ABSTRACT

Title of dissertation: THE IMPACT OF TRADE AND POLICY LIBERALIZATION ON ARGENTINA'S AGRICULTURAL SECTOR: TECHNOLOGY ADOPTION IN A DYNAMIC MODEL

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This dissertation analyzes the effect of policies associated with increased openness of the economy on the development of the agricultural sector, with a focus on adoption of technology. It investigates with the help of econometric tools the determinants of the adoption of technology in Argentina. In addition, it analyzes the possible growth paths that result with the implementation of policies using a recursive dynamic Computable General Equilibrium (CGE) model.

During the last 20 years Argentina experienced extraordinary changes in its agricultural production. Both production and productivity increased very significantly as well as exports. One of the main drivers of these changes was the massive incorporation of technological change such as improved seeds, greater use of agrochemicals and machinery and agronomic technologies such as zero tillage. This study analyzes the impact of the economic

environment on the adoption of technology. The results confirm the argument that the stability of the economy and liberalization motivates producers to adopt new technology. This motivation can be the consequence of the need to adopt new technology because otherwise producers lose competitiveness in the world market and/or because the stability and transparency of the economy makes producers more comfortable with the idea of innovation.

The second major element of the research is the analysis of the impacts that the possible trade agreements that the Argentine government is involved right now, one representing free trade world wide (WTO) and the other a Western hemisphere free trade bloc (FTAA), could have on agriculture.

The results leave us with the idea that for the agricultural sector it is worth pushing for the full implementation of free trade in the world rather than trying to only go forward with a regional free trade agreement. However, this is only true if there is a significant progress in reducing trade barriers and producers subsidies in developed countries. Otherwise the idea of only eliminating trade barriers between the FTAA bloc sounds very appealing with the gains that Argentina can take by better access to a larger market and the increase in bargaining power with outsiders of the bloc.

THE IMPACT OF TRADE AND POLICY LIBERALIZATION ON ARGENTINA'S AGRICULTURAL SECTOR: TECHNOLOGY ADOPTION IN A DYNAMIC MODEL

by

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DEDICATION

I would like to dedicate this dissertation

to my family and friends for not losing their faith in me.

to my parents, Martin and Cecilia for teaching me the important things in life.

to my husband, Jason, for being next to me all this time.

to my sons, Lucas, Gaspar and Felix.

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Many years have passed since I started this work, with many years dedicated to it and many others not. Which leaves me with lots of gratitude to many people. I would like to thank

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Like many developing countries, and especially in Latin America, Argentina implemented for many decades, from 1930 through the late 1980's, an import substitution development strategy marked by high levels of import tariffs and subsidies to infant industries. Because Argentine agriculture is export oriented the strategy unintentionally also implied a bias against the agricultural sector. The profound changes that took place in the world economy and the recurrent economic and institutional crisis faced by Argentina made this strategy unsustainable.

Starting in the mid eighties and more profoundly in the nineties the landscape changed quite dramatically. Globalization, the spreading trade liberalization agreements, and the aggressive policy recommendations offered by international organizations influenced economic thinking in Argentina and paved the way for substantive changes in the economic planning. In the late eighties a new economic strategy was implemented mainly driven by a more export-oriented approach to development. This development strategy, which has become dominant in Argentina, is based on a few simple concepts -trade liberalization, better management of fiscal and monetary policies, privatization of public enterprises and deregulation of the economy- creating more transparency in the markets, less distortion in the economy and more competition between agents.

One of the basic hypotheses on which this research is based is that this new economic framework permitted a change in expectations of agricultural firms that is reflected in more incentives to invest and more propensity to adopt new technologies. The logic is that in this economic framework producers that do not modernize lose competitiveness with respect to the rest of the world.

International competitiveness in agriculture becomes a major issue in an export-oriented economy. International prices for major commodities, which are the bulk of Argentine exports decreased over the last four decades as a consequence of the adoption of new technologies and the impact of agricultural subsidies in most of the developed countries. The results of the UR[1] helped to deviate from that tendency. In addition, in Argentina a number of changes in macroeconomic policies, especially the exchange rate, together with deregulation and trade liberalization, drove down some factor prices (fertilizers, pesticides, tractors). This caused a more intensive use of these factors of production

It is plausible that with a new macroeconomic scenario -- stability, transparency in the markets, no government regulations, and more integration with the rest of the world -- there has been a change in the producers' expectations, and that producers are now more willing to invest and improve the production process with new machinery, research and fertilizers.

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[1] / One of the results of the Uruguay Round was the reduction of the level of protection. However, the base year used for the calculations was one in which the tariff levels of protection were particularly high.

This dissertation analyzes the effect of policies associated with increased openness of the economy on the development of the agricultural sector. This research has a focus on adoption of technology. It investigates with the help of econometric tools the determinants of the adoption of technology in Argentina. In addition, it analyzes the possible growth paths that result with the implementation of policies using a recursive dynamic Computable General Equilibrium (CGE) model with endogenous growth. With this approach we can see the long run equilibrium of the economy, including the full effect of endogenous technological change on growth without losing microeconomic information.

We learned from this research that a favorable macroeconomic environment has a positive influence on adoption of technology and that trade integration is important in the process of production modernization not only from the point of view of “bigger markets and less trade barriers” but also for the spillover effects that these new trade brings. It will be very interesting in the near future with the availability of more recent data to redo the estimation of the adoption of technology and find out if the 2001 economic crisis had a negative influence on technological change and production modernization.

The research in this dissertation is presented as follows. In Chapter II, a descriptive analysis of the economic policies implemented in the nineties is done; Chapter III carries out a time series analysis of variables hypothesized to influence the adoption of new technology; Chapter IV states the connection between adoption of technology and growth and gives the framework for the inclusion of technology in the general equilibrium model; Chapter V gives the sources of the data used for this research; Chapter VI describes the recursive dynamic CGE model used for the simulated scenarios; Chapter VII presents the results obtained in the scenarios of trade liberalization and increases in agricultural R&D expenditures; Chapter VIII concludes this research with some policy recommendations.

CHAPTER II: ECONOMIC POLICIES AND THE PERFORMANCE OF THE AGRICULTURAL SECTOR

Like many other developing countries, after the world economic depression of the thirties, Argentina followed an import substitution development strategy. This strategy implied explicit policies for the protection of the local market (high tariffs) and subsidies for industrial development. Although unintentional, the strategy also created a strong bias against the agricultural sector, a sector in which the country has clear comparative advantages.

Toward the end of the 1980s changes in the world economy made the import substitution model unsustainable. Additionally, changes in the political ideology and the economic thinking both abroad and in Argentina set the stage for major changes in policy. Although new policies began to be implemented during the late 1980s the real and more dramatic changes started in 1991 and ran throughout the decade.

II.1 Major Policies implemented during the 1990s

Argentina’s economic strategy during the nineties was driven by an export-oriented approach and the main thrust of the new policies can be characterized by three elements: (i) macroeconomic stability based on a fixed exchange rate, (ii) trade liberalization and, (iii) economic deregulation.

These policies were accompanied by important changes in the international institutional arrangements governing international trade. The completion of the Uruguay round in 1994 and the growing importance of Mercosur as a trading bloc both represent new options and possibilities for development and growth.

Macroeconomic stability

The main element of the strategy to attain macroeconomic stability is the so called Convertibility Law (ley de convertibilidad No 23928, March 1991) which established a fixed exchange rate with the U.S. dollar and a number of monetary policy measures designed to sustain the fixed exchange rate These measures were strengthened by other accompanying policies directed at improving the international competitiveness of the economy. The most important ones are related to market deregulation and the elimination of distortive taxes that in general penalized the agricultural sector.

Trade liberalization

In the area of trade liberalization the government implemented a host of measures many of which directly affected agricultural production. The most important were tariff reductions, elimination of export restrictions (permits, customs procedures, etc) and export taxes. Export taxes were eliminated in all products with a few exceptions including leather (5%), and cereals and oilseeds (3.5%). These exceptions designed to protect the local processing industry by compensating for the higher tariffs applied by most of the developed countries to manufactured products as compared to raw materials.

The average tariff applied to imports decreased from 1987 to 1991 from 39% to 14% and later to 9% in 1994. In addition to these multilateral policies, the regional integration process, represented by the Mercosur agreement, had an additional effect on tariffs. It was signed in March 1991 and it established automatic and linear tariff reductions, granting a minimum trade preference of 40% as of January 1991, increasing semi-annually until achieving a 100% preference by December 31, 1994 (0% tariffs).

In December 1994, at the meeting at Ouro Preto the Customs Union within Mercosur was established. This created a common external tariff (CET) and free trade (FT) among the members (0% tariff), although in an imperfect form because of the exceptions to both the CET and the FT provisions. However these exceptions are not very significant (the exceptions to the CET are 300 products, giving a CET of 11% but with a range between 0% and 30% for the case of Argentina).

In January 1995, the full implementation of Mercosur was done with some restrictions: (i) exceptions to the 0% rule, which for the Argentine agricultural sector are tobacco, tobacco products and miscellaneous edible preparations[2], (ii) special regimes, like the case of sugar for Argentina (the only special regime for the Argentine agricultural sector) which maintain an intra-extra import tax of 20% until the asymmetries with Brazil are resolved and, (iii) other situations such as export rebates (which had to be reduced by 2.5 percent monthly from February 1995 unless

[2] / They should be eliminated in the period of 4 years (1999)

they are included in a list of exceptions). Finally, the so called “statistics tax” which is charged to all imports was eliminated for all imports from Mercosur countries and “Rules of origin “ were established for a number of products. (Manciana et al (2002) and Reca and Parellada (2001)).

Economic deregulation

The policies followed implied the elimination of a number of institutions created for market regulation. Among them the National Meat Board, The National Grains Board, National Institute for Forestry, the Fish Market, the National Institute for Horse racing activities, the Argentine Corporation of meat producers, The National Beef market, the Comisión for the regulation of the production and marketing of “Yerba Mate” and the National Directorate for Sugar. Some of the activities that were originally developed by these organizations were shifted to departments of the central government (Secretaria de Agricultura, Ganaderia y Pesca).

The broad elimination of institutions that regulated the market and provided for a number of services was accompanied by the elimination of quotas on harvesting, processing and commercialization that existed for sugar cane, yerba mate, grapes and their products (sugar, yerba and wine).

In addition, land transportation and ports were deregulated internally and restrictions on the movement of goods to Chile and Brazil were eliminated. Ports were privatized and new private ports authorized and constructed by the private sector. These measures resulted in substantial cost reductions (i.e., a reduction in waiting time, better storage and easier access to the ships made a reduction in costs in the order of US$5 per ton or a total reduction cost of 33%; see Manciana et al, 2002).

II.2 Analysis of the changes in the agricultural production structure.

When changes of the magnitude just described are made, it is expected to have also important changes in the way producers act. The two available input-output tables, which give indications of changes in the structure of production between the years are the one for 1993 (where the beginning of the changes were taking place) and the one for 1997 (one of the last years of changes before the economic crisis of 2001). These years let us see the variations in the production technology when the impacts of the policies taken in 1991 were taking effect. The input output tables display the structure of the economy at a point in time and provide details of links between different sectors within the economy.

The columns show the sectors from which a specific sector buys in order to produce the good at the top of the column. For example, if we look at the 1993 input-output table we can see that for wheat producers, 17% of their expenses are accounted for by seeds, 1% of textiles, 9% of petroleum products, 6% of chemicals, 1% of machinery, and 66% of services (gas, water, transportation, telecommunications, financial services, veterinary services) in order to produce the final commodity, wheat.

Table II.1: Input-Output table, 1993

	Wheat	Maize	Rice	Other grains	Oilseeds	Fruits&Veg	Other crops	Livestock
Wheat	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Maize	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.07
Rice	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00
Other grains	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.07
Oilseeds	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
Fruits&Veg	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
Other crops	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00
Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meat manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fruit & Veg Manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vegetable oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dairy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Wheat manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alcohol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
non alcohol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.00
Clothing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paper manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Petroleum Ref	0.09	0.13	0.31	0.13	0.11	0.06	0.11	0.02
Chemicals	0.06	0.05	0.05	0.05	0.10	0.21	0.12	0.10
Rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery	0.01	0.00	0.04	0.00	0.00	0.02	0.02	0.00
Auto sector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	0.00	0.00	0.03	0.00	0.00	0.01	0.01	0.01
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Services	0.66	0.49	0.34	0.49	0.66	0.50	0.51	0.12
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: author with data from Diaz Bonilla and Piñeiro (2000).

Table II.2: Input-Output table, 1997

	Wheat	Maize	Rice	Other grains	Oilseeds	Fruits&Veg	Other crops	Livestock
Wheat	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Maize	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.18
Rice	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Other grains	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01
Oilseeds	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.08
Fruits&Veg	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00
Other crops	0.20	0.23	0.11	0.13	0.15	0.05	0.09	0.02
Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
Forestry	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meat manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fruit & Veg Manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vegetable oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dairy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Alcohol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
non alcohol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Clothing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood manuf.	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00
Paper manuf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Ref	0.07	0.06	0.34	0.08	0.08	0.07	0.08	0.02
Chemicals	0.17	0.19	0.11	0.22	0.25	0.24	0.26	0.06
Rubber	0.01	0.01	0.01	0.01	0.01	0.09	0.07	0.01
Metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal products	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Machinery	0.03	0.03	0.03	0.03	0.04	0.05	0.04	0.01
Auto sector	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Other Manuf.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Electricity	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.02
Construction	0.03	0.03	0.03	0.03	0.04	0.01	0.02	0.03
Services	0.43	0.41	0.32	0.44	0.36	0.19	0.33	0.15
Government	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02

Source: author with data from Petri and Mendez Parra (2003).

The main changes we can see between the two input-output tables of the agricultural commodities are the increase in the use of chemicals, fertilizers and agrochemicals of around 180% for grains, 100% in other crops and only 14% for fruits and vegetables (represented in the chemicals sector row), decrease in the use of petroleum products in the order of 33% for the agricultural products and no change for livestock, and a decrease in services with a wide variety of magnitudes that go from 30% in wheat to 10% in other grains (mainly credit, transportation and telecommunications costs).

These changes are consistent with the information available in other sources (Manciana et al, 2002 and Reca, 2001) on input use and capital investment that took place during those years. Fertilizer use increased from around 600,000 tons in 1993 to 1,600,000 tons in 1997 (Camara Argentina de Sanidad Agropecaria y Fertilizantes (CASAFE)). The increase in the use of fertilizers can be explained by the decrease in the import tariffs of such inputs and the construction of a fertilizer plant (urea) in Bahia Blanca which resulted in a very significant decrease in its price of around 20% between 1991 and 1999 (Manciana et al, 2002), an increase in credit availability (indicated by total agricultural outstanding loans) of 122% between 1991 and 1999, and the expectations of higher prices of cereals and oilseeds. Something similar occurred in most agrochemicals. The most notable example was the glyphosate, a herbicide that was instrumental in the wide adoption of low tillage technology that went hand in hand with the modernization process. The price of glyphosate decreased threefold during the period considered and the amount used doubled. (Manciana et al, 2002 and FAO, 2004)

Similarly, the investment in machinery resulted in higher horsepower machines that covered more hectares per unit of time and which permitted lowering the costs of production. This process is exemplified by what happened with the tractors.

According to figures provided by the agricultural census and the association of tractor manufacturers the number of tractors in use decreased between 1988 and 1999 by around 25% (Manciana et al, 2002 and Asociacion de Fabricantes de Tractores (AFAT)). There are no national figures on the changes in the size of tractors. However a study on Pergamino (the Argentine equivalent to Iowa in the US) shows that between 1988 and 1999 the tractors 0 up to 100 HP decreased by 34%, those between 100 and 1140 HP increased by 60%, and those between 1150 and more HP increased by 90%. (Manciana et al, 2002)

These changes in the power of tractors had a significant impact on the use of petroleum products (less used per unit of output) and consequently on the costs of production. A similar process took place in relation to other machinery, especially in new harvesting machinery with its bigger coverage of land. The significant increase of low or zero tillage, a technology that requires considerably less energy per unit area also contributes to explain the overall decrease in use of petroleum products [3].

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[3] / Zero tillage (or no tillage) is the closest English denomination for the complex technological package identified in Argentina as Siembra Directa. The technology is relatively simple and is based in sowing, in some cases immediately after harvesting the previous crop, without doing any soil tillage. The technology, although simple, incorporates complex research on soils, agronomy, and more recently, biotechnology.

The basic concept of the technology has been known for many years and has been used in a number of countries, including the USA. However its rapid and extensive adoption in recent years in the Pampean region of Argentina responds to a complex combination of ecological, production, economic and cultural reasons. The most important of these are: (i) the multi-crop nature of agriculture, (ii) the short time that lapses between one crop and the other, (iii) the creation of herbicides with low costs of production, general applicability and environmental friendliness, conditions that facilitate the weed control in the absence of tillage, (iv) the emergence of crops (principally soybeans) that are resistant to the herbicide which further facilitates weed control and (v) research results that confirmed the beneficial effects of the technology on soil conditions specially in regards to nitrogen and organic matter accumulation.

The development of the technology implied the careful and imaginative articulation of this knowledge in a way in which the production processes where consistent with other elements of the production structure. It also required extensive and widespread activities of information and communication

Last, the decrease in the expenses in the service sector can be seen as the lower costs in the ports and telecommunications fees, the reduction of the real interest rate, and the lower insurance costs (See Annex 2).

In summary, the policy scheme that Argentina implemented in the 90's -- macro stability, trade liberalization and deregulation of the economy -- produced a significant structural change in the production process. The main impacts of these changes were: (i) higher input use; (ii) less use of energy; (iii) higher levels of production both because area expansion and higher yields; and (iv) decrease of costs in services. The aggregate effect of these changes, together with the expectations of higher prices in the international market (which did not really materialize in the following years) is likely to have generated positive expectations of higher profits, a general optimism towards agricultural production. These economic elements accelerated and supported the more general cultural and ideological changes that were taking place in the pampean rural sector setting in motion a process of technological adoption and production increases that it is still in motion.

In the next two chapters of this dissertation a more detailed analysis will be developed.

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activities with producers and farmers' organizations and the development and production of new machinery specially sowing machines adapted to work on soils that have not been tilled.
Although public research contributed significantly the major effort both in knowledge management and diffusion of the technology among farmers was performed by the private sector, mainly AACREA and APRESID. The latter organization created by individual farmers, researchers and institutions that took to itself the refinement and diffusion of the technology.

CHAPTER III: ADOPTION OF TECHNOLOGY IN THE AGRICULTURAL SECTOR

It has recently been estimated that Argentina invests only 0.4% of its agricultural GDP in R&D for the agricultural sector, while countries like Australia invest around 3% of their agricultural GDP (M. Piñeiro et al, 1997). Another important feature of the agricultural R&D in Argentina is that private R&D only represents 15% of total agricultural R&D spending. However, privately funded R&D, which comes mainly through investment from foreign multinational companies, is the most important source of new technology for the country (M. Piñeiro et al, 1997). Foreign investment in the agricultural sector represented 76% of the total R&D in the country during 1994-1997 (Perona and Reca, 1997).

The public institutions that carry out R&D in the sector are the Instituto Nacional de Tecnología Agropecuaria (INTA), Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET), National Universities, and the Instituto Nacional de Tecnología Industrial (INTI). Private institutions that are non-governmental organizations (NGOs) like the Consorcios Regionales de Experimentación Agrícola (CREA) implement agricultural R&D as well.

Table III.1: Total expenditures for R&D, 1996 ($ millions).

	AGRICULTURAL			**AGRO-INDUSTRY**			**TOTAL**
	Innovation	Diffusion	Total	Innovation	Diffusion	Total	
Public	117.4	72.0	189.4	17.8	2.9	20.7	210.1
Private	13.5	10.6	24.1	23.5		23.5	47.6
Total	130.9	82.6	213.5	41.3	2.9	44.2	257.7

Source: M. Piñeiro et al, 1997.

Table III.1 shows that 66% of the money spent on R&D is dedicated to innovation ($172.2 million) and 34% ($85.5 million) in diffusion and adoption. The distinction between the two classifications is that the first one is research while the second one is extension services that are not included in the data used for this analysis.

The classification of innovations according to form is useful for considering policy questions and understanding the forces behind the generation and adoption of innovations. Categories in this classification include mechanical innovations (tractors), biological innovations (new seed varieties), chemical innovations (fertilizers and pesticides), agronomic innovations (new management practices), and informational innovations that rely mainly on computer technologies.

Previous theoretical models[4] that include technological change in their analyses can be divided into different approaches as follows:

(i) Endogenous growth models: Romer (1987), Lucas (1988), Grossman and Helpman (1990). (Discussed in more detail in Chapter IV)

[4] / For more details, see Feder et al (1985), Ruttan (1997), and Evenson et al (1994).

(ii) Models of invention: Machlup (1958), Arrow (1962), Nordhaus (1969). These papers developed models that analyzed the incentives to engage in R&D that are afforded by intellectual property rights.

(iii) Search Models: Schmookler (1966), Binswanger and Ruttan (1978).

The search process is modeled as a sequence of experiments, each composed of n trials or draws. A single draw can be a new crop variety, a certain dose of fertilizers, etc. At the beginning of a research period, a distribution of potential inventions exists. This distribution is determined by factors that are importantly influenced by the country's level of technological development.

(iv) Diffusion Models: Griliches (1957). Diffusion models focus on the spread of innovations across firms engaged in similar activities. The general diffusion model assumes that the probability of a particular firm's deciding to adopt an innovation at a particular point in time depends on: the proportion of the firms in the industry that have already adopted the innovation; the benefits from adopting it; and the cost of its adoption.

In theories of induced innovation, technical change is induced by other economic factors (factor price changes, demand, growth) [5]. There are three major traditions: (i) Griliches, in his study of the invention and diffusion of hybrid maize demonstrated

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[5]/ Clarke (1994), looking at the United States productivity since 1930, concluded that the pace of technological diffusion deviated from its predicted rate because of farmers' hesitation to purchase the new technology in an uncertain investment climate. In her work she tried to answer the question of how farmers interacted with their investment climate, and the role of agricultural policies in creating that climate, to shape the diffusion of technology.

the role of *profitability* in determining the timing and location of the adoption of new technology; (ii) Fellner (1961) and Samuelson (1965) started a macroeconomic or growth theory in trying to explain the apparent stability in *factor shares* in the presence of increasing wages; and (iii) Hicks (1932) and Binswanger (1974) built a microeconomic model based on the idea that a change in the *relative prices* of factors of production is itself a spur to innovation. The main empirical results found by application of this model are that adoption decisions are economically motivated and that skills related to adoption also matter.

These models have the disadvantage that they do not explain explicitly the decision-making by individual farmers, that is, why some farmers adopt and other do not. "Threshold" models of technology diffusion have been developed to explain differences among farmers, assuming that producers are heterogeneous (see Sunding and Zilberman, 2001). David (1969) introduced this model in explaining the adoption of grain harvesting machinery in the United States in the 19th century. He assumed that the main source of heterogeneity among farmers was farm size and he derived the minimum farm size required for adoption of various pieces of equipment.[6] Another model of this type is Akerlof (1976), in which differences in human capital establish thresholds that result in differences in the adoption of different technologies and practices.

[6]/ Olmstead and Rhode (1993) criticized David's work, showing that in many cases much smaller farms adopted new machinery because farmers cooperated and jointly purchased the new equipment.

(v) Growth Accounting Models: Solow (1957). Based on the "residual" in the growth of per capita output that could not be attributed to the growth of per capita capital service flows. These models sought to explain the residual by more carefully and properly measuring inputs. Capital, labor, and output measures were disaggregated into distinct types to take account of changes in their quality. A second approach was to use statistical methods derived from hedonic regressions approaches to identify sources of economic and Total Factor Productivity (TFP) growth.

(vi) Evolutionary theory: Nelson and Winter (1973) is built upon the behavioral theory of the firm, modeling the search for better techniques and the selection of successful innovations by the market. The activities leading to technical change are: local search for technical innovations, imitation of the practices of other firms, and satisfying economic behavior.

(vii) Models that introduce specific characteristics of the investment, markets or policies that produce constraints or special opportunities:

- Risk. Roumasset (1976) concluded that risk considerations were very important in explaining why high yield varieties were not fully adopted by farmers; only part of their land was planted with these seeds.
- Irreversible investment. Thurow, Boggess, and Moss (1997) applied the real option approach[7] to assess how uncertainty and irreversibility considerations

[7]/ The adoption of some technologies entails irreversible investments with uncertain payoffs. Delaying the decision to adopt it may enable the producer to obtain more information, reducing overall uncertainty, and increasing expected discounted benefits by avoiding irreversible investment when it is not worthwhile. This approach is been used in the analysis of options in finance, and Dixit and Pindyck

will affect adoption of free-stall dairy housing (a technology that increases productivity and reduces pollution), delaying adoption when pollution regulations are stringent.

- Credit. Hoff, Braverman, and Stiglitz (1993) found that credit constraints, which appear as the result of asymmetric information between lenders and borrowers and the uncertain conditions in agriculture and financial markets, affect adoption behavior.
- Demand for complementarity inputs. McGuirk and Mundlak's (1991) analysis of the adoption of high-yield varieties (HYV) in the Punjab indicated that adoption was constrained by the availability of water and fertilizer, necessary inputs for the HYV.
- Agricultural policies. Cavallo and Mundlak (1982) found that the low growth of Argentinian agriculture between 1940 and 1973 was a result of output taxation and other policies that reduced relative prices of agricultural products and slowed investments and technological change in the sector. Carletto, de Janvry, and Sadoulet (1996) found that the opening of markets in the US led to the introduction of HYV in Central America. They concluded that when a change in trade rules seems permanent, it can promote investment in infrastructure, and that may enable adoption of new crops and modernization.

(1994) and McDonald and Siegel (1986) applied it to the analysis of capital investments. They viewed investments with unrestricted timing as "real options" since the decision about when to undertake an investment is equivalent to the decision about when to exercise an option. (See Sunding and Zilberman, 2001).

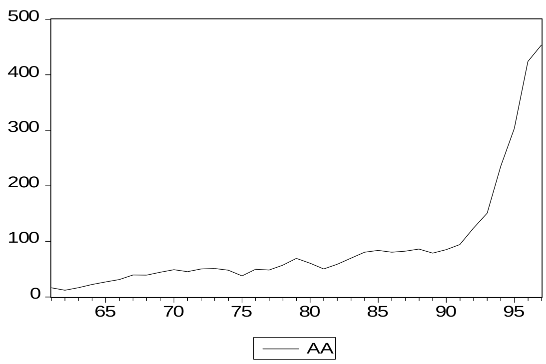
Our approach is based on the diffusion theory in the sense that the new level of adoption of technology that is seen in Argentina in the 1990s is the consequence of a change in the economic environment; changing the rules of the game, with more stability and transparency in the new scheme. These changes caused a change in the producer's expectations, increasing the attractiveness of making new investments because producers see the risk of failure as being decreased.

We consider two measures of the extent of adoption at a given time: (i) the share of the cropped area utilizing the new technology, or (ii) the per hectare quantity of new inputs used. Either dependent variable can be estimated as a function of variables that have affected the willingness of the producer to adopt the technology. An example of the first approach is Griliches (1957). He estimated the share of land utilized by hybrid corn as a logistic function of time $P(t) = K\left[1 - e^{-(a+bt)}\right]^{-1}$, where K is the long run adoption upper limit, "a" reflects the aggregate adoption at the start of the estimation, and "b" is the rate of acceptance of new technology. An alternative dependent variable was used by Lindner et al (1982). They looked at the factors that affect the time between farmers becoming aware of the innovation and when they decide to adopt it. The independent variables are size of the farm, distance to the innovation source, distance to nearest adopter, education, productivity increase and debt level.

Clarke (1994) used the number of tractors sold to farmers as the variable representing the new source of technology in explaining the diffusion of technology. She found that key issues in explaining the decision of farmers to buy a tractor, given its expected cost saving, were the financial situation and expectations of the farmer.

This chapter attempts to estimate the factors that determine the adoption of agricultural technology in Argentina, using as independent variables the factors that are expected to have an effect on the farmers' decision to adopt new technology. Analyzing the period 1961-1997, we can see (Figure III.1) a big jump in the variable representing the adoption of technology in 1991.

Figure III.1: Adoption of technology*



Source: Author

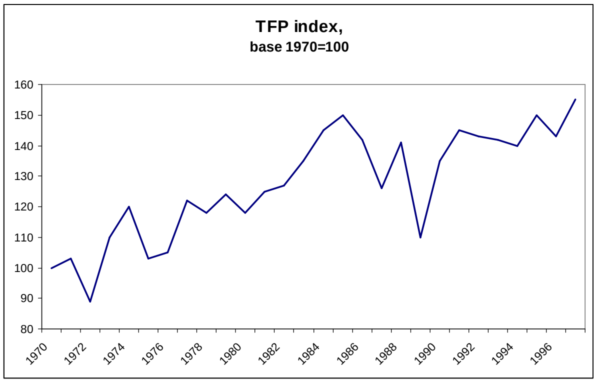
* Represented as a weighted average of the number of tractors sold and tons of fertilizers consumed.

An indicator of the consequences of technology adoption is given by changes in yield or other productivity measures. Lema (1999) estimated total factor productivity for the Argentine agricultural sector between 1970 and 1997.[8] Figure III.2, shows the evolution of agricultural TFP according to his estimates. There is a steady increase in

[8] / Calculated as the ratio of output to an index of inputs used during the production process.

the seventies, an increase and decrease in the eighties and a positive trend in the nineties. [9]

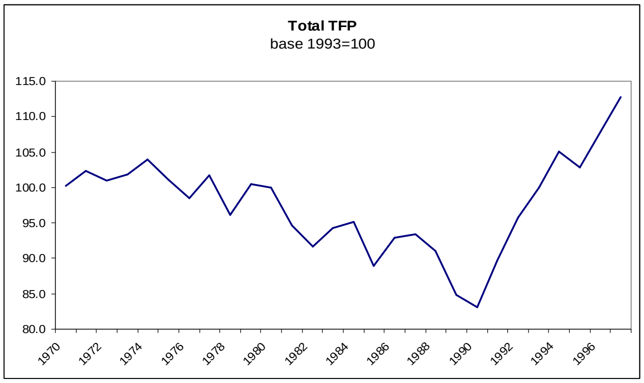
Figure III.2: Agricultural TFP index



Source: Lema (1999).

With respect to trends in the whole economy, Maia and Nicholson (2001) estimate the economywide TFP. As seen in Figure III.3, there is a structural break in the year 1991 like the one we saw for the adoption of technology in the agricultural sector.

Figure III.3: Economywide Total TFP



Source: Maia and Nicholson, 2001.

[9] / Lema (1999) fixed the relative shares of land, capital, labor and fertilizers as 15%, 47%, 35% and 3% respectively. The basic assumptions are: neutral technology change (like Hicks); lineal homogeneity production function; constant input-output elasticities; and maximization of revenues.

What were the main factors that affected the incremental adoption of technology? In particular what was the role of macroeconomic and structural reforms?

In trying to answer this question the research is reported in three stages, as explained below. An empirical analysis of the factors that affect adoption of technology is carried out after identifying the variables that are significant, with particular attention to variables related to policies. The stages are as follows;

(i) OLS regression with domestic variables that affect the willingness of the producers to adopt new technology as independent variables.

(ii) Analysis of the existence of cointegration between the adoption of technology and the policy reform indexes.

(iii) Analysis of the coefficients of the regression with the average of the three relevant policy reform indexes (capital account and commercial liberalization and financial reform), price of international agricultural commodities, US prime real interest rate and agricultural world imports as independent variables.

(i) First stage:

We begin with a time series regression intended to identify the significant variables that affect the producers' decisions about technology adoption. Following our hypothesis, we include variables that reflect trade liberalization and stabilization of the economy as well as relative prices and expenditures in agricultural R&D. Lacking data on a complete measure of technology adoption, the indicator used as a dependent variable in this chapter is a proxy variable, created as the weighted average[10] of the number of tractors sold and the tons of fertilizers consumed.

The changes in the use of fertilizers and tractor represent changes in the adoption of technology given the fact that these inputs are associated with technological innovation on farms. As mentioned in the previous chapter, a study on Pergamino (the Argentine equivalent to Iowa in the US) shows that between 1988 and 1999 the tractors of 0 up to 100 HP decreased by 34%, those between 100 and 1140 HP increased by 60%, and those between 1150 and more HP increased by 90%.

Other indicators, notably the use of improved seeds, transgenic seeds, and zero till techniques could not be included because of lack of data for some years, although they show an increase in use in the data for the available years. Looking at herbicides, for example, the use of glyphosate went from zero in 1990 to 83 million liters in 2000 (this is correlated with the beginning of the no till technique). These data reinforce the idea that production modernization took place in the nineties roughly parallel to our measure using fertilizers and tractors sold (See Annex 1).

[10] / The weights were calculated using the prices of 1986, which is the base year for the deflator used in the transformation of the expenditures in R&D. The price of a ton of fertilizers and a tractor are the implicit prices calculated from the FAO series of MT-quantities and dollars of fertilizers-tractors exported. The composition of the fertilizers used is very similar that of exports (for the years there were exports).

The independent variables are: (i) expenditures on public R&D in the agricultural sector (RD); (ii) degree of openness of the economy, measured as the share of total trade in total income (DO); (iii) the agricultural terms of trade, computed as the ratio between the total export price index and the total import price index (RPT); (iv) domestic relative price, computed as the ratio between the agricultural price index and the non agricultural price index (RP); (v) a dummy variable for years with bank crisis (D1); and (vi) dummy variable for years with hyperinflation (D2).

The estimated equation is:

$$AA = \beta_1 + \beta_2 RD + \beta_3 RD_{-1} + \beta_4 RD_{-2} + \beta_5 RD_{-3} + \beta_6 RD_{-4} + \beta_7 RD_{-5} + \beta_8 RD_{-6} + \beta_9 RD_{-7} + \beta_{10} RD_{-8} + \beta_{11} RD_{-9} + \beta_{13} RP + \beta_{14} RP_{-1} + \beta_{15} RPT + \beta_{16} RPT_{-1} + \beta_{17} DO + \beta_{18} D1 + \beta_{19} D2$$

Where:

AA is the index for adoption of technology

RD is the expenditures in public R&D in the agricultural sector

RP represents the domestic relative prices

RPT is the agricultural terms of trade

DO is the degree of openness of the economy

D1 is the dummy for years with bank crisis

D2 is the dummy variable for hyperinflation

Table III.2: data for regression #1

obs	LAAW	LDO	LRD	LRP	LRPT	D1	D2
1961	2.12	2.48	15.85	0.00	0.24	0	0
1962	1.77	2.64	16.17	0.00	0.30	0	0
1963	2.03	2.76	16.11	0.11	0.13	0	0
1964	2.31	2.41	16.27	0.13	0.15	0	0
1965	2.45	2.34	16.35	-0.04	0.27	0	0
1966	2.52	2.45	16.39	-0.03	0.25	0	0
1967	2.74	2.53	16.20	-0.02	0.31	0	0
1968	2.74	2.48	16.07	-0.02	0.41	0	0
1969	2.83	2.55	16.21	0.00	0.36	0	0
1970	2.93	2.34	16.32	0.04	0.37	0	0
1971	2.89	2.53	16.24	0.11	0.23	0	0
1972	2.98	2.64	15.98	0.25	0.26	0	1
1973	3.03	2.59	16.69	0.17	0.22	0	1
1974	2.99	2.58	17.02	0.05	0.19	0	1
1975	2.75	2.47	16.88	-0.20	0.32	0	1
1976	3.03	2.71	17.07	-0.13	0.26	0	1
1977	3.01	2.83	17.51	-0.05	0.11	0	1
1978	3.05	2.66	17.66	-0.08	-0.03	0	1
1979	3.24	2.55	17.87	-0.07	-0.25	0	1
1980	3.09	2.45	17.86	-0.17	-0.55	0	1
1981	2.90	2.66	18.11	-0.27	-0.44	1	1
1982	3.06	2.75	17.75	-0.14	-0.08	1	1
1983	3.24	2.71	17.94	-0.11	0.19	0	1
1984	3.40	2.51	18.07	-0.16	0.20	0	1
1985	3.41	2.89	17.98	-0.18	-0.02	0	1
1986	3.37	2.67	17.63	0.12	-0.33	0	0
1987	3.38	2.74	17.17	0.08	-0.27	0	0
1988	3.43	2.76	17.58	0.00	-0.26	0	0
1989	3.34	2.98	17.22	0.02	-0.40	1	1
1990	3.42	2.71	17.89	-0.06	-0.38	1	1
1991	3.51	2.62	17.95	-0.15	-0.42	0	1
1992	3.79	2.69	18.07	-0.03	-0.47	0	0
1993	3.98	2.67	18.05	0.02	-0.57	0	0
1994	4.42	2.77	17.97	-0.09	-0.18	1	0
1995	4.67	2.83	17.86	-0.03	-0.05	0	0
1996	5.01	2.93	17.91	0.02	0.01	0	0
1997	5.07	2.94	17.97	-0.02	0.02	0	0

Lags of R&D were included because it takes time to implement R&D initiatives and every innovation lasts longer than one year, so that we are looking at the effect of an increase in R&D on adoption of technology over time. The short-run effect is represented by the coefficient of R&D in the actual year and the long run effect in the coefficients of the lagged R&D variables. The shortcoming of using the lags is that we compromise the degrees of freedom of the regression, every additional year's lagged independent variable takes one observation out of the sample (the additional year we are lagging). Consequently, we tested for the optimal number of lags to be included in the regression[11]. Nine years turned out to be the optimal lag length. R&D is measured as public expenditures on agricultural research through INTA (which does not include extension expenditures).

The variable that measures the openness of the economy also is included in order to test the hypothesis that trade liberalization stimulates the adoption of technology (Levine and Renelt, 1992). Also, there is increasing evidence of trade-induced technology transfer to the domestic producers.[12] The problem with this variable is to find the proper translation of the trade barriers into an overall openness index of the trade regime. Michaely (1977) and Feder (1983) used the actual trade flows as a

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[11] / Following Davidson and MacKinnon (1993) we started with the maximum number of lags that are consistent with the idea that R&D takes time to fully develop and ran an unrestricted regression of adoption of technology as the dependent variable and expenditures in agricultural R&D as independent variables. Then we checked whether the fit of the model deteriorates as the number of lags is reduced. We looked at: i) maximizing R square; ii) minimizing Akaike's information criterion with respect to the number of lags; iii) minimizing Schwarz criterion with respect to the number of lags. All these reward good fit but penalize loss of degrees of freedom associated with increases on the number of lags.

[12] / Coe and Helpman (1995) found that domestic factor productivity was positively affected by the import-weighted sum of the trading partner's R&D expenditures. And Keller (1997) found that foreign R&D expenditures in one sector of the economy improve domestic productivity in that sector as well as in other industries through input-output linkages.

proxy, while Balassa (1985), Leamer (1988) and Edwards (1992) inferred the trade orientation based on the deviation of actual exports from that predicted by a theoretical trade model, and finally, Barro (1991), Easterly (1993) and Lee (1993) measured trade orientation on the basis of the divergence between domestic and international prices[13]. Following the first definition, this study measures the degree of openness of the economy by the share of total trade in total GDP.

A long discussion has occurred in Argentina about the factors that influence the adoption of technology. It has been said that relative price is the main factor, because with the openness of the economy inputs are less expensive and prices for export commodities are better. And, that the elimination of the bias towards the agricultural sector is an important factor in the level of adoption. That is the reason why relative prices between agricultural and non-agricultural goods and between exports and imports were included in the regression[14].

Two dummy variables are included to capture the effect of bank crisis and hyperinflation on adoption of technology. These two variables are the ones we think affect the most the financial situation and expectations of Argentinian farmers, in the period studied[15]. Part of our argument is that economic stabilization creates a better

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13 / In these studies they analyzed the relationship between trade and growth. Measuring the degree of openness of an economy in different ways but all giving the same result for a positive relationship between trade and growth. Hence, the trade flows data was used, given that it is the most straight forward approach.

14 / Fulginiti and Perrin (1992) included prices when estimating TFP in relation to the induced innovation hypothesis.

15 / See Clarke (1994).

environment for new investments, (higher profitability) and the use of more inputs that will increase yields.

(ii) Second stage:

In time series analysis there is always the potential problem of non-stationarity[16] of the variables. If both dependent and independent variables are trending upwards over time, we can easily make misleading inferences from OLS results because of spurious regression. We tested for the existence of unit roots in order to determine if the variables in the regression were non-stationary, using the adjusted Dickey-Fuller (ADF) test. Running the ADF test on all the variables used in the regression, we could not reject the null hypothesis of non-stationarity of the variables, being integrated of order 1 (except that RP is stationary). However, when the logarithms of the variables are used, in the cases of R&D, DO, RP and RPT the ADF test rejects the null[17]. We did the log transformation of the variables (see Ermini and Hendry, 1991) with the idea that there is a higher chance for them to be stationary than the level of the same variable[18]. Even with this transformation the dependent variable (LAA) is still non-stationary, leaving us with the need to take a closer look at the behavior of the log of adoption of technology. Graphically it is possible to see by the abrupt

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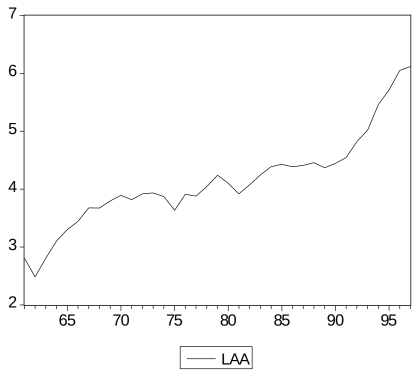
[16] / The variable will be stationary (or weak stationary) if its mean and variance are constant and independent of time and the covariances given by two points in time depend only upon the distance between the two time periods, but not the time periods per se.

[17] / The logarithm of the domestic openness index and expenditures in research are stationary with an intercept with a t-statistic of –2.76 and –2.98 respectively. The logarithm of relative prices and trade relative prices are stationary with a t-statistic of –2.72 and –1.71 respectively.

[18] / Banerjee, A. et al (1993): changes in the logarithms of economic data series seem more likely to be stationary than changes in the levels, because percentage growth shows no tendency to rise or fall, making it a more likely candidate for stationarity and the levels of many economic variables are initially positive, we can induced that stationarity of the rate of growth implies stationarity of the changes in the log of the variable.

change in the slope of the series that there is a structural change in AA in 1991 and it can be supported by the change in policies and the economic environment implemented that year.

Figure III.4: adoption of technology logarithm



The approach to structural change in this chapter is that of intervention analysis, from Box and Tiao (1975), in which the structural change is seen as a one-time shock that has permanent effects on the level of the variable studied. It is important to see not only the change in the level but also the transition to the new trend path. These changes have to be exogenous and at a known date. In this study the adjustments were assumed to be gradual.

Perron (1994, pg2) wrote: "the intuitive idea behind this type of modeling is that the coefficients of the trend function are determined by long-term economic fundamentals and that these fundamentals are rarely changed. In this sense, the exogeneity assumption about the changes in the trend function is a device that allows taking these shocks out of the noise function into the trend function without specific modeling of the stochastic behavior of the intercept and the slope." The implications of the existence of a structural change to this research is that we can treat the new policy scheme implemented in 1991 as a one-time event, leaving us with a variable for adoption of technology that it is "stationary" and will allow us to run an OLS regression.

To test for stationarity of the variable first we run the test for each of the subperiods, the one before the supposed "shock" and the one after it. Given the result that the log of adoption of technology series is stationary in each of the subperiods, the existence of a unit root is rejected at a 5% confidence for the periods 1961-1990 and 1991-1997[19].

Secondly, we test for the existence of unit roots including the structural change in LAA. For this the following test was used (see Holden and Perman, 1994):

$$y_t = \hat{\alpha} + \hat{\beta}_1 t + \left(\hat{\beta}_2 - \hat{\beta}_1\right) DT^*_t + \hat{\delta} y_{t-1} + \sum_{i=1}^{k} \hat{\gamma}_i \Delta y_{t-i} + \hat{e}_t \text{, } t=1,2,....,T$$

$$y_t = \hat{\alpha} + \hat{\beta}_1 t + \hat{\lambda} DT^*_t + \hat{\delta} y_{t-1} + \sum_{i=1}^{k} \hat{\gamma}_i \Delta y_{t-i} + \hat{e}_t$$

where, $DT^*_t = t - TB$ if $t > TB$ and 0 otherwise

TB is the year of the structural change

[19] / The logarithm of the adoption of technology index for the period 1961-1990 is stationary with an intercept with a t-statistic of –3.17. And for the period 1991-1997 is stationary with a trend and intercept with a t-statistic of –4.35.

In this test, under the alternative hypothesis, a change in the slope of the trend function without any sudden change in the level at the time of the break is allowed.

The critical values provided by Perron do not include the values for all possible λ (the ratio between pre-break sample size to total sample size, which is 0.84 in the LAA regression), hence the closest one was chosen (0.9 in Perron's table), given that the differences in the critical values over adjacent values for λ are not very different.

We did run the regression obtaining evidence of serial correlation in the residuals given by a Durbin-Watson statistic of 1.54, to correct for the serial correlation in the residuals, one lag in the first difference of LAA was included in the regression.

Table III.3: Structural change

Dependent Variable: D(LAAW)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.348021	0.142622	2.440166	0.0210
t (years)	0.472527	0.124034	3.809650	0.0007
DT (t-years of structural change*)	0.089705	0.024737	3.626329	0.0011
LAAW(-1)	-0.582715	0.119324	-4.883481	0.0000
D(LAAW(-1))	0.096171	0.127072	0.756823	0.4553
R-squared	0.635700	Mean dependent var		0.095211
Adjusted R-squared	0.585451	S.D. dependent var		0.153486
S.E. of regression	0.098823	F-statistic		12.65116
Durbin-Watson stat	2.193338	Prob(F-statistic)		0.000004

* if t>TB; 0 otherwise

The unit root hypothesis can be rejected at the 1% level for LAA (including the structural change)[20]. And, the alternative hypothesis of a trend stationary process cannot be rejected, being $\lambda \neq 0$ and $\beta \neq 0$[21]. These results are conditional on the existence of the change in the trend in 1991.

The results for the adoption of technology regression are as follows;

Table III.4: Adoption of technology regression

Dependent Variable: LAAW

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.40913	4.679762	-2.865344	0.0168
LRD	0.933138	0.307583	3.033774	0.0126
LRD(-1)	0.556365	0.356005	1.562801	0.1492
LRD(-2)	-0.411575	0.358877	-1.146843	0.2781
LRD(-3)	-0.063036	0.315269	-0.199945	0.8455
LRD(-4)	-0.670891	0.374715	-1.790404	0.1037
LRD(-5)	0.347782	0.321656	1.081223	0.3050
LRD(-6)	0.489250	0.305978	1.598969	0.1409
LRD(-7)	-0.011469	0.339114	-0.033822	0.9737
LRD(-8)	-0.503508	0.340809	-1.477390	0.1704
LRD(-9)	-0.002115	0.312692	-0.006764	0.9947
LDO	2.124186	0.643326	3.301881	0.0080
D1	0.041936	0.319004	0.131457	0.8980
D2	-0.808497	0.189640	-4.263332	0.0017
LRP(-1)	1.622922	1.019881	1.591285	0.1426
LRPT(-1)	-0.749507	0.728282	-1.029144	0.3277
LRPT	1.189056	0.500608	2.375224	0.0389
LRP	1.251032	1.075811	1.162873	0.2719

R-squared	0.906435	Mean dependent var	3.443392
Adjusted R-squared	0.747374	S.D. dependent var	0.632392
S.E. of regression	0.317852	Akaike info criterion	-2.036241
Sum squared resid	1.010301	Schwarz criterion	-1.179824
Log likelihood	6.777103	F-statistic	5.698660
Durbin-Watson stat	1.909280	Prob(F-statistic)	0.003982

[20] / The t-statistic value in Perron's table is –4.27.

[21] / For the coefficients of t and DT the null hypothesis is that the coefficients are equal to zero. For the coefficient of LAA the null hypothesis is that the coefficient is equal to one.

The F test allows rejection of the hypothesis that the coefficients of the explanatory variables are all zero at the 1% confidence level, and the regression satisfies a full set of misspecification tests, and the test for normality of the residuals[22].

The choices of the lag distribution of research expenditures with respect to flows of research benefits are important. Empirical works have used polynomial and trapezoidal lag structures and a lag length no higher than 20 years. Recently, Alston et al (1998) proposed to use a number of lags between research investments and the changes in the stock of knowledge to analyze the relationship between research investments and productivity [23].

We did try a linear and polynomial lag structure for the R&D lags included in the adoption of technology regression. In the linear case the R&D variable is significant only in the first year. And the lags of R&D seem not to be significant. And for the regression with a polynomial lag structure none of the R&D variables appeared to be significant[24]. We also did a joint test of significance for the R&D lags, not being able

[22] / The Jarque-Bera test is a joint test of the skewness and kurtosis with a X square distribution with two degrees of freedom, being the null hypothesis that the errors are normally distributed. In our regression we accept the null with a probability of 0.6205.

[23] / Alston et al (2000 pg.31): "Alston, Craig and Pardey laid out a model in which current production depends on the utilization of a stock of useful knowledge, which is itself a function of the elements in research and the effects on production."

[24] / Table III.5: Polynomial lag structure for R&D lags

Dependent Variable: LAAW

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-15.71751	4.837521	-3.249083	0.0054
LRD	-0.425260	1.018216	-0.417652	0.6821
LDO	1.505294	0.666710	2.257794	0.0393
D1	0.088384	0.313460	0.281962	0.7818
D2	-0.681868	0.203270	-3.354492	0.0043
LRP(-1)	1.945238	1.000173	1.944902	0.0708
LRPT(-1)	-0.145700	0.733699	-0.198583	0.8453
LRPT	0.971072	0.551198	1.761747	0.0985
LRP	1.010747	1.157809	0.872983	0.3964
PDL01	-0.158866	0.136396	-1.164741	0.2623

to reject the null hypothesis that all the R&D lag coefficients are equal to zero[25], however the joint F test for all the R&D variables (including the current R&D) turned out to be significant[26], reflecting the positive relation between investment and R&D.

Figure III.5: R&D expenditures

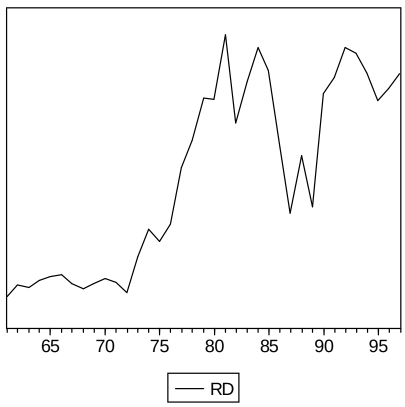


Figure III.5 represents expenditures in public agricultural R&D. It is interesting to see the increase in the seventies, decrease in the eighties, and recovery in the beginning of the nineties. Also, the maximum amount spent, in the decades analyzed, occurred at the end of the seventies and it was not matched until the beginning of the nineties.

PDL02	0.068355	0.096973	0.704888	0.4917
PDL03	0.049442	0.040240	1.228691	0.2381
PDL04	-0.013096	0.011770	-1.112618	0.2834

R-squared	0.821707	Mean dependent var	3.443392
Adjusted R-squared	0.679072	S.D. dependent var	0.632392
S.E. of regression	0.358253	Akaike info criterion	1.089262
Sum squared resid	1.925177	Schwarz criterion	1.707786
Log likelihood	-2.249669	F-statistic	5.760926
Durbin-Watson stat	1.378760	Prob(F-statistic)	0.001049

25 / Using a test proposed by Chow in which we run a regression with no restrictions (all the variables included) and a regression with the restrictions (eliminating the R&D lags). Creating an F-statistic such that $F_{9,10} = \frac{(8.37-4.1)/9}{4.1/10} = 1.16$

26 / Using Chow's test, where the regression with restrictions is the one eliminating the R&D variables. Give us an F-statistic such that $F_{10,10} = \frac{(8.37-1.01)/10}{1.01/10} = 7.29$

Figure III.6: trade relative prices logarithm log

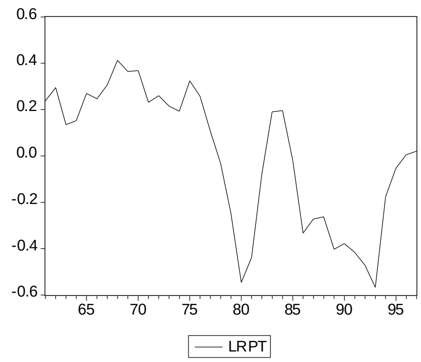
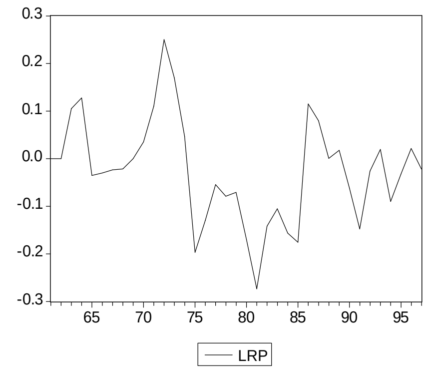


Figure III.7: domestic relative prices



Figures III.6 and III.7 plot the relative price variables used as independent variables. These two variables are the only ones in the analysis that represent short-term profitability. Note that there is no apparent trend in domestic relative prices between agricultural and non-agricultural goods, and the relative price of tradable goods has a decreasing trend. The trade relative prices variable is statistically significant at the 5% level in the regression, and the domestic relative price variable turn out to be not significant. We included one lag for each of these price variables with the idea that the previous price has an effect on the choices the farmers believe they have before adopting new technology. We estimated the model with and without the lagged variables to analyze the differences between the two of them[27], with the conclusion that we obtained better results when the lagged variables are included.

---

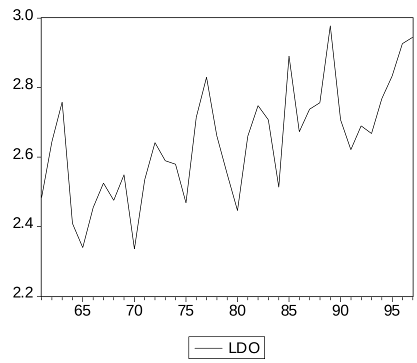
[27] / Table III.6: Adoption of technology regression without lagged variables for RPT and RP

Dependent Variable: LAAW

	Coefficient	Std. Error	t-Statistic	Prob.
C	-12.19416	4.193427	-2.907922	0.0131
LRD	0.874772	0.346351	2.525683	0.0266

The coefficient for the hyperinflation dummy is significant, suggesting that rapid inflation has a negative effect on adoption of technology. The logarithm of the index for openness of the economy is also significant, suggesting that openness has a positive effect on adoption of technology.

Figure III.8: domestic openness logarithm



LRD(-1)	0.333649	0.377712	0.883344	0.3944
LRD(-2)	-0.518936	0.348466	-1.489202	0.1622
LRD(-3)	0.118321	0.342719	0.345240	0.7359
LRD(-4)	-0.377004	0.385053	-0.979095	0.3469
LRD(-5)	0.099379	0.340042	0.292256	0.7751
LRD(-6)	0.500757	0.337307	1.484570	0.1634
LRD(-7)	-0.178904	0.369890	-0.483667	0.6373
LRD(-8)	-0.557293	0.369819	-1.506935	0.1577
LRD(-9)	0.376439	0.300547	1.252513	0.2342
LDO	1.632560	0.670800	2.433751	0.0315
D1	0.144364	0.258175	0.559172	0.5863
D2	-0.762933	0.211712	-3.603643	0.0036
LRPT	0.667012	0.442565	1.507151	0.1576
LRP	1.387328	1.185963	1.169791	0.2648

R-squared	0.855575	Mean dependent var	3.443392
Adjusted R-squared	0.675044	S.D. dependent var	0.632392
S.E. of regression	0.360494	Akaike info criterion	1.092877
Sum squared resid	1.559473	Schwarz criterion	1.854137
Log likelihood	0.699717	F-statistic	4.739217
Durbin-Watson stat	1.687179	Prob(F-statistic)	0.004918

At this point what we can say with most confidence is that the greater integration with the world and the change in expectations have had a positive relationship with the adoption of technology.

The existence of a structural change in 1991 raises the question; what are the policies implemented that caused the abrupt change in the rate of adoption of technology?
The answer to this cannot be fully addressed with the domestic openness (DO) variable and the two dummies (for hyperinflation and bank crisis) included in the previous regression.

(iii) Third stage

In order to answer this, we use the trade, domestic and international financial reform indexes formulated by Morley et al (1999) in an attempt to find a better measurement for the domestic openness of the economy,[28]. We also use their tax and privatization reform indexes. These variables represent the structural reforms implemented in Argentina in the early 1990s.

These indexes are based on policy variables under the control of the government. Each index is normalized to be between zero and one, with one being the most reformed or free from distortion or government intervention. The indexes are as follows:

[28] / Instead of the domestic openness (DO) index measured as the share of total trade in total income.

1. The trade reform index was calculated as the average of the level and the dispersion of tariffs. This information came from different studies because of lack of information for some of the years they needed to interpolated values for the intervening years. This index does not include non-quantitative restrictions.
2. The domestic financial reform index is the average of the control of borrowing and lending rates at banks and the reserves to deposits ratio. The control indexes zero-one variables with one if the rate is market determined and zero if it is controlled.
3. The international financial liberalization index was measured as the average of the limits on profit and interest repatriation, controls on external credits by national borrowers and capital outflows.
4. The tax reform index is the average of the maximum marginal tax rate on corporate incomes and personal incomes, the value added tax rate and the efficiency of the value-added tax[29].
5. The privatization index is one minus the ratio of value-added in state-owned enterprises to non-agricultural GDP.

[29] / The efficiency of the value-added tax was defined as the ratio of the VAT rate to the receipts from this tax expressed as a ratio of GDP.

Figure III.9: Capital liberalization

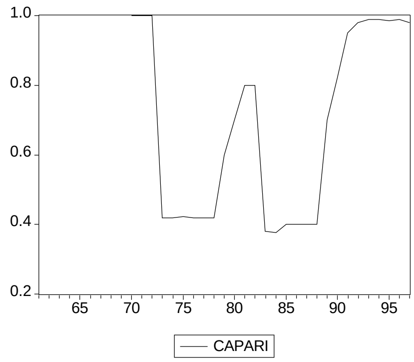


Figure III.10: Trade liberalization

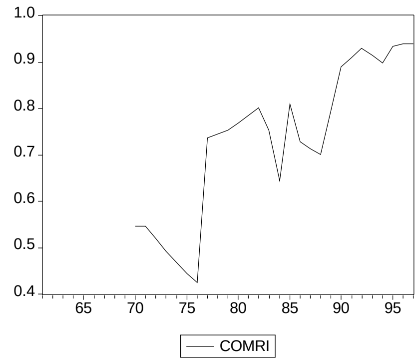


Figure III.11: Financial reform

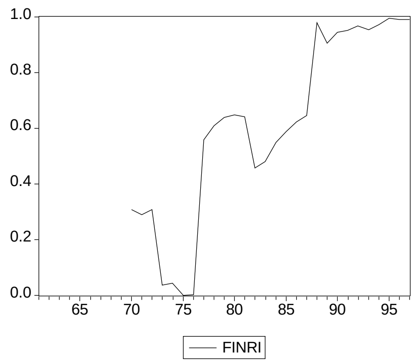


Figure III.12: Privatization reform

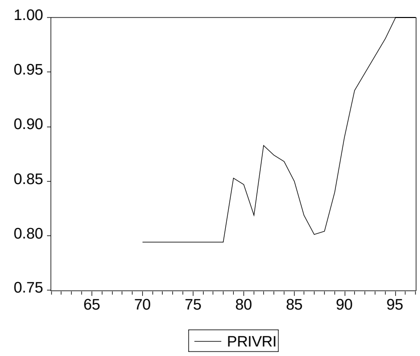


Figure III.13: Tax reform index

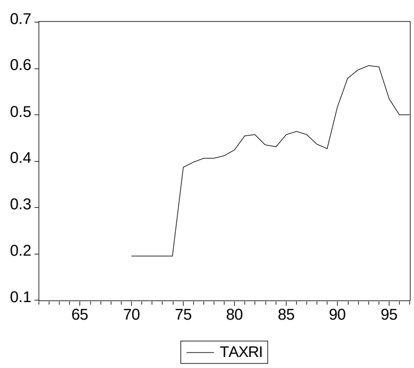


Figure III.14:Average of the five indexes

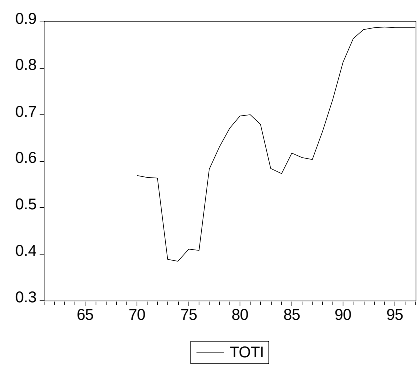
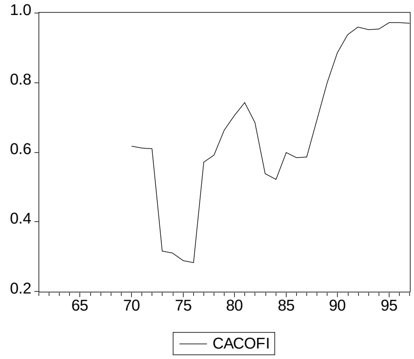


Figure III.15: Average of capital, trade and financial reforms.



These indexes were not included in the previous analysis because they are non-stationary, so their inclusion could have produced a spurious regression, invalidating the t and F-statistics. It is however possible to use the information given by these indexes and test for cointegration between the adoption of technology index and the five indexes. These variables will be cointegrated if they all have a unit root and there exists a linear combination of them that is stationary, meaning that there is a stable long run relationship between them.

Using the Johansen cointegration test for identifying the number of cointegrating relationships between the variables, and for estimating the parameters of the long run relationships,

$$AA = \beta_1 + \beta_3 CAPARI + \beta_4 COMRI + \beta_5 FINRI + \beta_6 PRIVRI + \beta_7 TAXRI \quad (1)$$

Table III.7: Johansen cointegration test

Trend assumption: Linear deterministic trend in the data
Series: AA CAPARI COMRI FINRI PRIVRI TAXRI

Unrestricted Cointegration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.929298	165.5680	94.15	103.18
At most 1 **	0.850139	96.68672	68.52	76.07
At most 2 *	0.587094	47.33742	47.21	54.46
At most 3	0.446379	24.33951	29.68	35.65
At most 4	0.286053	8.966354	15.41	20.04
At most 5	0.007881	0.205730	3.76	6.65

*(**) denotes rejection of the null hypothesis of no relationship at the 5%(1%) level
Trace test indicates 3 cointegrating equation(s) at the 5% level
Trace test indicates 2 cointegrating equation(s) at the 1% level

The likelihood ratio test indicates 3 cointegrating equation(s) at 5% significance level.

Table III.8: Normalized Cointegrating Coefficients; 1 Cointegrating Equation(s)

AA	CAPARI	COMRI	FINRI	PRIVRI	TAXRI	C
1.000000	-0.793853	-3.301065	-0.343187	18.64141	-2.233696	-12.26159
	(0.37942)	(1.39395)	(0.23580)	(7.25921)	(1.15976)	

Normalizing the equation by the Adoption of Technology variable (AA) gives the long run relationship of:

$$AA = 12.26 + 0.79 * CAPARI + 3.30 * COMRI + 0.34 * FINRI - 18.64 * PRIVRI + 2.23 * TAXRI$$

It is necessary to check the residuals from the cointegration regression, testing the null hypothesis that the residual has a unit root against an alternative that the series is stationary. If we accept the alternative hypothesis, there is cointegration. All the residuals for cointegration on equation *(1)* pass the test for stationarity, with the null hypothesis was rejected at the 1% confidence level.

In summary, we find cointegration between the reform policy indexes and the adoption of technology. There exists a positive relationship between the adoption and the indexes of commercial, financial and tax reforms and the openness of the capital account.

Given that we found that only three of the five indexes are relevant for this study, we use the average of the three relevant reform indexes for the Argentine agricultural sector in the 1990s created by Morley et al[30] and take the effect of international prices for food commodities and the world income (using as a proxy the world imports for food and the prime real interest rate in the United States) in order to separate or eliminate the external tendencies.

The tricky part of using cointegration is to find a way to be able to use the coefficients given by the regression. Engle and Yoo (1990) proposed a three- step estimator that gives t-ratios with normal distributions. The solution is (in the simplest case) to regress the residuals from the Error Correction Model[31] (ECM) on the I(1) variables. As it is explained in the following theorem (Engle and Granger 1987, pg. 262): The two step estimator of a single equation of an error-correction system with one co-integrating vector, obtained by taking the estimate α^ of α from the static

[30] / CACOFI includes capital account and commercial liberalization, and financial reforms. They are the three more representative of the five indexes for the changes in the agricultural sector. Hence, a new index was created using a simple average of the capital account liberalization, commercial liberalization and financial reform.

[31] / The ECM uses first differences and levels for the cointegrating relationship, leaving us with the possibility of looking at the long-term relationship and testing for spurious regression problems at the same time.

regression in place of the true value for estimation of the error-correction form at a second stage, will have the same limiting distribution as the maximum-likelihood estimator using the true value of α. Least-squares standard errors in the second stage will provide consistent estimates of the true standard errors."

THE ENGLE-YOO THREE STEP COINTEGRATION TEST

Variables: AAWI CACOFI PAGW IMPWORLD

Table III.9: Johansen cointegration test

Trend assumption: Linear deterministic trend
Series: AAWI PAGW IMPWORLD CACOFI
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.952606	114.4328	47.21	54.46
At most 1 **	0.657322	38.20146	29.68	35.65
At most 2	0.366873	11.42734	15.41	20.04
At most 3	1.02E-05	0.000255	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 2 cointegrating equation(s) at both 5% and 1% levels

There is at least one cointegrating equation.

Engle-Granger first step, the cointegrated equation: in order to get the residuals

Table III.10: Engle-Granger first step

Dependent Variable: AAWI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.352909	0.783170	-3.004341	0.0063
CACOFI	0.458194	0.455320	1.006313	0.3247
PAGW	0.002793	0.001980	1.411110	0.1716
IMPWORLD	0.012404	0.004011	3.092644	0.0051
INTRATEUS	-0.006568	0.023208	-0.283005	0.7797
R-squared	0.580465	Mean dependent var		0.402427
Adjusted R-squared	0.507503	S.D. dependent var		0.380509
S.E. of regression	0.267034	F-statistic		7.955654
Durbin-Watson stat	0.258032	Prob(F-statistic)		0.000352

Engle-Granger second step, the ECM equation: replacing the residuals of the equation of the first step, in order to get the coefficient of the ECM term.

Table III.11: Engle-Granger second step

Dependent Variable: D(AAWI)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.041599	0.027229	1.527741	0.1415
D(CACOFI)	-0.034134	0.242977	-0.140484	0.8896
D(PAGW)	0.000756	0.000908	0.832414	0.4145
D(IMPWORLD)	0.004350	0.004959	0.877262	0.3903
D(INTRATEUS)	0.001145	0.011610	0.098610	0.9224
RESIDEG1DBFN(-1)	0.039258	0.113307	0.346474	0.7324
R-squared	0.091953	Mean dependent var		0.052282
Adjusted R-squared	-0.124248	S.D. dependent var		0.107524
S.E. of regression	0.114008	F-statistic		0.425313
Durbin-Watson stat	0.651282	Prob(F-statistic)		0.825815

Engle-Yoo third step: to correct the estimates of the Engle-Granger second step. The residuals from the E-G second step are regress on the intercept and the coefficient of the residuals from the E-G first step variables lagged.

Table III.12: Engle-Granger third step

Dependent Variable: RESIDEG2DBFN

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.634768	0.225793	-2.811286	0.0102
CACOFI(-1)*0.039258	5.648625	3.211548	1.758848	0.0925
PAGW(-1)*0.039258	0.014482	0.013706	1.056650	0.3021
IMPWORLD(-1)*0.039258	0.065434	0.029259	2.236398	0.0358
INTRATEUS*0.039258	-0.130431	0.160744	-0.811419	0.4258
R-squared	0.560345	Mean dependent var		-4.24E-18
Adjusted R-squared	0.480408	S.D. dependent var		0.102438
S.E. of regression	0.073840	F-statistic		7.009807
Durbin-Watson stat	1.587293	Prob(F-statistic)		0.000850

RESIDEG2DB = C(1) + C(2)*(CACOFI(-1)*0.039258) + C(3)*(PAGW(-1)*0.039258) + C(4)*(IMPWORLD(-1)*0.039258) + C(5)*(INTRATEUS(-1)*0.039258)

The final estimates are the sums of the ones obtained in the E-G first step plus the corrections obtained from the E-Y third step. The standard errors are the ones from the E-Y third step.

CACOFI = 0.458194 + 5.648625 = 6.106819
PAGW= 0.002793 + 0.014482 = 0.017275
IMPWORLD= 0.012404 + 0.065434 = 0.077838
INTRATEUS= -0.006568 - 0.130431 = - 0.136999

The t-values are:

CACOFI = 6.106819 / 3.211548 = 1.901518
PAGW= 0.017275 / 0.013706 = 1.260396
IMPWORLD = 0.077838 / 0.029259 = 2.660309
INTRATEUS= - 0.136999 / 0.160744 = - 0.852280

At the 5% percent confidence level, the liberalization and reform index and the total imports of agricultural products are significant. These results indicate that the liberalization and reform process that Argentina went through had a positive effect on the adoption of technology.

Note that there are three apparent structural breaks in the average of the capital account, commercial and financial reform index (CACOFI, (see Figure III.15)). The first one occurs in 1976 with the oil crisis and the domestic political situation, the second one in 1981 with the debt crisis, and the last one in 1991 which was previously discussed. The 1976 and 1981 crises are not significant in explaining a change in the rate of adoption, while the 1991 structural change is very significant at the time of explaining the change in the adoption rate (with a t-statistic of 3.03).

Summary

The three stages of empirical analysis in this chapter were directed at the objective of analyzing the impact of the economic environment on the adoption of technology. The results confirmed the argument that the stability of the economy and liberalization motivates producers to adopt new technology. This motivation can be the consequence of the need to adopt new technology because otherwise producers lose competitiveness in the world market and/or because the stability and transparency of the economy makes producers more comfortable with the idea of innovation.

This last idea will be the motivation for Chapter VII, in which the variables we found significant in explaining the adoption of technology in the agricultural sector are used to run policy scenarios that can affect the agricultural sector development.

CHAPTER IV. THE ROLE OF TECHNOLOGY IN GROWTH

After a period of turbulence and crisis in the 1980s, many Latin American and Asian countries went through a process of economic reform. The results obtained on both continents varied from country to country. As a result, economists began looking at the data and the facts trying to explain the variables that play a role in the determination of growth.

One pervasive finding seems to be that macroeconomic stabilization and openness of the economy provide a good environment for adoption of technology through investments, and consequently a higher rate of growth. This is the connection that we are using in this research, between the adoption of technology and the growth paths that the Argentine economy has achieved.

Bleany (1996) found that macroeconomic uncertainty delays the investment decision and hurts the rate of growth. Uncertainty increases the value of delaying investment with the hope that the uncertainty will go away with time. He explained the average per capita growth rates of GDP (GR) by the growth rate of physical capital (INV, the investment share of output), a matrix of explanatory variables of growth (X), a matrix of measures of policy-induced macroeconomic instability (Z), with ε a random error term.

$$GR = \alpha + \psi * INV + X * \beta + Z * \gamma + \varepsilon$$

The variables used in the Z matrix are the fiscal balance, real exchange volatility or inflation and debt (as percentage of GDP, trying to capture the credit rationing that some developing countries suffer).

He supplemented this equation with one for investment:

$$INV = \delta + X * \phi + Z * \rho + \eta$$

Both equations give the result that poor macroeconomic management creates needless uncertainty in the economic environment, which increases the risk associated with investment.

Rodrik (1991) argued that a lack of credibility in government policy can be interpreted as a tax on investment, because there exists the possibility that the policy will not be sustained. Cottani et al (1990) found that real exchange rate instability is negatively correlated with investment and growth.

Fischer (1993, pg 488) found that growth is negatively associated with inflation and positively associated with good fiscal performance and undistorted foreign exchange markets. Even more interesting, he tested the causation between policies and growth, finding that causation runs from good macroeconomic policy to growth. As he stated: “The main reason macroeconomic factors matter for growth is through uncertainty.

There are two main channels through which uncertainty could affect growth. First, policy-induced macro uncertainty reduces the efficiency of the price mechanism. This uncertainty, associated with high inflation or instability of the budget or current account, can be expected to reduce the level of productivity and, in contexts where the reallocation of factors is part of the growth process, also the rate of increase of productivity. Second, temporary uncertainty about the macro-economy tends to reduce the rate of investment, as potential investors wait for the resolution of the uncertainty before committing themselves. Capital flight, which is likely to increase with domestic instability, provides another mechanism through which macroeconomic uncertainty reduces investment in the domestic economy" .

De Gregorio (1993) found that capital flights, pessimistic perceptions, and delays in investment decisions are among the main explanations for the negative effect that macroeconomic uncertainty has on capital accumulation. De Gregorio (1992) used panel data for 12 Latin American countries during the period 1950-1985, in order to capture the impact of macroeconomic stabilization on growth. The results showed the importance of the macroeconomic environment in nurturing growth.

Aizenman et al (1993) used an endogenous growth model with irreversible investment as the channel that links policy uncertainty with growth. The analysis was done for 46 developing countries for the period 1970-1985. They showed that macroeconomic uncertainty measures and growth are negatively correlated, and that macroeconomic uncertainty affects long run growth through the alteration of the investment pattern.

The results from these papers suggest that policy uncertainty affects growth through lower capital accumulation and growth rates of productivity. When there is uncertainty about the future, producers will not adopt new technologies, preferring to wait until the risk decreases with the passage of time. The literature is thus consistent with the hypothesis defended in this dissertation that the intermediate step between macroeconomic stability and growth is the adoption of technology (investment).

The second part of this chapter examines the characteristics of the growth models, as they pertain to this dissertation, that is, growth theory that includes technological change in the modeling. This branch of the literature can be divided into two approaches: i) models that include technological change as exogenous, and ii) models that treat technological change as endogenous to the model. An example of the first group is Solow's model, which assumed growth of population, savings and technological change are exogenous and that a constant fraction of output is invested:

$$Y(t) = T(t) * K(t)^{\alpha} * L(t)^{1-\alpha}, \quad \text{where } T(t) = T(0) * e^{gt}.$$

An example of the second group is Romer's model (1987), in which *T* is determined locally by knowledge spillovers from capital investment and assumed that each unit of capital investment not only increases the stock of physical capital but also increases the level of technology for all firms in the economy through knowledge spillovers:

$Y_j = T(K,L) * K_j^{\alpha} * L_j^{1-\alpha}$, where variables with subscripts are variables that the firm *j* can control, and variables without subscripts represent economywide totals.

This model does not explain the transitional dynamics (growth rates for capital, output and consumption are equal) and concludes that consumption growth does not depend on the stock of capital per person.

Another example of a model that has endogenous technological change is Jones and Manuelli (1990). They write $Y(t) = TK +$ ª(K,L), or in Cobb-Douglas form:

$$Y(t) = T(t) * K + BK(t)^{\alpha} * L(t)^{1-\alpha},$$

where $T(t) =$ ª(δ), is a shift factor, and this parameter does not measure movements along the production function, and where ª(K,L) satisfies the properties of a neoclassical production function, positive and diminishing marginal products, constant returns to scale, and the Inada conditions (see Inada, 1963). However, the whole equation violates the Inada condition because the $lim_{K\to\infty}\left[\partial Y / \partial K\right] = T > 0$. Also, the *TK* term gives the endogenous growth and the ª(K,L) part generates the convergence behavior. The most important aspect of this model (TK extended model) is that it restores the transitional dynamics during which the average and marginal products of capital decline gradually toward the steady state value, T. However, it keeps the convergence property, because the falling productivity of capital tends to generate a decline over time in per capita growth rates.

The way growth is introduced in the analysis in this dissertation is through the general equilibrium model that is explained in chapter VI. Following the already mentioned TK extended model a parameter is introduced into the production function representing the adoption of technology. This last parameter is endogenous to the model and we believe is the best approximation to reality because individual producers do not invest in R&D, instead, they buy or take the results of R&D made in different sectors (industry, government or/and international institutions), or in different countries (the case of multinational firms and capital imports). So, the level of technology in each product can be estimated as a function of the different variables that have an effect on the extent of utilization of available technology.

The preceding leaves us with two different cases. The first one is for the agricultural sector in which the parameter included in the production function (as explained in Chapter VI) that represents adoption of technology depends on the openness of the economy and the expenditures on agricultural R&D. The second case is for the industry and services sectors that depend on the openness of the economy solely.

CHAPTER V: SOURCES AND CONSTRUCTION OF DATA

V.1. The Social Accounting Matrix for the year 1997[32]

Data for the model is included in a Social Accounting Matrix (SAM) that corresponds to national accounts, trade data, and household surveys for 1997. This year captures the beginning of the impact of the 1991 program. The SAM includes 44 sectors ("activities") and commodities, 9 factors of production, and the standard accounts for households, firms, the government, and the rest of the world. The final SAM is disaggregated into 11 primary agricultural products, 4 non-agricultural primary sectors, 11 food-manufacturing sectors, 14 non-food manufacturing sectors, 3 service sectors, and the government.

The data needed to build a SAM can be divided in two groups depending on their disaggregation. The macroeconomic financial data comes from the national accounts of Argentina and the International Financial Statistics (IFS) of the IMF. They are aggregated at the national level for 1997 in current pesos of the same year.

At the industry-specific level, output-input coefficients, domestic final demand components (consumption, investment, change of stocks), trade data (exports, imports, import tariffs, export taxes), value added components (wages and returns to capital), gross output, indirect taxes, value added tax, capital stock and labor are included. The trade data covers bilateral trade data between Argentina and Brazil,

[32] / This chapter is based on Diaz Bonilla and Piñeiro, 1998.

Canada, Mexico, European Union, Rest of Latin America, and the Rest of the World, and comes from Instituto Nacional de Estadisticas y Censos (INDEC)

Input-Output Matrix.

Starting from the input-output matrix, final demand components and trade data were taken from the work done by Alejandro Vargas at the CEI with help from the INDEC (with data from the Economic National Survey of 1994). Changes were made to the input-output matrix in order to make it more adequate for analyzing the agricultural sector, as follows.

The original matrix had 64 sectors, with the agricultural sector taken as a whole and the agroindustry sector having 9 sub-sectors. The agricultural sector was disaggregated into 11 sub-sectors (rice, maize, wheat, other grains, bovines, other livestock, fruit and vegetables, milk, soybeans, and sugar cane).

In the case of agroindustry, chapter 151 (livestock, fruit and vegetables) was disaggregated into four subsectors: bovine meat, other meat, fruit and vegetable preparations, and vegetable oils. Chapter 154 (other manufactured agricultural products) was divided into three subsectors: sugar, wheat manufactured, and other products. Chapter 155 (beverages) was divided into alcoholic beverages and non-alcoholic beverages. Chapters 152 (dairy products) and 153 (milling) were kept as they were in the original matrix.

These disaggregations were done using data from the national survey from 1994, the 1996 INDEC year book, exports, imports, and producer prices from the FAO, and prices, exports, imports, production, and cost structure of the agricultural producers from Secretaria Agricultura, Ganaderia, Pesca y Alimentos (SAGPyA). With the cost structure of the producers it was possible to assign the acquisitions that each sector made from each other sector. The total values from the original matrix were used as controls.

Some industrial sectors and non-agricultural services from the original matrix that are peripheral to the analysis of this dissertation were aggregated. The final SAM used in this dissertation has 44 sectors, of which 11 are from the agricultural sector, 13 from the agroindustry, and the rest from the industry and other sectors (see Annex 1 for a detailed list of sectors).

Factors of Production

The nine factors of production include 8 labor types and capital (including land). The labor force is divided among rural male and female labor (2), and urban unskilled, urban semi-skilled, and urban skilled male and female labor (6). Unskilled labor is defined as those with at most completed primary schooling. Semi-skilled workers are those who have no more than a high school education or vocational training, while those with university or more are considered skilled labor.

Labor demand was estimated using the INDEC's Permanent Households Survey, and the cost structure of production. The average wages are those obtained in the Argentine Input-Output Matrix (MIPA 93).

Capital was calculated as the residual of the value added, net of labor wages. This is the mechanism by which land is included in the definition of capital.[33]

Households

Households receive income from the factors of production and transfers from other sources. With this income they pay taxes, save and consume. Using data from the INDEC'S Household Consumption Survey and other sources, the households' consumption for the different products was calculated. In this study direct taxes and transfers to other institutions are fixed shares of household incomes while saving shares are endogenous.

Firms

Firms receive capital factor income and transfers from other institutions. They use their income in direct taxes, savings, and transfers to other institutions. They do not consume goods. The income they receive from the factor of production (capital) was calculated as the residual between value added and wages. Data on direct taxes was given by the Direccion Nacional de Gastos Consolidados (DNGC).

[33] / Land is part of the residual of value added once we take out labor wages. But because we could not assigned a value for capital and land separately we include them as one. This does not mean that factor intensity of agricultural production is the same in crop production as in processing and industrial production.

Government

The government receives taxes and transfers from other institutions, spends on consumption and transfers to other institutions, and saves (surplus or deficit). The government includes the National Public Sector (including the Federal Government, the States' governments and the city governments). The government's investment data was given by the Direccion Nacional de Inversion Publica (DNIP), and the government consumption, collection of taxes and transfers were obtained from the DNGC.

Saving-Investment

Data from the Direccion Nacional de Cuentas Nacionales (DNCN) and capital estimations made by the Direccion Nacional de Coordinacion Politicas Macroeconomicas (DNCPM) was used to calculate the capital stock. Capital depreciation was based on DNCN's estimation of the stock of capital by sector. To this estimation, different coefficients of depreciation were used according to the sector and provided by SAGPyA and DNCN.

Rest of the World

In the SAM there are seven countries or groups of countries: Brazil, Mexico, Canada, United States, European Union, Rest of Latin America and Rest of the World. All the trade data (exports and imports) are based on the information given by the INDEC.

The SAM was balanced using consistency equations programmed in GAMS (Generic Algebraic Modeling System; See Brooke, Kendrick, and Meeraus, 1988). And following Robinson et al (2000) where a SAM was balanced using a cross-entropy approach.[34]

V.2. The Social Accounting Matrix for the year 2000[35]

Using the SAM built by Petri and Mendez Parra (2004), the number of sectors were aggregated to replicate the same sectors that we have for the SAM for 1997. In some cases, it was also necessary to add sectors in the previous SAM.

Petri and Mendez Parra dissagregated the input-output matrix of 1997, as a result of facing the same problems of insufficient disaggregation of the agricultural sector as described earlier in this chapter. For this exercise product cost structures were used; these were provided by SAGPyA specialized areas (Agriculture Direction, Livestock Farming Direction, Agricultural Economy Direction) and some private experts were consulted.

This SAM was built on data from 1997, with an update to the year 2000. They used this year because it was the year previous to the change of the convertibility law and the collapse of the economy.

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[34] / This methodology minimizes the distance between the original SAM (the one built with our data) and an objective SAM (the balanced SAM). The discrepancies between the two SAMs can be considered distances and are minimized in a mathematical way, that satisfies the double-entry accounting balance constraints, and other macro balance constraints.

[35] / This part of the chapter is based on Petri and Mendez Parra, 2004.

The updating process consisted of using the technical coefficients from the 1997 input-output matrix and applying to the row and column total and the final demand components the values from 2000. In this way, a SAM with final values for 2000 was obtained. It is important to note that this new SAM keeps the relative prices structure (and technology) of 1997, while including the final demand data for 2000.

V.3. Adoption of technology

For the estimation of the adoption of technological change, four groups of data were collected: 1) for the adoption of technology proxy, national data on consumption of fertilizers, herbicides and transgenic seeds, number of tractors and certified seeds sold, and number of hectares planted with no till techniques. From INASE, SAGPyA, APROF, AFAT and INPI are used, 2) relative prices, from available national data and FAO, 3) the amount spent on research by the central government and universities from INTA, trade and inflation data from INDEC, and 4) macroeconomic indexes from Morley et al. (1999). The first group of data mentioned above was used for the construction of the proxy for adoption of technology. The second and third groups were included as independent variables in the regression done for adoption of technology and the fourth group was used in the second estimation of adoption of technology in which we had more specific policy variables.

CHAPTER VI: Structure of the Recursive Dynamic CGE Model

Recursive dynamic CGE models have been used in Chenery et al (1999) and El-Said et al (2001) to analyze different development strategies in Korea and Egypt, respectively, in Lofgren (2001) as a tool to model changes in poverty resulting from various policy alternatives, and finally in Thurlow (2003), a recursive model for South Africa.

These models are solved in two stages. The first is to find a solution for a one-year equilibrium using a static CGE model. In the second stage, a model between periods is used to handle the dynamic linkages that update the variables that drive growth. The intertemporal equations provide all exogenous variables needed for the next period by the CGE model, which is then solved for a new equilibrium. The model is solved forward in a dynamically recursive fashion, with each static solution depending only on current and past variables. The model does not incorporate future expectations; instead the behavior of its agents is based on adaptive expectations, as the model is solved one period at a time. The parameters used as linkages between periods are the aggregate capital stock (which is updated endogenously, given previous investment and depreciation), population, domestic labor force, factor productivity, export and import prices, export demand, government policies, and transfers to and from the rest of the world (which are all modified exogenously).

The dynamic model used in this research follows the models developed by the International Food Policy Research Institute (IFPRI).[36] As is explained in this chapter, bilateral trade and endogenous growth are included as part of this work.

This model for Argentina is solved for 1997 (the base year for the data) until the year 2015, which allows us to see the rate of change of key parameters of the Argentine economy for the period. Once this growth path has been obtained, it is compared with the results for the year 2000 that were obtained using the 1997 Social Accounting Matrix (SAM) with the 2000 SAM. This provides information for model validation, comparing observed and simulated data.

The choice of the year 2000 is ideal for several reasons. It is the year before the "big crisis", an event which is properly omitted, as the recursive dynamic CGE model does not contain equations capable of simulating a financial crisis of the magnitude Argentina experienced in 2001. Our modeling assumes there was no change in the structure of production following the crisis, while it is unlikely that this has been the case. Data limitations prevent a more robust analysis until a new SAM that captures the actual changes resulting from the crisis, is estimated.

VI.1. First step: within a period

The static CGE model used in this part of the research was built based on the standard model used by IFPRI (see Lofgren et al, 2002), which follows the neoclassical-

[36] / Lofgren et al (2002) and Thurlow (2004).

structuralist tradition originally presented in Dervis et al (1982). Basic data for CGE models are obtained from a Social Accounting Matrix (SAM). A SAM is a comprehensive, economy-wide data framework, typically representing the economy of a country. As stated Lofgren et al: “a SAM is a square matrix in which each account is represented by a row and a column. Each cell shows the payment from the account of its column to the account of its row; the incomes of an account appear along its row, its expenditures along its column. The underlying principle of double-entry accounting requires that, for each account in the SAM, total revenue (row total) equals total expenditure (column total)”.

The CGE model has three components. The first shows the payments that are registered in the SAM, following the same disaggregation of factors, activities, commodities and institutions shown in the matrix. The second has the equations that represent the behavior of the different institutions present. The third has the system of constraints that have to be satisfied by the whole system covering the factor and goods markets, the balances for savings-investment, the government and the current account of the rest of the world.

Each producer maximizes profits under constant returns to scale and perfect competition. There are two factors of production, labor and capital represented in a constant elasticity of substitution function (CES) production function, which allows the producers to substitute these two inputs until they reach the point where the marginal revenue of each factor equals the factor price (wage or rent. See figure

VI.1). The second choice the producers make is the amount of intermediate inputs they will use. This specification is made assuming fixed shares that specify the appropriate amount of intermediate inputs per unit of output and labor/capital (value added. Finally, output prices depend on the value added (cost of L and K), intermediate inputs and any relevant taxes and subsidies.

Figure VI.1: Sectoral production technology

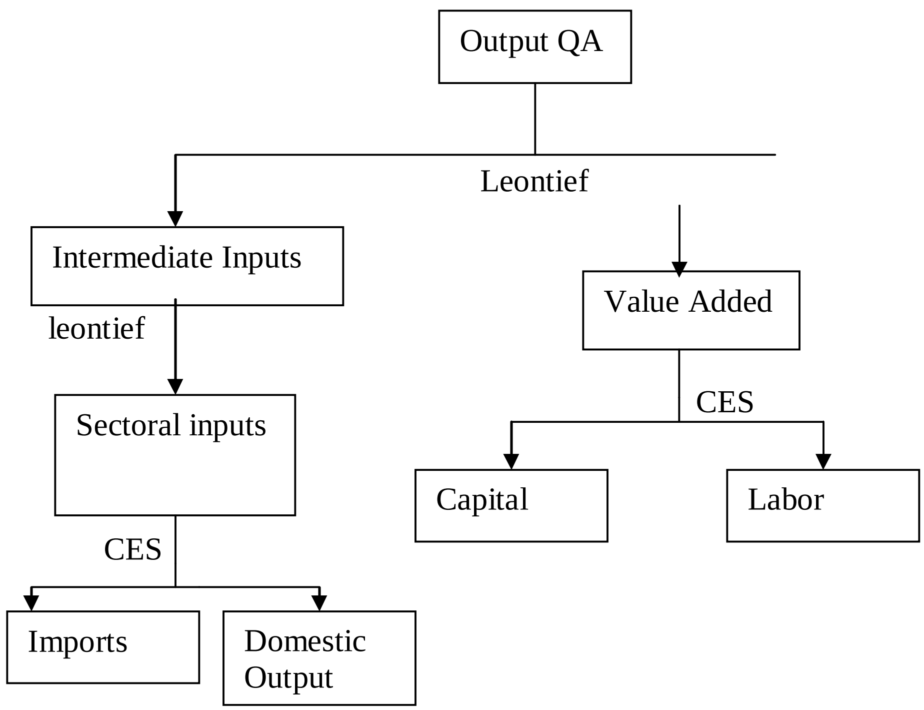
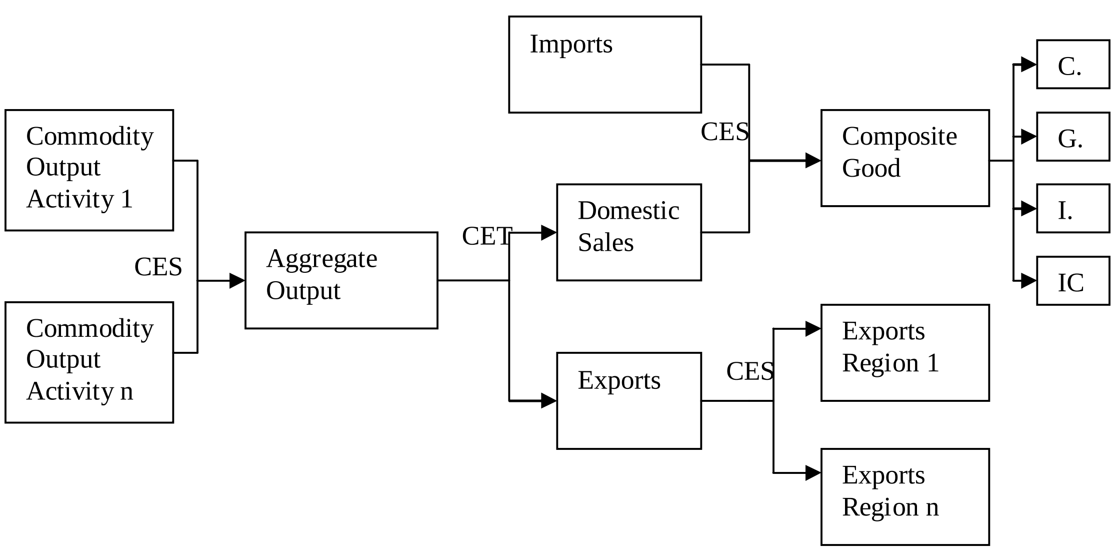


Figure VI.2 shows the flow of a single commodity from producers to final demand. First, there is the combination of a particular commodity from all producers into an aggregate commodity output. This is achieved using a CES product demand system with the intention of leaving the option to the buyers as to how much to buy from each individual product (maximizing their consumption). The aggregate output is sold domestically or internationally. The producers' allocation between domestic sales and exports is specified via a constant elasticity of transformation (CET) function, assuming imperfect transformability between them (exports and domestic sales). The producers will sell their products to the market with the higher profitability. The domestic price is the international price times the exchange rate plus any possible export taxes or export subsidies. For exported commodities there is an additional CES function that distributes the export shares between trade partners. This substitution is based on price differentials. The domestic good is combined with imports to produce the composite commodity. For this the Armington[37] specification is used, which means that the domestically produced good is different from the imported one.

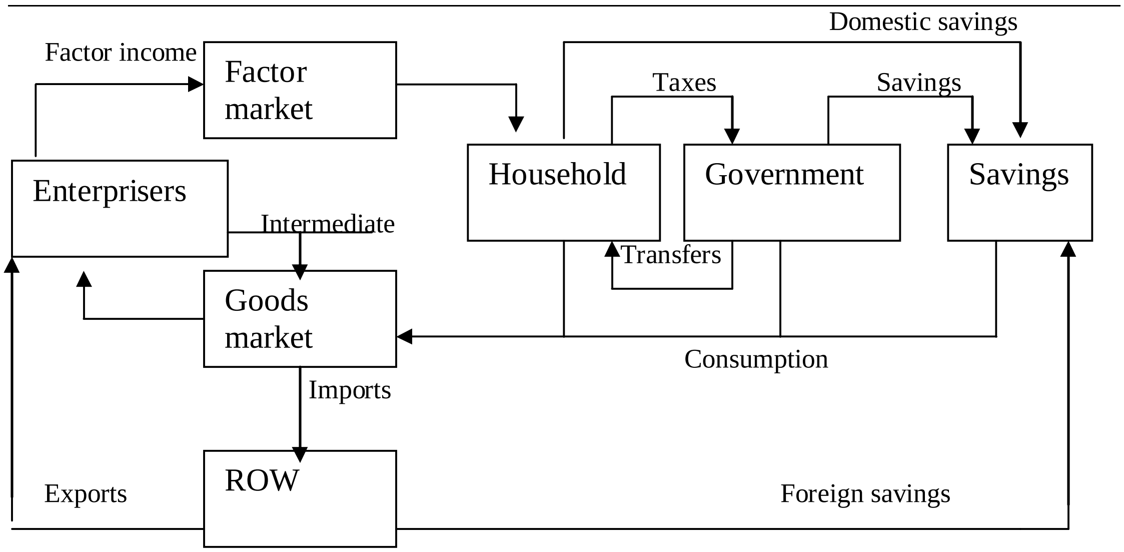
Figure VI.2: Flow of goods from producers to the national composite commodity



37/ Armington (1969).

In this model there are four institutions, households, enterprises, government and the rest of the world, which do three things: a) produce, b) consume, and c) accumulate capital. Households save a constant share of their disposable income and buy consumption goods. They have ownership of the enterprises and they work in those enterprises. As a result, household income is the sum of salaries, profits and government and rest of the world transfers. Household consumption of goods and services is determined following a linear expenditure system (LES). Firms buy intermediate goods, hire factors of production, produce commodities and services, and sell them in the market. Government receives taxes, consumes goods and services and makes transfers to households. The capital account collects the savings from the households, firms, government, rest of the world and buys capital goods (investment).

Figure VI.3: Circular flow of income in the CGE model



The model includes a cash in advance constraint (Clower, 1967) that is used to anchor the nominal variables (Díaz-Bonilla and Piñeiro, 1999, and Díaz-Bonilla, Reca, and Piñeiro, 2000). If all the nominal variables can move freely, the model behaves like the classic dichotomy of the Walrasian models (between the determination of relative prices and the determination of the absolute price level), where the relative prices are determined endogenously and affect the allocation of real resources, and where money determines only the absolute level of the nominal variables (Patinkin, 1965). However, if there is rigidity in a nominal variable, the changes in supply or demand of money will have impacts in the real economy. The changes caused by those real effects will depend on the number of variables affected by the nominal resistance and the degree of resistance.

In this model the monetary constraint is applied equally to the supply as well as the demand side. On the supply side, a monetary constraint linked to the production value is included in the production function (Fischer, 1974). On the demand side, the monetary constraint is seen in the utility function linking the monetary technology to the value of the goods consumed

Another characteristic of this model is the inclusion of an equation that relates trade to changes in total factor productivity (TFP). An increase of trade can bring changes in national TFP through several channels: learning by doing, access to new knowledge, economies of scale, technological spillovers given by access to capital goods and intermediate goods of better quality, and an increase in competitiveness in markets that used to be protected (See Balassa, 1989; Grossman and Helpman, 1995, Romer, 1994, and Wacziarg, 1998; examples of CGE models with linkages between trade and productivity are de Melo and Robinson, 1995; Lewis, Robinson, and Wang, 1995; Diao and Somwaru, 2001). The model includes an equation that relates total exports and imports as a share of GDP to TFP for each production function.

The equation used in the model is as follows:

$$TFP_i = \overline{A}_i \left(\frac{\frac{1}{2} \cdot EXR \cdot \left(E_i + M_i \right)}{GDP_i} \right)^{\varepsilon}$$

where *TFP* represents total factor productivity, *EXR* is the real exchange rate[38], *E* total exports, and *M* total imports. $\overline{A}$ is a constant, and ε is the coefficient that defines the impact of changes in trade on productivity (the same one for all sectors)[39]. The subscript *i* represents sectors.

The third characteristic of this model is that it includes a technological change parameter in the production function of the agricultural products that depends on government expenditures in agricultural R&D (see Annex A.2). There are not sufficient data to be able to disaggregate the impact on each agricultural sector, hence we only examined at the impact of total expenditures on R&D in all the agricultural sectors. The values for the coefficients that relate expenditures in agricultural R&D to changes in productivity were derived from the rates of return for agricultural R&D

[38] / Exchange rate is included in order to convert exports and imports into pesos.

[39]/ The values used are 0.1 for developed countries and the third part of that for developing countries (0.033) (see Wacziarg, 1998).

reported in Alston, Chan-Kang, Marra, Pardey, and Wyatt (2000). The values of the rates of return are the medians reported in that study for each region. From those rates of return it is possible to derive a simple relationship between public expenditure in R&D as a percentage of agricultural GDP and agricultural production, representing a shift in the agricultural production function, under the assumption that the benefits are a perpetual annual flow and that the costs occurred only once in the base year (see Alston et al, 2000 p.25-26), and that Argentina cannot affect the international price of its exports.

The equation is as follows:

$$G\_TFP = \beta \left(\frac{GEXP\_TFP}{AGGDP} \right)$$

G_TFP represents total factor productivity in the agricultural sector; *GEXP_TFP* represents those government expenditures that are oriented toward improving technology and productivity; *AGGDP* is the total value of the agricultural sector; β is the coefficient that determines the relationship between public expenditures in agricultural R&D and the sector's productivity.

As previously noted, it is not possible to differentiate the returns obtained in each group of agricultural products from the available data. The sources of information used (as in Diaz Bonilla et al, 2003) are the IRRs reported in Alston et al, (ie. 42.9%

for agricultural products in developing countries).[40] In addition, a sensitivity analysis was performed using the results from Cirio and Castronovo (1993) which produced the same range of returns as the ones obtained by Alston et al. (See Annex 2.)

The fourth characteristic of this model is that it includes bilateral trade. Argentina exports and imports from different trading partners including: Brazil, Mexico, Canada, United States, European Union, Rest of Latin America and Rest of the World. The small country assumption is adopted in the case of imports, so that the country faces a perfectly elastic supply curve. In the case of exports, geographic differentiation is assumed, so the country faces a downward sloping demand curve in each of its trading partners' markets. The behavior of these other countries and regions are exogenous to the model. Greater detail in the treatment of the external sector allows us to simulate different trade policy scenarios.

Closures

The closures or the mechanisms for equilibrating supplies and demands are as follows: (i) for the labor markets, the model allows the existence of unemployment. Labor is mobile across sectors, and maintains fixed real wages by labor category, (ii) for capital, total national stock is fixed, but its sectoral allocation may vary (i.e. capital is mobile across sectors).

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[40] / In our notation: $\beta_{ag} = 0.429$

Argentina had a fixed exchange rate during this period leaving foreign savings as the equilibrating variable. For the government, the level of consumption and income taxes are fixed across simulations, except for the simulation of R&D in which public expenditures are increased exogenously. These expenditure increments are financed by cuts in other areas, leaving the total public expenditures constant. Investment demands for capital goods and inventories are kept constant in real values and savings by households adjust.

VI.2. Second step: between periods

In the second step of the recursive model, the linkages between periods are introduced. This is done by solving the static model for one specific year and then updating the capital stock, population, domestic labor force, factor productivity, export and import prices, and export demand parameters. After this step, the model is solved again for the following year and so on.

The model used in this research is based on Dervis et al (1982) and Thurlow (2003). Total capital accumulation is endogenous. It is calculated as the last period's capital stock plus total investment minus depreciation[41].

[41] / In other models like Thurlow (2003) the allocation of new capital across sectors is done by adjusting the proportion of each sector's share in aggregate capital income as a function of the relative profit rate of each sector compared to the average profit rate of the economy as a whole. Sectors with higher (lower) average profit rates will get higher (lower) shares of the available investment than their share in capital income.

The closure for labor is the same one used for the static part of the model, labor is not fully employed; there is unemployment at a fixed real wage. Population growth is imposed exogenously on the model based on calculated growth projections taken from INDEC.

Population growth is reflected in the private consumption variable in the model. Through time as population grows, the level of each household consumption of a commodity moves upwards to account for the increase in the consumption demand.[42]

One of the critiques that this type of model receives is that it is not able to include the changes in the structure of production that occur over time. For this research, we address this critique by using the 2000 SAM for Argentina[43] which enabled us to include changes in the use of inputs during the period 1993-1997. Specifically, the I-O used for the first year solution corresponds to data for 1997 and the one used for 2000 and the following years correspond to the 2000 I-O[44]. For the years in between, the corresponding value of the linear relationship between the two points (1997 and 2000 data) was used.

Finally, productivity growth, real government consumption and transfers, world price of exports and current account balances are set exogenously based on observed trends.

[42] / The population growth trend was considered as 1,01% per year and the labor growth 1,4% per year, using data from the 1991 and 2001 survey done by INDEC.
[43] / Built by Petri and Mendez Parra (2003).
[44] / Built by Petri and Mendez Parra (2003).

To summarize, the dynamic accumulation process is:

1. Updated by exogenous trends (labor force growth, productivity changes, capital stock growth and population growth).
2. Updated by economic behavior (distribution of investment by sector of destination, distribution of labor force by category).
3. Updated by implemented policies (changes in tariffs and international prices as result of implementation of WTO and FTAA, changes in agricultural R&D expenditures).

Table VI.1 highlights the steps that are followed in a recursive model for each of the markets involved and their respective variables.

Table VI.1: steps taken in a dynamic recursive model.

	Static model		***Dynamic model***
Economic relations	Principal relations	Structural features	Cumulative processes
Factor markets			
Labor Capital	Labor demand equations Marginal product equations	Fixed wages Fixed segmented sectoral capital stocks	Labor growth force Capital stock growth
Commodities market			
Production Demand	Production functions Expenditure functions		Productivity growth Composition changes
Foreign trade			
Exports Imports	Export supply functions Trade aggregation functions	Segmented domestic and export markets Imperfect substitutability	World market trends
Macro balance			
Savings-investment External capital	Domestic savings rates Endogenous foreign capital inflows	 Fixed exchange rate	Trends in saving rates

Source: based on Chenery et al.

CHAPTER VII: POLICY SIMULATIONS USING THE CGE MODEL

Using the econometric analysis of Chapter III, we found that economic stability and a greater degree of integration with the rest of the world have a positive effect on the level of adoption of technology. There are therefore two main drivers for the agricultural sector. The first is the cross relationship between investment in R&D and openness of the economy. The second is the openness of the economy and its impact on the overall economy.

These two drivers are in turn affected by two types of domestic policies: (i) trade policies that the Argentine government can implement and (ii) policies directed toward encouraging research (related to the amount of public expenditures, access to international knowledge, etc.). Inflation in Argentina is assumed to be under control or at least not to represent a threat to macroeconomic stability[45].

Specific scenarios that come from this research are the implementation of the WTO, the FTAA, an increase in R&D expenditures in the agricultural sector, and a combination of trade policy and R&D. We have included the R&D simulation despite it being found only marginally significant in the Chapter III analysis because it would be useful to observe the cross relationship between trade liberalization and investment in R&D.

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[45] / There is therefore no reason to run a scenario for a domestic policy that controls inflation, even though in chapter III we showed the importance that macroeconomic stability has on investment in technology.

With the use of general equilibrium models we are able to see these scenarios for the Argentine economy looking at the growth paths of the driven variables and compare the "base year" path (in which nothing changes, business as usual path) and the paths obtained with the proposed policy changes. We have a recursive dynamic CGE model with bilateral trade, and endogenous growth and want to use the domestic policies available from the Argentine government to improve production in the agricultural sector. The simulations run with the Argentine model give us the growth path for the Argentine economy for the period 1997-2010. These paths are compared to the one obtained with the Base simulation (in which no exogenous changes were included) to see the trade offs of implementing the policies.

For the free trade simulations, two different Computable General Equilibrium models (CGE) were used. The first is a world model (Diao et al., 2002) while the second is the single recursive dynamic country model.[46] This is necessary to capture the changes that will occur in the rest of the world as a consequence of trade liberalization. The results were obtained in two steps. First the world model was used to solve for the international price and tariff vectors that result from the simulation of the FTAA and WTO scenarios (See Diaz Bonilla et al, 2003). Second, the international price and tariff vectors that result from the world model are included as exogenous parameters in the recursive dynamic model for Argentina as explained in Chapter V. The results obtained here capture the changes in domestic production, exports, imports, consumption, factor markets and trade balances as a consequence of the trade policy implementation.

[46] / This part is based on Morley and Piñeiro, (2003).

VII.1 Global Model[47]

The data used in the world model come from Version 5 of the Global Trade Analysis Project (GTAP) and include the 39 sectors (shown in Table VII.1) and 28 regions or countries[48]. These data correspond to the state of the global economy in 1997.[49] Trade restrictions are measured as tariff equivalents and are calculated as a proportion of the product price (ad valorem). In both simulations it is assumed that there is free market access for the participant countries. Non-tariff barriers and phytosanitary barriers are not included in this measure of protection.

For the FTAA scenario, all tariffs between countries in the Western Hemisphere were eliminated, but producer subsidies were left at the current levels. Note that non-tariff barriers and phytosanitary restrictions were not included in the analysis, which means that they were assumed constant. For the WTO simulation all trade barriers and producer subsidies were eliminated worldwide[50]. (See Annex 3)

The closures for the world model are as follows: labor markets were differentiated between developed and developing countries. For developed countries there is full employment and wages are flexible. For developing countries, there is unemployment and the wages are fixed. For the capital market full employment was assumed, and

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47 / This model was done by Diaz Bonilla et al., 2003.

48/ The countries and regions included are: US, Canada, Mexico, Central America and the Caribbean, Colombia, Peru, Venezuela, Rest of the Andean Pact, Argentina, Brazil, Chile, Uruguay, Rest of South America, Australia and New Zealand, Japan and Korea, EU, China, Indonesia, Philippines, India, Asia export (countries with agricultural exports), Other Asia, East Europe, Turkey, Northern Africa and Rest Middle East, South Africa, Africa with trade with EU and Rest of Africa.

49/ For more information on this database go to http://www.gtap.agecon.purdue.edu/

50 / For more information go to http://www.wto.org/english/res_e/booksp_e/special_study_6_e.pdf

the total quantity of capital stayed fixed in each country in the simulations. However, capital can move between sectors and the price of capital is flexible.

In the case of the external balance, the exchange rates of all the countries are flexible and float relative to the US dollar. The exchange rate of the US is the *numeraire* and is fixed while all the other exchange rates can change. Foreign savings are fixed, which means that the total trade balance of each country does not change. However the bilateral trade between countries and the composition of commodities can change. Finally, government consumption is assumed fixed in the world model.

In both integration scenarios, international prices for the agricultural sector increase (see Table VII.1). In the case of the FTAA the aggregate increase is approximately 0.5%. Rice, sugar and fruits and vegetable prices increase the most in the primary sector and meat products and dairy increase the most in the food processing industry. Wool, forestry and fishery are the only agricultural products where prices decrease. For the rest of the industry and oil products all prices decrease under the FTAA.

The impact on relative and absolute prices is much higher in the case of the WTO. For agriculture as a whole, the increase in price is approximately 11%. Prices go up the most where producer subsidies in the OECD countries are the most significant and that is in grains, dairy products and meat. In those sectors a full free trade agreement would raise prices by over 20%. The vectors of prices showed in table VII.1 are the output of the world model done by Diaz Bonilla et al (2002) and the ones that are used in the model for Argentina done in this research as international prices.

Table VII.1: Percentage changes in international prices resulting from the FTAA and WTO simulations with the GTAP model *.

	FTAA	WTO
rice	1.3	14.9
wheat	0.1	23.1
other grains	0.2	20.4
fruits and vegetables	0.5	5.2
oil seeds	0	11.3
sugar	0.9	10.6
vegetables	-0.2	1.1
other crops	0.2	1.5
wool	-0.5	6.6
forestry products	-0.4	0.1
fish	-0.4	1.6
beef	0.9	21.3
other meat products	0.2	19.0
vegetable oils	0	4.4
dairy products	0.7	26.2
other food products	0.2	6.8
drinks and tobacco products	0	8.7
energy	-0.3	-2.0
mining	-0.5	-0.2
textiles	-0.2	1.4
clothing	-0.3	-0.7
leather products	-0.3	-0.8
paper and printing	-0.2	1.0
oil-based products	-0.3	-0.4
chemical products	-0.2	1.3
mineral products	-0.3	1.2
cars and car parts	-0.1	1.3
transport equipment	-0.3	0.2
electronic products	-0.3	0
machinery and equipment	-0.3	0.7
electricity and water	0	0
construction	0	0
services	0	0
government sector	0	0

* Changes in the levels from the initial situation, base year 1997.
Source: Diaz Bonilla et al, 2003.

VII.2 Single Country Model

Using the single country model explained in the previous chapter and using as an exogenous variable the international prices that resulted from the global model, we run one scenario in which “nothing changes”, where the economy follows the growth path and the scenarios of trade and R&D already mentioned, in which the economy is shocked in 1997 to see the changes occurred. We found that, in the case of trade liberalization policies, the annual percentage growth rate between 1997 and 2015 in Argentina’s GDP is 2.87% for the case of the WTO and 2.78% per year for the FTAA. The rates of increase of exports and imports are 6.83% and 4.54% per year, respectively, for the case of the WTO and 6.64% and 4.42% per year for the FTAA. These results highlight the larger effect in the totality of the economy in the case of the WTO[51]. This can be explained principally by the larger commitments that are made by developed countries in the WTO agreement, by rising international prices for agricultural commodities that are important in the Argentine basket of exports, and eliminating trade barriers that are not included in the FTAA case.

A simulation of an increase in agricultural R&D expenditures was included to be able to see the relationship between trade integration and research. When only R&D expenditures are modified, the results obtained do not show big changes in the structure of production. The changes seen come from the decrease of government

[51] / When looking at these results it is important to consider that they represent the effects on the whole economy (where the changes in international prices obtained with the world model are not in the same magnitude for agricultural and industrial products) and they are the result of a thirteen year adjustment process (not a one shot change like in the case of the static world model).

consumption, given the closure imposed, in which the bigger expenditures in research needed to come from some other expenditures, leaving a constant deficit.

Table VII.2: Annual percentage change from initial value, nominal values
Except first column that are initial values, 1997 prices.

	INITIAL VALUE 1997*	**BASE**	**FTAA**	**WTO**	**R&D**
		Annual Percentage growth rate (1997-2015)			
Absorption	278.88	2.64	2.62	2.71	2.64
Private Consumption	204.85	3.12	3.08	3.18	3.13
Fixed Investment	47.88	0.89	1.02	1.00	0.90
Government Consumption	22.86	1.73	1.78	1.97	1.71
Exports	16.24	6.37	6.64	6.83	6.37
Imports	20.87	3.81	4.42	4.54	3.81
GDP (market price)	274.25	2.82	2.78	2.87	2.83

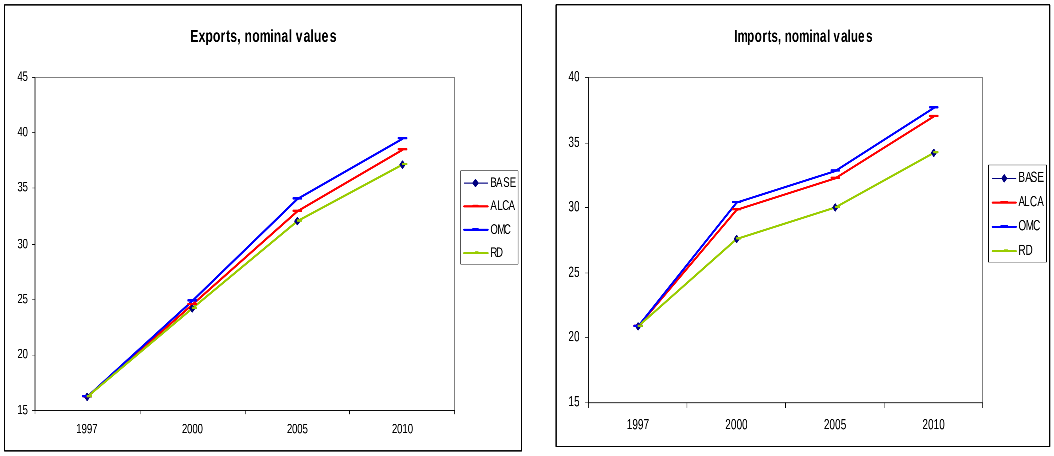
* 1997 billions of pesos.
Source: author.

Table VII.3: Annual percentage change from initial value, real values
Except first column that are initial values.

	INITIAL VALUE 1997*	**BASE**	**FTAA**	**WTO**	**R&D**
		Annual Percentage growth rate (1997-2015)			
Absorption	278.88	2.51	2.49	2.58	2.52
Private Consumption	204.85	3.14	3.10	3.20	3.15
Fixed Investment	47.88	0.68	0.78	0.84	0.69
Exports	16.24	5.10	5.30	5.31	5.10
Imports	20.87	3.08	2.65	3.67	3.08
GDP (market price)	274.25	2.65	2.68	2.69	2.65

* 1997 billions of pesos.
Source: author.

Figure VII.1: Export and Import growth paths under different scenarios, real values



Source: author.

Table VII.4: exports, imports and production

*Share of total amount of exports, imports and GDP respectively.

	INITIAL SHARE 1997*	BASE	FTAA	WTO	R&D
		Annual Percentage growth rate (1997-2015)			
Exports					
Agricultural sector	16.51	4.99	4.87	3.91	4.99
Primary sector	20.20	4.89	4.83	4.09	4.89
Manufacturing sector	63.22	5.00	5.08	4.95	5.01
Food Industry	28.21	6.23	6.29	5.94	6.23
Imports					
Agricultural sector	1.04	4.67	4.84	5.08	4.67
Primary sector	3.14	3.02	3.23	3.47	3.02
Manufacturing sector	64.77	2.99	3.15	3.39	2.99
Food Industry	4.42	2.34	2.50	3.09	2.34
GDP					
Agricultural sector	4.80	3.39	3.44	3.36	3.40
Primary sector	7.49	3.08	3.15	3.16	3.08
Manufacturing sector	13.29	3.18	3.28	3.38	3.18
Food Industry	4.14	3.04	3.16	3.20	3.05

Source: author.

To observe the impact of trade liberalization policies in a more disaggregated way, we find that for the agricultural sector the implementation of FTAA creates an increase in exports of 4.87% per year, an increase in imports of 4.84% per year, and an increase in production of 3.44% per year. In particular, maize, rice, oilseeds and other crops were the most affected, with increases on the order of 8% per year in exports and 7% per year in production. Other commodities including fruit and vegetables and livestock were not altered significantly in the case of production and in particular we observe a decrease in exports and imports for fruits and vegetables. For the agro-industry, vegetable oils were the most successful sector, with an increase of 7.79% per year in production and 8.22% per year in exports, followed by other food and dairy products with an increase in production of 4.31% and 3.99% per year respectively, and increases in exports of 5.39% and 5.48% per year, respectively (see tables VII.5 and VII.6).

For the WTO scenario, all grains are favored, with maize, rice and wheat the most affected with increases in production on the order of 8% per year and 11% per year in exports. The results for livestock and other crops are very similar but with slightly smaller changes than for FTAA scenario in the case of production and definitely smaller changes in the case of exports. For the agro-industry, the story is very similar; the largest increases in production and exports are seen in vegetable oils, dairy products, and other food and in this case also the meat industry. It is interesting to note that vegetable oils are the only agricultural product where exports increase more in the case of the FTAA (8.22% per year) versus the WTO (6.79% per year).

Table VII.5: Production of agricultural products

PRODUCTION	INITIAL SHARE 1997*	BASE	FTAA	WTO	RD
		Annual Percentage growth rate (1997-2015)			
Wheat	0.30	4.11	4.33	8.35	4.11
Maize	0.27	7.61	7.85	10.23	7.61
Rice	0.05	7.32	7.76	7.82	7.33
Other grains	0.07	1.18	1.27	3.06	1.18
Oilseeds	0.73	5.57	5.95	4.50	5.58
Fruits and vegetables	0.68	1.43	1.32	0.49	1.43
Other crops	0.34	7.78	7.82	7.64	7.79
Livestock	2.36	2.63	2.67	2.52	2.63
Meat	0.49	3.03	3.06	3.35	3.03
Fruit and vegetable manuf.	0.36	-1.03	-0.99	-0.99	-1.03
Vegetable oils	0.31	7.38	7.79	6.92	7.38
Dairy	0.23	4.02	3.99	4.02	4.02
Milling	0.29	1.90	1.90	1.95	1.90
Other food	0.27	4.34	4.31	4.32	4.34

*Share of total amount of production.
Source: author.

Table VII.6: Exports of agricultural products

EXPORTS	INITIAL SHARE 1997*	BASE	FTAA	WTO	RD
		Annual Percentage growth rate (1997-2015)			
Wheat	2.20	5.03	5.35	10.65	5.04
Maize	1.61	8.68	9.02	12.91	8.69
Rice	0.23	8.17	8.90	8.99	8.18
Other grains	0.30	2.74	2.95	6.39	2.75
Oilseeds	1.83	5.85	6.21	5.14	5.86
Fruits and vegetables	1.17	-1.99	-2.13	-5.18	-1.98
Other crops	0.55	5.79	5.75	2.77	5.80
Livestock	0.37	6.49	6.92	3.93	6.49
Meat	3.07	4.41	4.55	5.33	4.41
Fruit and vegetable manuf.	0.68	-0.58	-0.49	-0.61	-0.58
Vegetable oils	9.04	7.79	8.22	6.79	7.80
Dairy	0.26	5.43	5.48	6.38	5.43
Milling	0.43	2.73	2.81	3.11	2.73
Other food	0.01	5.37	5.39	5.49	5.37

*Share of total amount of exports.
Source: author.

Table VII.7: Imports of agricultural products

IMPORTS	INITIAL SHARE 1997*	BASE	FTAA	WTO	RD
		Annual Percentage growth rate (1997-2015)			
Wheat	0.00	2.46	1.84	1.49	2.47
Maize	0.01	6.46	6.04	5.41	6.46
Rice	0.00	6.38	5.75	6.59	6.38
Other grains	0.00	-0.05	-0.56	-0.77	-0.05
Oilseeds	0.01	6.34	6.38	5.44	6.34
Fruits and vegetables	0.30	3.90	3.43	4.36	3.91
Other crops	0.13	9.73	9.13	10.96	9.73
Livestock	0.07	1.79	1.21	2.66	1.79
Meat	0.32	3.06	2.56	2.51	3.06
Fruit and vegetable manuf.	0.30	-2.15	-2.53	-1.83	-2.14
Vegetable oils	0.22	2.69	2.41	2.86	2.69
Dairy	0.29	4.20	3.39	3.43	4.20
Milling	0.31	1.48	1.00	1.63	1.49
Other food	0.26	4.50	4.09	4.81	4.50

*Share of total amount of imports.
Source: author.

The results obtained for the scenario assuming an increase of 25% in public agricultural R&D expenditures are, as expected, not very significant as given the results obtained in Chapter III, where it was found that a positive macroeconomic environment and openness of the economy were the major factors that drove the acquisition of technology and not the investment in agricultural R&D. These results do not change even if we consider the whole period analyzed (allowing time for the implementation of the new technology). There are many factors involved in these results. The first is that the data used in this research does not cover all of the extension expenditures and the second, more important, is that the new technologies during the major agricultural transformations in the Pampean region in the last decade have been developed outside of the country, as Cap (2004) stated. This was made possible by the similarities in the agro-ecosystems of Argentina and the Midwest of the United States. That said, the small impact we see on variables such as production of agricultural products only covers part of the adjustments to imported technology.

Investment in public agricultural R&D and the simultaneous implementation of one of the trade agreements does not seem to alter the results we obtained on production and trade, as the case in which only the free trade agreement scenarios were run[52]. This suggests that public R&D has no major role in increasing activity level of the agricultural sector. While this result was unexpected, we refer back to the issues of data source and also the actual origin of the R&D. One thing is to develop the technology in the country in question, however a different effect is caused when the technology is developed in a separate country and we only receive the resulting spillover effects.

Finally, the accuracy of the model was tested comparing the observed and simulated growth rates for the period 1997 through 2000 using the SAM for 1997 (Diaz Bonilla and Piñeiro, 1998) and 2000 (Petri and Mendez Parra, 2003) for the actual data calculation of percentage change and the results obtained in the benchmark solution of the model for the simulated data. Recall that the model is initially solved for the base year data which provides the benchmark to which the results for the experiments were compared. This base run is important as it helps set up the closures so that the model can replicate the macro changes in the economy.

[52] / The results were not significantly different from the ones where only expenditures in R&D were increased by 25%. The results can be provided by request.

TableVII.8 shows the simulated and actual percentage changes for the period 1997-2000. In general, the simulated data replicates the observed data reasonably, allowing for the difference between the two to be measurement errors for observed data (Lofgren, 2001). The only discrepancy to be considered is imports, but as Lofgren stated, it could be a reflection of errors in data (given by gaps between data from exchange and customs authorities) or errors in the model specification[53].

Table VII.8: Actual and Simulated percentage changes (1997-2000)

	Simulated data	**Actual data**
Private consumption	9.00%	6.08%
Fixed investment	5.15%	7.90%
Exports	93.00%	86.86%
Imports	34.00%	56.30%
GDP (market price)	12.00%	8.70%

Source: Author with data from the two SAMs and results from model

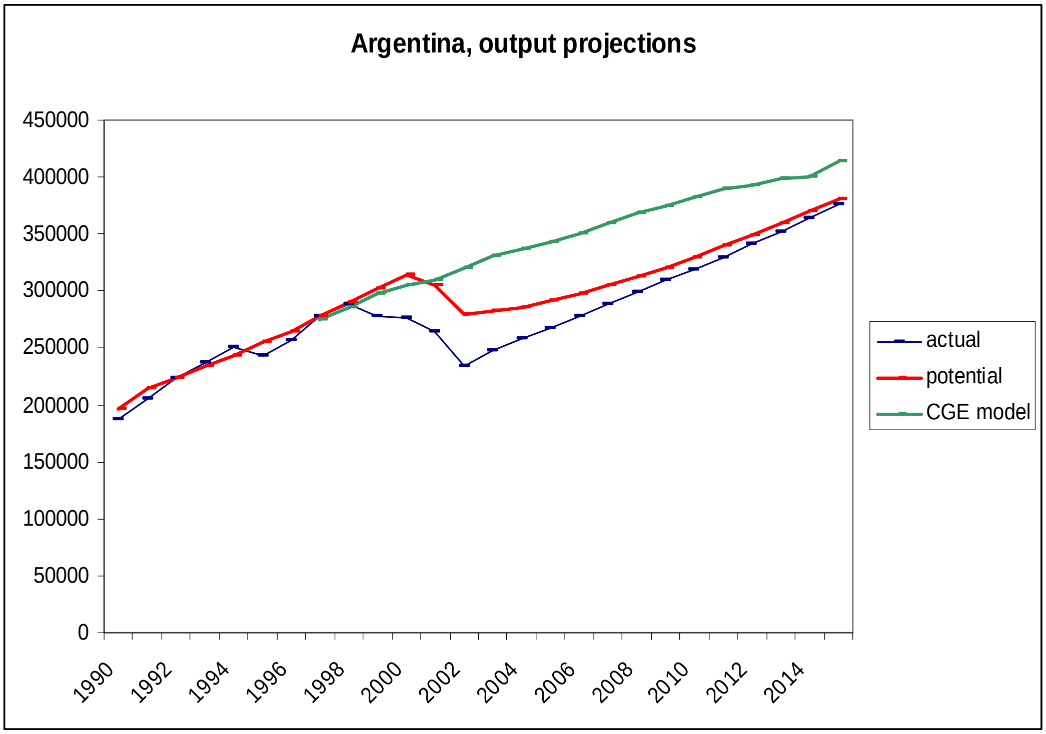
In any case, the above information indicates that with a high degree of confidence the model tracks the evolution of the Argentine economy.

Another piece of information valuable to this validation exercise is the results obtained by Maia and Kweitel (2003). They performed an output projection until the year 2030. If we compare their trend with the one obtained using the model in this research, they are not very different (see Figure VII.2), excluding the years of the major crisis and some years for recovery. With this information we feel confident that

[53] / Given the closures used in the solution of the model.

the growth paths observed in this research are consistent with other views of the real Argentine economy, given that it does not cover the financial crisis of 2001.

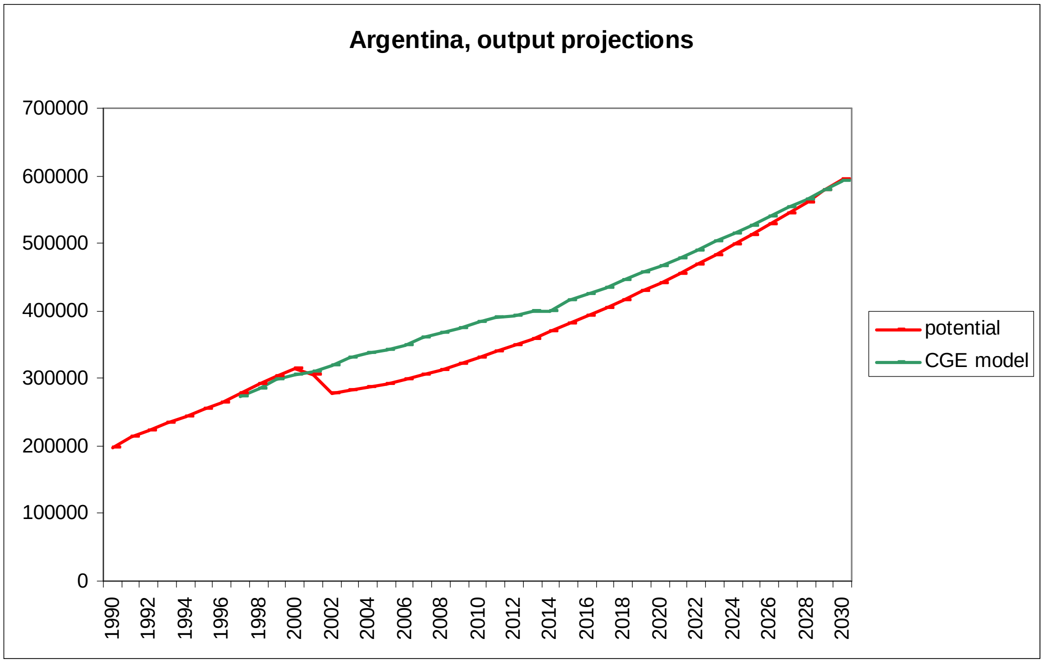
Figure VII.2: Output projections



Source: Author with data from Maia and Kweitel (2003) and own results.

Even though the CGE model was run until the year 2015, we can use the percentage change per year to project the GDP for 2030 (the last year for the work done by Maia). The values are practically the same, 594.7 for the projection analysis and 593.2 for the CGE model (see Figure VII.3).

Figure VII.3: Adjusted output projections



Source: Author with data from Maia and Kweitel (2003) and own results.

CHAPTER VIII: CONCLUSIONS

During the past 20 years Argentina has experienced extraordinary changes in its agricultural sector. Production, productivity and exports have all increased significantly. One of the main drivers of these changes was the massive incorporation of technological change such as improved seeds, greater use of agrochemicals and machinery and agronomic technologies such as zero tilling. The findings of Chapter III indicate that changes in the macroeconomic environment and the consequent greater confidence of producers explain a great deal of these favorable changes. Looking ahead and assuming that the more favorable macroeconomic environment is maintained, two major elements of uncertainty appear: (i) the effects of possible trade liberalization that could emerge from trade negotiations in the context of the WTO and other regional trade agreements and (ii) the specific government policies affecting technical change.

The research developed in this dissertation addresses these two questions. The first was the influence of public investment in technology and analysis of its impact was, to our surprise, not very significant. Trade liberalization and a stable macroeconomic environment were estimated to have a larger effect on adoption of technology than increases in agricultural R&D expenditures. These results can be explained, at least in part, by the fact that the majority of the technologies adopted were developed outside Argentina, both in the public sector of developed countries and by the international private sector. That is, Argentina benefited as a result of its ecological conditions and particular agrarian structure resulting in a high level of utilization of spillovers. This process also utilized accumulated knowledge in agronomy and management procedures, where local research had a major role in its development. In addition the impact of investments in technology development may have longer lags than the data available allow to be investigated, and strong interactions with trade liberalization scenarios.

The second major element of the research was the analysis of the potential impacts on the agricultural sector resulting from the various trade agreements in which the Argentine government is involved currently. These include free trade world wide (WTO) and a Western hemisphere free trade bloc (FTAA). The methodology used was a dynamic general equilibrium model to capture the linkages between these economy-wide changes. The results gave us estimates of price and real income changes, and of changes in the sectoral structure of production and trade.

The analysis generated several major conclusions:

1. The general equilibrium models utilized reproduce quite accurately the evolution of the Argentine economy. This can be seen by the comparison of actual data from 2000 and the results obtained for that year with our model. In addition, the results we obtained for the GDP growth path were consistent with the ones obtained by Maia and Kweitel (2003) in an output projection study until the year 2030. With this validation exercise we can conclude that the behavior of the model fits the Argentine

economy. With this approach we can see the long run equilibrium of the economy, including the full effect of endogenous technological change on growth, without losing microeconomic information.

2. A favorable macroeconomic environment had a positive influence on technological change and production modernization.

3. We found that both trade integration scenarios are expansionary for both output and exports in general. Consequently, successful trade liberalization agreements are an important element in a development strategy for the Argentine economy. The WTO agreement was seen as the most favorable of the two for the agricultural sector because the elimination of producer subsidies in developed countries causes increases in the prices of agricultural products, with higher increases in production and exports, particularly in the case of grains, dairy, and other food.

4. Finally, we note that the interaction effect between public investment in technology and liberalization policies is not very significant given the data we used in our analysis. This reaffirms the great importance of spillover effects in the agricultural modernization process of the last few decades. However these results should be taken with due caution. The utilization of spillovers may not be as important in the future and local research may be needed to create the appropriate environment for the successful adaptation and adoption of new technologies.

In sum, we are left with the idea that for the agricultural sector it is more beneficial to push for the full implementation of global free trade than trying to pursue a regional free trade agreement. However, this is only true if there is significant progress in reducing trade barriers and producer subsidies in developed countries. Otherwise the idea of only eliminating trade barriers between the FTAA bloc sounds very appealing with the gains that Argentina can take by better access to a larger market and the increase in bargaining power with countries outside the bloc.

CHAPTER IX: ANNEXES

ANNEX 1: DATA

Table A1.1: Data on certified seeds

Certified Seed Area
hectares

	1994	1995	1996	1997	1998
Soja	117840.00	149479.90	139787.20	198700.00	234890.58
Maize hibrid	22907.00	24592.60	33427.20	49400.00	49467.90
Wheat	97583.00	87313.21	75285.50	107527.00	86275.90
Potato	4158.00	3161.85	3945.01	4498.63	5552.49
Sunflower hibrid	32835.00	35358.70	53981.90	49162.20	56009.00
Cotton	40165.00	67066.70	85082.50	100686.46	101960.00
cebada cervecera	5868.00	4559.00	8582.00	16287.00	18775.00
forrajera	79941.00	76269.74	68707.79	67901.79	49679.69
Sorghum forrajero hibrid	4798.00	4637.50	5618.60	7630.00	8501.50
Sorghum granifero hibrid	2547.00	2133.06	2320.00	5622.70	7383.00
Rice	146.00	733.40	992.46	1663.60	2095.60
Oats	2985.00	3511.00	5870.50	5118.50	4141.20
Peanut	462.00	808.00	2326.00	5320.00	10045.36
Maize varieties	2424.00	3102.32	1800.00	2105.00	2013.00
Strawberry	73.00	106.00	65.61	53.58	33.99
centeno	1388.00	1042.00	1424.00	2681.00	1971.00
Beans	1108.00	1139.25	1393.86	232.00	840.50
lino	1196.00	1180.50	2022.50	782.00	970.00
arveja	..	255.00	1.00	..	133.00
colza	1012.00	1326.00	1062.00	287.00	162.00
Sunflower variety	745.00	1529.00	479.00	359.00	300.00
Pumkin	..	..	..	..	109.00
Sorghum forrajero variety	125.00	284.50	111.00	98.00	65.00
Onion	..	..	10.75	11.80	11.52
mijo	..	27.00	6.00	36.00	30.00
pimiento	..	..	3.50	2.00	1.20
Garlic	..	24.33	7.09	16.00	..
total	420306.00	469640.56	494312.97	626181.26	641417.43

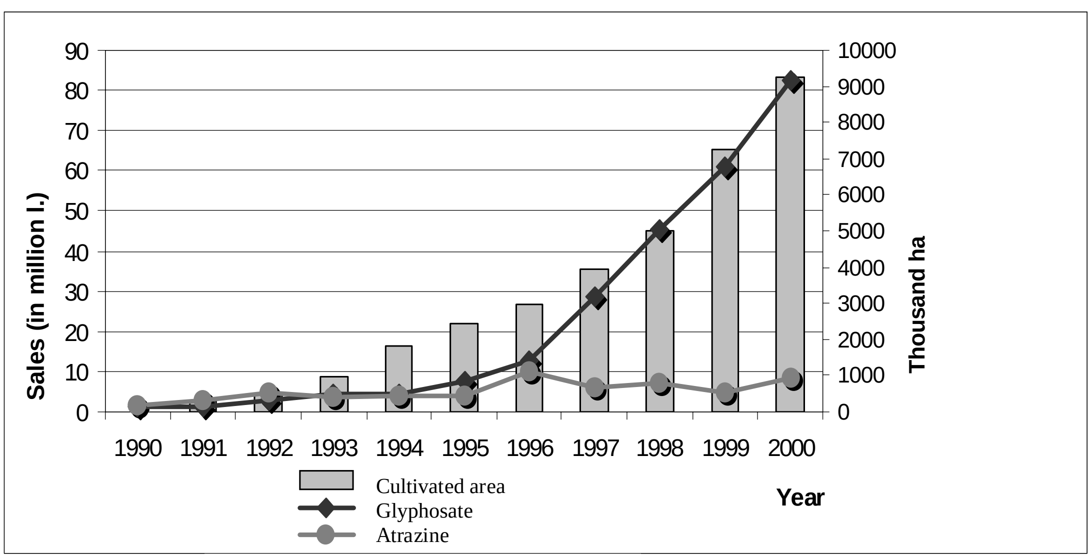
Source: INASE

Certified Seed Area
thousands of tons

	1994	1995	1996	1997	1998
Soja	140.00	188.83	198.95	261.20	275.97
Maize hibrid	..	57.23	72.72	93.63	81.80
Wheat	125.00	134.01	134.19	172.60	121.27
Potato	24.40	28.50	45.95	54.48	58.66
Sunflower hibrid	14.86	17.40	20.13	18.95	15.72
Cotton	19.53	38.36	35.68	42.73	24.12
cebada cervecera	7.32	11.91	17.06	25.61	34.88
forrajera	11.63	15.21	10.57	10.89	16.16
Sorghum forrajero hibrid	8.03	10.47	10.46	13.59	12.50
Sorghum granifero hibrid	5.30	4.41	3.57	9.15	8.63
Rice	0.58	1.69	4.01	8.07	9.91
Oats	3.57	4.36	7.49	6.91	6.20
Peanut	0.29	0.78	3.17	2.82	5.00
Maize varieties	2.56	5.39	4.05	3.52	3.63
Strawberry	14.23	9.76	24.34	22.73	0.00
centeno	0.30	0.53	1.13	1.67	1.31
Beans	0.50	0.94	0.74	0.22	0.92
lino	0.64	0.76	1.11	0.47	0.68
arveja	..	0.19	0.00	..	0.29
colza	0.08	0.32	0.23	0.09	0.12
Sunflower variety	0.25	0.42	0.14	0.10	0.08
Pumkin	..	..	..	..	0.02
Sorghum forrajero variety	0.08	0.84	0.07	0.03	0.06
Onion	..	..	0.00	0.01	0.01
mijo	..	0.01	0.01	0.05	0.05
pimiento	..	..	0.00	0.00	0.00
Garlic	..	0.01	0.03	0.04	..
total	364.89	522.56	571.46	726.84	677.99

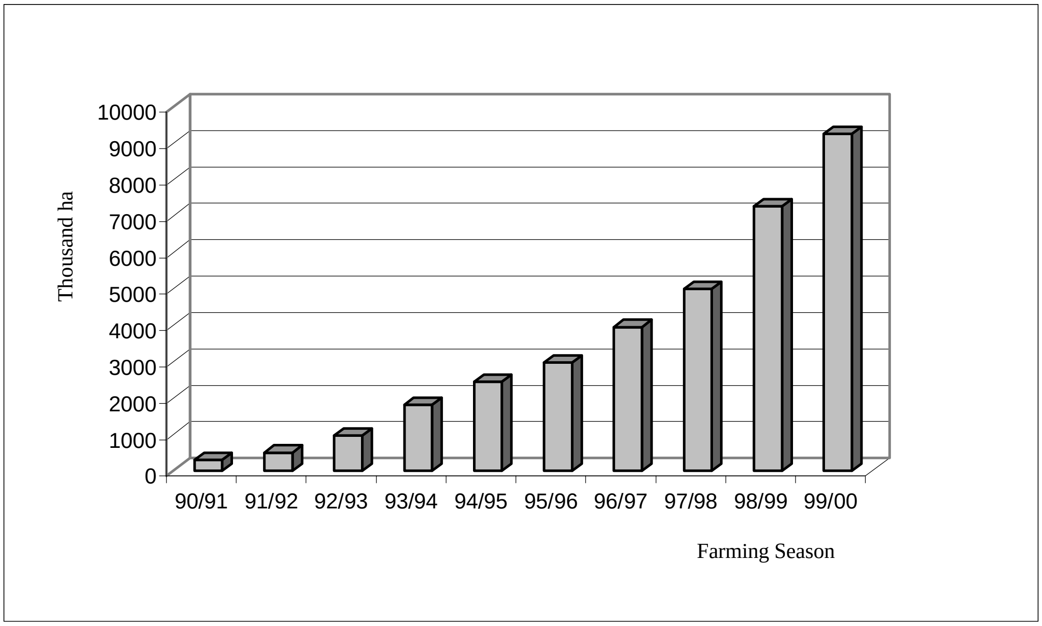
* Strawberries plantines

Figure A1.1: Evolution of no-till techniques and composition of the type of herbicides used in Argentine agriculture



Source: Trigo et al (2002).

Figure A1.2: Evolution of No Till planting area



Source: Trigo et al (2002).

Table A1.3: Port costs

	General port administration costs			
	Rosario	Buenos Aires	Necochea	Bahia Blanca
1993	0.72	0.80	0.72	0.72
1995	0.30	0.36	0.40	0.42
1997	0.38	0.38	0.38	0.38
2000	0.30	0.30	0.30	0.30

Source: SAGPyA

Table A1.4: Storage costs

	Storage costs	
	cereals	sunflower
1991	0.04	0.60
1993	0.03	0.45
1995	0.03	0.45
1997	0.03	0.45
2000	0.03	0.45

Source: SAGPyA

Table A1.5: Gas oil consumption, agricultural sector
thousands of t.e.p.

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
gas oil consumption	1537	1689	1663	1436	1479	1636	1827	2001	2359	2506	2654	2601	2480

Source: SAGPyA and AFAT.

Table A1.6: Telecommunications

Telephone service	1995	1996	1997	1998	1999
Lines instaled	6.362.352	7.040.167	7.265.229	7.587.622	7.957.775
Lines in service	5.531.702	6.119.555	6.824.425	7.132.095	7.109.498
Digital lines	4.932.804	5.984.142	7.146.533	7.857.622	7.957.775
Public phones	69.998	80.393	94.532	113.749	150.737
Population covered	34.795.320	35.332.683	35.614.710	36.124.933	36.578.358
Number of employees	29.691	27.264	23.105	21.225	19.461
Investments (millions of pesos)	2.044	1.71	1.287	1.547	1.653
Revenues (millions of pesos)	4.664	4.307	4.674	4.906	4.838
Celular phones in service	340.743	667.02	2.009.073	2.670.862	3.861.529

Source: Comisión Nacional de Comunicaciones.

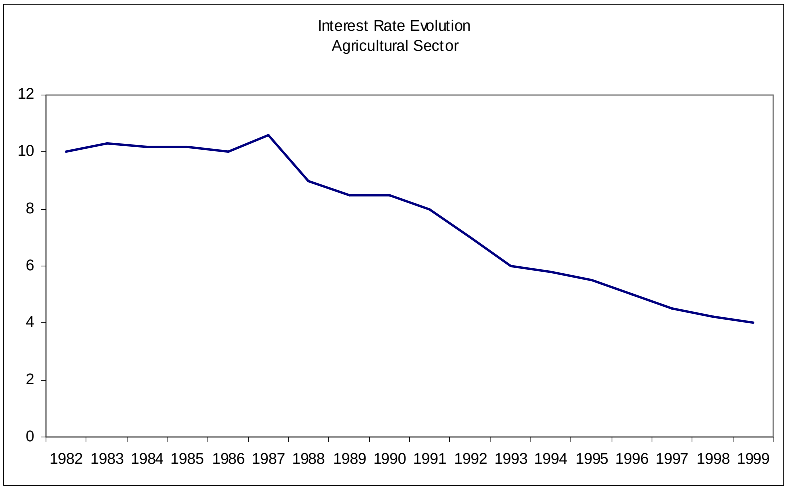
Table A1.7: Credit

Credit loans
thousands of pesos, 2003 constant prices

	1999	2000	2001
Hail	96894	103289	157352
Credit	2545	5235	6046

source: INDEC

Figure A1.3: Interest rate evolution in the Agricultural sector



Source: Banco Central Republica Argentina.

ANNEX 2: RETURNS TO AGRICULTURAL R&D

The analysis of IRR's applied to the agricultural research was done by Schultz (1953). He considered it as another economic activity in which case a cost-benefit analysis was possible. His work showed high returns to the agricultural research.

More recently, Alston et al (2000) did a comprehensive study looking at the estimations made by 292 papers between 1953 and the end of the nineties. The results showed a high dispersion between the studies that led them to consider the median of them. This is shown in table A2.1.

They do not find decreases in the returns over time. And, they showed the high profitability of the agricultural research and extension activities.

Table A2.1: Returns to agricultural R&D

	%
DEVELOPED	46.00
North America	46.50
Europe	62.20
Australasia	28.70
Other Developed	37.40
DEVELOPING	43.00
Africa	34.30
Asia and Pacific	49.50
Latin America	42.90
Other Developing	36.00

Source: Alston et al (2000, page 62).

Table A2.2:
Returns to agricultural R&D in LAC by commodity

	LAC
all agricultural products	41.03
crops and livestock	55.02
field crops	40.66
maize	44.11
wheat	37.30
rice	47.84
livestock	49.43
tree crops	31.06

Source: Author with data from Agricultural Science and Technology Indicators (ASTI)

Cirio and Castronovo (1993) analyzed a wide range of agricultural products for Argentina, they represent the 15% of the agricultural value added. Their results are reported in table A2.3 As we can see the numbers are similar that the one calculated by Alston et al for a basket of agricultural goods for Latin American countries and the ones reported by ASTI per group of agricultural commodities for LAC.

Table A2.3:
Returns to agricultural R&D in Argentina by commodity

Returns on investment	*Commodity*	*IRR*	*Period analyzed*
Ex-post analysis			
	Wheat	32%	1966-1990
	Corn	47%	1964-1992
	Sunflower	34%	1969-1992
	Cotton	44%	1965-1988
	Potato	49%	1971-1991

Source: Cirio and Castronovo (1993).

ANNEX 3: MACRO SAMs FOR 1997 AND 2000

MACRO SAM 1997
in 1997 millions of pesos

	ACT	COMM	VA	HH	ENTR	TAX	GOV	CAPk	TAR	ROW	S-I	*TOTAL*
ACT		456060730.51										*456060730.51*
COMM	197981142.84			204849478.27			23369887.67	3290441.36		16237000.00	47878780.37	*493606730.51*
VA	232171916.70											*232171916.70*
HH			83648738.69		121789006.01		12513100.00					*217950844.70*
ENTR			148523178.01				4033700.00					*152556878.01*
TAX	4159000.00	14245000.00		12533250.00	14668450.00							*45605700.00*
GOV						45605700.00			2431000.00			*48036700.00*
CAPk	21748670.97			568116.43	16099422.00		5206012.33	3858557.79		7547000.01		*55027779.54*
TAR		2431000.00										*2431000.00*
ROW		20870000.00					2914000.00					*23784000.00*
S-I								47878780.37				*47878780.37*
TOTAL	*456060730.51*	*493606730.51*	*232171916.70*	*217950844.70*	*152556878.01*	*45605700.00*	*48036700.00*	*55027779.53*	*2431000.00*	*23784000.01*	*47878780.37*	

Source: Diaz Bonilla and Pineiro, 1998

MACRO SAM 2000
in 2000 millions of pesos

	ACT	COMM	VA	HH	ENTR	TAX	GOV	CAPk	TAR	ROW	S-I	*TOTAL*
ACT		447001485.77										*447001485.77*
COMM	170661475.29			217310902.08			23346476.97	8067706.80		30344753.46	51664449.50	*501395764.11*
VA	241162844.79											*241162844.79*
HH			105261858.18		108147736.93		17396299.79					*230805894.90*
ENTR			135900986.61				4919024.80					*140820011.41*
TAX	10223154.42	19999903.01		12926876.39	16524326.52							*59674260.33*
GOV						59674260.33			1774083.16			*61448343.49*
CAPk	24954011.26			568116.43	16147947.96		5644449.50	8635823.23		12417631.15		*68367979.53*
TAR		1774083.16										*1774083.16*
ROW		32620294.16					10142092.45					*42762386.61*
S-I								51664449.50				*51664449.50*
TOTAL	*447001485.77*	*501395766.10*	*241162844.79*	*230805894.90*	*140820011.41*	*59674260.33*	*61448343.51*	*68367979.53*	*1774083.16*	*42762384.61*	*51664449.50*	

Source: Petri and Mendez Parra, 2004

ANNEX 4: EQUATIONS OF THE RECURSIVE DYNAMIC CGE MODEL

I. **Table A.4 Mathematical Summary Statement for the Standard CGE Model**[54]

SETS

II.	Explanation	III.	Explanation
$a \in A$	activities	$c \in CMN(\subset C$	commodities not in *CM*
$a \in ACES(\subset$	activities with a CES function at the top of the technology nest	$c \in CMR(\subset C$	imported commodities by region
$a \in ALEO(\subset$	activities with a Leontief function at the top of the technology nest	$c \in CER(\subset C$	exported commodities by region
$c \in C$	commodities	$c \in CT(\subset C)$	transaction service commodities
$c \in CD(\subset C)$	commodities with domestic sales of domestic output	$c \in CX(\subset C)$	commodities with domestic production
$c \in CDN(\subset C)$	commodities not in *CD*	$f \in F$	factors
$c \in CE(\subset C)$	exported commodities	$i \in INS$	institutions (domestic and rest of world)
$c \in CEN(\subset C$	commodities not in *CE*	$i \in INSD(\subset I$	domestic institutions
$c \in CM(\subset C)$	imported commodities	$i \in INSDNG($	domestic non-government institutions
		$h \in H(\subset INS$	households

PARAMETERS

$cwts_c$	weight of commodity c in the CPI	$\overline{qg}_c$	base-year quantity of government demand
$dwts_c$	weight of commodity c in the producer price index	$\overline{qinv}_c$	base-year quantity of private investment demand
ica_{ca}	quantity of c as intermediate input per unit of activity a	$shif_{if}$	share for domestic institution i in income of factor f
$ica93_{ca}$	quantity of c as intermediate input per unit of activity a. year 1993.	$shii_{ii'}$	share of net income of i' to i (i' ∈ INSDNG'; i ∈ INSDNG)
$ica97_{ca}$	quantity of c as intermediate input per unit of activity a. year 1997.	ta_a	tax rate for activity a
$icd_{cc'}$	quantity of commodity c as trade input per unit of c' produced and sold domestically	te_c	export tax rate
$ice_{cc'}$	quantity of commodity c as trade input per exported unit of c'	tf_f	direct tax rate for factor f
$icm_{cc'}$	quantity of commodity c as trade input per imported unit of c'	$\overline{tins}_i$	exogenous direct tax rate for domestic institution i

[54] / Based on Lofgren et al (2001) and Thurlow (2003)

$inta_a$	quantity of aggregate intermediate input per activity unit	$tins01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
iva_a	quantity of aggregate intermediate input per activity unit	tm_{cr}	import tariff rate by region
$\overline{mps}_i$	base savings rate for domestic institution i	tq_c	rate of sales tax
$mps01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates	$trnsfr_{i\,f}$	transfer from factor f to institution i
pwe_{cr}	export price (foreign currency)	tva_a	rate of value-added tax for activity *a*
pwm_{cr}	import price (foreign currency)	WGT_{ca}	Weight Input-output different years
$qdst_c$	quantity of stock change	$CTET0_a$	Intercept trade TFP equation

α_a^a	efficiency parameter in the CES activity function	δ_{cr}^t	CET function share parameter
α_a^{va}	efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	shift parameter for domestic commodity aggregation function	γ_{ch}^m	subsistence consumption of marketed commodity c for household h
α_c^q	Armington function shift parameter	γ_{ach}^h	subsistence consumption of home commodity c from activity a for household h
α_c^t	CET function shift parameter	θ_{ac}	yield of output c per unit of activity a
β_{ach}^h	marginal share of consumption spending on home commodity c from activity a for household h	ρ_a^a	CES production function exponent
β_{ch}^m	marginal share of consumption spending on marketed commodity c for household h	ρ_a^{va}	CES value-added function exponent
β^t	Trade TFP exponent	ρ_c^{ac}	domestic commodity aggregation function exponent
β_a^g	R&D TFP intercept	ρ_c^q	Armington function exponent
δ_a^a	CES activity function share parameter	ρ_c^{ex}	Export demand exponent
δ_{ac}^{ac}	share parameter for domestic commodity aggregation function	Ω_{cr}	Export demand intercept
δ_{cr}^q	Armington function share parameter	ρ_c^t	CET function exponent

EXOGENOUS VARIABLES

$\overline{CPI}$	consumer price index	$\overline{MPSADJ}$	savings rate scaling factor (= 0 for base)
$\overline{DTINS}$	change in domestic institution tax share (= 0 for base; exogenous variable)	$\overline{QFS}_f$	quantity supplied of factor
$\overline{EXR}$	exchange rate	$\overline{TINSADJ}$	direct tax scaling factor (= 0 for base; exogenous variable)

$\overline{GADJ}$	government consumption adjustment factor	$\overline{WFDIST}_{fa}$	wage distortion factor for factor f in activity a
$\overline{IADJ}$	investment adjustment factor		

ENDOGENOUS VARIABLES

$DMPS$	change in domestic institution savings rates (= 0 for base; exogenous variable)	QF_{fa}	quantity demanded of factor f from activity a
DPI	producer price index for domestically marketed output	QG_c	government consumption demand for commodity
EG	government expenditures	QH_{ch}	quantity consumed of commodity c by household h
EH_h	consumption spending for household	QHA_{ach}	quantity of household home consumption of commodity c from activity a for household h
EXR	exchange rate (LCU per unit of FCU)	$QINTA_a$	quantity of aggregate intermediate input
$GOVSHR$	government consumption share in nominal absorption	$QINT_{ca}$	quantity of commodity c as intermediate input to activity a
$GSAV$	government savings	$QINV_c$	quantity of investment demand for commodity
$INVSHR$	investment share in nominal absorption	QM_{cr}	quantity of imports of commodity by region
MPS_i	marginal propensity to save for domestic non-government institution (exogenous variable)	QQ_c	quantity of goods supplied to domestic market (composite supply)
PA_a	activity price (unit gross revenue)	QT_c	quantity of commodity demanded as trade input
PDD_c	demand price for commodity produced and sold domestically	QVA_a	quantity of (aggregate) value-added
PDS_c	supply price for commodity produced and sold domestically	QX_c	aggregated quantity of domestic output of commodity
PE_{cr}	export price by region (domestic currency)	$QXAC_{ac}$	quantity of output of commodity c from activity a
$PINTA_a$	aggregate intermediate input price for activity a	$TABS$	total nominal absorption
PM_{cr}	import price by region (domestic currency)	$TINS_i$	direct tax rate for institution i (i ∈ INSDNG)
PQ_c	composite commodity price	$TRII_{ii'}$	transfers from institution i’ to i (both in the set INSDNG)
PVA_a	value-added price (factor income per unit of activity)	WF_f	average price of factor
PX_c	aggregate producer price for commodity	$WFREAL_f$	real average price of factor
$PXAC_{ac}$	producer price of commodity c for activity a	YF_f	income of factor f
QA_a	quantity (level) of activity	YG	government revenue
QD_c	quantity sold domestically of domestic output	YI_i	income of domestic non-government institution

QE_{cr}	quantity of exports by trade partner	YIF_{if}	income to domestic institution i from factor f
$MONEY$	money	T_TFP_a	trade TFP
		G_TFP_a	R&D TFP

#	Equation	Description
1	$PM_{cr} = pwm_{cr} \cdot (1+tm_{cr}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$ $\begin{bmatrix} import \\ price \\ (LCU) \end{bmatrix} = \begin{bmatrix} import \\ price \\ (FCU) \end{bmatrix} \cdot \begin{bmatrix} tariff \\ adjust- \\ ment \end{bmatrix} \cdot \begin{bmatrix} exchange\ rate \\ (LCU\ per \\ FCU) \end{bmatrix} + \begin{bmatrix} cost\ of\ trade \\ inputs\ per \\ import\ unit \end{bmatrix}$	Import Price
2	$PE_{cr} = pwe_{cr} \cdot (1-te_{c}) \cdot EXR - \sum_{c' \in CT} PQ_{c} \cdot ice_{c'c}$ $\begin{bmatrix} export \\ price \\ (LCU) \end{bmatrix} = \begin{bmatrix} export \\ price \\ (FCU) \end{bmatrix} \cdot \begin{bmatrix} tariff \\ adjust- \\ ment \end{bmatrix} \cdot \begin{bmatrix} exchange\ rate \\ (LCU\ per \\ FCU) \end{bmatrix} - \begin{bmatrix} cost\ of\ trade \\ inputs\ per \\ export\ unit \end{bmatrix}$	Export Price
3	$PDD_{c} = PDS_{c} + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$ $\begin{bmatrix} domestic \\ demand \\ price \end{bmatrix} = \begin{bmatrix} domestic \\ supply \\ price \end{bmatrix} + \begin{bmatrix} cost\ of\ trade \\ inputs\ per \\ unit\ of \\ domestic\ sales \end{bmatrix}$	Demand price of domestic non-traded goods
4	$PQ_{c} \cdot (1-tq_{c}) \cdot QQ_{c} = PDD_{c} \cdot QD_{c} + \sum_{r \in R} PM_{cr} \cdot QM_{cr}$ $\begin{bmatrix} absorption \\ (at\ demand \\ prices\ net\ of \\ sales\ tax) \end{bmatrix} = \begin{bmatrix} domestic\ demand\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} import\ price \\ times \\ import\ quantity \end{bmatrix}$	Absorption
5	$PX_{c} \cdot QX_{c} = PDS_{c} \cdot QD_{c} + \sum_{r \in R} PE_{cr} \cdot QE_{cr}$ $\begin{bmatrix} producer\ price \\ times\ marketed \\ output\ quantity \end{bmatrix} = \begin{bmatrix} domestic\ supply\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} export\ price \\ times \\ export\ quantity \end{bmatrix}$	Marketed Output Value
6	$PA_{a} = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$ $\begin{bmatrix} activity \\ price \end{bmatrix} = \begin{bmatrix} producer\ prices \\ times\ yields \end{bmatrix}$	Activity Price

7	$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{c\,a}$ $\begin{bmatrix} aggregate \\ intermediate \\ input\ price \end{bmatrix} = \begin{bmatrix} intermediate\ input\ cost \\ per\ unit\ of\ aggregate \\ intermediate\ input \end{bmatrix}$	Aggregate intermediate input price
8	$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$ $\begin{bmatrix} activity\ price \\ (net\ of\ taxes) \\ times\ activity\ level \end{bmatrix} = \begin{bmatrix} value\text{-}added \\ price\ times \\ quantity \end{bmatrix} + \begin{bmatrix} aggregate \\ intermediate \\ input\ price\ times \\ quantity \end{bmatrix}$	Activity revenue and costs
9	$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$ $\left[CPI \right] = \begin{bmatrix} prices\ times \\ weights \end{bmatrix}$	Consumer price index
10	$DPI = \sum_{c \in C} PDS_c \cdot dwts_c$ $\begin{bmatrix} Producer\ price\ index \\ for\ non\text{-}traded\ outputs \end{bmatrix} = \begin{bmatrix} prices\ times \\ weights \end{bmatrix}$	Producer price index for non-traded market output
11	$QA_a = \alpha_a^a \cdot \left(\delta_a^a \cdot QVA_a^{-\rho_a^a} + (1 - \delta_a^a) \cdot QINTA_a^{-\rho_a^a} \right)^{-\frac{1}{\rho_a^a}}$ $\begin{bmatrix} activity \\ level \end{bmatrix} = CES \begin{bmatrix} quantity\ of\ aggregate\ value\text{-}added, \\ quantity\ aggregate\ intermediate\ input \end{bmatrix}$	CES technology: activity production function
12	$\dfrac{QVA_a}{QINTA_a} = \left(\dfrac{PINTA_a}{PVA_a} \cdot \dfrac{\delta_a^a}{1 - \delta_a^a} \right)^{\frac{1}{1+\rho_a^a}}$ $\begin{bmatrix} value\text{-}added - \\ intermediate\text{-} \\ input\ quantity \\ ratio \end{bmatrix} = f \begin{bmatrix} intermediate\text{-}input \\ - value\text{-}added \\ price\ ratio \end{bmatrix}$	CES technology: Value—Added—Intermediate—Input ratio
13	$QVA_a = iva_a \cdot QA_a$ $\begin{bmatrix} demand\ for \\ value\text{-}added \end{bmatrix} = f \begin{bmatrix} activity \\ level \end{bmatrix}$	Leontief technology: Demand for aggregate value-added
14	$QINTA_a = inta_a \cdot QA_a$ $\begin{bmatrix} demand\ for\ aggregate \\ intermediate\ input \end{bmatrix} = f \begin{bmatrix} activity \\ level \end{bmatrix}$	Leontief technology: Demand for aggregate intermediate input
15	$QVA_a = \alpha_a^{va} \cdot T\_TFP_a \cdot G\_TFP_a \cdot \left(\sum_{f \in F} \delta_{f\,a}^{va} \cdot QF_{f\,a}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$ $\begin{bmatrix} quantity\ of\ aggregate \\ value\text{-}added \end{bmatrix} = productivity \cdot CES \begin{bmatrix} factor \\ inputs \end{bmatrix}$	Value-added and factor demands

16	$$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot (1 - tva_a) \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta^{va}_{fa} \cdot QF_{fa}^{-\rho^{va}_a} \right)^{-1} \cdot \delta^{va}_{fa} \cdot QF_{fa}^{-}$$ $$\begin{bmatrix} \text{marginal cost of} \\ \text{factor } f \text{ in activity } a \end{bmatrix} = \begin{bmatrix} \text{marginal revenue product} \\ \text{of factor } f \text{ in activity } a \end{bmatrix}$$	Factor demand
17	$$QINT_{ca} = ica_{ca} \cdot QINTA_a$$ $$\begin{bmatrix} \text{intermediate demand} \\ \text{for commodity } c \\ \text{from activity } a \end{bmatrix} = f \begin{bmatrix} \text{aggregate intermediate} \\ \text{input quantity} \\ \text{for activity } a \end{bmatrix}$$	Disaggregated intermediate input demand
18	$$QXAC_{ac} + \sum_{h \in H} QHA_{ach} = \theta_{ac} \cdot QA_a$$ $$\begin{bmatrix} \text{marketed quantity} \\ \text{of commodity } c \\ \text{from activity } a \end{bmatrix} + \begin{bmatrix} \text{household home} \\ \text{consumption} \\ \text{of commodity } c \\ \text{from activity } a \end{bmatrix} = \begin{bmatrix} \text{production} \\ \text{of commodity } c \\ \text{from activity } a \end{bmatrix}$$	Commodity production and allocation
19	$$QX_c = \alpha^{ac}_c \cdot \left(\sum_{a \in A} \delta^{ac}_{ac} \cdot QXAC_{ac}^{-\rho^{ac}_c} \right)^{-\frac{1}{\rho^{ac}_c - 1}}$$ $$\begin{bmatrix} \text{aggregate} \\ \text{marketed} \\ \text{production of} \\ \text{commodity } c \end{bmatrix} = CES \begin{bmatrix} \text{activity-specific} \\ \text{marketed} \\ \text{production of} \\ \text{commodity } c \end{bmatrix}$$	Output Aggregation Function
20	$$PXAC_{ac} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta^{ac}_{ac} \cdot QXAC_{ac}^{-\rho^{ac}_c} \right)^{-1} \cdot \delta^{ac}_{ac} \cdot QXAC_{ac}^{-\rho^{ac}_c - 1}$$ $$\begin{bmatrix} \text{marginal cost of com-} \\ \text{modity } c \text{ from activity } a \end{bmatrix} = \begin{bmatrix} \text{marginal revenue product of} \\ \text{commodity } c \text{ from activity } a \end{bmatrix}$$	First-Order Condition for Output Aggregation Function
21	$$QX_c = \alpha^t_c \cdot \left(\sum_{r \in R} \delta^t_c \cdot QE_{cr}^{\rho^t_c} + (1 - \delta^t_c) \cdot QD_c^{\rho^t_c} \right)^{\frac{1}{\rho^t_c}}$$ $$\begin{bmatrix} \text{aggregate marketed} \\ \text{domestic output} \end{bmatrix} = CET \begin{bmatrix} \text{export quantity, domestic} \\ \text{sales of domestic output} \end{bmatrix}$$	Output Transformation (CET) Function
22	$$\frac{QE_{cr}}{QD_c} = \left(\frac{PE_{cr}}{PDS_c} \cdot \frac{1 - \sum_{r \in R} \delta^t_{cr}}{\delta^t_{cr}} \right)^{\frac{1}{\rho^t_c - 1}}$$ $$\begin{bmatrix} \text{export-domestic} \\ \text{supply ratio} \end{bmatrix} = f \begin{bmatrix} \text{export-domestic} \\ \text{price ratio} \end{bmatrix}$$	Export-Domestic Supply Ratio

23	$QX_c = QD_c + \sum_{r \in R} QE_{cr}$ $\begin{bmatrix} aggregate \\ marketed \\ domestic\ output \end{bmatrix} = \begin{bmatrix} domestic\ market \\ sales\ of\ domestic \\ output\ [\ for \\ c \in (CD \cap CEN)] \end{bmatrix} + \begin{bmatrix} exports\ [\ for \\ c \in (CE \cap CDN)] \end{bmatrix}$	Output Transformation for Non-Exported Commodities
24	$QE_{cr} = \Omega_{cr} \cdot \left(\frac{PW_{cr}}{PWE_{cr}} \right)^{\rho_c^{ex}}$ $\begin{bmatrix} exports\ to\ trade \\ partners \end{bmatrix} = f \begin{bmatrix} price\ ratios \end{bmatrix}$	Export demand function
25	$QQ_c = \alpha_c^q \cdot \left(\sum_{r \in R} \delta_{cr}^q \cdot QM_{cr}^{-\rho_c^q} + (1 - \sum_{r \in R} \delta_{cr}^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}}$ $\begin{bmatrix} composite \\ supply \end{bmatrix} = f \begin{bmatrix} import\ quantity,\ domestic \\ use\ of\ domestic\ output \end{bmatrix}$	Composite Supply (Armington) Function
26	$\frac{QM_{cr}}{QD_c} = \left(\frac{PDD_c}{PM_{cr}} \cdot \frac{\delta_{cr}^q}{1 - \sum_{r \in R} \delta_{cr}^q} \right)^{\frac{1}{1+\rho_c^q}}$ $\begin{bmatrix} import\text{-}domestic \\ demand\ ratio \end{bmatrix} = f \begin{bmatrix} domestic\text{-}import \\ price\ ratio \end{bmatrix}$	Import-Domestic Demand Ratio
27	$QQ_c = QD_c + \sum_{r \in R} QM_{cr}$ $\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} domestic\ use\ of \\ marketed\ domestic \\ output\ [\ for \\ c \in (CD \cap CMN)] \end{bmatrix} + \begin{bmatrix} imports\ [\ for \\ c \in (CM \cap CDN)] \end{bmatrix}$	Composite Supply for Non-Imported Outputs and Non-Produced Imports
28	$QT_c = \sum_{c' \in C'} \left(\sum_{r \in R} icm_{c\,c'} \cdot QM_{c'r} + \sum_{r \in R} ice_{c\,c'} \cdot QE_{c'r} + icd_{c\,c'} \cdot QD_{c'} \right)$ $\begin{bmatrix} demand\ for \\ transactions \\ services \end{bmatrix} = \begin{bmatrix} sum\ of\ demands \\ for\ imports,\ exports, \\ and\ domestic\ sales \end{bmatrix}$	Demand for Transactions Services
	Institution block	
29	$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{f\,a} \cdot QF_{f\,a}$ $\begin{bmatrix} income\ of \\ factor\ f \end{bmatrix} = \begin{bmatrix} sum\ of\ activity\ payments \\ (activity\text{-}specific\ wages \\ times\ employment\ levels) \end{bmatrix}$	Factor Income

30	$YIF_{i\,f} = shif_{i\,f} \cdot \left[\left(1 - tf_f\right) \cdot YF_f - trnsfr_{r\,f} \cdot EXR\right]$ $\begin{bmatrix} \textit{income of} \\ \textit{institution } i \\ \textit{from factor } f \end{bmatrix} = \begin{bmatrix} \textit{share of income} \\ \textit{of factor } f \textit{ to} \\ \textit{institution } i \end{bmatrix} \cdot \begin{bmatrix} \textit{income of factor } f \\ \textit{(net of tax and} \\ \textit{transfer to RoW)} \end{bmatrix}$	Institutional factor incomes
31	$YI_i = \sum_{f \in F} YIF_{i\,f} + \sum_{i' \in INSDNG'} TRII_{i\,i'} + trnsfr_{i\,gov} \cdot \overline{CPI} + \sum_{r \in R} trnsfr_{i\,r} \cdot EX$ $\begin{bmatrix} \textit{income of} \\ \textit{institution } i \end{bmatrix} = \begin{bmatrix} \textit{factor} \\ \textit{income} \end{bmatrix} + \begin{bmatrix} \textit{transfers} \\ \textit{from other domestic} \\ \textit{non-government} \\ \textit{institutions} \end{bmatrix} + \begin{bmatrix} \textit{transfers} \\ \textit{from} \\ \textit{government} \end{bmatrix} + \begin{bmatrix} \textit{transfers} \\ \textit{from} \\ \textit{RoW} \end{bmatrix}$	Income of domestic, non-government institutions
32	$TRII_{i\,i'} = shii_{i\,i'} \cdot (1 - MPS_{i'}) \cdot (1 - TINS_{i'}) \cdot YI_{i'}$ $\begin{bmatrix} \textit{transfer from} \\ \textit{institution } i' \textit{ to } i \end{bmatrix} = \begin{bmatrix} \textit{share of net income} \\ \textit{of institution } i' \\ \textit{transfered to } i \end{bmatrix} \cdot \begin{bmatrix} \textit{income of institution} \\ i'\textit{, net of savings and} \\ \textit{direct taxes} \end{bmatrix}$	Intra-Institutional Transfers
33	$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{i\,h}\right) \cdot \left(1 - MPS_h\right) \cdot (1 - TINS_h) \cdot YI_h$ $\begin{bmatrix} \textit{household income} \\ \textit{disposable for} \\ \textit{consumption} \end{bmatrix} = \begin{bmatrix} \textit{household income, net of direct} \\ \textit{taxes, savings, and transfers to} \\ \textit{other non-government institutions} \end{bmatrix}$	Household Consumption Expenditure
34	$QH_{c\,h} = \gamma_{c\,h} + \dfrac{\beta^m_{ch} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{ac'} \cdot \gamma^h_{ac'h}\right)}{PQ_c}$ $\begin{bmatrix} \textit{quantity of} \\ \textit{household demand} \\ \textit{for commodity } c \end{bmatrix} = f \begin{bmatrix} \textit{household} \\ \textit{consumption} \\ \textit{spending,} \\ \textit{market price} \end{bmatrix}$	Household Consumption Demand for Marketed commodities
35	$QHA_{ach} = \gamma^h_{ach} + \dfrac{\beta^h_{ach} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{ac'} \cdot \gamma^h_{ac}\right.}{PXAC_{ac}}$ $\begin{bmatrix} \textit{quantity of} \\ \textit{household demand} \\ \textit{for home commodity } c \\ \textit{from activity } a \end{bmatrix} = f \begin{bmatrix} \textit{household} \\ \textit{disposable} \\ \textit{income,} \\ \textit{producer price} \end{bmatrix}$	Household Consumption Demand for Home Commodities
36	$QINV_c = \overline{IADJ} \cdot \overline{qinv}_c$ $\begin{bmatrix} \textit{fixed investment} \\ \textit{demand for} \\ \textit{commodity } c \end{bmatrix} = \begin{bmatrix} \textit{adjustment factor} \\ \textit{times} \\ \textit{base-year fixed} \\ \textit{investment} \end{bmatrix}$	Investment Demand

37	$$QG_c = \overline{GADJ} \cdot \overline{qg}_c$$ $$\begin{bmatrix} government \\ consumption \\ demand\ for \\ commodity\ c \end{bmatrix} = \begin{bmatrix} adjustment\ factor \\ times \\ base\text{-}year\ government \\ consumption \end{bmatrix}$$	*Government Consumption Demand*
38	$$YG = \sum_{i \in INSDNG} TINS_i \cdot YI_i + \sum_{f \in F} tf_f \cdot YF_f + \sum_{a \in A} tva_a \cdot PVA_a \cdot QVA_a$$ $$+ \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{c \in CM} \sum_{r \in R} tm_{cr} \cdot pwm_{cr} \cdot QM_{cr} \cdot EXR$$ $$+ \sum_{c \in CE} \sum_{r \in R} te_c \cdot pwe_{cr} \cdot QE_{cr} \cdot EXR$$ $$+ \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\ f} + \sum_{r \in R} trnsfr_{gov\ r} \cdot EXR$$ $$\begin{bmatrix} government \\ revenue \end{bmatrix} = \begin{bmatrix} direct\ taxes \\ from \\ institutions \end{bmatrix} + \begin{bmatrix} direct\ taxes \\ from \\ factors \end{bmatrix} + \begin{bmatrix} value\text{-} \\ added \\ tax \end{bmatrix} + \begin{bmatrix} activity \\ tax \end{bmatrix} + \begin{bmatrix} import \\ tariffs \end{bmatrix}$$ $$+ \begin{bmatrix} export \\ taxes \end{bmatrix} + \begin{bmatrix} sales \\ tax \end{bmatrix} + \begin{bmatrix} factor \\ income \end{bmatrix} + \begin{bmatrix} transfers \\ from \\ RoW \end{bmatrix}$$	Government Revenue
39	$$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\ gov} \cdot \overline{CPI}$$ $$\begin{bmatrix} government \\ spending \end{bmatrix} = \begin{bmatrix} government \\ consumption \end{bmatrix} + \begin{bmatrix} transfers\ to\ domestic \\ non\text{-}government \\ institutions \end{bmatrix}$$	Government Expenditures
	System Constraint Block	
40	$$\sum_{a \in A} QF_{f\ a} = \overline{QFS}_f$$ $$\begin{bmatrix} demand\ for \\ factor\ f \end{bmatrix} = \begin{bmatrix} supply\ of \\ factor\ f \end{bmatrix}$$	Factor market
41	$$QQ_c = \sum_{a \in A} QINT_{c\ a} + \sum_{h \in H} QH_{c\ h} + QG_c$$ $$+ QINV_c + qdst_c + QT_c$$ $$\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} intermediate \\ use \end{bmatrix} + \begin{bmatrix} household \\ consumption \end{bmatrix} + \begin{bmatrix} government \\ consumption \end{bmatrix}$$ $$+ \begin{bmatrix} fixed \\ investment \end{bmatrix} + \begin{bmatrix} stock \\ change \end{bmatrix} + \begin{bmatrix} trade \\ input\ use \end{bmatrix}$$	Composite Commodity Markets
42	$$\sum_{c \in CM} \sum_{r \in R} pwm_{cr} \cdot QM_{cr} + \sum_{f \in F} \sum_{r \in R} trnsfr_{r\ f} = \sum_{c \in CE} \sum_{r \in R} pwe_c \cdot QE_c + \sum_{i \in INSD} \sum_{r \in R}$$ $$\begin{bmatrix} import \\ spending \end{bmatrix} + \begin{bmatrix} factor \\ transfers \\ to\ RoW \end{bmatrix} = \begin{bmatrix} export \\ revenue \end{bmatrix} + \begin{bmatrix} institutional \\ transfers \\ from\ RoW \end{bmatrix} + \begin{bmatrix} foreign \\ savings \end{bmatrix}$$	Current Account Balance for RoW (in Foreign Currency)
43	$$YG = EG + GSAV$$ $$\begin{bmatrix} government \\ revenue \end{bmatrix} = \begin{bmatrix} government \\ expenditures \end{bmatrix} + \begin{bmatrix} government \\ savings \end{bmatrix}$$	Government Balance

44	$$TINS_i = \overline{tins_i} \cdot \left(1 + \overline{TINSADJ} \cdot tins01_i\right) + \overline{DTINS} \cdot tins01_i$$ $$\begin{bmatrix} \text{direct tax} \\ \text{rate for} \\ \text{institution } i \end{bmatrix} = \begin{bmatrix} \text{base rate adjusted} \\ \text{for scaling for} \\ \text{selected institutions} \end{bmatrix} + \begin{bmatrix} \text{point change} \\ \text{for selected} \\ \text{institutions} \end{bmatrix}$$	Direct institutional tax rates
45	$$MPS_i = \overline{mps_i} \cdot \left(1 + \overline{MPSADJ} \cdot mps01_i\right) + DMPS \cdot mps01_i$$ $$\begin{bmatrix} \text{savings} \\ \text{rate for} \\ \text{institution } i \end{bmatrix} = \begin{bmatrix} \text{base rate adjusted} \\ \text{for scaling for} \\ \text{selected institutions} \end{bmatrix} + \begin{bmatrix} \text{point change} \\ \text{for selected} \\ \text{institutions} \end{bmatrix}$$	Institutional savings rates
46	$$\sum_{i \in INSDNG} MPS_i \cdot \left(1 - TINS_i\right) \cdot YI_i + GSAV + EXR \cdot \overline{FSAV} =$$ $$\sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$$ $$\begin{bmatrix} \text{non-govern-} \\ \text{ment savings} \end{bmatrix} + \begin{bmatrix} \text{government} \\ \text{savings} \end{bmatrix} + \begin{bmatrix} \text{foreign} \\ \text{savings} \end{bmatrix} =$$ $$\begin{bmatrix} \text{fixed} \\ \text{investment} \end{bmatrix} + \begin{bmatrix} \text{stock} \\ \text{change} \end{bmatrix}$$	Savings-Investment Balance
47	$$TABS = \sum_{h \in H} \sum_{c \in C} PQ_c \cdot QH_{ch} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{ac} \cdot QHA_{ach}$$ $$+ \sum_{c \in C} PQ_c \cdot QG_c + \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$$ $$\begin{bmatrix} \text{total} \\ \text{absorption} \end{bmatrix} = \begin{bmatrix} \text{household} \\ \text{market} \\ \text{consumption} \end{bmatrix} + \begin{bmatrix} \text{household} \\ \text{home} \\ \text{consumption} \end{bmatrix}$$ $$+ \begin{bmatrix} \text{government} \\ \text{consumption} \end{bmatrix} + \begin{bmatrix} \text{fixed} \\ \text{investment} \end{bmatrix} + \begin{bmatrix} \text{stock} \\ \text{change} \end{bmatrix}$$	Total Absorption
48	$$INVSHR \cdot TABS = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$$ $$\begin{bmatrix} \text{investment-} \\ \text{absorption} \\ \text{ratio} \end{bmatrix} \cdot \begin{bmatrix} \text{total} \\ \text{absorption} \end{bmatrix} = \begin{bmatrix} \text{fixed} \\ \text{investment} \end{bmatrix} + \begin{bmatrix} \text{stock} \\ \text{change} \end{bmatrix}$$	Ratio of Investment to Absorption
49	$$GOVSHR \cdot TABS = \sum_{c \in C} PQ_c \cdot QG_c$$ $$\begin{bmatrix} \text{government} \\ \text{consumption-} \\ \text{absorption} \\ \text{ratio} \end{bmatrix} \cdot \begin{bmatrix} \text{total} \\ \text{absorption} \end{bmatrix} = \begin{bmatrix} \text{government} \\ \text{consumption} \end{bmatrix}$$	Ratio of Government Consumption to Absorption
	TFP equations	
50	$$T\_TFP_a = CTET0_a \cdot \sum_{c \in C} \left(\frac{\sum_{r \in R} \frac{1}{2} \cdot EXR\left(QE_{cr} + QM_{cr}\right)}{QX_c} \right)^{\beta^t}$$ $$\left[\text{trade TFP}\right] = \left[\text{trade share in production}\right]$$	Trade TFP

51	$$G\_TFP_a = \beta^g \cdot \left(\frac{\sum_{c \in C} 0.004 \cdot QX_c}{\sum_{a \in A} QVA_a} \right)$$ $$\left[\textit{ag. R\&D TFP} \right] = \left[\begin{array}{l} \textit{share government expenditures} \\ \textit{on ag. output divided by ag. value added} \end{array} \right]$$	Agricultural R&D TFP
	Money	
52	$$MONEY = 0.5 \cdot \sum_{c \in C} PQ_c \cdot QQ_c + 0.5 \cdot \sum_{c \in C} PX_c \cdot X_c$$	
	Update Input-Output Equation	
53	$$ICA_{ca} = WGT_{ca} \cdot ICA93_{ca} + (1 - WGT_{ca}) \cdot ICA97_{ca}$$	Updating input-output
	Capital Accumulation and Allocation Equations	
54	$$AWF_{f\,t}^{a} = \sum_{a} \left[\left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot WF_{f\,t} \cdot WFDIST_{f\,a\,t} \right]$$ $$\left[\begin{array}{c} \textit{average capital} \\ \textit{rental rate} \end{array} \right] = \left[\begin{array}{c} \textit{weighted sum of sectors'} \\ \textit{capital rental rates} \end{array} \right]$$	average economy-wide rental rate of capital
55	$$\eta_{f\,a\,t}^{a} = \left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot \left(\beta^a \cdot \left(\frac{WF_{f,t} \cdot WFDIST_{f\,a\,t}}{AWF_{f\,t}^{a}} - 1 \right) + 1 \right)$$ $$\left[\begin{array}{c} \textit{share of} \\ \textit{new capital} \end{array} \right] = \left[\begin{array}{c} \textit{share of} \\ \textit{existing capital} \end{array} \right] \cdot \left[\begin{array}{c} \textit{capital rental} \\ \textit{rate ratio} \end{array} \right]$$	each sector's share of the new capital investment
56	$$\Delta K_{f\,a\,t}^{a} = \eta_{f\,a\,t}^{a} \cdot \left(\frac{\sum_{c} PQ_{c\,t} \cdot QINV_{c\,t}}{PK_{f\,t}} \right)$$ $$\left[\begin{array}{c} \textit{quantity of new} \\ \textit{capital by sector} \end{array} \right] = \left[\begin{array}{c} \textit{share of} \\ \textit{new capital} \end{array} \right] \cdot \left[\begin{array}{c} \textit{total quantity of} \\ \textit{new capital} \end{array} \right]$$	New capital stock
57	$$PK_{f\,t} = \sum_{c} PQ_{c\,t} \cdot \frac{QINV_{c\,t}}{\sum_{c'} QINV_{c'\,t}}$$ $$\left[\begin{array}{l} \textit{unit price} \\ \textit{of capital} \end{array} \right] = \left[\begin{array}{c} \textit{weighted market price} \\ \textit{of investment commodities} \end{array} \right]$$	Capital price
58	$$QF_{f\,a\,t+1} = QF_{f\,a\,t} \cdot \left(1 + \frac{\Delta K_{f\,a\,t}^{a}}{QF_{f\,a\,t}} - \upsilon_f \right)$$ $$\left[\begin{array}{c} \textit{average capital} \\ \textit{rental rate} \end{array} \right] = \left[\begin{array}{c} \textit{weighted sum of sectors'} \\ \textit{capital rental rates} \end{array} \right]$$	Updating capital quantities by sector

59	$$QFS_{f\,t+1} = QFS_{f\,t} \cdot \left(1 + \frac{\sum_{a} \Delta K_{f\,a\,t}}{QFS_{f\,t}} - \upsilon_{f} \right)$$ $$\left[\begin{matrix} average\ capital \\ rental\ rate \end{matrix} \right] = \left[\begin{matrix} weighted\ sum\ of\ sectors' \\ capital\ rental\ rates \end{matrix} \right]$$	Updating total capital

CHAPTER X: REFERENCES

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