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THE ECONOMIC IMPACTS OF THE PROCISUR PROGRAM: AN INTERNATIONAL STUDY

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THE ECONOMIC IMPACTS OF THE PROCISUR PROGRAM:

AN INTERNATIONAL STUDY

Abstract

The PROCISUR program installed in several Latin American countries in 1988 is designed to facilitate the exchange of agricultural scientific findings between member countries. This paper reports a statistical evaluation of the program's economic impact. The model utilized specifies that the "spill-in" of technology from one country to another is enhanced by the program. Statistical estimates confirm that the program did enhance spill-in of technology in all three commodity programs evaluated (corn, wheat and soybeans). The economic return to program investment, calculated from the estimates, was extraordinarily high indicating that programs of this type can be quite effective.

THE ECONOMIC IMPACTS OF THE PROCISUR PROGRAM: AN INTERNATIONAL STUDY

I. Introduction

The PROCISUR (Programa Cooperativo de Investigación Agricola del Cono Sur) program agreement was signed in 1978 by the countries of Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay. Funding for the program was provided by the Inter-American Development Bank (IADB), by the Inter-American Institute for Cooperation in Agriculture (IICA), and by the participating countries. The original stated purposes of PROCISUR were as follows:

- the strengthening and consolidation of creative research;
- the cooperation in technology transfer from other countries and international agricultural research centers;
- the support in adaptive research efforts;
- the intensification of the interchange of knowledge, experience and information, among the participating countries;
- the cooperation in the search of solutions to common problems.

The administration of the program was the responsibility of IICA and the implementation of the program was assigned to the following agencies in each country:

INTA - Instituto Nacional de Tecnologia Agropecuaria - Argentina

IBTA - Instituto Boliviano de Tecnologia Agropecuaria - Bolivia.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuaria - Brazil

INIA - Instituto de Investigaciones Agropecuarias - Chile

DIEAF - Direccion de Invest. y Extension Agrop. y Florestal - Paraguay

CIAAB - Centro Invest. Agricolas Alberto Boerger - Uruguay

The implementation of the program started in 1980, with emphasis on research cooperation for corn, wheat, soybeans and beef cattle. Starting in 1984, a second stage of PROCISUR, (IICA/BID/PROCISUR), was implemented. In this new stage, training activities and reciprocal cooperation arrangements were emphasized, with the addition of winter cereals, summer cereals, oilseeds, and cattle as program areas. The main programs in PROCISUR are:

Production Systems
Information and Documentation
Technology Transfer
Training
Communication
Administration

PROCISUR is thus a program of scientific exchange between member countries. It supports observation travel, scientific consultancy, participation in scientific meetings and post-graduate training. It has also facilitated the exchange of genetic materials. Its role is primarily to enhance the national agricultural research programs in member countries in facilitating the "spill-in" of research contributions from other countries. It is not intended to be an independent research program. This "spill-in" enhancement effect on national programs will differ according to the relative strength of the national research programs in member countries.

In this paper we develop an analysis of the production data and an evaluation of the PROCISUR program as it affects productivity change in wheat, maize, and soybean production in the member countries since the inception of the program in 1978.[1] We also undertake economic analysis of the benefits of the PROCISUR program in this paper and compare this analysis with other studies in Latin America.

Our analysis requires the development of a statistical model designed to capture the enhancement features of the PROCISUR program as well as accounting for the simultaneity between PROCISUR investment decisions and productivity change and national research programs strengths in the respective countries.[2] An application of the model for the three major commodity programs in PROCISUR; wheat, maize and soybeans, is developed and reported.

Section II of this report summarizes PROCISUR activities relevant to the three commodities. Section III presents the methodology utilized and reports a summary of the data. Section IV presents a summary of the estimates of model parameters. The concluding section interprets the estimates in terms of returns to investments.

II. PROCISUR Activities: A Summary

Most PROCISUR activities can be associated with a receiving and a sending country. They can further be classified according to whether they are oriented to wheat, maize, soybeans, or to general support activities.

The following describes the distinction between sending and receiving countries or regions for ten types of activities supported by PROCISUR:

1. Support for scientific observation travel from country A to country B. (A is the receiving country, B the sending country.)

2. Support for participation in congresses and seminars by scientists from country A but hosted by country B. (A is the receiving country.) All countries are sending countries if it is an international seminar. (B is the sending country if it is a national seminar.)

3. Support for administrative and technical assistance by scientists from country A in country B. (A is the sending country, B the receiving country.)

4. Support for administrative and technical assistance and support by scientists from non-member countries and international centers in country A. (A is the receiving country.)

5. Support for post graduate courses by researchers from country A in

country B or a non-member country. (A is the receiving country.)

6. Support for scientific consultants from country A to work in country B. (B is the receiving country.)

7. Support for scientific consultants from non-member countries to work in country A. (A is the receiving country.)

8. Support for scientific consultants from International Agricultural Research Centers to work in country A. (A is the receiving country.)

9. Support for attendance and participation in technical meetings held in country A. (B is the receiving country.)

10. Support for attendance in technical courses in country A by researchers from country B. (B is the receiving country.)

Some examples will be useful to illustrate the nature of the PROCISUR program. In the PROCISUR corn program, the breeding component of PROCISUR involved a joint program with member countries. The program was successful in the release of several new varieties, including "Compuesto Cono Sur I", from grains of the "flint" class, of high quality (orange coloring). This composite grain was obtained from a recombination of eight different germplasms from Brazil, Uruguay, Paraguay, Bolivia, Chile and Argentina. A convergent-divergent selection method was applied in southern Brazil, Uruguay, Paraguay and Argentina to facilitate the development of the variety.

In the wheat program, a typical example of a PROCISUR contribution to member countries occurred in Brazil. The southern cone yield trials (ERCOS), take place in several locations in the member countries, and the Chilean variety ONDE INIA had the highest yields (6.1 tons/ha) in a trial performed in Brasilia-DF. With some local adaptations, this variety will soon be recommended for the whole of central Brazil.

Brazil is actively engaged in assisting the Argentinian, Paraguayan and Bolivian soybean programs, via PROCISUR. Emphasis is given on the Brazilian integrated pest management control system, and on Brazilian soybean germplasm. The variety CARCARANA INTA (Argentina), for example, has Brazilian germplasm provided through the program. The variety DOKO, from Brazil, is now the most widely planted variety in Bolivian agriculture. Paraguay soybeans technology was brought from Brazil and most of the local producers are Brazilians.

Table 1 summarizes the expenditure of roughly 1.7 million dollars on the 10 activities noted above for the 1980-1987 period. Note that these expenditures cover only the specific activities associated with the three study commodities plus activities that are related to all three commodities.[3] No overhead or administrative expenditures are included. If administrative costs are taken into account these PROCISUR expenditures represent approximately one percent of national agricultural research expenditures on these three commodities over the period since 1980.[4]

The data show that each member country is a significant recipient of PROCISUR activities. Only Brazil sends more than it receives. Bolivia and Paraguay are significant recipients of activities but are not sending countries. International sources (primarily CIMMYT and CIAT) constitute 31 percent of all sources. Brazil accounts for 33 percent of all sources (and 22 percent of all recipients). Thus the program has an "equalizing" effect in that the smaller countries with the least developed national research systems are significant recipient countries even though they are not sending countries.

III. Methods and Data

A. Methods

The methods utilized in this study require an extension of standard productivity decomposition methods in two dimensions. First, the PROCISUR investments must be modeled as being responsive to conditions in both sending and receiving regions and thus simultaneously determined with productivity

Table 1: PROCISUR Activities 1980-1987

Sending Country	Receiving Country: Argentina	Brazil	Bolivia	Chile	Paraguay	Uruguay	Total
I. Maize							
Argentina	-	17867	11418	7641	8595	5394	51915
Brazil	28315	-	22463	5696	26654	11349	94477
Chile	2562	2192	756	-	735	1400	7645
Uruguay	3709	4060	2152	4190	2395	-	16506
International	34254	15281	10500	17000	68313	348	145696
Total Maize	68840	39400	47289	34527	106692	18416	316139
II. Soybeans							
Argentina	-	13691	14620	4371	2164	4999	39845
Brazil	51128	-	24276	18846	36581	15476	146307
Chile	2354	5110	842	-	1718	-	10024
Uruguay	2745	9895	350	2970	2538	-	18498
International	20145	30982	3876	4263	2801	7428	69495
Total Soybeans	76372	59678	43964	30450	45802	27903	284169
III. Wheat							
Argentina	-	15581	11054	18341	12973	10652	68601
Brazil	28153	-	28261	42700	35314	27041	161469
Chile	12396	33148	10341	-	10071	13969	79925
Uruguay	457	10858	4134	9316	3304	-	28069
International	16335	97504	18081	43698	9378	30788	215784
Total Wheat	57798	157091	71871	114055	71040	82450	553848
IV. General							
Argentina	-	31946	11503	22962	9566	15319	91296
Brazil	52101	-	36744	43198	16281	4096	152420
Chile	20856	33864	19184	-	19422	24287	117613
Uruguay	16806	46036	37366	28353	15563	-	144124
International	-	8675	3634	4097	1602	-	18008
Total General	89763	120521	108431	98610	62434	43702	523461
V. Total	292773	376690	271555	277624	285968	172471	1677717

growth. Second the PROCISUR activities must be modeled as <u>enhancing</u> national research programs.

Consider the basic productivity decomposition model:

$$(1)\quad P_{it} = F(R^N_{it}, R^S_{it}, H_{it}, W_{it}, I_{it}, e_{it})$$

where P_{it} is an index of productivity. This may be an index of output per unit of total input. (i.e., "Total Factor Productivity" index) or an index of output per hectare, (a "Partial Factor productivity" index). It is measured for region i and for different time periods.

R^N_{it} is a research "stock" variable constructed from past expenditures on research directed toward improving P_{it} for the region for which P_{it} is measured (i.e., region i). Timing weights are used in the construction of R^N_{it}.[5]

R^S_{it} is a similar research "stock" variable constructed from past expenditures on research directed toward improving P_{jt} in other regions but where those improvements may potentially "spill-in" to region i.

H_{it} is a measure(s) of the human capital skills of farmers in region i. This may also include measures of extension services.

W_{it} is a weather index measuring weather effects in region i, time t.

I_{it} is a measure(s) of public sector infrastructure investments in region i, time t.

e_{it} is an error term.

Equation (1) is often estimated in logarithmic form with cross-section and time series data.

The most critical specification issue for the PROCISUR analysis is the specification of the spill-in variable(s) R^S_{it}. The spill-in of technology is relevant to regions even where a local research program exists. It is also relevant when the receiving region is in a different country from the origin region. Indeed it is this spill-in that the PROCISUR program seeks to facilitate.

Spill-in of technology can be considered to be of three basic types:

Direct - as when the technology originating in region A is directly adopted in region B.

Semi-direct - as when the technology originating in region A is modified or adapted by the research program in region B to be better suited to the conditions in B.

Indirect (or Germplasmic)-as when the research and technical discoveries originating in region A enhance and stimulate the technological research undertaken in region B. This can be thought of as "germplasm" spill-in when the term germplasm is broadly defined to include biological, mechanical and intellectual materials that serve as parents to the further development of materials.

The PROCISUR program does not support the development of the origin technology or germplasm but is designed to facilitate and enhance more international spill-in, chiefly of the indirect type. Thus if we are to measure its impact we require international data and we require an interaction specification to test for a PROCISUR impact. We have the further econometric problem that the PROCISUR activities might be responsive to productivity changes and thus be endogenous in the model. Simultaneous equations estimates will be required to deal with this problem. Finally, we also have to deal with the fact that geo-climate factors affect spill-in (and spill-out) and these must be taken into account.

Our procedure entails defining three research variables: R_{it}^{N}, R_{it}^{S} as discussed above and an additional PROCISUR enhancement variable, R_{it}^{SP}.

The first variable, R_{it}^{N}, is the research stock variable where the research activities are directed toward improving productivity in region i:

$$(2) \quad R_{it}^{N} = \sum_{\ell} W_{t-\ell} r_{i,t-\ell}$$

Where the $W_{t-\ell}$ are time weights reflecting the time relationship between research expenditure, $r_{i,t-\ell}$ and productivity. Research conducted in time t typically will not have an immediate impact on productivity. Many research projects do not have impacts for several years (some never do). These timing weights have been estimated in other studies (e.g., da Cruz and Evenson, 1989). Based on these other estimates they are taken to be:

0 for $\ell = 0,1$
.2 for $\ell = 2$
.4 for $\ell = 3$
.6 for $\ell = 4$
.8 for $\ell = 5$
1 for $\ell = 6$ and higher

This procedure effectively creates a research stock where the service flow creating productivity gains from that stock may be considered to be constant over time.

The second variable, R_{it}^{S}, is the basic spill-in variable. It is defined as:

$$(3) \quad R_{it}^{S} = \sum_{j} G_{ij}^{\alpha} R_{jt}^{N}$$

where the R_{jt}^{N} are research stocks (defined as in (2)) directed toward region j, but which can potentially spill-in to region i. The G_{ij}^{α} are geo-climate spill-in weights measuring the proportionate value of research in region j to productivity enhancement in region i via direct, semi-direct and indirect spill-in. These weights are estimated in three steps (see below). They are designed to adjust for geo-climate impediments to technology spill-in.

The third variable is the PROCISUR enhancement variable. It is defined as:

$$(4)\quad R_{it}^{SP} = \sum_j G_{ij}^{\alpha} R_{jt}^{N} PR_{ijt}$$

where the G_{ij}^{α} and R_{jt}^{N} are defined above. The PR_{ijt} are the cumulated (to time t) expenditures on PROCISUR activities where i is the receiving region and j is the sending region. Thus R_{it}^{SP} is an interaction variable designed to test whether PROCISUR activities increase or enhance the value of spill-in research. It is defined with respect to sending and receiving regions. (See below for a further discussion.) (Note that since the R_{it}^{S} variable is also included in the regression this variable picks up the PROCISUR enhancement effect.)

It can be reasonably argued that the time lag inherent in the $W_{t-\ell}$ weights effectively creates a "recursive" structure between the research spending variables and productivity change. Since it takes time before research affects productivity, the current research stock is unlikely to be influenced by current productivity change. It cannot be argued, however, that the PROCISUR activities do not respond to the perceived opportunities for research enhancement. We would expect that PROCISUR activities, PR_{ij}, would respond positively to the past productivity performance in region j and negatively to the current research capacity in region i. Accordingly the R_{it}^{SP} variable should be treated as an endogenous variable in a simultaneous system with equation (1). We thus have the following two equation system that we will estimate using Zellner's SUR procedure.

(5) $P_{it} = f(R^{N}_{it}, R^{S}_{it}, R^{SP}_{it}, W_{it}, I_{it})$

(6) $R^{SP}_{it} = f(R^{N*}_{it}, P^{*}_{jt}, I_{it})$

where P^{*}_{it} is defined as $\sum_{j} G_{ij} P_{jt}$, * indicates lagged values.

B. Data and Variable Definitions

Data have been assembled from a number of sources for 14 regions for the 1966-87 period. The regions included 6 states in Brazil (Mato Grosso, Minas Gerais, Parana, Sao Paulo, Santa Catarina and Rio Grande do Sul), 4 states in Argentina (Buenos Aires, LaPampa, Cordoba and Santa Fe), Bolivia, Chile, Paraguay and Uruguay. Table 2 reports variable definitions. Note that we have used a logarithmic specification. This is a general and flexible functional form.

Table 3 reports comparative mean values for the key research and extension variables for alternative groupings of states (regions). These data show that PROCISUR impacts have been highest for other countries and lowest for Brazil. (This is defined as the ratio R^{SP}_{it}/R^{S}_{it}.)

C. Estimation of the G^{α}_{ij} Spill-in Weights.

The estimation of the G^{α}_{ij} is weights actually entailed 3 steps:

Step 1. Establishing Geo-climate Region Relationships.

Appendix 1 provides the geo-climate classification and a map of geo-climate regions by Papadakis (1975). This classification is the most detailed available with international coverage. The relevant geo-climate regions for the PROCISUR states include 1.2, 1.4, 1.9, 2.4, 4.1, 4.3, 3.8, 5.7, 5.1, 7.1, 5.3, 6.2, and 6.3. A ratio of relative productivity between each pair of regions was constructed based on the geo-climate "distance" between the

Table 2: Variable Definitions: PROCISUR Analysis

I. Endogenous Variables

LIYIELD: Natural logarithm of the commodity yield index. For each region or state and commodity this index was constructed as the ratio of yield in year t to the 1966-70 average yield. Thus regional differences in the 1966-70 average yields are not incorporated in this index.

LPRNGHI: Natural logarithm of the PROCISUR spill-in research stock (see equation 4). This is the PROCISUR enhancement variable (see below for estimation of the G_{ij} weights). PROCISUR data include the cumulated commodity data plus the general data (see Table 1).

II. Exogenous Variables (1 indicates that the variable is included in LIYIELD equation, 2 that it is included in the LPRNGHI equation)

(1) LCRESEXP: Natural logarithm of the states research stock, R_{it}^{N} (see equation 2). This variable is constructed from research expenditures in the state.

(1) LRNGHI: Natural logarithm of the spill-in research stock, R_{it}^{S}, (see equation 3). This is the basic spill-in research stock (see below for estimation of the G_{ij} weights.

(1) LSRNR: LCRESEXP times R_{it}^{S} the spill-in research stock.

(1) LEXTA: Natural logarithm of field extension staff (for all crops) per hectare of cultivated land. The time weights are .25 for $\ell = 0$, .5 for $\ell = 1$, .25 for $\ell = 2$, 0 for ℓ greater than 2).

(1) LRESEX: LCRESEXP times the extension stock.

(2) LSTRESA: The average of LCRESEXP for periods t-1, t-2, t-3, and t-4.

(2) LNYIELDA: Natural logarithm of the spill-in in weighted yield index averaged for periods t-1, t-2, t-3 and t-4. Defined as:

$$\sum_{j} G_{ij}^{\alpha} Y_{jt}^{*}$$

(2) YEAR: A time variable, 1966, 1964, etc.

(1) GOOD, POOR, BAD: Dummy variables for weather effects: GOOD = 1 if yields are more than 1-1/2 standard deviations above trend. POOR = 1 if yields are from 1-1/2 to 2 standard deviations below trend. BAD = 1 if yields are more than 2 standard deviations below trend.

(1, 2) BRMT, BRMG --- Bolivia: Dummy variables for states.

Table 3: Comparative Means: PROCISUR Data

	Brazil	Argentina	Others	All
I. Maize				
State Research Stock	702	1,995	7,445	2,257
Neighbors Research Stock	15,249	8,905	11,150	12,452
State Extension	.0009	.029	.37	.070
PROCISUR	392	513	933	523
II. Wheat				
State Research Stock	1,550	2,633	5,911	3,105
Neighbors Research Stock	23,239	15,543	17,249	19,329
State Extension	.0009	.03	.32	.10
PROCISUR	782	1,059	1,586	1,091
III. Soybeans				
State Research Stock	1,825	2,202	5,093	2,736
Neighbors Research Sock	19,339	11,493	16,166	16,584
State Extension	.0009	.03	.25	.070
PROCISUR	294	1,856	1,435	970

regions. For example between regions 1.2 and 1.4 the ratio was .9, between 1.2 and 2.4 it was judged to be .8, between 1.2 and 6.2 it was judged to be only .1. These relative ratios were thus constructed for all geo-climate region pairs.

Step 2: Conversion to state G_{ij} ratios.

For each commodity the distribution of acreage within a state was determined. The proportions were then used as weights in state i to determine the relative spill-in potential weight G_{ij} from state j.

State 3. Estimating α.

This entailed a simple iteration where α was alternatively set equal to 1, 2 and 3. Table 4 reports R^2 values for the first equation and for the SUR system for alternative α's. For all three commodities the $\alpha = 1$ weights were estimated to be the appropriate weights. These estimated G_{ij}^{α} weights between regions for maize are reported in Table 5.[6]

IV. Model Estimates

Table 6 summarizes estimates of the key parameters of the model for the third stage simultaneous equations estimates for pooled data for all 14 states and for the 6 Brazilian states. Appendix 2 reports the full set of regressions on which the summary is based.

Table 6 does not report estimates for the second equation in the system. Reference to Appendix 2, however, will show that in all cases the expected relationship between PROCISUR inputs and the key predicting variables is borne out. The sign on the lagged state research variable, LSTRESA, is always negative. The sign of the lagged productivity variable, LNYIELDA is always positive. All coefficients are statistically significant. This indicates that, as expected, PROCISUR activities repond positively to spill-in potential as measured by the productivity performance of spill-in geo-climate neighbors. These activities also respond positively to low research capacity in the

Table 4: PARAMETER ESTIMATES

	Maize		Wheat		Soy	
α	$R^2(1)$	$R^2(S)$	$R^2(1)$	$R^2(S)$	$R^2(1)$	$R^2(S)$
$\alpha = 1$	.5987	.7374	.7215	.6910	.7438	.7098
$\alpha = 2$	.5015	.7238	.7012	.6922	.7429	.7202
$\alpha = 3$	.4377	.7044	.6735	.6878	.7351	.7177

Notes: $R^2(1)$ is the R^2 for equation (1)

$R^2(S)$ is the R^2 for the system

Table 5: Interregional G_{is} Weights (Maize)

Receiving Region	Sending Region													
	Brazil						Argentina							
Brazil	Mato Groso	Minas Gerias	Parana	Sao Paulo	Santa Caterina	Rio Grande de Sul	Buenos Aires	La Pampa	Cordoba	Santa Fe	Bolivia	Chile	Paraguay	Uruguay
Mato Groso	1													
Minas Gerias	.8	1												
Parana	.5	.5	1											
Sao Paulo	.55	.5	.55	1										
Santa Caterina	.6	.8	.8	.7	1									
Rio Grande de Sul	.6	.8	.8	.7	1.0	1								
Argentina														
Buenos Aires	.2	.2	.3	.25	.3	.3	1							
La Pampa	.1	.2	.2	.15	.3	.3	.6	1						
Cordoba	.2	.4	.3	.35	.6	.6	.8	.8	1					
Santa Fe	.3	.3	.4	.3	.5	.5	.6	.6	.7	1				
Bolivia	1.0	.8	.5	.85	.6	.6	.2	.1	.2	.3	1			
Chile	.2	.3	.4	.25	.4	.4	.2	.4	.4	.4	.2	1		
Paraguay	.8	.4	.4	.6	.7	.7	.4	.4	.4	.2	.8	.7	1	
Uruguay	.6	.8	.8	.7	1.0	1.0	.3	.3	.6	.5	.6	.4	.7	1

Table 6: Third Stage Estimates of Key Parameters: PROCISUR Analysis

	6 Brazil States			All PROCISUR States		
	Maize	Wheat	Soybeans	Maize	Wheat	Soybeans
I. Parameter Estimates						
LN (State Research) LCRESEXP	-.0111**	-.0049	-.0021	.0135**	.0058*	-.0003
LN (State Research) x Spill-in Research LSRNR	-7.613(12)	6.831(10)	-2.375(10)**	-3.455(10	1.103(10)	-2.741(10)***
LN (State Research) x Extension	6.064**	9.006**	4.028	.0002	-.0007	-.0065**
LN (Spill-in Research) LRNGHI	.0254**	.0061	.0773***	.0321**	.0502***	.0669***
PROCISUR Enhancement LPRNGHI	.0061**	.0065***	.0104***	.0165***	.0067***	.0145**
LN (Extension) LEXTA	.0131	-.054*	-.045	-.061**	-.083	-.044
Wtd. R^2 for System	.825	.835	.815	.750	.720	.784
II. Computed Marginal Elasticity						
State Research	.0188	.0258	.0343	.0096	.0886	.0238
PROCISUR	.0061	.0065	.0104	.0165	.0067	.0145
III. Computed Marginal Products						
State Research	1.3	1.5	2.3	.8	5.9	1.6
PROCISUR	12	11	20	33	11	29
IV. Computed Marginal Internal Rates of Return						
State Research	36	39	50	26	78	41
PROCISUR	115	110	148	191	110	179

Notes:

Appendix 2 provides full regression estimates
Numbers in parentheses are E (-N) indicators, i.e., the decimal point is moved n place to the left
* indicates "t" ratio between 1.5 and 2.0
** indicates "t" ratio between 2.0 and 3.0
*** indicates "t" ratio greater than 3.0
Elasticities are evaluated at mean levels of interacted variables.
State Research includes spill-in.

recipient state. These results support the general validity of the model and lend credence to the PROCISUR enhancement estimates reported in Table 6.

The estimates reported in Table 6 are reported for Brazil states and for the aggregate of all states. We expect the aggregate results to be the most reliable generally because they capture the international effect of PROCISUR through cross-section variation. It would be much more difficult to measure a PROCISUR effect for a country with only a single time series (e.g., Paraguay) because of the limited number of observations. Nonetheless it is of interest to disaggregate the data to some extent to investigate whether there are significant differences between groups of states.

We have provided computed marginal productivity elasticities and marginal products to enable the reader to interpret the net impacts of the research variable. The marginal elasticity for state research is computed as:

(7) $dln(Y)/dln(R^N) + dln(Y)/dln(R^S)$

where the interacting variables entering into these derivatives are evaluated at mean levels in the relevant data set. Thus the fact that for maize and soybeans the interaction terms (LSRNR) between state and spill-in research are negative (indicating that spill-in research is a substitute for state research) does not mean that the marginal product of research is negative. The negative term is more than offset by other positive terms.

The results are generally as expected for the agricultural research variable in all three commodities. Spill-in research is highly significant in all commodities for Brazil and for all states combined. Spill-in research is a substitute for state research in maize and soybeans. State research is also significantly positive in maize and wheat. The combined effects of state research plus spill-in are significantly positive for all commodities in all regional groupings.

The results for extension are much weaker. Few significant extension coefficients are estimated.

Our chief interest is in the PROCISUR enhancement variable, LPRNGHI. If PROCISUR has had an impact, we expect first that spill-in research is a significant determinant of productivity, and second that it has a higher impact when enhanced by PROCISUR activity. The estimates show significant PROCISUR enhancement effects for all 3 commodities for both data sets. This can be regarded to be a strong result given the data and given the consistency of the second equation results. The finding of PROCISUR impacts of roughly similar magnitude in each commodity and data set lends further credence to the results.

V. Economic Implications

Table 6 reports the calculated estimated marginal productivity elasticities for the state research programs and for PROCISUR. These are computed as the logarithmic derivatives of the estimated equations. Where a variable is involved in the calculation it is set to its mean value in the relevant data set. These elasticities are approximately comparable to those obtained in other studies of this nature (see Evenson, 1988, for a review).

It is possible to compute the marginal products from the elasticities by making use of the relationship:

(8) MP = Elasticity (times) Average Product

This is the general formula for the marginal product of the research stock. The average product must thus be computed as the ratio of the cumulated stock to the value of agricultural product. The average stock is approximately 5 times the average investment level in the PROCISUR data since research spending is rising. Data for Brazil and other PROCISUR countries indicate that research expenditures relative to commodity value was approximately .003 for maize and soybeans and .0035 for wheat. PROCISUR spending as noted earlier is actually only one percent of national research expenditures for the recent years.

These factors are then used to convert the elasticity estimates into marginal product estimates in Table 6. These marginal products are to be interpreted as the annual benefit stream (adjusted for time weights) from a single one dollar investment in time "t". Thus a one dollar investment in maize research in time "t" will produce an income stream of .8 dollars that will be realized in future periods according to the time weights. They indicate that nothing will be realized in year t+1, .16 in year t+2 (.2x.8), .32 in year t+3 (.4x.8), .48 in year t+4 (.6x.8), .64 in year t+5 (.8x.8), and .8 thereafter (.8x1). This can then be treated in an investment context and an internal rate of return to investment calculated. (See Table 6.)[7]

In the case of maize research, a one dollar investment in time t will yield an internal rate of return to investment of 26 percent. The comparable internal rate of return for wheat in all PROCISUR regions is a very high 78 percent. The internal rate of return for soybeans is 41 percent.

For Brazilian research the comparable internal rates of return are 36 percent for maize, 39 percent for wheat and 50 percent for soybeans. These returns (except for wheat) are somewhat lower than estimated in other studies but nonetheless represent high returns to investment. (See Evenson, 1989, for a review.)

The returns to PROCISUR research can also be computed. Note that the marginal products are extraordinarily high for PROCISUR impacts. Since PROCISUR enhances national research programs and since there is a lag between PROCISUR spending and enhancement, the time lags are somewhat longer than for national research spending. Taking these time lags to be double those of national research spending we find internal rates of return to PROCISUR of 191 percent for maize, 110 percent for wheat and 179 percent for soybeans. (The comparable figures for the six Brazilian states are 115 percent for maize, 110 percent for wheat, and 148 percent for soybeans.) These are extraordinarily high rates of return. Even if they are overestimated by a factor of 4, they are still extraordinarily high. They are higher than the rates of return of International Agricultural Research Centers (IARCs). For the case of IARC investment in maize, millets and sorghum, in Latin America, Evenson (1988) found rates of return above 80 percent.

For purposes of comparison we report in Table 7 a compilation of a number of other studies evaluating returns to investment in agricultural research in Latin American countries. These studies generally report high estimated rates of returns. The estimates reported for national research programs in this study are generally comparable to those summarized in Table 7. The estimated returns to PROCISUR programs exceed virtually all such estimates for investment in national programs.

It would seem reasonable to conclude that the marginal returns to PROCISUR appear to be extremely high. They indicate that the PROCISUR program, which is actually a relatively small program (only one percent of national research spending), has had an extraordinarily high "leverage" factor giving it very high returns. The program clearly has been effective and has yielded large benefits. The signals presented by this study indicate that it can fruitfully be continued and expanded.

The relevance of PROCISUR type programs to other regions and countries will depend on the willingness of the research units to cooperate in the program. Cooperation in the PROCISUR program appears to have been very good and the program appears to have been effectively administered.

Table 7: Internal Rates of Return for Selected Studies in Latin America

Study	Year	Country	Commodity	IRR - %
Barletta	1970	Mexico	Crops	45-93
Barletta	1970	Mexico	Wheat	90
Barletta	1970	Mexico	Maize	35
Ayer	1970	Brazil	Cotton	77
Ayer & Schuh	1972	Brazil	Cotton	77-110
Hines	1972	Peru	Maize	35-40
Hertford, Ardilla	1977	Colombia	Rice	60-82
			Soybeans	79-96
			Wheat	11-12
			Cotton	None
Wennergren and Whitakker	1977	Bolivia	Sheep	44
			Wheat	-48
Scobbie & Posada	1978	Bolivia	Rice	79-96
Norton, Ganoza & Pomareda	1987	Peru	Rice	17-44
			Corn	10-31
			Wheat	18-36
			Potatoes	22-42
			Beans	14-24
			Aggregate	17-38
Monteiro	1975	Brazil	Cocoa	16-18
Fonseca	1976	Brazil	Coffee	23-26
Moricochi	1978	Brazil	Citrus	18-28
Avila	1980	Brazil	Irrigated Rice	87-119
Ribeiro	1982	Brazil	Rice	36
			Cotton	69
			Soybean	48
Pinazza & Gemente	1983	Brazil	Sugarcane	35
Roessing	1984	Brazil	Soybean	45
Ambrosi & da cruz	1984	Brazil	Wheat	59
Ayres	1985	Brazil	Soybean	46

Sources: Evenson (1988), Echeverria (1989)

FOOTNOTES

1. A preview study by Evenson and da Cruz (1989) provided an earlier analysis of PROCISUR data. The PROCISUR evaluation project also entailed national studies for Brazil, Paraguay, Bolivia, Uruguay, Argentina and Chile.

2. A central feature of our analysis is that we do not treat PROCISUR investments as exogenously determined. We specifically model the determinants of this investment and treat PROCISUR investments as an endogenous variable in our estimates.

2. Sending and receiving countries are determined as noted in the text above.

4. This, of course, is a small percentage of total research spending. PROCISUR, however, is by its nature, an enhancing and facilitating program and should not be expected to be large relative to the national programs.

5. See Evenson, 1982 and Huffman and Evenson, 1989 for a fuller development.

6. Maximizing R^2 over α is equivalent to minimizing the sum of squared errors in the equation. This is effectively a non-linear least squares procedure for estimates α.

The estimated weights for soybeans and for wheat differed from those for maize only slightly.

7. The internal rate of return is the discount interest rate at which the discounted benefits over future periods is equal to one in period t.

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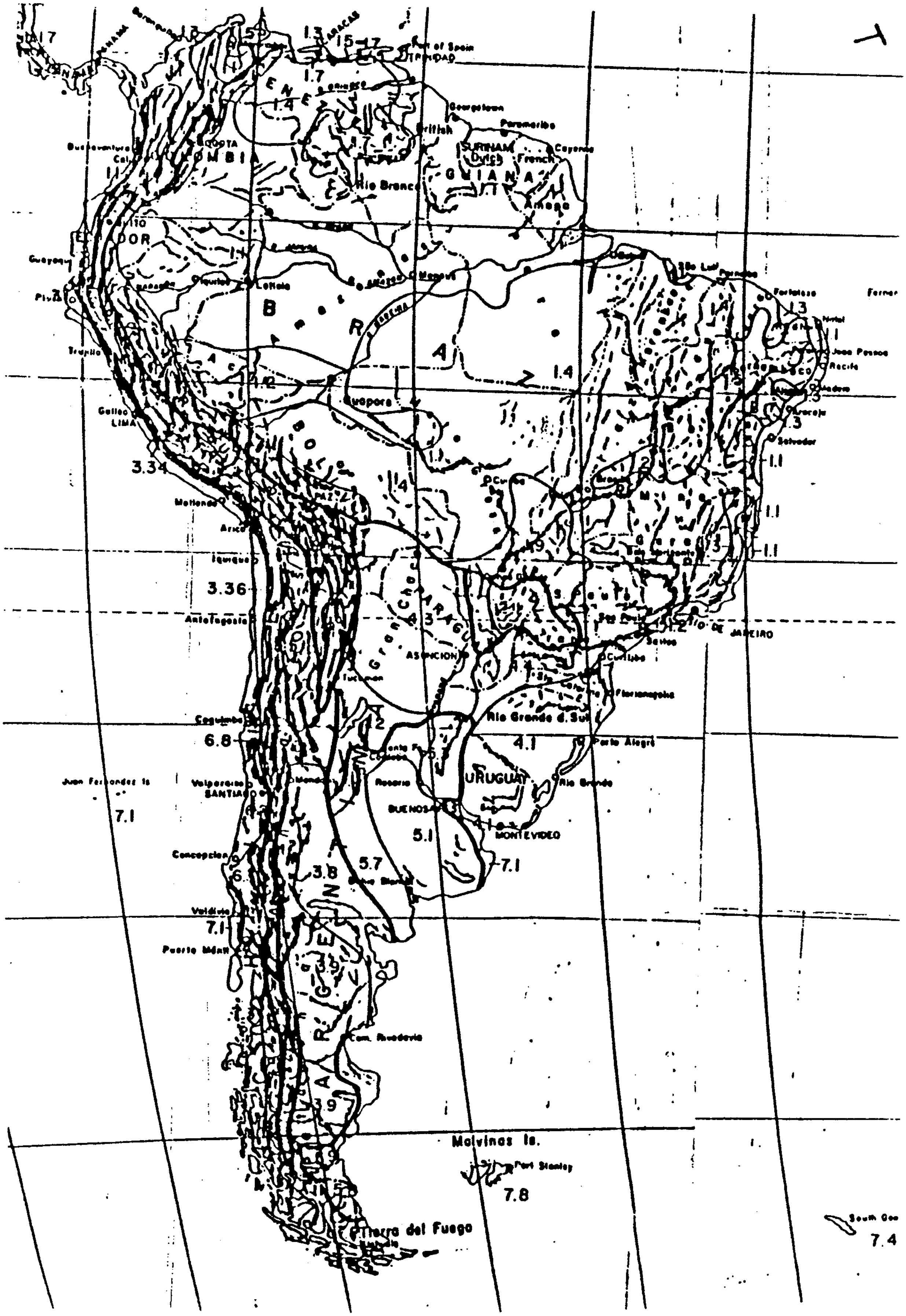
APPENDIX 1: GEO-CLIMATE REGIONS



1. TROPICAL

- 1.1 Semi-hot equatorial. Ex. Jakarta, Indonesia
- 1.2 Semi-hot tropical. Ex. Rio de Janeiro, Brasil
- 1.3 Dry semi-hot tropical. Ex Accra, Ghana
- 1.4 Hot tropical. Ex. Madras, India
- 1.5 Semiarid tropical. Ex. Niamey, Niger
- 1.6 Cool tropical. Ex. Hamilton, Bermuda
- 1.7 Humid tierra templada. Ex. San José, Costa Rica
- 1.8 Dry tierra templada. Ex. Tabora, Tanzania
- 1.9 Cool winter hot tropical. Ex. Calcutta, India

2. TIERRA FRIA

- 2.1 Semi-tropical tierra fria. Ex. Bulawayo, Rhodesia
- 2.2 Low tierra fria. Ex. Tananarive, Madagascar
- 2.3 Medium tierra fria. Ex. Mexico City, Mexico
- 2.4. High tierra fria. Ex. La Paz, Bolivia
- 2.5 Low andine. Ex. Puno, Peru
- 2.6 High andine. Ex. Cerro de Pasco, Peru
- 2.7 Andine mist forest. Ex. Pangerango, Indonesia
- 2.8 Andine tundra
- 2.9 Andine sub-glacial desert

3. DESERT

- 3.1 Hot tropical desert. Ex. Massawa, Ethiopia
- 3.2 Hot subtropical desert. Ex. Cairo, U.A.R.
- 3.3 Semi-hot or cool tropical desert. Ex. Lima, Peru
- 3.4 Cool subtropical desert. Ex. Walwis Bay, S.W. Africa
- 3.5 Tropical highland desert. Ex. Las Anod, Somalia
- 3.7 Continental desert. Ex. Kashgar, China
- 3.8 Pampean desert. Ex. Mendoza, Argentina
- 3.9 Patagonian desert. Ex. Col. Sarmiento, Argentina

4. SUBTROPICAL

- 4.1 Humid subtropical. Ex. Porto Alegre, Brasil
- 4.2 Monsoon subtropical. Ex. Lahore, Pakistan
- 4.3 Hot semi-tropical. Ex. Asunción, Paraguay
- 4.4 Semi-hot semi-tropical. Ex. Miami, Fl., U.S.A.
- 4.5 Semi-mediterranean subtropical. Ex. Cherat, Pakistan

5. PAMPEAN

- 5.1 Typical pampean. Ex. Nueve de Julio, Argentina
- 5.2 Highland pampean. Ex. Pigué, Argentina
- 5.3 Subtropical pampean. Ex. Houston, Tex., U.S.A.
- 5.4 Marine pampean. Ex. Christchurch, N. Zealand
- 5.6 Monsoon peri-pampean. Ex. Cordoba, Argentina
- 5.7 Semiarid peri-pampean. Ex. San Angelo, Tex., U.S.A.
- 5.8 Patagonian grassland. Ex. Fairlie, N. Zealand
- 5.9 Semiarid patagonian. Ex. Lago Argentino, Argentina

6. MEDITERRANEAN

- 6.1 Subtropical mediterranean. Ex. Sevilla, Spain
- 6.2 Marine mediterranean. Ex. San Francisco, Cal., U.S.A.
- 6.3 Cool marine mediterranean. Ex. Seattle, Wash., U.S.A.
- 6.4 Tropical mediterranean. Ex. Funchal, Madeira
- 6.5 Temperate mediterranean. Ex. Marseille, France
- 6.6 Cold temperate mediterranean. Ex. Erzurum, Turkey
- 6.7 Continental mediterranean. Ex. Thessaloniki, Greece
- 6.8 Subtropical semiarid mediterranean. Ex. Murcia, Spain
- 6.9 Continental semiarid mediterranean. Ex. Teheran, Iran

7. MARINE

- 7.1 Warm marine. Ex. Auckland, N. Zealand
- 7.2 Cool marine. Ex. London, U.K.
- 7.3 Cold marine. Ex. Sitka, Alaska, U.S.A.
- 7.4 Polar marine. Ex. Heard Island
- 7.5 Warm temperate. Ex. Bordeaux, France
- 7.6 Cool temperate. Ex. Berlin, Germany
- 7.7 Cold temperate. Ex. Helsinki, Finland
- 7.8 Humid patagonian. Ex. Ushuaia, Argentina

Appendix 2. Regression Estimates

Appendix Tables 2.1, 2.2 and 2.3 report third stage (least squares) SUR estimates for maize, wheat and soybeans for all regions. Note that regional dummy variables are included.

Appendix Tables 2.4, 2.5 and 2.6 report comparable estimates for Brazil states only.

Appendix 2: Third Stage Estimates (SUR System)
Equation (1) Estimates: All PROCISUR Regions,
Dependent Variable LIYIELD (t-ratio in parenthesis)

	Maize	Wheat	Soybean
INTERCEPT	-1.1024(3.22)	-1.5161(4.37)	-1.1684(3.07)
BRMT	.1173(2.13)	.0733(1.14)	-.3700(5.01)
BRMG	.0994(.150)	.1856(3.21)	.2840(4.03)
BRSP	.1321(2.13)	.1906(3.54)	-.0064(.10)
BRPR	.0097(.19)	-.1150(2.66)	.0631(1.31
BRSC	.1155(1.93)	.2033(3.89)	-.1103(1.76)
SANTAFE	.5231(3.16)	.8728(5.82)	.3419(1.67)
CORDOBA	.5395(3.07)	.7849(4.82)	.3184(1.50)
BUENOS	.4892(2.96)	.6171(4.02)	.2546(1.27)
LAPAMPA	.9117(5.35)	.7534(4.88)	-
URUGUAY	-	-.1652(1.71)	-.4790(3.44)
PARAGUAY	.5725(2.35)	.7362(3.25)	.3848(1.32)
BOLIVIA	-.0836(1.39)	.1776(3.34)	-.0265(.41)
CHILE	-	.7440(3.26)	-
LCRESEXP	.0135(3.81)	.0058(1.85)	-.00003(.01)
LRNGHI	.0321(2.55)	.0502(3.85)	.0669(5.23)
B1.LPRNGH1	.0165(5.36)	.0067(3.09)	.0145(5.65)
LRESEX	.0002(.13)	-.0008(.52)	-.0066(3.89)
LSRNR	-3.4558E-10(2.50)	1.1033E-11(.16)	-2.7447E-10(3.06)
LEXTA	-.0649(2.39)	-.0829(3.24)	-.0441(1.31)
GOOD	.1009(1.71)	.2106(4.39)	.2034(4.02)
POOR	-.1469(6.04)	-.2137(9.97)	-.1904(7.64)
BAD	-.3389(7.84)	-.6269(13.11)	-.3916(10.76)

Equation (2) Estimates: All PROCISUR Regions,
Dependent Variable LPRNGH1

	Maize	Wheat	Soybean
INTERCEPT	-2496.04(6.84)	-2302.56(7.21)	-2617.11(7.24)
BRMT	-4.1182(1.87	-3.9881(1.74)	-.8110(.28)
BRMG	-.4090(.20)	.4062(.19)	.4314(.20)
BRSP	.1399(.07)	.3474(.16)	.7983(.37)
BRPR	.2865(.14)	.5535(.26)	.3664(.17)
BRSC	.0431(.02)	-.1521(.07)	.0343(.02)
SANTAFE	-3.5668(1.73)	.5790(.27)	-.9392(.42)
CORDOBA	-2.8410(1.40)	.9381(.44)	.4886(.20)
BUENOS	-3.3527(1.64)	.4680(.22)	.5878(.27)
LAPAMPA	-7.1711(3.12)	-4.2235(1.76)	-
URUGUAY	-	-1.3384(.62)	-1.8412(.63)
PARAGUAY	-.5578(.28)	1.5486(.71)	2.5250(1.14)
BOLIVIA	.3294(.16)	1.6691(.77)	2.7908(1.26)
CHILE	-	-.2815(.12)	-
LSTRESA	-.5767(3.68)	-.5267(3.26)	-1.0066(4.48)
LNYIELDA	17.5862(2.89)	20.8993(4.99)	19.0251(3.21)
YEAR	1.2707(6.86)	1.1727(7.23)	1.3343(7.28)

Appendix 2 (continued)

Equation (1) Estimates: Brazil, Dependent Variable LIYIELD

	Maize	Wheat	Soybean
INTERCEPT	-.0762(.23)	-.5037(1.28	-1.3156.(2.56)
BRMT	-.0608(1.70)	-.0726(1.06)	-.3964(5.80)
BRMG	-.0929(1.81)	-.0389(.53)	.2306(2.35)
BRSP	-.0077(.18)	.0372(.69)	-.0436(.54)
BRPR	-.0211(.87)	-.1406(4.81)	.0499(1.12)
BRSC	-.0398(.96)	.0852(1.69)	-.1520(2.05)
LCRESEXP	-.0111(2.62)	-.0049(1.03)	-.0022(.57)
LRNGH1	.0254(2.46)	.0061(.39)	.0773(4.23
B1.LPRNGH1	.0061(3.42)	.0065(3.12)	.0104(2.72)
LRESEX	6.0638(2.21)	9.0066(2.53)	4.0287(.74)
LSRNR	-7.6127E-12(.10)	6.8345E-11(1.29)	-2.3750E-10(2.13)
LEXTA	.0131(.55)	-.0548(2.08)	-.0451(.99)
GOOD	.1120(3.12)	.1244(2.82)	.1975(2.27)
POOR	-.1349(8.44)	-.1321(5.64)	-.1760(5.14)
BAD	-.3526(12.48)	-1.7381(20.32)	-.4103(11.96)

Equation (2) Estimates: Brazil, Dependent Variable LPRNGH1

	Maize	Wheat	Soybean
INTERCEPT	-2369.53(4.42)	-2019.44(3.98)	-1875.94(3.61)
BRMT	-4.0639(1.58)	-5.429(2.19)	-1.7266(.55)
BRMG	-.2692(.14)	.5458(.24)	.9843(.44)
BRSP	.2069(.11)	.5887(.26)	1.6545(.73)
BRPR	.3898(.21)	.7673(.33)	.8614(.38)
BRSC	.0550(.03)	-.2047(.09)	.0707(.03)
LSTRESA	-.5337(1.68)	-.8490(2.92)	-1.9589(4.38)
LNYIELDA	22.4091(2.44)	28.1169(3.43)	39.2495(3.63)
YEAR	1.2063(4.43)	1.0311(4.01)	.9652(3.67)