The Adoption of Genetically Modified Organisms in Uruguay's Agriculture: An Ex-Ante Assessment of Potential Benefits

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(ABSTRACT)

The present study analyzes the economic impact of the introduction of Genetically Modified Organisms (GMOs) in Uruguay's agriculture. Using a partial equilibrium framework the impacts of transgenic varieties are simulated for two crops, rice and potatoes, in small open and closed economies respectively. The model accounts for the presence of market imperfections created by the monopolistic behavior of the genes' patent owner. The change in economic surplus generated after the adoption of the new technology is projected to be positive, although the seed markup charged by the monopolist reduces the surplus compared to a perfectly competitive market. Total deadweight losses and domestic losses are found to increase with the seed premium, as additional monopolist profits are extracted out of the country. Adoption decreases with the seed premium, further reducing the domestic consumer and producer surplus. The results of the study suggest an active role for national technology policies and for the agricultural R&D system in Uruguay to generate conditions that attract the technology's owner to a small market while at the same time reducing the potential losses that monopoly power creates[1].

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Chapter 1: Introduction

1.1. The Agricultural Sector in Uruguay

Uruguay is a small country in South America bordered by Argentina and Brazil. Its population of 3.1 million inhabitants is distributed half and half between the capital city, Montevideo, and the rest of the country. More than 90 percent of the 178,000 square kilometers are devoted to agricultural activities carried out by 55,000 farmers. Livestock production for meat, wool and dairy occupy more than 80 percent of the total agricultural land. The rest is under crop production activities including rice, winter wheat, barley, sunflower, corn and some other minor crops like potatoes. Except for dairy, where the production system includes rotations of cultivated pastures and crops, the livestock activities are mainly based on natural grassland grazing. During the past decade, forestry has become an important production activity in areas previously devoted to livestock production. Per capita Gross National Income (GNI) in year 2000 was 6,000 dollars (The World Bank, 2002), but a 4-year recession in the country and the region and recent changes to the exchange rate system suggest that per capita GNI is falling.

Due to the natural resource endowment and the small domestic market, Uruguay's economy has relied for long time on commodity exports. The Agriculture Gross Domestic Product represents on average 11 percent of the Gross National Product, but more than 40 percent of the total exports come from a few agricultural products (Figure 1.1, based on OPYPA 2001). More than 55 percent of the Industrial Gross Domestic Product is related to the processing of agricultural products (Picerno, Antía and Sáder 2001). Meat exports increased their total value and their contribution to exports from agriculture due to the higher prices and new markets developed after the country was declared Foot and Mouth Disease free in 1995. The country lost the categorization in April 2001 after new cases of the disease were found, and meat exports are expected to decline.

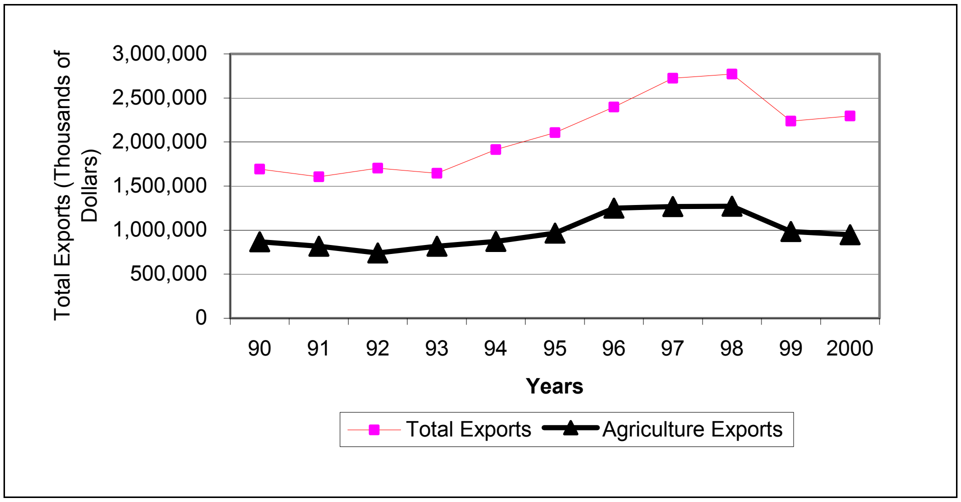

Figure 1.1. Uruguay: total annual exports and exports from agriculture[2], period 1990-2000.

Meat, rice and dairy products represented the largest shares of agricultural exports in 2000, accounting for 42, 17.4 and 14.4 percent respectively of the total (Figure 1.2, based on OPYPA 2001). While wool used to be important, the decline in international prices and the subsequent reduction of the ovine herd have decreased its share of exports from more than 45 percent in 1991 to around 23 percent in 2000. The share is expected to diminish further in the future. Rice is the major export crop, and since 1990 its contribution to total crop exports has varied between 61 and 86 percent.

After several decades of stagnation, total agricultural production and productivity rose during the 90's due to rapid technological adoption at the farm level. Livestock and dairy in particular, the largest agricultural sectors in terms of area, have incorporated advanced technologies at an increasing rate since 1990. The share of livestock production for meat and wool under improved pastures increased from 6.4 percent in 1994 to 10.1 percent in 1999. In the dairy sector, the percentage of land under improved pastures also increased during the same period from 43.2 percent to 47.8 percent (DIEA, 2001a). A common measure of productivity in the country is the equivalent meat index, which converts meat, wool and milk production to a single unit of meat production per hectare. The relevance of the index is that it covers a large percentage of farms and area of the total agricultural sector. The equivalent meat index increased between 1991 and 1997 from 69.4 to 77.4 kilograms per hectare (DIEA, 2000). Wheat average

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[2] Agriculture exports as defined for this reference include the following major commodities and crop products: meat (bovine and ovine), wool, dairy products, rice (grain and oil), sunflower (grain and oil), wheat (grain and flour), corn, sorghum, barley and oat.

yield for the period 1992-1999 was 2.29 tons per hectare, 76 percent above the 1.3 tons per hectare averaged during the 80's. As another indicator of technological adoption at the farm level, by the year 2000 35 percent of the wheat producers were applying non-tillage techniques (DIEA, 2001c).

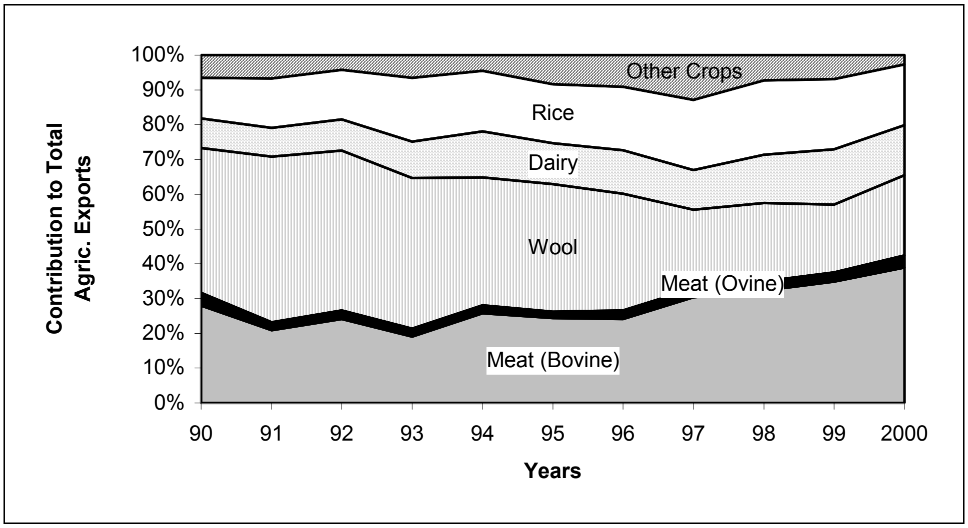

Figure 1.2. Uruguay: contribution of major agricultural products to agriculture exports, period 1990-2000.

While not conclusive, these trends indicate that the agricultural sector adopts technological advances when favorable general market conditions and stable macroeconomic environment reduce the chances for speculative profits (Preve, 2000). Further proof that farmers in Uruguay value improved technologies is their commitment to the funding and management of agricultural research, which led to the creation of the National Agricultural Research Institute (INIA) in 1989 (Beintema, Hareau, Bianco and Pardey, 2000; Horton and Hareau, 1999). Public investment represents more than 90 percent of the total agricultural research expenditure in the country, and private expenditure accounts for the remainder. In 1996, the country's expenditure on agricultural research and development (R&D) represented 1.7 percent of the agricultural Gross Domestic Product (GDP). The figure is high compared to other developing countries, but still low with respect to developed regions. In the same year, Colombia's agricultural R&D expenditure represented 0.53 percent of the agricultural GDP (Beintema et al, 2000). In 1997, US public agricultural research expenditures relative to the gross value of agricultural production was 1.38 percent, but the ratio rises to 3.51 percent when private agricultural R&D expenditures are considered (Alston, Christian and Pardey, 1999).

The figures above are an indication of the country's commitment to develop the agricultural sector and to invest in agricultural R&D. However, the country's capacity for large R&D investments required in some technologies is still a major constraint. Beintema et al report that a total of 328 full-time equivalent agricultural researchers were employed in Uruguay in 1996, and that the total agricultural R&D expenditure for the same year was 38 million (1993 international dollars).

1.2. Biotechnology and Agriculture: the Advent of the Genetically Modified Organisms

According to Jung (2000), the advance of the molecular biology and genetic engineering science in the last two decades changed the conventional plant-breeding paradigm by introducing new techniques based on the manipulation of individual genes. By these techniques, mainly marker assisted selection and marker-based genetic distance analysis, a gene containing specific characteristics from one living organism is isolated and introduced into another living organism so that the latter can express the desired characteristic. The most important impact of these new techniques will be to accelerate the release of new crop varieties, and to allow development of varieties with specific tolerance to herbicides, viruses and diseases, as well as improved quality characteristics. For example, the Vitamin A content of rice could be improved by introducing a gene that increases its beta-carotene content, a precursor of Vitamin A. This might alleviate nutritional problems for more than 400 million people around the world whose diet is based on rice and is Vitamin A deficient. Rice is the commercial crop with the smallest genome (DNA content) among the cereals, and its genome was sequenced as a working draft by Monsanto Company and given to the International Rice Genome Sequence Project (IRGSP), an international consortium established by research centers from 10 countries to develop the complete sequence of the rice genome (Jung, 2000; IRGSP, 2002). In potato, genetic engineering can reduce the Amylose content of the starch, meeting the demand of the industry processing potato as raw material. Crop varieties produced using any of the techniques involving gene transfer between different species are usually known as transgenic crops or more generally as Genetically Modified Organisms (GMOs).

James (2000) surveyed seven different transgenic crops being produced in 12 countries around the world and totaling 39.9 millions of hectares in 1999, an increase of 44 percent compared to 1998. Out of the total, the USA, Argentina and Canada are the leading countries, accounting for 72 percent, 17 percent and 10 percent respectively of the area under GMOs. Soybean (54 percent), Maize (28 percent), Cotton (9 percent) and Canola (9 percent) are the major crops in terms of total area devoted. Other transgenic crops already available for commercialization around the world are Potato, Squash and Papaya. In terms of the type of transgenic characteristic and the area it occupies, tolerance to herbicide represents 71 percent, insect resistance 22 percent and both combined 7 percent.

The production of a GMO is complex and involves an extensive array of basic knowledge, high-technology procedures and skills, as well as the availability and proper manipulation of desired characteristics. The research and development of GMOs has been led by private companies, which seek to recover the research costs and make profits through patent protection. Patent protection is a form of Intellectual Property Rights (IPR) that gives the patent holder monopoly power over the product. Since intellectual property rights can be claimed on final outputs and on intermediate procedures and inputs as well, it's highly likely that any GMO commercialized in the future will be completely or partially protected by IPR. To give an example, the rice genome is already a public good, but genes improving its quality can be patented and varieties including those genes would be protected by IPR (IRRI, 1997). It's then likely that final users of the improved variety will be facing monopolist markets and thus charged higher prices than in perfectly competitive markets. Market power will have important implications for how new technologies are evaluated.

1.3. Problem Statement

Publicly funded agricultural research in Uruguay has increased since 1991, mainly after the creation of INIA (Beintema et al, 2000). During the same decade, IPR for biological innovations have been strengthened around the world and are likely to change the role of public research and public-private institutional arrangements for agricultural research (Falck-Zepeda, Traxler and Nelson, 2000; Fuglie et al, 1996). High invention costs and the need for a strong research capacity are amongst the reasons why the new process for technology generation is concentrating in large multinational firms, along with the economic incentive made possible through IPR enforcement (Caswell, Fuglie and Klotz, 1994). From the demand side, the pace at which these products are being adopted is faster than that observed for other agricultural inventions such hybrid seeds (Fuglie and Schimmelpfennig, 2000).

For a small developing country like Uruguay with an agricultural based economy, the question is whether the introduction of GMOs into the agricultural sector will be beneficial for the economy. One issue is whether profits derived from GMOs use will go primarily to a multinational firm and not benefit the country. Another issue is whether the country can build the necessary research capacity to develop the technology on its own. Falck-Zepeda, Traxler and Nelson (2000) estimated that for 1996 the adoption of the new Bt Cotton variety by US farmers increased total surplus in the world's economy by 240.3 million dollars. Out of the total change, US farmers' gains accounted for 59 percent, the gene developer 21 percent, US consumers 9 percent and the germplasm supplier 5 percent. The rest of the world (ROW) also gained 6 percent, although ROW producers had an absolute loss due to decreasing world prices for cotton.

Few studies have been conducted on the surplus distribution resulting from the adoption of GMOs in developing countries[3]. The results of such studies would provide useful insights for policy formulation at institutional and government levels. In Uruguay, an additional concern is the national declaration that Uruguay is a natural based agricultural country. Since the worldwide debate around the risks and ethics of GMO use is still in process, the country's declaration could be seen as contradictory with the use of this technology in the agricultural sector. An estimation of the benefits that can be expected from the use of GMOs in Uruguay would provide important economic information to the debate. The magnitude of the expected benefits can be compared against the benefits that would be generated under alternative policies. On the other hand, the distribution of the benefits among the different economic agents involved may give an indication of who are the winners and who are the losers when adopting such technologies, setting up the background for the design of compensating policies.

The present research aims to simulate the size and distribution of the economic surplus generated by the introduction and adoption of GMOs in Uruguay. The study will be conducted

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[3] In one of these studies, Elena (2001) concluded that the adoption of Bt Cotton in Argentina had a positive economic impact for argentine farmers.

on two different crops: rice, an export commodity, and potatoes, basically produced for the domestic market.

1.4. Objectives

The specific objectives of the study are:

1. To estimate the change in total surplus derived from the introduction of a transgenic rice variety in Uruguay and its distribution amongst producers, consumers, and GMO patent owners.
2. To estimate the change in total surplus derived from the introduction of a transgenic potato variety in Uruguay and its distribution amongst producers, consumers, and GMO patent owners.
3. To compare the estimated changes in economic surplus for both crops under different market structures for the GMOs.
4. To identify implications of the introduction of GMOs for national agricultural research policy.

1.5. Thesis Structure

The remainder of the thesis is structured as follows. Chapter 2 introduces the general economic surplus model to evaluate research-induced changes in agriculture. The traditional economic surplus model is adjusted to reflect an input supplier with market power, and applied to two crops: rice and potatoes. Details on the methods and techniques used in the simulation of the two transgenic crops and data sources are provided in Chapter 3. Chapter 4 lays out the results and discusses the findings. Chapter 5 draws general conclusions and implications from the results and provides some policy implications.

Chapter 2: Conceptual Framework and the Applied Model

This Chapter presents the theoretical foundations of the economic surplus model used to analyze the impact of agricultural technologies, and how the model can be adjusted to reflect the market power present in the market for GMOs. The model specifications for the cases of rice and potatoes in Uruguay are laid out in section 2.3.

2.1. Theoretical Framework for the Measurement of Benefits from Agricultural Innovations: the Economic Surplus Model[4]

Alston, Norton and Pardey (1995) provide extensive evidence supporting the use of the economic surplus model to evaluate welfare effects of new agricultural technologies. The model has been widely used in empirical analysis. One of its advantages is that it can be modified to incorporate effects such as research-induced quality changes, market-distorting policies and other type of economic distortions (i.e., externalities). They also state "there is little written on the effects of the market power of firms on the size and distribution of research benefits in agriculture…because a widespread belief that the competitive model provides a good approximation for agriculture".

Economic surplus is the measurement of the consumer (CS) and producer surplus (PS) generated in a transaction. Consumer surplus (CS) reflects the consumer's willingness to pay more for a good than the market price, and producer surplus (PS) is the return to quasi-fixed factors of production to producers from selling the good at that equilibrium price.

Graphically, CS is represented in Figure 2.1 as the area PAC. It can also be interpreted as the total surplus received by the consumer less the cost of buying quantity Q of the good at price P. Similarly, area PAB represents the PS, which can be explained as the total revenue less the cost of producing quantity Q of the good. Any change in CS, PS or Total Surplus (TS) can be measured as a change in these areas.

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[4] The section is based on Alston, Norton and Pardey (1995).

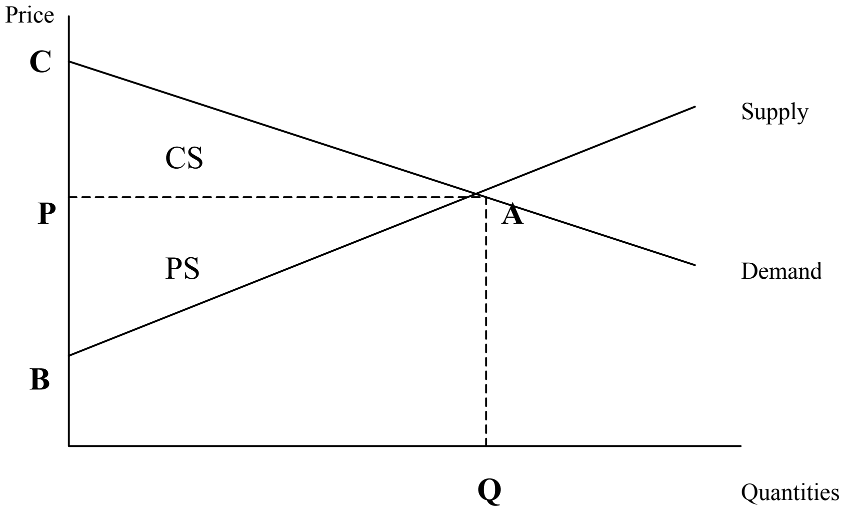

Figure 2.1. Partial equilibrium analysis: consumer and producer surplus.

Technological change due to research in agriculture increases the yield or reduces the cost of production once the new technology is adopted. If the new technology is yield increasing, the producer sells more of the good in the market and if demand is downward sloping the price decreases. Alternatively, a cost-reducing technological change allows the producer to sell the same quantity than before but at a lower price. The final effect of the technological change is for both cases a reduction in the cost of producing one unit of output, whether by producing an increased output with the same cost or by reducing the cost of producing the same amount of output. In both cases, a new equilibrium is formed due to a shift in the supply curve, and the new equilibrium is achieved at a lower price and higher quantity.

As a consequence of the new equilibrium, changes occur in the consumer and producer surplus. The change is shown graphically on Figure 2.2 from the original supply curve S to the new curve S_1. The new price is P_1 and the new quantity produced is Q_1. The total surplus change is area BAA_1B_1, and is the sum of the change in consumers' and producers' surplus.

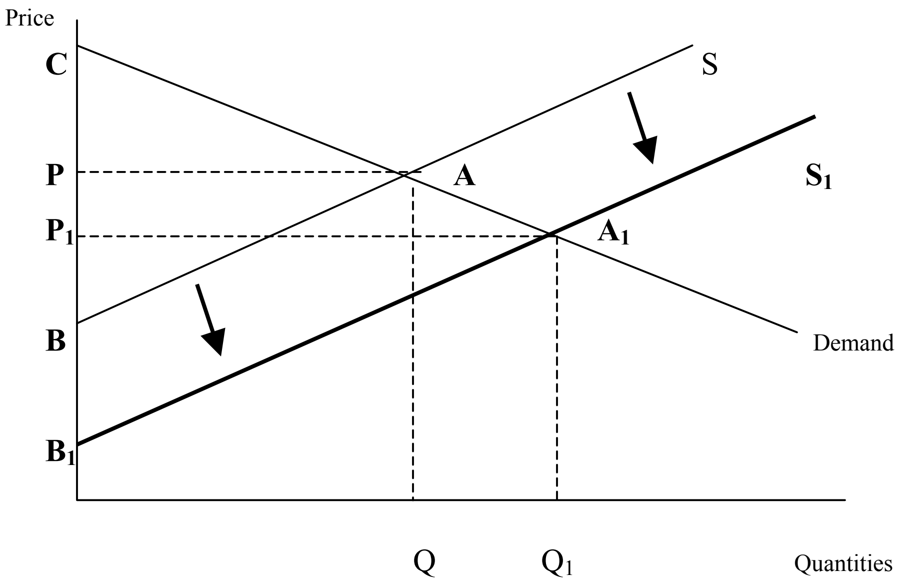

Figure 2.2. Change in total surplus with technological change.

The distribution of the change in total surplus between consumers and producers depends on the supply and demand price elasticities, or the proportional change of demand and supply with respect to a proportional change in prices. A shift due to technological change in a supply curve facing a perfectly elastic demand curve changes producer surplus (area BAA_1B_1 in Figure 2.3) but has no effect on consumer surplus, since they will still be paying the same price as before the change.

Change in total surplus also varies with the nature of the technological change and thus the type of research-induced supply shift. A parallel shift of a linear supply curve is represented in both Figures 2.2 and 2.3 for the case of small closed and open economies respectively. The supply shift can also be divergent-pivotal, divergent-proportional or convergent. The supply shift depends amongst other factors on the type of innovation causing the shift (biological, chemical, mechanical or organizational).

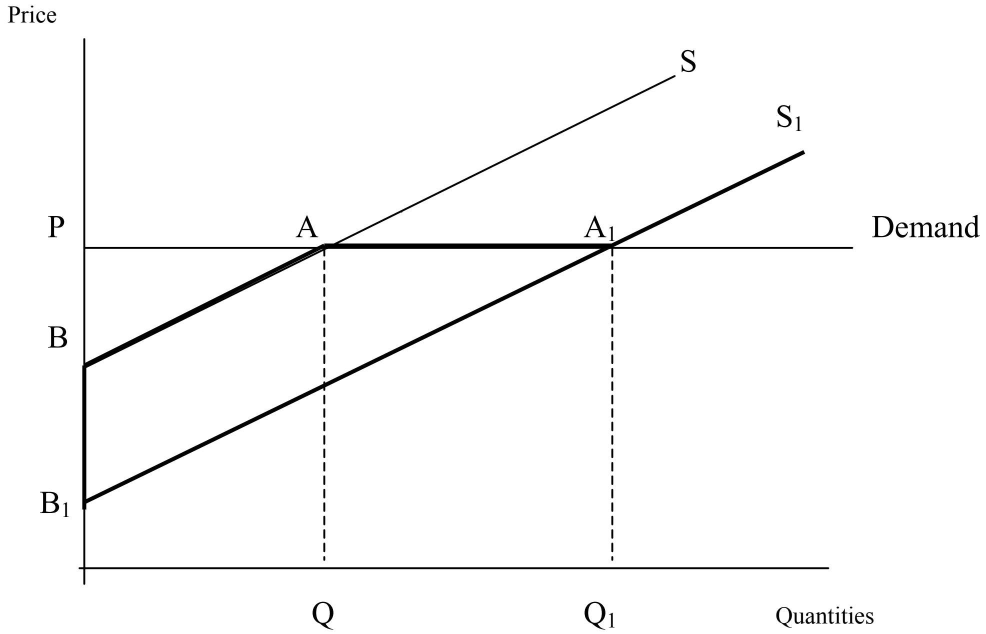

Figure 2.3. Change in total surplus with perfectly elastic demand curve.

Use of the economic surplus model as a measure of welfare changes has criticisms that must be discussed. As part of the field of welfare economics, economic surplus is about normative economics since it implies value judgments about the distribution of benefits to economic agents. Even when no explicit distributional assumptions are made implicitly means that equal weights are attached to consumers and producers. Value judgments are relevant because the economic surplus method relies on the compensation principle: if as a consequence of the new equilibrium winners and losers exist, the new equilibrium is still Pareto optimal if winners can compensate losers and still be better off than before[5].

Consumer and producer surplus also are not exact money metric measures of welfare since they do not consider income effects of price changes. Alternative measures such as compensating (CV) and equivalent variation (EV) are more precise to evaluate changes in utility and account for the income effect. However, other sources of error that arise when estimating compensating and equivalent variation (ie: from estimated demand equations) may reduce their precision and make the attempt not relevant for empirical analysis. On the other hand, changes in producer surplus may be an acceptable representation of changes in producer profits.

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[5] A variation of the Pareto criterion is the Kaldor-Hicks criterion, in which the compensation must be feasible but not necessarily be made effective.

In general, critical assumptions regarding the functional form of the supply and demand curve, the nature of the supply shift and supply and demand elasticities are greater source of error than the model imperfections discussed above. However, these assumptions are often inevitable in empirical analysis due to the lack of proper data or the cost of estimating their real form.

Another criticism refers to the partial nature of the analysis, which may be inaccurate when changes in the market for one commodity have effects in other markets, and multi-market models should be used instead. The point refers more to the application of the model rather than to the theory itself, and can be corrected by properly modeling spillovers when believed to be present. It also refers to whether the assumption of perfect competition holds in those markets. As shown in the present study, the applied analysis can be modified to represent different market structures.

The presence of externalities and transaction costs when moving from the initial to the new equilibrium is also an empirical issue that must be specifically addressed if the magnitude of these costs is significant enough to modify the conclusions of the analysis. Externalities such as environmental impact can be valued and included in the model as costs, as well as transaction costs such as fixed costs that become obsolete after the change.

Finally, critics have argued that economic agents and decision-makers have trouble understanding the economic surplus concept and therefore it may become irrelevant for policy analysis. The issue may be addressed by explicitly explaining the assumptions of the model (ie: the distributional value judgements) and by communicating the results in such a way that the objectives of target audiences are met.

Given the criticisms and how they can be overcome, Alston, Norton and Pardey conclude, "…for most purposes, the partial equilibrium economics surplus model is the best available method to evaluate returns to research".

The formulae for measuring the change in economic surplus depend on the nature of the market. In the special case of an exporter small open economy, the total surplus change is equivalent to the producer surplus change since all the benefits from research go to producers. The general formula is:

Change TS = Change PS = $P_w Q_0 K (1+ 0.5K\varepsilon)$

P_w: world price

Q_0: pre-research quantity

K: technical change, shift of the supply curve as a proportion of the initial price

ε: supply elasticity

The coefficient for the technical change K can be calculated from the following formula:

$$K = \left(\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1 + E(Y)} \right) p A_t (1 - d_t)$$

E (Y) : expected increase in yield per hectare after the adoption of the new technology

E (C) : proportionate change in variable input costs per hectare

ε : supply elasticity

p : probability of success of research in achieving the expected change in yield

A_t : rate of adoption of the new technology

d_t : depreciation factor for the new technology

In the special case of a small closed economy represented by Figure 2.2, the general formulae include the calculation of changes in consumers and producers' surplus:

Change in TS = Change in CS (ΔCS) + Change in PS (ΔPS)

$\Delta CS = P_0 Q_0 Z (1 + 0.5Z\eta)$

$\Delta PS = P_0 Q_0 (K - Z) (1 + 0.5Z\eta)$

$\Delta TS = P_0 Q_0 K (1 + 0.5Z\eta)$

P_0: initial equilibrium price

Z: relative reduction in price due to supply curve shift

η: demand elasticity

Q_0 and K are the same as before. The price reduction factor Z can be calculated from the formula:

$$Z = K\varepsilon / (\varepsilon + \eta)$$

2.2. Intellectual Property Rights and Agricultural Innovations: an Adjusted Model

Intellectual Property Rights over innovations are the means by which private firms recover their research investment. The rights are usually limited to a finite period of time, after which the innovation can be freely produced and sold by any firm. In agricultural research, IPR have been embedded in inventions like chemicals, machinery and post-harvest technology. Most recently, IPR are being used to protect crop varieties, seeds, and even genes.

Moschini and Lapan (1997) argue that the presence of IPR in agricultural innovations modifies the theoretical framework and assumptions of the conventional economic surplus approach to evaluate agricultural research developed above. The reasoning is based on the fact that IPR confer limited monopoly power to firms producing the innovation. Since these innovations are in general embedded in the inputs used by agriculture, the basic assumption of perfect competition in the inputs market does not hold. The firms producing the innovation will set the input price to maximize their private profit according to their monopoly power. This price will be higher than the marginal cost of producing the innovation, with the magnitude depending on the pre-existing market structure. Therefore, there will be a positive profit for the input supplier instead of the zero profit result that the perfect competition assumption would suggest. This monopoly profit needs to be accounted for when evaluating the welfare change after an agricultural innovation is adopted.

Since the economic surplus approach is based on the commodity market, and the monopolist's profit is produced in the input market, the adjusted theoretical model proposes to evaluate the total welfare change as the sum of the change in the marshallian surplus in the agricultural market and the monopoly profit in the input market. The model assumes that there is a new technology that substitutes for an old one, and both are related to each other by an augmentation factor α. The augmentation factor allows comparing the new and old input use in terms of efficiency units. Specifically, Moschini and Lapan describe the relationship between the two technologies assuming the general form:

$$g\,(x_1,z) = f\,(\alpha x_1,z)$$

Where "g" represents the new production technology as a function of the new improved input x_1 and the set of all the other inputs z, which remain unchanged. The old technology is represented by "f" and the amount of the new input is multiplied by the augmentation factor "α" because more efficiency units of the new input are needed in the old production function to substitute the old input ($\alpha>1$).

The price level that monopolist's firms can charge for their innovation, w1, depends basically on two factors: the pre-existing market structure for the input before the innovation is adopted, and whether the innovation is drastic or non-drastic. If the market before the innovation is adopted were under perfect competition and the innovation were drastic (meaning there is an effective unit-cost reduction technology for producers), then the total welfare change can be measured using the following equation:

$$\Delta SW^{D,C} = \int_{W1}^{C} X\,(w)\,dw \quad + (w1 - c/\alpha)\,x^{*}_{1}$$

$\Delta SW^{D,C}$: Change in social welfare for a drastic (D) innovation and competitive (C) pre-existing input market structure

X (w): derived marshallian demand curve for efficiency units of the innovated input, as a function of its price w

w1: profit-maximizing monopolistic price per efficiency units of the innovation

c: marginal cost of production of the innovated input

α: efficiency factor of the innovated input

x^{*}_{1}: effective demand for efficiency units of the innovated input

The first term on the right hand side of the equation is equivalent to the change in total surplus measured in the output market, while the second term accounts for the monopolist's profit produced in the input market. Graphically, they can both be simultaneously represented in the input market under the marshallian demand curve for the improved input, as in Figure 2.4.

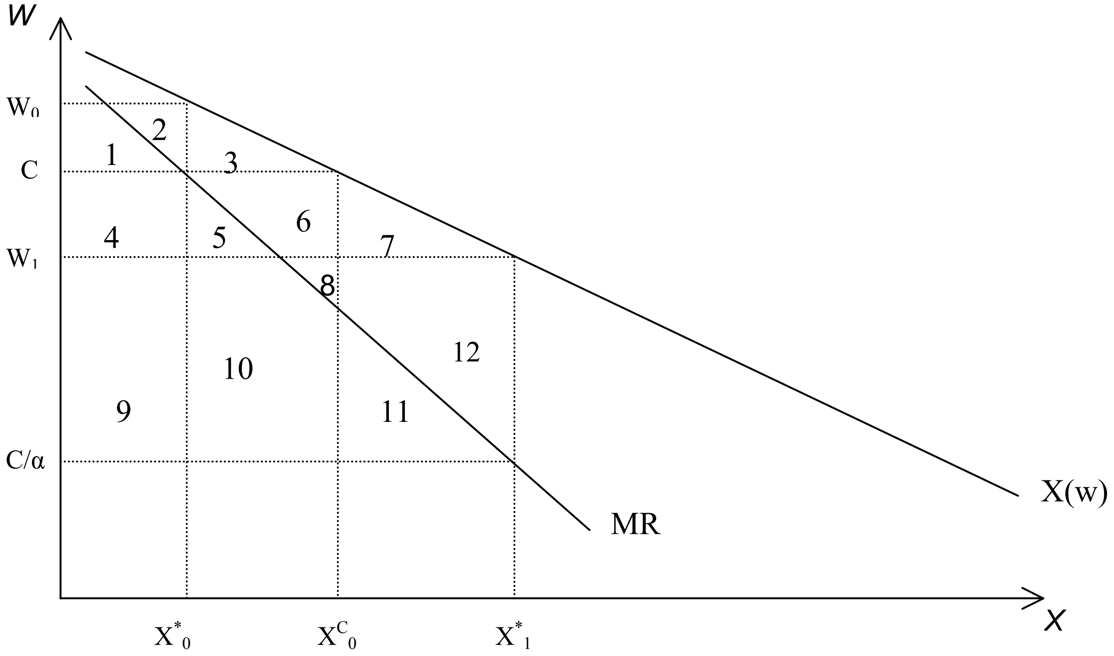

Figure 2.4. Marshallian surplus and monopolist's profit in the input market

As before, X(w) is the marshallian demand for efficiency units of the improved input as a function of its price w. MR is the marginal revenue curve of the monopolist. W_1, C and C/α are the price per efficiency unit of the new input (or efficiency price), the marginal cost of production of the input and the marginal cost per efficiency unit respectively. W_0 is the efficiency price of the old input. x^*_0 and x^c_0 are the effective demands for efficiency units of the old input under pre-existing monopoly and under perfect competition respectively, and x^*_1 is the demand in efficiency units of the new input. The sum of the areas 4, 5, 6 and 7 represent the change in marshallian surplus and is equivalent to the change in economic surplus calculated in the output market under the conventional approach. The monopolist's profit is represented by the sum of areas 8, 9, 10, 11 and 12, as the difference of the monopolist's price in efficiency units and the marginal cost per efficiency unit, multiplied by the demand for efficiency units of the new input.

According to Moschini and Lapan, the adjusted model is appropriate to evaluate total welfare changes when markets for the innovations are not perfectly competitive. Compared to the traditional approach, they show that this model corrects downward the size of total welfare changes and represents more accurately the distribution of the change between consumers, producers and innovating firms. Simulating welfare changes for Constant Elasticity of Substitution (CES) functional forms, they also show that assuming perfect competition may give results for the change in CS and PS that accrue completely to the innovator monopolist under the adjusted model.

Alston, Sexton and Zhang (1997), analyzing the effects of imperfect competition on the size and distribution of agricultural research benefits, conclude that for parallel research-induced supply shifts the total benefits are reduced compared to the benefits produced when markets are perfectly competitive. The difference represents the deadweight losses created in the economy. The deadweight losses are surplus that is lost and is not captured by any agent, and they are proportional to the degree of monopoly power existing in the markets.

2.3. The Applied Model to Evaluate Biotechnologies in Agriculture

Drawing on the theoretical model described above, Falck-Zepeda, Traxler and Nelson (2000) developed an empirical model that combined the conventional economic surplus approach in output markets with the calculation of monopolist's profit in the input market to determine the welfare change and distribution of the introduction of Bt cotton in the USA in 1996. Marshallian surplus was calculated following the same procedures suggested in Alston, Norton and Pardey (1995) for the calculation of economic surplus change in the output market. Then, the monopolist's profit was calculated as suggested by the theoretical model, and added to the marshallian surplus. The applied model allows the authors to calculate the total welfare change and the distribution of the change among producers, consumers, and innovators. Linear supply and demand curves and a parallel supply shift due to technological change were assumed.

The same approach is followed in the present research to determine the impact of the introduction of GMOs in Uruguay. Two different crops (rice and potatoes) are evaluated under this conceptual and empirical framework. The crops are selected based on their importance for the Uruguayan agricultural sector, on the likelihood of GMO varieties being introduced into the country, and because potatoes are produced for a closed economy domestic market and rice for an open economy export market.

Until year 2000 and except for a small area of transgenic Roundup Ready Soybean®, there were no GMO varieties under production in Uruguay for any crop. This is basically due to the fact that most GMO varieties released to the world market for commercialization and production are of little significance for the agricultural sector in Uruguay. For some relevant new GMO varieties like the Bt cotton, the crop is not produced in the country. For others, the technological problems they tackle do not represent major production constraints in the country such as the insects controlled by Bt maize. To overcome the lack of real data, the transgenic varieties are simulated using an ex-ante partial budgeting framework. Some key variables like the seed markup on the new varieties are estimated using available data for other GMOs in different countries. The achievable per-unit cost reduction and expected adoption rates are estimated using available information from private companies and research centers working on the selected crops and from historic data in Uruguay. Models for both crops assume linear supply and demand curves and a parallel research-induced supply shift.

2.3.1. *The Applied Model for a Small Open Economy: the Case of Rice*

Rice is the most important commercial crop for Uruguay, and a major source of national income as an export crop. Despite some periods of negative net profits for farmers, between 1987 and 1999 cropping area increased 158 percent from 79,400 to 205,000 hectares, a 7.6 percent annual rate. In the same period, physical productivity increased 53 percent from 4,000 to 6,250 kilograms per hectare, a 3.4 percent annual rate. In 1999, more than 80 percent of the total production was exported, generating 195 million dollars of gross revenue. This revenue represented 8.8 percent of the total exports of the country, and ranked rice as the second most important export commodity after meat products (19.2 percent). In 1998, with higher international prices, the gross revenue from rice exports was 273 million dollars. The most important export markets in 1999 were Brazil (56 percent), Iran (26 percent), Trinidad and Tobago (4.9 percent) and Peru (5.6 percent). Another twenty-eight different countries accounted for portions below 5 percent. Based on the net exports of rice, in 1999 Uruguay ranked as the seventh country in the world with a market share of 2.85 percent. Due to declining world prices, the area under rice production decreased to 125,000 hectares in 2002 (OPYPA, 2000; Revista Arroz, 2002).

Rice is also important for the future of GMOs because by the end of 2002 it will be the first cereal for which the genome is totally codified. This accomplishment increases the possibility of creating GMOs based on rice, although GMOs for other cereals are already being commercialized (Jung, 2000; IRGSP, 2002).

Being a major export commodity the rice case follows the model of a small open economy facing a perfectly elastic demand curve at the world price for rice (Figure 2.3). All changes in total surplus go to producers. The model is better represented on partial equilibrium analysis for an exporter small open economy with a local downward sloping demand curve. Producers and consumers face an international price Pw above the partial equilibrium price for the closed economy. Differences between quantities produced before and after the research-induced shift (Qp and Qp') and consumed (Qc) represent the quantities exported (Figure 2.5). In this model all the change in total surplus still accrues to producers and the formulae previously presented still apply. The monopolist's profit is calculated as in Falck-Zepeda, Traxler and Nelson (2000), multiplying the seed premium per hectare charged to farmers for the use of the transgenic seed and the expected adoption area in each year. The monopolist's profit is then added to the change in producers' surplus to estimate the total surplus change.

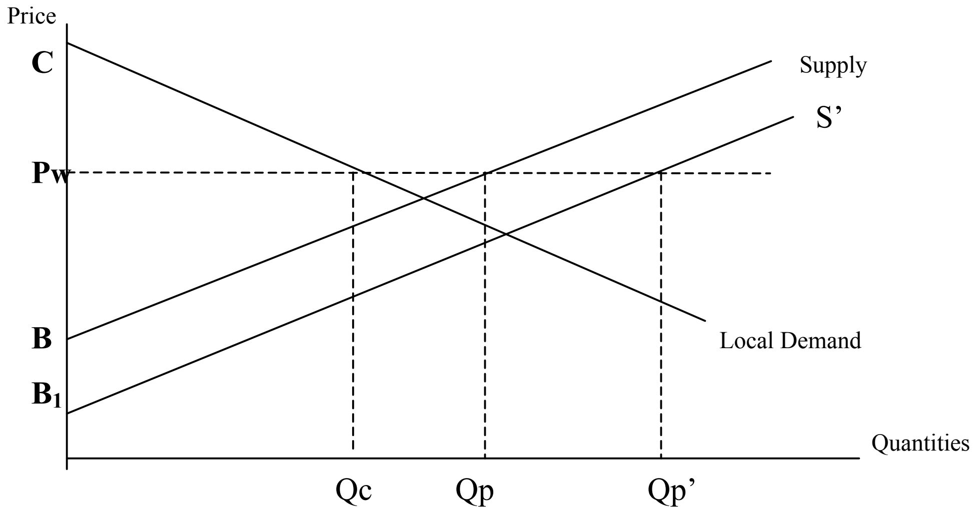

Figure 2.5. Change in total surplus for an exporter small open economy: the case of rice

2.3.2. *The Applied Model for a Closed Economy: the Case of Potatoes*

With an area that varies annually between 7,000 and 9,000 hectares, potatoes are an important domestic vegetable crop in Uruguay. Domestic production meets a domestic demand that averages 120,000 tons annually. Productivity has increased in the past ten years by 50 percent, from 10 tons per hectare to an average of 15 tons per hectare in 1997 and 1998. The increased productivity has reduced the imports from neighboring countries that used to cover the excess demand (OPYPA, 2000).

Potatoes are also important as a GMO since a transgenic variety, Bt potato, is already available in the world market. However, the specific resistance provided by the Bt potato is not a current production problem for Uruguay and most likely it will not be commercialized and produced as such. Therefore, figures and data available for the Bt potato cannot be directly applied to the analysis. This study simulates a potato transgenic variety with another type of characteristic that eventually could be attractive for the Uruguayan conditions.

Since potatoes are grown almost exclusively for domestic consumption, they are modeled as a closed economy where the supply curve is upward sloping and demand curve is downward sloping (Figure 2.2). The price level is set by the intersection of the curves. Change in domestic surplus is composed of both changes in consumer and producer surplus. Monopolist's profit is again calculated as in Falck-Zepeda, Traxler and Nelson (2000), by multiplying the seed premium per hectare and the adoption area in each year. The total surplus change is the sum of producers' and consumers' surplus and monopolist's profit.

While in this model it is unambiguous that consumers gain after the technological change due to the consumption of higher quantities at lower prices, producers' gain is not clear and depends on the nature of the research- induced supply shift (the K variable) and the demand and supply elasticities. The presence of a monopolist adds additional uncertainty about the benefits to consumers and producers so the distribution of benefits is carefully analyzed in the study.

Chapter 3: The Empirical Simulation

This chapter presents the information used to estimate the potential impact of transgenic rice and potato varieties in Uruguay. Since data for GMOs' performance in Uruguay is not available, their impact is simulated using partial budgeting techniques. The chapter first introduces the procedure for the simulation of both rice and potato transgenic varieties, then data and information sources are presented.

3.1. Empirical Simulation: Techniques

The empirical simulation uses partial budget figures for rice and potatoes as a starting point to simulate the impact of transgenic varieties. It is assumed that transgenic varieties impact some variables of the partial budget, changing their value with respect to the benchmark figures (which represent the cost of producing under the actual or traditional technology). The key variables in the partial budget are: the difference between the per hectare cost of inputs used in the traditional technology and the new per hectare cost of inputs under the transgenic technology, the expected increase in yield per hectare of the transgenic technology with respect to the traditional one, and the increase in price of the transgenic seeds (seed premium or seed markup) compared to the price of the traditional seeds. To account for the uncertainty of the final value of these variables, the analysis is conducted across a range of feasible values. Each combination of values produces a scenario for the impact of the transgenic variety.

The following sections explain the creation of scenarios for each crop, including the data used and the values selected for specific variables.

3.2. The Simulation of Transgenic Varieties for Rice and Potatoes

3.2.1. *Methodology*

The research-induced supply curve shift that occurs when a new agricultural technology is adopted is captured by the concept of the per-unit cost reduction, which measures both the potential productivity gains and the new optimal input use. The per-unit cost reductions associated with transgenic varieties are created based on actual budget figures for rice and potatoes and the potential advantages of a new genetically transformed variety. The simulated transgenic characteristics are: a herbicide-resistant transgenic variety for rice and a disease-resistant transgenic variety for potatoes. Three critical variables are expected to change with the new technology:

a) the use of variable inputs per hectare
b) the seed markup (or seed premium) charged for the new variety
c) the yield per hectare

The combined effect of these variables yields the potential per-unit cost reduction to be achieved. Use of variable inputs per hectare changes due to the substitution of the traditional technology for the new one. In the case of rice, for example, the cost of herbicide applications is reduced because the package of several applications of the traditional technology is substituted by a single application of a more effective herbicide. In the potato case, the reduction comes from the use of fewer pesticide applications to control diseases. In both cases, the original level of input use in the traditional technology is substituted for a costless new level of input use associated with the transgenic technology.

The change in seed cost is in principle a component of the change in variable inputs per hectare (by changing the price of one input), but its analysis is carried out separately from other inputs to specifically account for the monopolist's profit, where it represents a key variable. The cost of seeds is changed by the seed markup charged by the owner of the innovation, and represents the monopoly power. The seed markup is therefore the difference between the price for seeds of the transgenic varieties and the normal price for seeds of traditional varieties.

The per-hectare yield change measures the change in physical productivity of the new variety. Although the transgenic characteristics simulated in the study do not necessarily lead to higher yields, some scenarios are simulated assuming that better weed or disease control can have a positive side effect on yields.

The following sections detail the creation of the different scenarios for the two crops under study.

3.2.2. *Simulation of the Transgenic Rice Scenarios*

Herbicide resistant transgenic rice has already been developed in the United States to improve control of red rice using glufosinate (Oard et al, 1996). Although red rice is not a current production problem in Uruguay, the analysis assumes that a similar technology to control *Echinocloa sp. ("Capín"),* the most important rice weed, would be beneficial. The simulation of the impact of a transgenic rice variety to address this production constraint contains the following per-unit cost reduction components.

Change In Herbicide Costs Per Hectare

Use of herbicides in rice production in Uruguay amounts on average to 90 dollars per hectare, 8.2 percent of the average production cost of 1,100 dollars per hectare for a five-year period, 1995-1999 (Lavecchia, 2000; Asociación de Cultivadores de Arroz, 2001). If the weed control were based on gliphosate at 4 liters per hectare (as in Round-up Ready® technologies), the new technology would reduce the cost of herbicide use to 15 dollars per hectare. The cost reduction due to the change in herbicide use is then 75 dollars per hectare, the difference between the actual cost of applications and the cost under the new technology. The study also explores an intermediary level of 45 dollars per hectare, obtained when assuming a higher cost of herbicide use with the new technology of 45 dollars per hectare.

Seed Premium

The price increase of the transgenic rice seed, which is related to the premium paid to the gene's patent owner and the licensee of the new variety, is difficult to estimate. In the United States, markups on transgenic varieties follow two strategies: a premium paid above the price of seeds of the variety, and a technology fee paid by planted acre. Although the second strategy seems to be more important in terms of capturing monopoly profits, it requires strong IPR enforcement and on-field monitoring. For the purpose of the present study, it is not identified which strategy is followed and only the total combined premium is simulated. For two crops in the United States comparable to rice, Bt cotton and Round-up Ready Soybean®, technology fees have varied from 7 to 32 dollars per acre (Hubbell, Marra and Carlson, 2000; Carpenter and Gianessi, 1999; Couvillion, Kari, Hudson and Allen, 2000) or 6.50 dollars per bag (Moschini, Lapan and Sobolevsky, 1999). Annou, Wailes and Cramer (2000) evaluate the impact of transgenic Liberty Link rice and apply a seed markup range between 5 and 25 dollars per acre. The approach followed in this study is to determine the lower and upper levels for the seed premium, and to include two values within that range. The lower level can be set at the no-premium value. Although unrealistic, this level serves as a benchmark where the new technology is released in a competitive input market. To determine the upper level, it is assumed that the seed premium cannot be higher than the cost reductions achieved due to the change in herbicide costs per hectare. Farmers know in advance these potential benefits and a higher seed premium would mean the monopolist could extract benefits derived from increases in yield, a variable not controlled by the new technology per se[6]. Thus, the upper level for the seed premium is set equal to the per-hectare cost reduction from herbicide use in each scenario, and therefore the monopolist extracts all the new variety's potential benefits. For simplicity, it is assumed that even at this level farmers adopt the new technology since the expected increase in yield would still reduce the per-unit cost of production. Based on these criteria, the maximum seed premium is 75 dollars per hectare for the scenarios with higher cost reductions in herbicide use and 45 dollars per hectare for the scenarios with lower cost reductions in herbicide use. Any increase of the seed premium above these levels is assumed sufficient for farmers not to adopt the new technology. Within the range set by the upper and lower levels, technology fees paid for Bt cotton and Roundup Ready Soybean® are used as a benchmark to create two other scenarios: one with a low markup of 15 dollars per hectare, and another with a higher markup of 35 dollars per hectare, approximately half of the maximum herbicide cost reduction of 75 dollars per hectare.

Yield Increase Per Hectare

Simulations conducted by Moschini and Lapan (1999) indicate that yield is a critical parameter in the determination and distribution of economic benefits of new technologies. Although results are not definitive, preliminary field results presented by Oard et al (1996) show that herbicide-resistant transgenic rice varieties can increase yields through better weed control.

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[6] Couvillion, Kari, Hudson and Allen (2000) show that this has been the case with Round-up Ready Soybeans® in some regions of the US.

Based on their reports, the yield increase per hectare for the rice simulation is set at zero percent (no yield increase), 2.5 percent and a maximum of 5 percent. These estimated yield increases are lower than the 7 percent upper level reported by Oard et al.

Figure 3.1 combines all the above information to show how 24 scenarios are created for the case of rice. The scenarios are depicted from a decision tree with each decision level corresponding to each of the variables used for the simulation. The first level on the tree is the base cost per hectare of herbicide use under the traditional technology. The second level is the decrease in cost due to the use of a new package of herbicides. The next two levels include the different values for yield increase per hectare (in percentage) and the seed markup. Twenty-four scenarios are created for the simulation of the transgenic variety in rice.

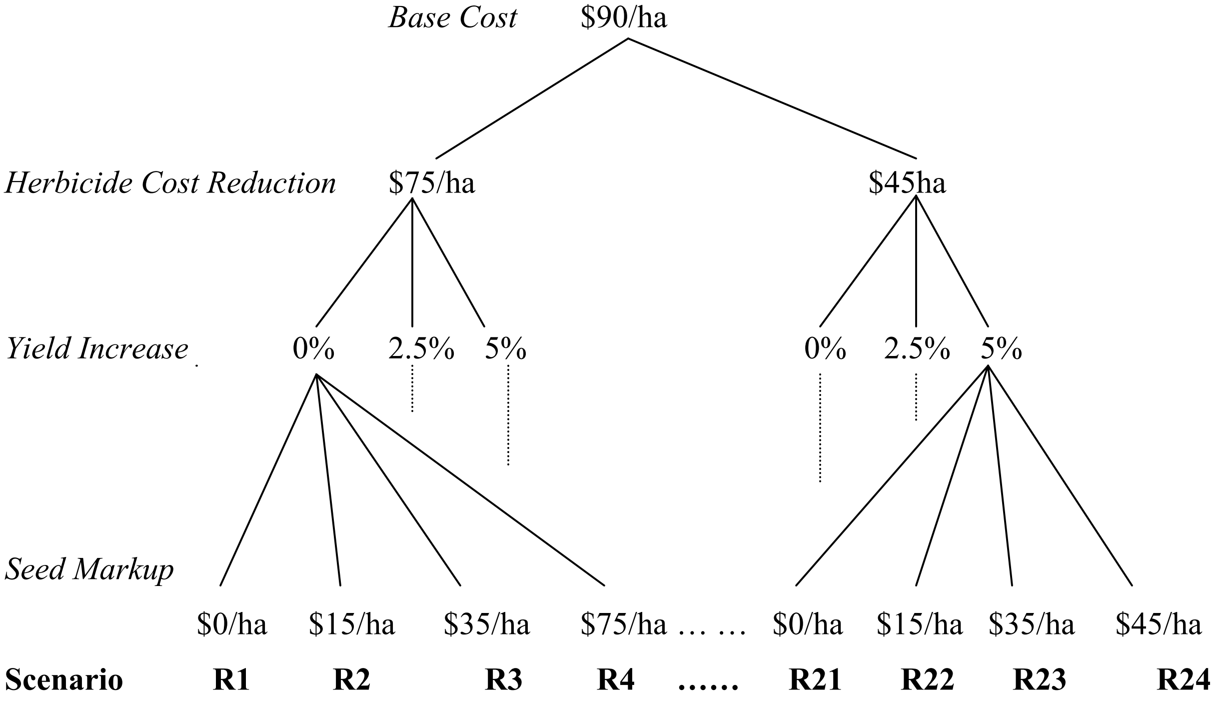

Figure 3.1. Simulation of transgenic rice: construction of different scenarios

For the purpose of the simulation, it is convenient to include the seed premium as the last variable in the tree. In this way, scenarios with different markups but *ceteris paribus* in the rest of the variables can be compared to simulate the effect of different levels of market power.

3.2.3. Simulation of the Transgenic Potato Scenarios

As with the rice case, transgenic potatoes are currently not being cropped in Uruguay. Adoption rates of transgenic potatoes in the United States are very low, between 2 and 3 percent for the year 2000. Carpenter and Gianessi (2001) cite two major factors for the low adoption rates.

a) The simultaneous introduction with the Bt potato of a new herbicide (imidacloprid) that provides effective control over the pests to which the transgenic potato is resistant. Farmers' response has been to adopt the alternative herbicide technology instead of the transgenic variety.

b) The refusal of major potato demanders like McDonald's to buy transgenic potatoes has been transmitted down the potato chain, resulting in a very limited demand for transgenic varieties.

The present study does not consider the possible implications of these facts for Uruguay, although it is recognized that they can eventually affect the adoption of the technology in the country and its economic impact.

Transgenic potatoes released by Monsanto provide genetic resistance to several diseases, including the Potato Leafroll Virus (PLRV), the Potato Virus Y (PVY) and the Potato Virus X (PVX) (Monsanto, 2001). The same approach as for rice is followed to simulate the potential impact of a transgenic potato in Uruguay with resistance to the most important local plant disease, Late Blight. The simulation of the impact of a transgenic potato variety to address this production constraint contains the following per-unit cost reduction components.

Change In Pesticides Costs Per Hectare

Potato crops are grown in two different seasons in the country: fall potatoes (60 percent of the total annual area) and spring potatoes (40 percent of the total annual area). Budget figures for a technology using imported seeds and complete mechanization show that total variable costs are 2,475 dollars per hectare for fall potatoes and 1,772 dollars per hectare for spring potatoes (Junta Nacional de la Granja, 2001). Total phytosanitary costs represent on average 17 percent of the total variable costs (432 dollars per hectare for fall potatoes, 300 dollars per hectare for spring potatoes). Weighted average of total variable costs and phitosanitary costs amount to 2,194 dollars per hectare and 379 dollars per hectare, respectively. The weights represent the area share between fall and spring potatoes. Out of the total phytosanitary costs, preventive and curative treatments aimed at controlling Late Blight represent on average 192 dollars per hectare, with the average infestation of the disease. The latter is therefore the maximum cost reduction per hectare that could be achieved with the introduction of a disease-resistant variety, assuming the imbedded protection would make additional phytosanitary treatments unnecessary. However, the study assumes that additional treatments are still necessary when very intensive attacks occur. The cost of this treatment is set at 50 dollars per hectare, double of the cost for curative treatments during the spring season. A unique value for the cost reduction from pesticide use for transgenic potatoes is then set at 142 dollars per hectare, 6.5 percent of the actual total variable cost.

Seed Premium

Technology fees charged by Monsanto for different transgenic potatoes have varied between 30 and 46 dollars per acre (Carpenter and Gianessi, 2001). The study includes three different possible values for the seed markup: no markup, 70 and 142 dollars per hectare. Following the same criteria than for rice, the highest markup captures all the cost reduction in pesticide use per hectare gained with the new technology, but does not capture potential increases in yield gains. Again, it is assumed the monopolist does not consider these increases in yield when setting the seed premium. Thus, even though per-unit cost reductions may come solely from yield increases in some scenarios, the new technology is still economically attractive for farmers.

Yield Increase Per Hectare

Yield increases are highly expected when a crop disease is controlled. Monsanto reports on yield increases for transgenic potatoes range from 5 to 22 percent (Monsanto, 2001). For the present study the yield increase is varied within that range, with an additional intermediate value of 12 percent.

Figure 3.2 describes the 9 scenarios created for the potato case by combining all possible values for each variable[7], depicted from the same type of decision tree used for rice.

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[7] Appendices A and B show the per-unit cost reductions achieved for each scenario and for both crops.

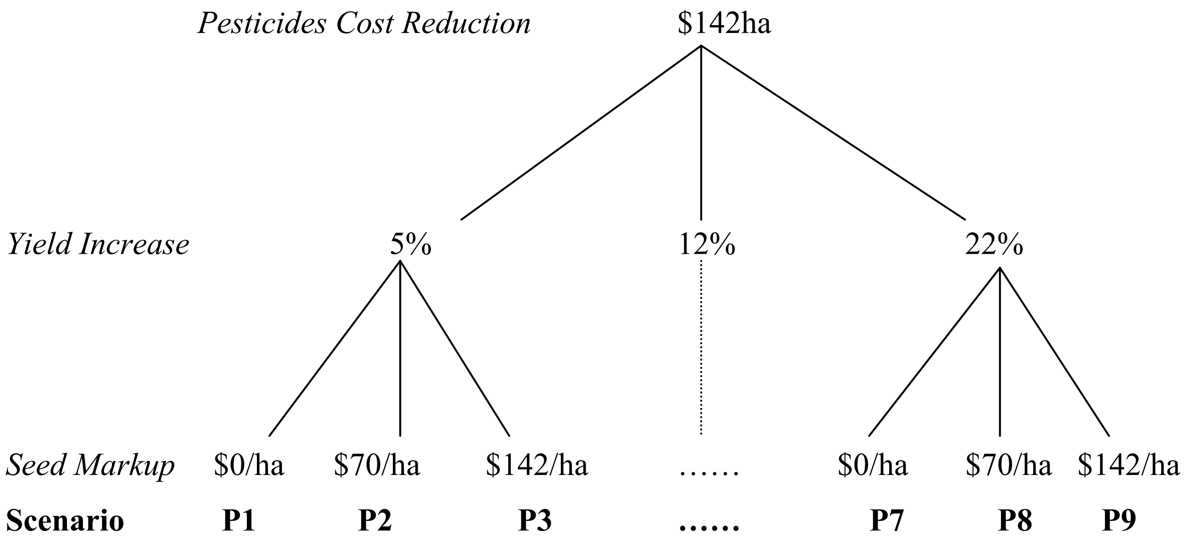

Figure 3.2. Simulation of transgenic potato: construction of different scenarios

3.3. Data Collection

The following section describes the collection of the adoption and commodity market data needed for the study.

Adoption Rates and Adoption Profiles

Adoption rates are crucial for the analysis because, all else equal, they are a main determinant of the magnitude of the change in total economic surplus, including monopolist's profits. The study assumes that the seed company considers the expected maximum adoption rates when the value of the seed markup is set. Farmers' adoption rates of a new technology also increase as the expected net benefit increases, reducing the risk associated with the technology (Mills, 1998). Allowing the maximum adoption rates to vary with the size of the net benefits of the technology provides useful insights for policy analysis about the trade-off between the seed markup and economic benefits.

The procedure for developing adoption profiles is now presented. In the case of rice, about 80 percent of the total cropping area in Uruguay is currently under relevant weed infestation, but in only 80 percent of the infested area weed control techniques are applied using different types of herbicides. According to these figures, the maximum potential adoption level for the transgenic variety is therefore 64 percent of the total rice area. In the rice sector, if a variety proves to be successful and increases farmers' benefits it will be widely adopted. Such was the case for the most popular variety during the season 1999 – 2000 (*"El Paso 144")* which occupied 69% of the total area (Asociación de Cultivadores de Arroz, 2000). It is assumed that all the potential adoption area (the one that apply herbicides technology) can be occupied by the new variety if potential benefits are high enough. The potential adoption rate for the new variety is then 64 percent, and the maximum for the purpose of the simulation is set at 60 percent.

It was argued that adoption rates depend on the profitability of the new technology, which in the study is represented by the per-unit cost reduction. This variable also depends on the values assigned to the change in herbicide and pesticides costs per hectare, the seed markup and the expected increase in yield per hectare in each scenario. Historic data linking the profitability of different technologies to the achieved adoption rates was not available for the study and therefore an ad-hoc procedure is developed to simulate the relationship. The total range of the per-unit cost reductions resulting from the simulation of each scenario is divided into four different quartiles, and each quartile assigned a different maximum adoption rate. The maximum adoption rates range from 60 to 24 percent with 12 points intervals. Table 3.1 indicates the maximum adoption rate corresponding to each rice scenario and to each range of the per-unit cost reduction (for more details see Appendix A).

Table 3.1. Rice: maximum adoption rates for each scenario

Scenarios	***Range of Per-Unit Cost Reduction***	***Maximum Adoption Rate***
R5, R9, R10, R21	8.62% - 11.49%	60%
R1, R6, R7, R11, R17, R22, R23	5.74% - 8.62%	48%
R2, R3, R12, R13, R18, R19, R24	2.87% - 5.74%	36%
R4, R8, R14, R15, R16, R20	0% - 2.87%	24%

Although time series data for potato adoption rates is not available, a similar approach is followed for this case. In the 1998 season, one single variety *("Chieftain")* covered 40 percent of the total annual area and three other varieties ("*Kennebec*", *"Norland"* and *"Red Pontiac*") occupied from 10 to 13.3 percent. Several other varieties were below 10 percent each (DIEA, 2001b). The large dispersion in the number of varieties used by potato growers may represent the greater heterogeneity of the sector compared to the rice sector, with large commercial farms and small individual farmers producing together in a single season applying different technologies. The maximum potential adoption rate for potatoes is set according to the information available at 40 percent. The range of the per-unit cost reductions arising from the simulation of each potato scenario is divided into thirds and assigned maximum adoption rates of 40, 25 and 10 percent for the upper, middle and lower range respectively. Table 3.2 shows the maximum adoption rates corresponding to each potato scenario and each range (for more details see Appendix B).

Table 3.2. Potatoes: maximum adoption rates for each scenario

Scenarios	***Range of Per-Unit Cost Reduction***	***Maximum Adoption Rate***
P7, P8, P9	22% - 27.31%	40%
P4, P5, P6	12% - 17.78%	25%
P1, P2, P3	5% - 11.16%	10%

The study evaluates the stream of benefits derived from the adoption of transgenic technologies for a 15-year period. Having set a maximum adoption rate according to the expected net benefits, there is still the need to define a proper adoption profile for the period. Alston, Norton and Pardey (1995) suggest considering linear (trapezoidal) or logistic curve forms for adoption paths on ex-ante evaluations, although the linear approach has been used more often on empirical studies (Mills, 1998). Past adoption paths can give useful information to fit the best adoption profile for new technologies. The study combines all this information to define the adoption paths for the transgenic varieties. Historical data is first used to infer the proper adoption pattern. Figure 3.3 graphs the adoption paths for the 5 most popular rice varieties in Uruguay during the period 1990 – 2000 (based on Zorrilla, 2001).

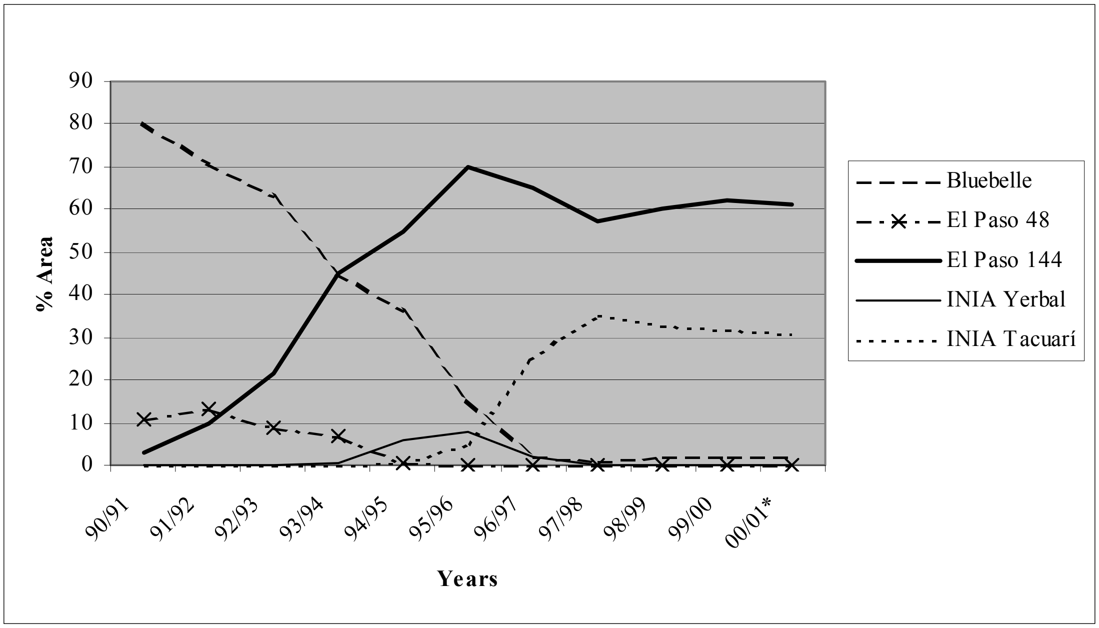

Figure 3.3. Rice: adoption pattern for most popular varieties in Uruguay, 1990 - 2001

Figure 3.3 shows that two of the most used varieties in the 90's ("El Paso 144" and "INIA Tacuarí") had an initial adoption phase which began slowly and increased its rate until a maximum was reached, between 4 to 6 years after the beginning of adoption. The maximum remained on average stable for a certain number of years (4 to 6 years), although it's not possible to conclude from the above information that it will not stay longer. The decline phase for the most popular variety during the 80's (Bluebelle) lasted for 6 years and it was almost linear[8]. The information given by figure 3.3 is used to define a proper adoption profile for the transgenic rice variety. For the simulation purposes, the adoption profile is approximated by a logistic-shaped initial adoption phase of 5 years, a plateau phase of 5 years, and a linear decline phase (Figure 3.4).

Since past adoption profiles for potatoes are not available, the study assumes the new varieties follow the same adoption pattern as for rice, with different duration for each adoption phase. The maximum adoption rates are reached after 8 years of the release of the technology, and adoption begins to decline after year 12. The slower pace of adoption corresponds again to

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[8] Many factors affect the rate of adoption and its shape, including the commercial availability of seeds of the new variety, the release of new substitute technologies, the breakdown of specific resistances built in the technology, the expansion or contraction of area, and the risk behavior of the farmers. The study considers that these factors are constant during the period under evaluation, although they can influence a specific adoption pattern of a new technology at any time.

the characteristics of a more heterogeneous potato sector, where large-scale and small-scale farmers respond in different ways to the presence of a new technology.

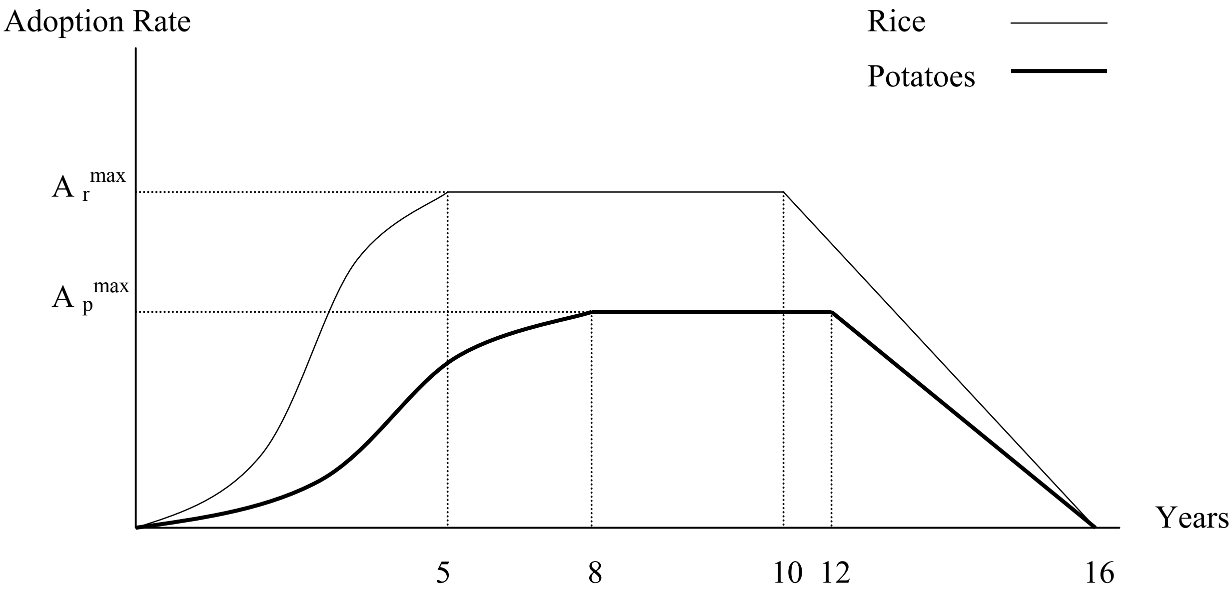

Figure 3.4. Simulated adoption profile for transgenic rice and potato varieties

The logistic phase of adoption is calculated for each maximum adoption rate[9] and for each crop (Tables 3.3 and 3.4). It is realistic to show a decline phase due to two interrelated factors: a) weeds and pathogens may become resistant to the chemical applications and reduce the effectiveness of the technology; and b) since research into new high-yielding germplasm would have continued, there will probably be new varieties to be released with higher yield potential. These will compete with the existent varieties and thus begin a process of disadoption.

Following the procedure in Falck-Zepeda, Traxler and Nelson (2000), the study does not consider the research investment period (research costs are assumed sunk) and adoption begins in year 1.

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[9] The study uses the formulae in Alston, Norton and Pardey (1995) to calculate the logistic curve of adoption and the parameters α and β. The three needed points are set as follow: a) for rice in year 1, A_l=2%; A^{max} accordingly, and 50% of A^{max} in year 3; and b) for potatoes in year 1, A_l=1%, A^{max} accordingly, and 50% of A^{max} in year 5. The logistic curve converges asymptotically to A^{max}, thus the calculated maximum adoption rates given by the formulae are not exactly as initially assumed. The simulations use the final values given by the logistic formula.

Table 3.3. Rice: simulation of adoption paths for transgenic varieties. Adoption rates per year.

Year	*Maximum Expected Adoption rate*			
	60%	*48%*	*36%*	*24%*
1	1.9	1.9	1.9	1.8
2	10.1	8.6	7.0	5.2
3	33.1	25.6	18.4	11.4
4	52.9	41.1	29.5	18.0
5	58.7	46.5	34.2	21.8
6	59.8	47.7	35.6	23.3
7	60.0	47.9	35.9	23.8
8	60.0	48.0	36.0	23.9
9	60.0	48.0	36.0	24.0
10	60.0	48.0	36.0	24.0
11	50.0	40.0	30.0	20.0
12	40.0	32.0	24.0	16.0
13	30.0	24.0	18.0	12.0
14	20.0	16.0	12.0	8.0
15	10.0	8.0	6.0	4.0

Table 3.4. Potatoes: simulation of adoption paths for transgenic varieties. Adoption rates per year.

Year	*Maximum Expected Adoption Rate*		
	40%	*25%*	*10%*
1	1.0	1.0	0.9
2	2.5	2.1	1.5
3	6.2	4.4	2.3
4	13.3	8.3	3.3
5	23.0	13.4	4.6
6	31.5	18.2	5.9
7	36.4	21.6	7.1
8	38.6	23.4	8.1
9	39.5	24.3	8.8
10	40.0	24.7	9.3
11	40.0	25.0	10.0
12	40.0	25.0	10.0
13	30.0	18.0	7.5
14	20.0	12.0	5.0
15	10.0	6.0	2.5

Elasticities

No data was found regarding the own-price elasticities of supply and demand for rice and potato in Uruguay. Comparison with estimates for other countries and regions available in the literature offers a starting point to select approximate values for the simulation.

Demand elasticities

The own-price elasticity of demand is needed for the potato case (small closed economy). For the case of rice, the small open economy model implicitly assumes an infinite demand elasticity.

Huang and Lin (2000) analyzed the elasticities of demand for different groups of food and different income groups in the United States. The absolute values range from 0.06 for eggs to 1.01 for juice, with an average of 0.54. For the vegetable group the absolute value of the demand elasticity is 0.74.

Fuglie (1995) reports the demand elasticity for potatoes in Tunisia to be -0.75, and varies this value for his analysis between -0.35 and -1.15 to calculate welfare effects from the reduction of storage losses.

Qaim (1998) calculated the price elasticity of demand for potatoes in Mexico to be -0.41, and the supply elasticity to be in the range of 0.3 to 0.5 depending on the farm size. He also points out that potatoes in Mexico are considered more a member of the vegetable group of food rather than a staple food.

Babula, McCarty, Newman and Burket (1998) report the price-elasticity of demand for potatoes in the U.S. to be within the range of -0.3 to -0.5.

Scott, Rosegrant and Ringler (2000) showed a positive relationship between income and consumption for potatoes, although its role in the diet is different across countries. In developed countries it is considered a cheap staple. In some developing countries, however, it is a luxury good. For modeling purposes, they estimated income elasticities of demand for potatoes to be between 0.20 and 0.55 in 8 different developing countries or regions (Brazil, Nigeria, Central and Western Sub-Saharan Africa, Egypt, Turkey, India, Thailand and China). Being a neighboring country to Uruguay, the 0.40 value for Brazil is particularly relevant and represents the average value for the group analyzed. Their estimates for a baseline scenario are assumed to decrease by year 2020, when the average and also the value for Brazil is set at 0.30.

According to Alston, Norton and Pardey (1995) if the homogeneity condition holds the price elasticity for a normal good can be inferred to be slightly higher than the income elasticity[10]. Given the values reported by Scott, Rosegrant and Ringler, the price elasticity for potatoes might be within the range of -0.4 to -0.5.

Potatoes in Uruguay appear to be a staple food and a normal good, suggested by a stable relative high level of consumption of 40 kilograms per capita per year. For the purpose of the study, the absolute value of the price elasticity of demand for potatoes is set at 0.5.

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[10] The homogeneity condition specifies that for a specific commodity the sum of the income elasticity of demand, the own-price elasticity of demand and the cross-price elasticities is zero. It is also assumed that for highly aggregated commodities the sum of the cross-price elasticities is a small positive number.

Supply elasticities

Supply elasticities are needed to run both the rice and potatoes models. Chavas and Cox (1995) found own-price elasticities of supply in the United States for different groups of commodities to vary between 0.42 and 3.09, according to the type of commodity and two types of production technology. The estimate for the vegetable group is between 0.42 and 1.77, and for "other field crops" is between 0.60 and 1.31.

Rao (1989) surveyed supply response studies for developing countries, finding that acreage elasticities for specific crops varied from 0 to 0.8 in the short-run to 0.3 to 1.2 in the long-run. He points out that acreage elasticities are used in most studies as a proxy for supply response because the variable is better controlled by farmers than output. He also cites a study for Argentina, a neighboring country of Uruguay, showing that aggregate agricultural output elasticities varied from 0.42 to 0.52 in the short-run.

Tsakok (1990) presents a list of price elasticities of supply compiled from different studies. The short-run elasticities vary from 0.1 to 0.8, while the long-run elasticities vary from 0.3 to 1.5. For rice, the long-run estimates vary from as low as 0.02 to as high as 2.72. For potatoes, they range between 0.35 and 2.85. Some studies have reported even negatives numbers in both cases.

Estimating the rate of return to research on rice in Uruguay, Echeverría, Ferreira and Dabezies (1991) assumed a supply response to prices of 0. They also cite previous work that estimated the acreage response of rice in Uruguay to be close to 0, although the specific value was not indicated.

For the simulation analysis and given the period of time under evaluation (15 years), the elasticities of interest are the long-run ones. Alston, Norton and Pardey (1995) suggest that most long-run elasticities can be high since in the long-run most fixed factors become variable. Rice in Uruguay is irrigated and is constrained by the land factor since it can only be planted in soils with specific characteristics (e.g., very flat slope). This might impose a constraint in the long-run expansion of area, but currently only 25 percent of the potential area is occupied.

The literature review does not provide precise information from which to infer a proper value for the supply elasticity of both rice and potatoes in Uruguay. Alston, Norton and Pardey state that for empirical work related to priority-setting and when data is scarce, the supply elasticity can be set at 1.0. Following this approach the supply elasticities are then set at 1.0 for both crops.

Prices

For potatoes, wholesale prices for the period 1996 –2000 are averaged, giving a mean value of 330 dollars per ton (OPYPA, 2000).

For rice, the average price received by farmers for the period 1995 – 1999 was 9.5 dollars per bag (50 kilograms per bag), including indirect taxes compensation (Asociación de Cultivadores de Arroz, 2001). The price is then set constant at 190 dollars per ton.

In both cases, the prices are held constant over the fifteen year period defined for evaluation and for the different scenarios.

Quantities

Base quantities are calculated using average cropping area for each commodity and the current average yield. For the case of rice, annual internal consumption has been stable at 11 kilograms per person for a period of 6 years (1993 – 1999) and represents less than 5 percent of the total production (Asociación de Cultivadores de Arroz, 2001). The average domestic consumption is subtracted from total production. For the case of potatoes, no exports or imports are assumed and all quantities produced are for the domestic market.

For rice, average cropping area for the period 1991 – 2000 was 152,000 hectares, with a low level of 109,000 hectares in 1991 and a high of 210,000 hectares in 1999. The average yield for the five year period of 1995 – 1999 was 6.08 tons per hectare. The five year period average is used instead of the ten year average since it incorporates technological advances that are supposed to be stable. Total average rice production is then 924,000 tons, and total production available for export (net of domestic consumption) is 889,200 tons.

Average yield for potatoes between 1997 and 2000 was 14.9 tons per hectare, and the average cropping area for the same period was 8,900 hectares. In 1990, the potato crop area was 8,276 hectares, showing that it has been relatively constant during the last ten years. However, average yield for 1990 was 10 tons per hectare, showing that technological progress has increased the average yield (OPYPA, 2001b and 2001c). Yield figures for 1990 are thus not considered and average total production is set at 132,600 tons.

Monopolist's profit

The monopolist's profit is calculated using the markup per hectare estimated in the partial budget for the transgenic varieties, the adoption rate in each year, and the average cropping area estimated above. The value of the seed markup for each scenario multiplies the adoption area in each year, giving the total profit of the monopolist per year. The adoption area in each year (in number of hectares) is calculated from the total base area estimated for each crop, and the corresponding adoption rate in each year given by the estimated adoption paths (Tables 3.3 and 3.4).

Patents in Uruguay give effective protection for a maximum of ten years, therefore the markup per hectare is dropped after year 10. Since the per-unit cost reductions are calculated considering the markup, the fact that the markup is ineffective after year 10 changes their value. Nevertheless, for simplicity the path of adoption is assumed to remain unchanged and follows the initial assumptions.

Other variables

The simulation assumes that the technology has already been released and the relevant probability of research success is set at 1.0. A linear technological depreciation of 10 percent yearly is assumed to begin at year 10, and the exogenous output growth variable is assumed to be 1 percent per year.

Chapter 4: Results and Discussion

This chapter synthesizes the results obtained from the simulation experiments. Each scenario for each crop is not analyzed on detail. Instead, the most representative results are considered to draw general conclusions related to the potential economic impacts of transgenic technologies in Uruguay. Findings indicative of areas for further relevant research are also introduced.

4.1. Organization of the Results and the Discussion

The simulation produced a set of 24 scenarios for rice and 9 scenarios for potatoes, each one as a result of the particular combination of variable values discussed in the previous chapter. In order to compare the results and infer the implications of the seed markup for the distribution of economic benefits, scenarios are grouped holding the simulation variables "herbicides/pesticides cost reduction per hectare " and "yield increase per hectare " constant. The different levels for the seed markup are then compared within each group of scenarios. For each group, the scenario where the seed markup level is set at zero per hectare simulates the perfectly competitive scenario (PC), where according to the theory the total economic surplus is maximized. Following this procedure, six groups of four scenarios each are obtained for rice and three groups of three scenarios each are obtained for potatoes.

A second approach used to analyze the results is to compare the total domestic surplus change, given by the sum of producers' and consumers' benefits, with the total surplus change that includes the monopolist's rent. The results can then be analyzed from the Uruguay's perspective in order to determine the effects of a foreign firm with monopoly power on the size and distribution of the economic surplus change within the country.

The discussion of the results also addresses in separate sections the implications of the adoption rate assumptions for the magnitude and distribution of the benefits, and the effects on benefits of the commodity market structure (open or closed small economy).

Tables 4.1 and 4.2 present the simulation results for both the rice and potato case. The first column in each Table indicates the group of scenarios with the same value for the variables "herbicides/pesticides cost reduction per hectare" and "yield increase per hectare". The groups are numbered I to VI for rice and I to III for potatoes. The second column indicates the specific scenario for which results are presented to the right. The scenarios are labeled R1 to R24 for rice and P1 to P9 for potatoes. On the third column the results for the Net Present Value (NPV) of the total surplus change for each scenario are presented. The fourth column presents, for each group, the total surplus change in each scenario as a percentage of the surplus change in the scenario simulating perfect competition (PC). The perfectly competitive scenarios are the first scenario of each group and are highlighted on the table to make the reading easier[11]. To illustrate, in Table 4.1, rice scenario R1 represents the perfectly competitive scenario of group I (the seed markup level is zero per hectare). The row below shows scenario R2, where the seed markup is 15 dollars per hectare. Scenario R2 produces a total surplus change that is 73 percent of the perfectly competitive scenario R1. The comparison is made in similar manner in group I for scenarios R3 and R4, where the seed markup is 35 and 75 dollars per hectare respectively.

The fifth and sixth columns of Tables 4.1 and 4.2 show similar results to the two previous columns, but accounting only for the total domestic surplus (the sum of producers' and consumers' surplus) without considering the monopolist's profit. The latter can be computed as the difference between the total domestic surplus and the total surplus. For the perfectly competitive scenarios, the results are the same for both total and domestic surplus, since there is no monopolist profit. The last column in each Table, Domestic Share of Total, indicates how much of the total surplus generated in each scenario corresponds to domestic surplus. It is calculated as the percentage share of the total domestic surplus (fifth column) of the total surplus (third column) for each scenario.

The next sections discuss on detail the results presented on Tables 4.1 and 4.2.

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[11] The perfectly competitive scenarios are: R1, R5, R9, R13, R17 and R21 for rice; and P1, P4 and P7 for potatoes.

Table 4.1. Rice simulation: results for total and domestic economic surplus change in absolute magnitude and as a percentage of the perfectly competitive (PC) scenario

Group	*Scenario*	*Total Surplus*		*Total Domestic Surplus*		*Domestic Share Of Total*
		NPV	**% of PC**	**NPV**	**% of PC**	
I	**R1**	$39,244,673	**100%**	$39,244,673	**100%**	***100%***
	R2	$28,717,906	**73%**	$24,264,511	**62%**	***84%***
	R3	$28,262,515	**72%**	$17,788,956	**45%**	***63%***
	R4	$17,981,964	**46%**	$3,293,050	**8%**	***18%***
II	**R5**	$66,771,455	**100%**	$66,771,455	**100%**	***100%***
	R6	$52,448,540	**79%**	$46,417,832	**70%**	***89%***
	R7	$51,871,727	**78%**	$37,800,075	**57%**	***73%***
	R8	$24,874,835	**37%**	$10,185,920	**15%**	***41%***
III	**R9**	$84,347,067	**100%**	$84,347,067	**100%**	***100%***
	R10	$83,770,844	**99%**	$76,190,671	**90%**	***91%***
	R11	$65,935,158	**78%**	$51,863,506	**61%**	***79%***
	R12	$48,517,679	**58%**	$26,074,339	**31%**	***54%***
IV	**R13**	$17,416,336	**100%**	$17,416,336	**100%**	***100%***
	R14	$11,194,275	**64%**	$8,256,492	**47%**	***74%***
	R15	$10,917,900	**63%**	$4,063,073	**23%**	***37%***
	R16	$10,785,704	**62%**	$1,972,355	**11%**	***18%***
V	**R17**	$37,337,707	**100%**	$37,337,707	**100%**	***100%***
	R18	$27,465,335	**74%**	$22,976,667	**62%**	***84%***
	R19	$27,138,081	**73%**	$16,664,522	**45%**	***61%***
	R20	$17,706,864	**47%**	$8,893,515	**24%**	***50%***
VI	**R21**	$64,863,758	**100%**	$64,863,758	**100%**	***100%***
	R22	$51,104,465	**79%**	$45,073,757	**69%**	***88%***
	R23	$50,740,073	**78%**	$36,668,422	**57%**	***72%***
	R24	$37,629,764	**58%**	$24,163,760	**37%**	***64%***

Table 4.2. Potatoes simulation: results for total and domestic economic surplus change in absolute magnitude and as a percentage of the perfectly competitive (PC) scenario

Group	*Scenario*	*Total Surplus*		*Total Domestic Surplus*		*Domestic Share Of Total*
		NPV	**% of PC**	**NPV**	**% of PC**	
I	**P1**	$2,516,863	**100%**	$2,516,863	**100%**	***100%***
	P2	$2,255,487	**90%**	$2,025,996	**80%**	***90%***
	P3	$1,986,983	**79%**	$1,521,443	**60%**	***77%***
II	**P4**	$10,611,299	**100%**	$10,611,299	**100%**	***100%***
	P5	$9,977,187	**94%**	$9,356,783	**88%**	***94%***
	P6	$9,327,333	**88%**	$8,068,800	**76%**	***87%***
III	**P7**	$26,845,517	**100%**	$26,845,517	**100%**	***100%***
	P8	$25,942,893	**97%**	$24,927,042	**93%**	***96%***
	P9	$25,019,975	**93%**	$22,959,248	**86%**	***92%***

4.2. Transgenic Crops in Developing Countries: the Effects of Monopoly Power in the Market for the Transgenic Seed

As expected from the model supporting this study, the total and domestic surplus change after the introduction of transgenic crops increase with two factors: the increase in cost reduction and the yield increase produced by the technological change. In Table 4.1, groups I, II and III for rice simulate a herbicide cost reduction of 75 dollars per hectare. For groups IV, V and VI the simulated cost reduction is 45 dollars per hectare. As an example, comparing rice scenarios R1 and R13 isolates the effect of the cost reduction per hectare. For scenario R1, the total surplus change is 39.2 million dollars, while for scenario R13 the total surplus change is 17.4 million dollars. Higher cost reductions per hectare increase the change in total surplus. The conclusion is similar when comparing the effects on the change in domestic surplus[12].

The impact produced by the yield increase per hectare is similar to the impact of the cost reduction in input use per hectare. The case of potatoes is used as an example to illustrate the point, since for potatoes the value of the input (pesticides) cost reduction per hectare is the same for all scenarios. Comparing scenarios P1, P4 and P7 isolates the effects of three different values for the yield increase per hectare: 5, 12 and 22 percent respectively. While scenario P1 with the lowest value for the yield increase produced 2.5 million dollars of total surplus change, scenario P4 produced 10.6 million dollars and scenario P7 produced 26.8 million dollars of total surplus change. Thus, increases in yield per hectare increase the benefits of the technology in the same direction as increases in the cost reduction in input per hectare.

What is the effect of the seed markup, the other variable contributing to the per-unit cost change associated with the transgenic varieties? According to the economic theory, the difference between the total surpluses generated under perfect and imperfect competition in the markets is lost from the economy and is called the economy's deadweight loss. Neither the producers' and consumers' surpluses nor the monopolist's rent recover it. Larger deadweight losses imply larger reductions in the change of economic surplus. The deadweight loss is therefore a measure of the degree of imperfect competition in the market, or the degree of monopolist's power. It must be noticed at this point that positive welfare impacts for the country are beneficial despite their magnitude. Even in cases where these impacts may be small, the economy is still better off than before the technology is adopted. The monopolist's profit, on the other hand, is necessary to recover the research costs to produce the technology. Otherwise, no welfare effects would be realized.

From Tables 4.1 and 4.2 the deadweight losses are calculated as follows: within each group, the total surplus generated in the scenarios where the monopolist is present is subtracted from the total surplus in the perfectly competitive scenarios. The differences are then expressed as a percentage of the perfectly competitive surplus. Scenario R10 for rice on group III has a total deadweight loss of 0.57 million dollars. Expressed as a percentage of the total surplus in rice scenario R9, the total deadweight loss is 1 percent. For rice, the deadweight loss under

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[12] There is an additional effect of increased adoption, but as shown in the next section the conclusion is still valid when this factor is removed.

scenario R2 in group I is 10.5 million dollars, the difference between the total surplus of scenario R2 (29.7 million dollars) and the surplus of 39.2 million dollars of scenario R1. Expressed as a percentage of the surplus under perfect competition the deadweight loss is 27 percent.

The losses can have a different interpretation from the domestic point of view, since the monopolist's profit is not considered in the calculation of the total domestic surplus. For the purpose of analyzing the results of the study they are referred to as ”domestic losses”. Continuing with the same example above, the domestic loss under rice scenario R2 is almost 15 million dollars (38 percent), the difference with the total domestic surplus generated under the perfectly competitive scenario R1.

The monopolist profit is the difference between the total and domestic surplus, and can also be expressed as a percentage of the total surplus under perfect competition.

As a general conclusion from all the scenarios considered for both crops, the presence of the firm with monopoly power reduces the total economic welfare generated if the new technology were to be released under perfect competition. The total deadweight losses in the case of rice range from 1 percent (scenario R10 against scenario R9) to 63 percent (scenario R8 against scenario R5). In the case of potatoes they range from 3 percent (scenario P8 against scenario P7) to 21 percent (scenario P3 against scenario P1). The results confirm what was expected from economic theory and imperfect competition in the market for the transgenic seed diminish the total gross economic surplus generated by the technological change. The result is also consistent for situations where the imperfect competition is present upstream the production process or for other types of technological changes protected by IPR (Huang and Sexton, 1996; Alston, Sexton and Zhang, 1997).

For the present study the monopolist is assumed to be a foreign firm. From the perspective of the adopting country the monopolist's profit cannot be considered as domestic surplus and increases the domestic loss. For each scenario considered, when there is monopoly power the domestic surplus is always lower in magnitude than the total surplus. For example, on group III and for rice scenario R10 the total surplus change is 83.7 million dollars, but the domestic surplus change is 76.2 million dollars. The difference of 7.5 million dollars accounts for the monopolist's profit. These results are summarized in Table 4.3, where the range for the total deadweight losses and domestic losses are compared as a percentage of the surplus generated in the perfectly competitive scenarios.

Table 4.3. Total deadweight losses, domestic losses and monopolist's profit, as a percentage of the perfectly competitive surplus change.

Case	*Total Deadweight Losses*	*Domestic Losses*	*Monopolist Profit*
Rice	1% - 63%	10% - 92%	9% - 51%
Potatoes	3% - 21%	7% - 40%	4% - 19%

Total deadweight losses for the case of rice range from 1 percent (scenario R10) to 63 percent (scenario R8), while for the case of potatoes they range from 3 percent (scenario P8) to 21 percent (scenario P3). Domestic losses for the case of rice range from 10 percent (scenario R10) to 92 percent (scenario R4), while for the case of potatoes they range from 7 percent (scenario P8) to 40 percent (scenario P3). The range and magnitude of the domestic losses are larger than the range and magnitude of the total deadweight losses. As shown in Table 4.3, for the case of rice the monopolist's rent relative to the perfectly competitive surplus represents from 9 percent (scenarios R6 and R10) to 51 percent (scenario R16). For the case of potatoes, it represents from 4 percent (scenario P8) to 19 percent (scenario P3).

The economic literature has stressed the fact that the total deadweight loss derived from imperfect market competition is low in magnitude, although the changes in distribution can be significant (Alston, Sexton and Zhang, 1997). The results presented above show that for a small developing country distributional issues can become relevant and can considerably affect the magnitude of the domestic benefits if the private rent accrues to a foreign economic agent. Not only the absolute size of the domestic surplus change decreases when the monopolist's market power increases, but also the ratio between the domestic and the total surplus decreases. As long as the monopolist's power in the market increases, the domestic agents (consumers and producers) capture a reduced proportion of reduced total benefits.

The endogenous adoption rate in the model causes an additional distortion that exacerbates the deadweight losses. The importance of this factor gives rise to separate analysis in section 4.3. To remove this effect and concentrate the discussion on the primary impacts of the monopolist power, the results of the simulation are analyzed holding adoption profiles constant across the range of per-unit cost reductions. Table 4.4 presents the results for the case of rice when the maximum adoption rate is set arbitrarily at 24 percent for all the scenarios[13].

As expected, the magnitude and range of variation of the total and domestic change in economic surplus are smaller when the determined endogenous adoption rate is removed. For rice, scenario R4 in group I produced a maximum reduction on total surplus to 94 percent, compared to the scenario under perfect competition. On group III, the reduction is to 98 percent. The monopoly power still reduces the total surplus, but the reduction is relatively small in magnitude. However, from the domestic perspective, the reduction is still large. Scenario R4 produces a total domestic surplus change that is 17 percent of scenario R1, the perfectly competitive situation. Thus, from the domestic perspective, the changes in magnitude are relevant, and come from the fact that the private profits are not considered benefits accruing to the country.

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[13] For the case of potatoes, the results when controlling for the adoption rate variable do not show variation within each group of scenarios compared to the results presented in Table 4.2. This is due to the assumption on how the adoption rate varies with the size of the per-unit cost reductions, making that for each group the adoption rate is the same for all the scenarios.

Table 4.4. Rice simulation: results for total and domestic surplus change when maximum adoption rate is set constant at 24% for all scenarios.

Group	***Scenario***	***Total Surplus***		***Total Domestic Surplus***		***Domestic Share On Total***
		NPV	**% of PC**	**NPV**	**% of PC**	
I	**R1**	$19,070,800	**100%**	$19,070,800	**100%**	***100%***
	R2	$18,811,542	**99%**	$15,897,275	**83%**	***85%***
	R3	$18,534,715	**97%**	$11,679,888	**61%**	***63%***
	R4	$17,981,964	**94%**	$3,293,050	**17%**	***18%***
II	**R5**	$25,656,553	**100%**	$25,656,553	**100%**	***100%***
	R6	$25,483,100	**99%**	$22,545,317	**88%**	***88%***
	R7	$25,265,136	**98%**	$18,410,309	**72%**	***73%***
	R8	$24,874,835	**97%**	$10,185,920	**40%**	***41%***
III	**R9**	$32,294,519	**100%**	$32,294,519	**100%**	***100%***
	R10	$32,180,345	**100%**	$29,242,562	**91%**	***91%***
	R11	$32,040,794	**99%**	$25,185,967	**78%**	***79%***
	R12	$31,805,171	**98%**	$17,116,256	**53%**	***54%***
IV	**R13**	$11,412,042	**100%**	$11,412,042	**100%**	***100%***
	R14	$11,194,275	**98%**	$8,256,492	**72%**	***74%***
	R15	$10,917,900	**96%**	$4,063,073	**36%**	***37%***
	R16	$10,785,704	**95%**	$1,972,355	**17%**	***18%***
V	**R17**	$18,150,230	**100%**	$18,150,230	**100%**	***100%***
	R18	$17,993,887	**99%**	$15,056,104	**83%**	***84%***
	R19	$17,798,736	**98%**	$10,943,909	**60%**	***61%***
	R20	$17,706,864	**98%**	$8,893,515	**49%**	***50%***
VI	**R21**	$24,933,284	**100%**	$24,933,284	**100%**	***100%***
	R22	$24,835,415	**100%**	$21,897,632	**88%**	***88%***
	R23	$24,717,603	**99%**	$17,862,776	**72%**	***72%***
	R24	$24,664,132	**99%**	$15,850,783	**64%**	***64%***

The concept of domestic losses can again be useful to further illustrate the point. Table 4.5 compares the relative deadweight losses for the case of rice when the adoption rate is endogenous and when it is held constant for all scenarios[14].

Table 4.5. Total deadweight losses, domestic losses and monopolist's profit under endogenous and constant adoption rates, as a percentage of perfectly competitive surplus change. Rice case.

Adoption Rate	***Total Deadweight Losses***	***Domestic Losses***	***Monopolist Profit***
Constant	0% - 6%	9% - 83%	9% - 78%
Endogenous	1% - 63%	10% - 92%	9% - 51%

Total deadweight losses are lower under constant adoption rate assumption, from zero to 6 percent. However, domestic losses are still high, and reach a maximum of 83 percent in rice scenario R4. Compared to the scenarios with an endogenous adoption rate, the results confirm that total losses due to the imperfectly competitive input market are low in magnitude relative to changes that occur in the distribution of benefits. Figure 4.1 represents graphically the rice scenarios R9 to R12 for a constant maximum adoption rate. While the changes in total surplus remain relatively small between almost inexistent and 2 percent, the changes in distribution between monopolist's profit and domestic surplus increase with the level of seed markup. Total domestic surplus share of total surplus changes from 100 percent (perfect competition) to 54 percent. When the domestic surplus change is analyzed, the changes in magnitude compared to the perfectly competitive surplus are still high, from 91 percent for scenario R10 to 53 percent for scenario R12.

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[14] Since the adoption paths are assumed to follow the same pattern for all adoption rates, the results are similar in relative value for all adoption rates, although different in absolute magnitude. Thus, showing the results for only one adoption rate value is enough for the analysis.

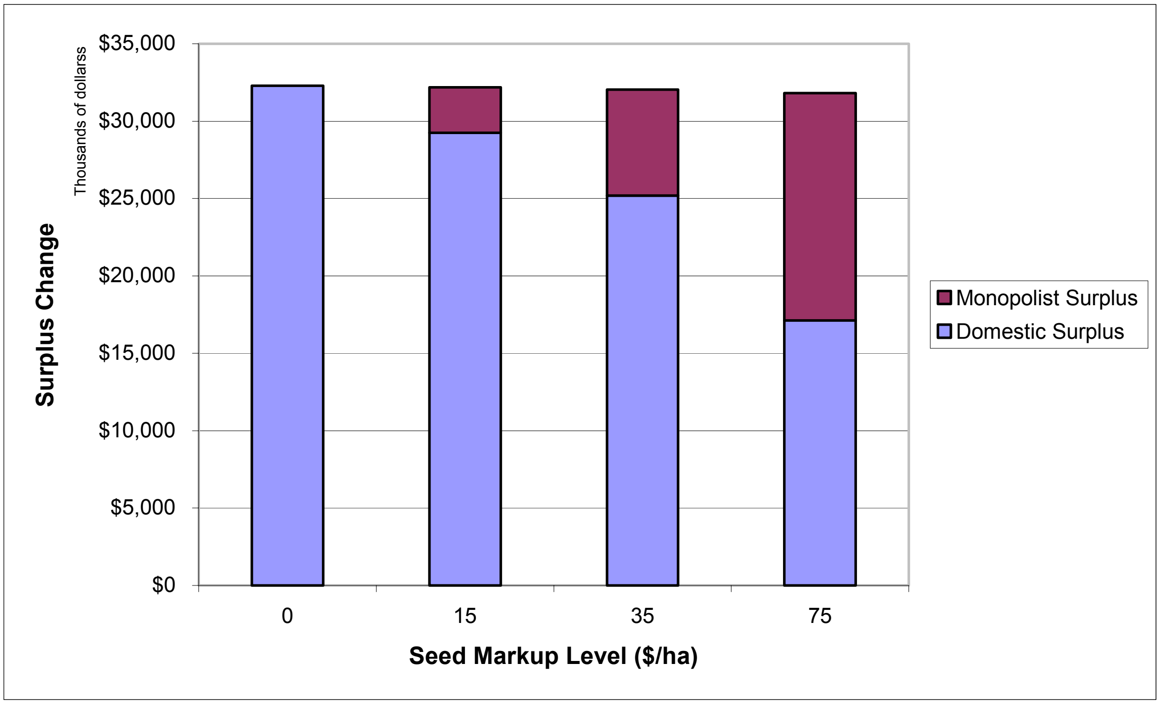

Figure 4.1. Changes in the distribution of economic surplus for different markup levels with constant adoption rate (rice scenarios R9 to R12, maximum adoption rate 24%)

The conclusion from the results is that when the adopting region does not benefit from the profits captured by the monopolist, the distribution of benefits affects their magnitude. The share of the domestic surplus on the total surplus generated is reduced at higher levels of monopoly power (higher seed markup)[15]. From the domestic point of view and according to the results of this study, the magnitude of the losses derived from changes in distribution outweigh those arising from the imperfect competition, becoming an incentive to partially recover the lost rent with technology license fees or similar policies.

4.3. The Effects of the Endogenous Adoption Rate

The model in the study assumes an endogenous maximum adoption rate that changes with the size of the per-unit cost reduction achieved in each scenario. While the seed markup increases for given values of the variables "yield increase per hectare" and "herbicides/pesticides

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[15] Annou, Wailes and Cramer (2000) reach similar conclusions when evaluating the impact of Liberty Link rice in the US.

cost reduction per hectare", the per-unit cost reduction for producers is smaller and thus the maximum adoption rates are also lower.

From the theoretical point of view, the monopolist faces a constrained profit maximization problem where the optimal markup level is set considering the endogenous adoption rate. Monopolist profit π is a function of the seed markup level per hectare p^m and the adoption area q^a, less the variable and fixed costs C. The maximization problem takes the form:

$$(1)\ \text{Max}\ \pi = f(p^m, q^a, C)$$

The assumption of the study is that the adoption area is a function of the per-unit cost reduction κ, which in turn depends on three variables: the cost reduction c due to the reduction in use of inputs like herbicides and pesticides, the expected yield increase y of the new variety, and the seed markup p^m. Equations (2) and (3) show these relationships:

$$(2)\ q^a = \varphi(\kappa)$$

$$(3)\ \kappa = \phi(c, y, p^m)$$

The per-unit cost reduction κ is increasing in c and y and decreasing in p^m, while q^a is increasing in κ. When a gene is introduced and embodied in a new variety, the variables c and y are determined and become exogenous to the final determination of the per-unit cost reduction. The only variable left is the seed markup under the decision of the monopolist. Substituting (3) into (2) and accounting for this fact, the constraint faced by the monopolist is:

$$(4)\ q^a = \varphi^e(p^m)$$

By assumption, the adoption area q^a is a decreasing function of the seed markup level p^m. Substituting (4) into (1) leads to the final unconstrained profit maximization problem (5):

$$(5)\ \text{Max}\ \pi = f[\, p^m, \varphi^e(p^m), C\,]$$

Assuming constant total costs, the profit function is at the same time directly increasing in p^m and indirectly decreasing in p^m through $\varphi^e(.)$. Therefore, there must be a profit maximizing value of p^m, the premium price of the transgenic seed. Further, one would expect the seed premium with endogenous technology adoption to be less than the seed premium when adoption is assumed exogenous.

The first order conditions of the problem are useful to understand how the assumption affects the solution to the problem. A convenient functional form for the profit function is the reduced form:

$$\pi(p^m) = p^m\, \varphi^e\ -\ C$$

The first order conditions under endogenous and exogenous assumption are respectively:

$$(1)\qquad p^m\, (\delta\varphi^e /\, \delta p^m) + \varphi^e = \delta C/\delta p^m$$

$$(2)\qquad Q^a = \delta C/\delta p^m$$

Where Q^a is the exogenous adoption rate. Clearly, the exogenous adoption rate is higher than φ^e , the endogenous assumption, unless the seed premium is zero.

An example of the effect of the endogenous adoption rate is presented in Table 4.6, analyzing the group III of rice scenarios R9 to R12. Scenarios R11 and R12 with higher level of seed markup (35 and 75 dollars per hectare respectively) achieve lower maximum adoption rates than scenarios R9 and R10 (where the seed markup is zero and 15 dollars per hectare respectively). Compared to the perfectly competitive scenario R9, the lower adoption rate reduces the total surplus change to 78 percent in scenario R11 and 58 percent in scenario R12. If the maximum adoption rate does not vary with the price markup, the total surplus are 99 percent and 98 percent respectively.

Table 4.6. Rice simulation: example of the endogenous adoption rate effects in total and domestic surplus change.

Scenario	***Max. Adoption Rate***[16]	***Total Surplus***	***% of PC***	***% of PC for constant maximum. adoption rate***	***Domestic Surplus***	***%of PC***	***% of PC for constant maximum adopt. rate***
R9	*60%*	$84,347,067	**100%**	**100%**	$84,347,067	**100%**	**100%**
R10	*60%*	$83,770,844	**99%**	**100%**	$76,190,671	**90%**	**91%**
R11	*48%*	$65,935,158	**78%**	**99%**	$51,863,506	**61%**	**78%**
R12	*36%*	$48,517,679	**58%**	**98%**	$26,074,339	**31%**	**53%**

The results show that farmers adoption decisions exacerbate the distortion caused by the presence of the monopolist, further augmenting the reduction in the total and domestic surplus

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[16] As assigned for each scenario in the simulation.

caused by the imperfectly competitive market itself. The direction of the results shown in Table 4.6 can be generalized to all other rice scenarios.

What is the effect on monopolist's profits? The monopolist is also affected by endogenous adoption and can even see profits decline if the markup is set above the economically optimal level. Figure 4.2 shows the results for the rice scenarios R17 to R20, where a 28 percent increase of the markup from 35 to 45 dollars per hectare reduces the rent extracted by the monopolist by 16 percent.

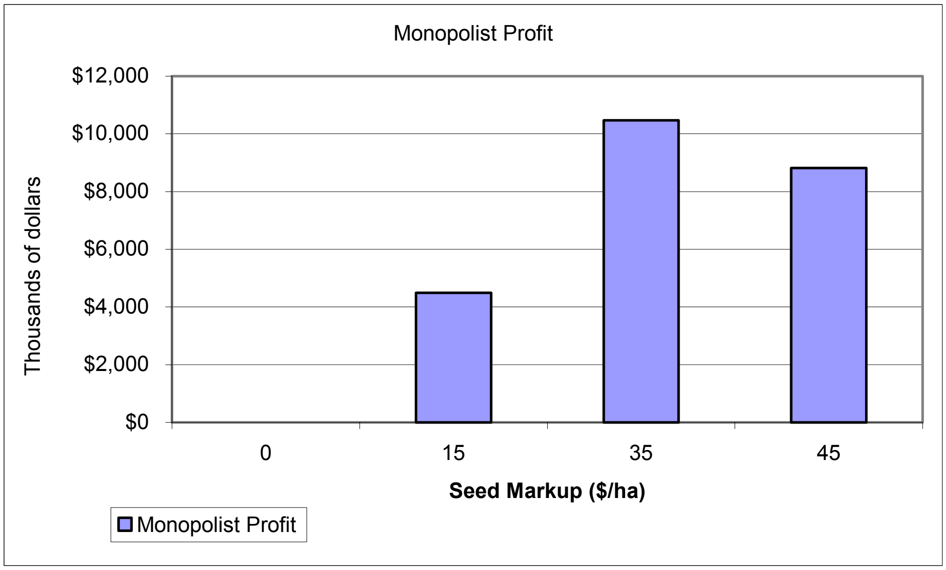

Figure 4.2. Monopolist's profit as a function of the seed markup level. Rice scenarios R17 to R20.

The results discussed in this section show that the presence of the monopolist is not only responsible for deadweight losses due to the monopoly power itself, but also because through the seed markup it effectively reduces the potential economic benefits of the new variety and the willingness of farmers to adopt it, therefore reducing the area planted with the new technology.

When yield increases and the cost reduction in input use per hectare are large compared to the seed premium, the change in the maximum adoption rate with the level of markup is lower. Particularly, since farmers in general take the yield effect as a proxy for per-unit cost reductions, a large expected yield increase effect relative to the seed premium might eventually become strategic for the monopolist to achieve higher profits. This issue has implications for the relationship between the gene owner's and germplasm breeders in small developing countries that will be addressed as a general conclusion in Chapter 5.

4.4. The Impact of Genetically Modified Organisms Under Open and Closed Economy Models

Comparing the rice and potato cases gives some insight on the possible economic impacts of the GMOs whether the market for the respective commodity is a small open or closed economy. As presented in Tables 4.1 and 4.2, the share of domestic surplus in the total surplus generated by the new technology is greater for potatoes (closed economy) than for rice (open economy). In the closed economy case consumers capture between one half (51 percent) and almost two thirds (64 percent) of the total surplus, while producers capture between one quarter (25.5 percent) and one third (32 percent). Total domestic surplus accounts for 77 to 96 percent of the total surplus. Monopolist's profit varies between 4 percent and 23 percent of the total surplus, although the lower proportions are greater in absolute magnitude and thus are more attractive scenarios for the private firm. In the open economy case, producers (and also domestic surplus) capture between 18 percent and 91 percent, and correspondingly monopolist captures between 9 and 82 percent. The closed economy is able to capture on average higher proportions of the total benefits through the consumers, who benefit from increased quantities and lower prices. From the monopolist point of view, however, the small size of the market and of the expected benefits can be reason enough to decide not to enter. In the best scenario for potatoes (P9) the Net Present Value of profits is slightly above 2 million dollars. The foreign firm may want to avoid small closed markets because the ability to make profits is lower and most of the benefits go to local consumers. On the other hand, the attractiveness of the open economy is based on the elastic demand curve and the ensuring of reaching larger markets and creating larger surpluses for the economy and for the monopolist.

Chapter 5: Conclusions

This chapter presents general conclusions from the study on the impacts of GMOs in Uruguay. Implications for national policy and for the agricultural R&D system in Uruguay are discussed. The final section briefly considers limitations in the study and issues for further research.

5.1. The Impact of Genetically Modified Organisms in Uruguay

Three major issues regarding the impacts of GMOs in Uruguay have been identified in the study. First, biotechnology innovations applied to the country's agricultural sector have a potential positive economic impact and increase the society's economic welfare. All the scenarios simulated for rice and potatoes increased the domestic economic surplus. The worst rice scenario (R16) produced national benefits of 1.9 million dollars, while for the best rice scenario the national benefits are 76.2 million dollars. The worst scenario for potatoes (P3) increased the domestic surplus by 1.5 million dollars, while the best scenario (P8) increased it by 24 million dollars. However, the monopoly power of the owner of the transgenic characteristic reduces the domestic surplus that can be achieved were the innovation be released under perfectly competitive markets for the transgenic seed. In rice scenario R16, where the seed markup is equal to the cost reduction in herbicide use per hectare and where no yield increase is assumed, the total economic surplus is 10.8 million dollars. Under the assumption of perfect competition (no seed markup), 17.4 million dollars can be generated instead. Differences between perfect and imperfectly competitive markets are less drastic in the potato case due to the closed nature of the economy. The potato scenario P3 (seed markup at 142 dollars per hectare, yield increase at 5 percent) increases the total surplus by 1.9 million dollars when the monopolist is present, and by 2.5 million dollars under perfect competition. Total economic benefits to the country are lower than the maximum potential due to two factors:

a) monopoly power of the owner of the gene that creates a distortion in the economy and,
b) the monopolist is assumed to be of foreign origin.

A second issue comes from the extent of adoption of the GMOs, which largely influences the magnitude of the domestic benefits and depends among other factors on the seed premium farmers pay to the gene owner. In all the scenarios analyzed for both rice and potatoes, higher adoption rates lead to increased benefits. The country desires to maximize the adoption of the new technology. At the same time, adoption rates are dependent on how the monopolist uses its market power (e.g., the price differential for the transgenic seed). For the monopolist, profits may increase with higher seed markups under certain conditions, but through lower adoption rates they may also decrease. There is therefore an economic trade-off between the seed markup and the adoption rates.

A third issue identified in the study concerns the nature of the market where the technology is introduced. Due to the size of the Uruguayan economy, crops like potatoes devoted to internal consumption produce smaller benefits compared to export crops like rice. Monopoly rent is also lower for the potato case and lower profits reduce the incentive to enter into the market. The introduction of GMOs in Uruguay is then more likely to occur for export crops, which have access to larger world markets.

5.2. Policy Implications at the National Level

An important implication of the above conclusions is that the range of the expected private profits in Uruguay may reduce the likelihood of private research investments aimed at developing specific biotechnology solutions to local production constraints. Expert opinions cite the latter as the main reason why GMOs are still not being planted in the country. In the case of potatoes, where the market behaves as a closed economy, potential benefits for private companies may be too small to even consider entering with products already developed, unless they expect to recover the penetration costs under more broad regional strategies by including the neighboring countries of Argentina and Brazil. To be able to retain higher levels of changes in economic surplus from GMOs, Uruguay needs to put in place an array of different strategies and policies. These strategies and policies should consider some of the issues that are briefly outlined below.

Multinational companies producing GMOs are willing to enter small markets in developing countries if some conditions are met: proper IPR law enforcement, a science-based regulatory process for transgenic varieties, acceptance of the new technology by the local community, and access to adapted germplasm (Traxler, 1999). The agricultural sector in Uruguay may be interested on applying new potentially profitable technologies in order to maintain or increase the market share of some commodities. Uruguayan authorities should seek to clearly demonstrate that the country is attractive for the introduction of GMOs based on factual evidence that the conditions hold in the country.

Uruguay has taken some steps towards allowing biotechnology products to be produced and commercialized in the country, both from the legal and from the scientific point of view (Delpiazzo, 1991; Uruguay, 2000). An explicit policy definition would probably accelerate the process (Vazquez Platero and Young, 2000). The country may focus on how to maximize the domestic economic benefits only after each of the necessary conditions cited by Traxler (1999) are met. The results of the study give some indications on how to improve the benefits derived from adopting biotechnology innovations.

National policies can be established to diminish the monopoly power of the gene's owner and to make the market for the GMOs as close to perfect competition as possible. Such measure would increase the magnitude of the domestic welfare. One possible measure is to impose a tax on the monopolist to partially recover the rent extracted out of the country. If properly designed, this type of policy does not thwart the monopolist's incentives on research investment. The tax mechanisms matter and theory suggests that flat taxes (license fees) produce less distortion. The tax amount must also be carefully determined on a case-by-case basis, since the magnitude of the profits is highly dependent on the size of the market for the innovation. The imposition of tax rates large enough to threaten the private profitability and turn the country unattractive for the firm should be avoided. A drawback of these types of policies is the loss of incentive for the private firm, since the ability to capture profits and to recover the research investment through IPR would be reduced. This may lead to reduced or no research at all, and subsequently to no benefits for the country. The optimal size of such fees is to be determined and represent a potential area for further research.

The country may also design instruments to monitor the seed premium charged to farmers, a measure which indirectly aims at reducing monopoly power, increasing farmers' profitability and improving adoption rates. Implementation of this policy, however, may be difficult in practice.

5.3. Implications for the Agricultural R&D Sector in Uruguay

The agricultural R&D sector in Uruguay has a significant role to play both in introducing GMOs into the country and in maximizing the benefits for the national economy. It has been discussed that the size of the market constrains the interest that multinational companies might have in generating GMOs specifically for Uruguayan conditions. The agricultural R&D system of a small country like Uruguay has little chance of developing GMOs by itself due to the large investments and capacities needed. Moreover, the likelihood that transgenic products, if developed, could be successfully commercialized without the concurrence of large specialized firms is also small (Traxler, 1999). However, the national agricultural R&D system is crucial in providing locally adapted germplasm that gene owners need to enter small markets. Strong local breeding programs generating high yielding varieties, along with some local biotechnology research capacity, can be beneficial in the following ways:

- They increase the expected profitability of adopting farmers and reduce the chance of failure from planting foreign germplasm without any adaptation process.
- Higher profitability increase the adoption rates and the national benefits.
- Higher expected adoption rates are attractive to gene owners, meaning extended markets.
- Local biotechnology research capacity can reduce foreign firms' costs of introducing the gene into the variety.
- The learning by doing process increase the chances that the national agricultural R&D system will develop products subject to IPR protection or share IPR rights with international firms.

Strategic alliances between the agricultural R&D sector and the gene owners may lead to license fee agreements (Manicad, 1999). From an economic perspective and according to the results in this study, the shared interest in achieving higher adoption rates does not necessarily imply agreement on a lower seed premium, but might include license fee contracts with a portion of the private profits remaining in the country without restricting the monopolist's ability to choose the optimal seed premium. In that sense, strategic alliances become an instrument of national policy to increase domestic welfare. Strategic alliances may seek other goals such as the establishment of joint-venture research in areas of common interest, promoting the transfer of knowledge from the high-specialized firms. Research institutions from Argentina and Brazil with greater capacity can also be included as possible partners for the joint venture[17].

The possibility of the national R&D system to reap returns from such partnerships may have negative implications if revenues are needed to complement the core budget in publicly financed institutions, especially in periods of financial crisis. Negative externalities can arise if profitable research is weighted heavily against other research areas and reduces the allocation of resources to the generation of technologies that have large social benefits, which are not appropriable through such an arrangement. On the other hand, Alston, Sexton and Zhang (1997) point out that when farmers partially control the agricultural R&D system, they may avoid the allocation of resources to areas where significant deviations from perfect competition is present. Decision makers need to acquire a thorough understanding of the causes and consequences when solving the apparently contradictory problem, and this study is intended to provide input from an economic point of view to the decision-making process.

5.4. Summary and Further Research

The present study analyzed the economic impact of the introduction of Genetically Modified Organism (GMOs) in Uruguay's agriculture. Transgenic varieties were simulated for two crops, rice and potatoes, and modeled as small open and small closed economies respectively, in a partial equilibrium framework. The model accounts for the presence of imperfect competition in the market for the transgenic seed due to the monopolistic nature of gene ownership. The change in economic surplus generated after the adoption of the new technologies was found to be potentially positive, although the seed markup charged by the monopolist reduces its magnitude compared to expected benefits in perfectly competitive markets. The total and domestic benefits in the economy decrease with the increase in the seed premium level, and more private profits are extracted out of the country. At the same time

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[17] Brazilian authorities have not yet authorized the production and commercialization of GMOs, and concern about their food and environmental safety arise from consumers' groups. However, the largest governmental agricultural research institution in Brazil is conducting biotechnology research and expects positive benefits for the country as a whole (Dias Avila, Quirino, Contini and Rech, 2001). This may be considered an indication that in the future GMOs will be authorized in Brazil.

adoption is also lower, further reducing the domestic benefits. The results of the study suggest an active role for national policies and for the agricultural R&D system in Uruguay. A combination of both can attract the technology's owner to a small market and reduce the potential losses that it presence creates.

The study and the results presented here can be improved in several ways. As an ex-ante analysis, many key parameters are uncertain. The uncertainty may be specifically accounted for with stochastic simulation techniques. Another shortcoming of the study is the inability to predict the expected size of the benefits for both the domestic agents and the monopolist. Including probability distributions for the occurrence of the different scenarios may address this limitation.

The accuracy of the results can also be improved by determining more precisely the relationship between the expected profitability of agricultural innovations and adoption rates at the farm level. The information is of interest for the agricultural R&D system and for the private firms producing the innovation as well. Should GMOs begin to be planted in the country, an evaluation of the accuracy of the parameters used in the study with real data would be useful.

Some issues have not been investigated and deserve more attention for future research. The study has concentrated on the pecuniary benefits and costs of transgenic crops and did not address issues such as environmental externalities. A lower use of herbicides or pesticides has positive impacts on the environment, while the risk of the gene migration to native germplasm can create new problems like weed resistance. Proper accounting of environmental impact and use of natural resources can be included in the model, and private returns estimated here can be compared with social returns that would include, for example, the cost of government intervention to correct for negative impacts.

Another relevant issue related to GMOs is resistance from local consumers in export markets, which may lead to non-tariff trade barriers for the commodities. Price differentials, storage and transportation costs would then need to be accounted for if the export industry has to develop new markets for the products. These costs and concerns need to be weighted along with the benefits demarcated in this study.

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Appendix A: Per-Unit Cost Reductions and Maximum Adoption Rates for the Transgenic Rice Case

Cost Reduction	Yield Increase	Seed Markup (/ha)	Group	Scenario	Per-Unit Cost Reduction	Max. Adoption Rate
$75/ha	0%	$0	I	R1	6.82%	48%
		$15		R2	5.45%	36%
		$35		R3	3.64%	36%
		$75		R4	0.00%	24%
	2.5%	$0	II	R5	9.15%	60%
		$15		R6	7.82%	48%
		$35		R7	6.05%	48%
		$75		R8	2.50%	24%
	5%	$0	III	R9	11.49%	60%
		$15		R10	10.19%	60%
		$35		R11	8.46%	48%
		$75		R12	5.00%	36%
$45/ha	0%	$0	IV	R13	4.09%	36%
		$15		R14	2.73%	24%
		$35		R15	0.91%	24%
		$45		R16	0.00%	24%
	2.5%	$0	V	R17	6.49%	48%
		$15		R18	5.16%	36%
		$35		R19	3.39%	36%
		$45		R20	2.50%	24%
	5%	$0	VI	R21	8.90%	60%
		$15		R22	7.60%	48%
		$35		R23	5.87%	48%
		$45		R24	5.00%	36%

Appendix B: Per-Unit Cost Reductions and Maximum Adoption Rates for the Transgenic Potatoes Case

Cost Reduction	Yield Increase	Seed Markup (/ha)	Group	Scenario	Per-Unit Cost Reduction	Max. Adoption Rate
$142/ha	5%	$0	I	P1	11.16%	10%
		$70		P2	8.13%	10%
		$142		P3	5.00%	10%
	12%	$0	II	P5	17.78%	25%
		$70		P6	14.93%	25%
		$142		P7	12.00%	25%
	22%	$0	III	P9	27.31%	40%
		$70		P10	24.69%	40%
		$142		P11	22.00%	40%

Vita

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Guy G. Hareau was born in Montevideo, Uruguay in 1961. In 1987 he graduated as an Agricultural Engineer from the School of Agriculture, University of the Republic (Uruguay). He is a researcher at the National Agricultural Research Institute (INIA) of Uruguay since 1991. After obtaining a grant from the Fulbright Commission, in August 1999 he began his graduate studies in Agriculture and Applied Economics at Virginia Tech, where he is continuing in order to earn a Doctorate's degree in Economics. He is married to Elena D'Alessandro and they have three children, Sylvie, Chantal and Etienne.