Argentine Case, 1937-38/1966-67". Ph.D. diss. MIT. Cambridge. USA.
1968-87. INTA. Estación Experimental Marcos Juarez.
1988. Censo Agropecuario.

PRICE OF LAND (Pa).

Sources. 1950-69. Fundación Mediterránea. IEERAL. (1986). Estudios no 39.
1970-92. La Nación. It indicates the price of corn land.

WAGE RATE (W).

Rural wages by a year.

Sources. 1950-84. Fundación Mediterránea. IEERAL. (1986). Estudios no 39.
1985-92. INTA. Estación Experimental Pergamino.

PRICE OF MACHINERY (Pm).

It refers to nonrural wholesale prices.

Sources. 1950-92. Indice de Precios al por Mayor no Agropecuario Total. INDEC.

PRICE OF FERTILIZER (Pf).

It indicates the price of Urea (N).

Sources. 1960-92. Gallacher M. and INTA. Estación Experimental Pergamino.

RURAL WHOLESALE PRICES (Pag).

Agricultural output prices.

Source: Indice de Precios al por Mayor Agropecuario Nacional. INDEC.

INTEREST RATES (i).

Nominal lending rates.

Source: The World Bank.

UNITED STATES.

Sources. 1947-91. Economic Report of the President. Transmitted to the Congress. 1992 and 1993.

OUTPUT (Y).

1950-58: Farm output. It includes feed grains, food grains, oil crops and livestock and products. Farm output measures the annual volume of net farm production.

1959-91: Gross Domestic Product of farm sector, in 1987 dollars.

LAND (A).

Acreage harvested (crops) plus acreages in fruits, tree nuts and farm gardens.

LABOR (L).

Farm labor. Family workers and hired workers.

MACHINERY (M).

Mechanical power and machinery.

FERTILIZER (F).

Includes fertilizers, lime and pesticides.

PRICE OF LAND (Pa).

Average (for 48 States) farm real estate value per acre.

PRICE OF MACHINERY (Pm).

Tractors and self-propelled machinery. Prices paid by farmers.

WAGE RATE (W).

Wages paid by farmers.

PRICE OF FERTILIZER (Pf).

Prices paid by farmers.

INTEREST RATES (idr).

Discount rate of Federal Reserve Bank of New York.

PRICES RECEIVED BY FARMERS (PRF).

All farm products.

PRICES PAID BY FARMERS (PPF).

All commodities, services, interest, taxes and wage rates.

PRICES PAID BY FARMERS (PPF).

Tractors and self-propelled machinery, fertilizers and fuels and energy.