Adoption Patterns of Herbicide-Tolerant Soybeans in Argentina

Robert Finger, Michael Hartmann, and Michael Feitknecht

ETH Zurich (Swiss Federal Institute of Technology)

The adoption of herbicide-tolerant soybeans (HTS) in Argentina was a very rapid process, as HTS covered virtually all of the area under soybean cultivation less than 10 years after their introduction in 1996. In our analysis, we focus on the patterns of HTS adoption. Using a survey-based analysis, we compare early and late adopters in the subdivisions of Pergamino and Salto (in the northeast of the Argentinean province of Buenos Aires) with regard to their expectations related to HTS adoption, as well as the characteristics of the farm and farmers. Moreover, we analyze the role of seed companies in the adoption and diffusion processes. This study shows that the expectations of cost reduction and easier crop management were the main drivers for farmers in the adoption of HTS. Furthermore, our results suggest that seed companies played a major role in providing farmers with their first information on HTS and their role has been influential for the farmers' adoption decisions.

Key words: adoption, Argentina, GM crops, herbicide tolerance, logistic regression, soybeans.

Introduction

Argentina is one of the major adopting countries of genetically modified (GM) crops. In particular, Argentinean soybean production almost completely adopted herbicide-tolerant (HT) varieties, with a share of 98% of the total area under soybean in the 2004/2005 season, (Chudnovsky, 2007). The speed of this adoption process was unique; within the first seven seasons after their introduction in 1996, herbicide-tolerant soybeans (HTS) covered about 90% of the total soybean planted area in Argentina (Trigo & Cap, 2003).

HTS adoption is associated with potential changes in management systems and new cropping techniques (Champion et al., 2003; Schütte, Stachow, & Werner, 2004; Senior & Dale, 2002). For instance, HTS enables more effective weed management techniques, which reduce energy costs compared to conventional farming. An effective weed management system has important synergies with no-till farming and facilitates the double cropping of soybeans following wheat. As a result, no-till soybean farming has increased five-fold since the introduction of GM crops (Brookes & Barfoot, 2006). Furthermore, the arable land in Argentina has been quasi-expanded by 4 million hectares due to double cropping in areas where only one crop was planted before the availability of the GMO varieties (Trigo & Cap, 2003). In addition to the economic benefits (i.e., cost savings), HTSs provide important positive environmental impacts that supported the adoption process (cf. Graef, Stachow, Werner, & Schütte, 2007; Schütte et al., 2004; Squire et al., 2003). Because it is much faster

decomposed in the soil and has no residual activity, the herbicide that is applied in HTS farming (glyphosate) is less environmentally harmful than herbicides that are used in conventional soybean farming systems. Even though the total amount of herbicides used increased (in particular due to the increased need for pre-seeding weed control because of more no-till farming), HTS introduction led to a reduction in the application of the most toxic herbicides (Qaim & Traxler, 2005). Moreover, the severe problems with soil erosion that resulted from conventional tillage practices in Argentina were reduced because of the synergy effect of HTS and no-till farming adoption (Trigo & Cap, 2003). Potential negative environmental effects, such as gene transfer from HTS into wild varieties and the loss of biodiversity in weed species, are currently evaluated as small (e.g., Qaim & Traxler, 2005; Sanvido, Romeis, & Bigler, 2007; Vitta, Tuesca, & Puricelli, 2004).

Another key factor in the rapid adoption of HTS in Argentina was the legal framework. Weak intellectual property rights, the permission to retain seeds after harvest for future plantings, and the existence of a considerable black market for seeds led to much smaller price differences between HT and conventional soybean seeds in Argentina than, for instance, in the United States (Brookes & Barfoot, 2006; Qaim & Traxler, 2005; Trigo & Cap, 2003). The much smaller extent of labeling obligations for GM crops in Argentina than, for instance, in the European Union (Anderson & Jackson, 2003), and the much more positive consumer response to GM crops in the developing world compared to the developed

world (Curtis, McCluskey, & Wahl, 2004) further supported HTS adoption in Argentina. In particular, marketplace acceptance is crucial for farmers to accept and adopt new technologies (e.g., Cook & Fairweather, 2003; Novoselova, Meuwissen, & Huirne, 2007).

The determinants for GM crop adoption by farmers are analyzed in several survey-based studies, for example Alexander, Fernandez-Cornejo, and Goodhue (2003), Bernard, Pesek, and Fan (2004), Chimmiri, Tudor, and Spaulding (2006), Fernandez-Cornejo, Daberkow, and McBride (2001), Hategekimana and Trant (2002), Kolady and Lesser (2006), Marra, Hubbell, and Carlson (2001), and Qaim and Traxler (2005). These studies analyze adoption decisions with respect to farm characteristics (e.g., farm size and distance to markets), farmers' characteristics (e.g., age, education, and farming experience), the economic performance of GM crops (e.g., cost savings and yield development), and the institutional environment (e.g., uncertainty of consumers' acceptance of GM crops and cost of GM crop seeds). However, the comparison of results among studies is limited due to differences in the geographic scope and in the applied empirical procedures (Chimmiri et al., 2006). Most of these studies compare adopters and non-adopters in order to identify what characteristics explain adoption. In our analysis, we focus on the patterns of HTS adoption. In particular, we compare early and late adopters in the subdivisions (partidos) Pergamino and Salto in the northeast province of Buenos Aires with regard to their expectations of HTS adoption, as well as the characteristics of the farms and the farmers. The identification of innovators' characteristics is important because it can help governments and policy programs assist the agriculture industry with future structural change (Hategekimana & Trant, 2002). Trigo and Cap (2003) point out the importance of multinational seed companies for the development of GM crops in Argentina. In addition, we analyze the influence of these companies on farmers' adoption decisions towards HTS.

Data Collection and Methodology

A questionnaire (filled out during interviews) was designed based on a literature review and has been pre-tested by key informants that are local experts, which served to identify the relevant issues at stake. The data were collected in the subdivisions Pergamino and Salto in the northeast of the Buenos Aires province in June and July of 2007. The province of Buenos Aires—in the humid Pampa region—is one of the major soybean-pro-

ducing regions in Argentina (Qaim & Traxler, 2005). In total, 50 soybean-producing farms were selected randomly from a regional client list provided by Monsanto. The list contained roughly 1,200 farms, representing about 70% of the total farms in these two subdivisions (La Dirección Provincial de Estadística, Ministerio de Economía, la Provincia de Buenos Aires, 2002). All of the selected farmers participated in the interviews.

The questionnaire contained three groups of questions. First, farmers were asked for information about their age, farming experience, level of education, farm size in 1996 and in 2007, ownership of the cropped land, off-farm occupation in 1996 and in 2007, and the first years of adopting HT soybean and no-till. This section contained information on farm and farmers' characteristics.

The second group of questions addressed the first source of information on HTS. The farmers were asked to indicate from which information source they first heard about HTS. The pre-test survey with key informants generated the following list of information sources: INTA (Instituto Nacional de Tecnología Agropecuaria [National Agricultural Technology Institute]), seed companies (such as Monsanto, Nidera, Syngenta, or Pioneer), farmers' organizations (e.g., AApresid [Asociacion Argentina de Productores en Siembra Directa, or in English, Argentine No-till Farmers Association]), personal contact with other farmers and other sources (e.g., universities, NGOs, and the government). The questioned farmers indicated how much these information sources influenced their decision to plant HTS on a five-point scale anchored by *none at all* and *very much*.

The third group of questions focused on the reasons for the adoption of HTS. On a five-point scale (ranging from *absolutely irrelevant* to *decisive*), farmers indicated the importance of the combination of HT soybean adoption with other new cropping practices such as no-till and double cropping (wheat-soybean) on the adoption decision. The importance of the expected impacts of HTS adoption on yield levels, herbicide costs, and on the ease of management was indicated on the same scale. Moreover, the importance of the perceived advantages of HT soybean adoption by the farmers on their neighbors' field and in field trial areas, the security to sell products without problems, and the impact of rising land rent prices on the adoption decision were indicated. The pre-test revealed that farmers have no concerns about the general ecological risks, such as gene transfer into wildland populations and loss of biodiversity. Thus, we included just a single question concerning the on-
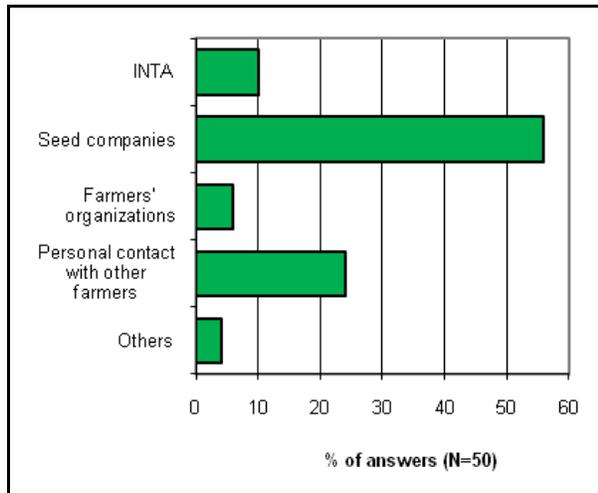
Figure 1. From where did you first hear about HT soybean?

Table 1. What information source influenced your decision to plant HT soybean?

Item†		Early adopters	Late adopters
INTA	Mean	2.50	3.30
	SD	1.71	1.39
	N	16	30
Seed companies	Mean	4.44	3.82*
	SD	1.09	1.29
	N	16	34
Farmers' organizations	Mean	3.0	2.46
	SD	1.6	1.55
	N	15	28
Personal contact with other farmers	Mean	3.56	4.24
	SD	1.59	1.12
	N	16	33
Others	Mean	1.64	1.22
	SD	1.15	0.85
	N	14	23

†Note: Range from 1 (none at all) to 5 (very much) for all items.
By choosing "I do not know," missing values are created.
*Significant difference between Early and Late Adopters at the 10% level (2-sided Wilcoxon-Mann-Whitney test).

farm environmental impacts of HT soybean adoption in the questionnaire.

This article will present the mean and standard deviations (SD) of the item scores for all three groups of questions in the first step of the analysis. In this presentation of results, the analysis is separated into the early and the late adopters of HTS. Early adopters had already planted HTS in 1996, the year of introduction. The group of late adopters included the remaining farmers that planted HTS after 1996. The Wilcoxon-Mann-Whitney test was used to examine the differences between early and late adopters for all items.

We conducted a binary logistic regression in the second step of the analysis. The purpose of this binary logistic regression was to determine which questionnaire items could be used to classify farmers as early or late adopters. Thus, the binary response (early/late adoption) should be explained by a set of independent variables. This analysis further enabled the comparison of single variables with regard to their contribution to the adoption time. We identified the most important variables using a stepwise variable selection. Variables that significantly (assuming a 0.05 level of significance) contributed to the explanation of the dependent variable were entered and all variables that were no longer significant were removed from the model at each forward selection step. This procedure reduces the number of independent variables and thus solves problems of having too few degrees of freedom. Moreover, variable selection reduces multicollinearity problems. The set of explanatory variables were highly intercorrelated. This precluded the distinction of variables with respect to their effect on the dependent variable, because the

effects of the explanatory variables overlap. Furthermore, the interpretation of a single variable's effects on the binary variable in terms of the odds ratios is erroneous in the case of multicollinearity. The logistic regression was conducted with respect to farm and farmers' characteristics and with respect to the reasons for the adoption of HTS.[1] The analysis identified the important variables for the early adoption within the farm and farmers' characteristic, as well as within farmers' expectations. We used the LOGISTIC procedure in SAS (2004) to conduct the binary logistic regression.

Data and Results

All farmers in the sample had adopted HTS by 2007 (the year of the survey). In particular, 32% of the interviewed farmers started planting HT soybeans in the first year of introduction in (1996). Subsequent adoption of HTS by 26%, 28%, 6%, and 8% occurred for the first time in 1997, 1998, 1999, and 2000 or later, respectively. The sample contains two groups: early and late

---

1. *Several missing values, which preclude sufficient inference of regression analysis, are created by choosing the answer "I do not know" for items from the second group of questions, which is thus omitted in the analysis.*

Table 2. Reasons given for planting HT soybeans.

Item†		Early adopters (N=16)	Late adopters (N=34)
I expected facilitated wheat-soybean double cropping	Mean	3.88	3.35
	SD	1.36	1.55
I expected facilitated introduction of no-till farming	Mean	4.5	4.09
	SD	0.97	1.48
I expected increasing yields	Mean	3.81	3.12*
	SD	0.98	1.41
I expected to reduce costs	Mean	4.75	4.94*
	SD	0.58	0.34
I expected easier crop management	Mean	5	4.94
	SD	0	0.24
I saw advantages on my neighbors' field	Mean	2.13	3.74***
	SD	1.45	1.68
I had the security of selling products	Mean	4.13	4.65*
	SD	1.31	0.85
Rising prices for land rent	Mean	1.63	3.56***
	SD	1.02	1.56

†Note: Range from 1 (absolutely irrelevant) to 5 (decisive) for all items.

*, **, *** denote significant difference between Early and Late Adopters at the 10%, 5%, 1% level, respectively (2-sided Wilcoxon-Mann-Whitney test).

Table 3. Farm and farmers' characteristics.

Item		Early adopters (N=16)	Late adopters (N=34)
Farmers' age (in years)	Mean	51.19	49.97
	SD	11.10	14.36
Farmers' experience (in years)	Mean	30.5	29.85
	SD	12.49	16.07
Farmers' education†	Mean	2.19	1.71*
	SD	0.83	0.72
Farm size in 1996 (in ha)	Mean	1084.38	316.18 ***
	SD	919.73	305.88

†Note: Range from 1 (Primary Education) to 3 (tertiary education) for farmers' education.

*, **, *** denote significant difference between Early and Late Adopters at the 10%, 5%, 1% level, respectively (2-sided Wilcoxon-Mann-Whitney test).

adopters. The group of early adopters consists of those farmers that planted HT soybean in 1996, and the group of late adopters contains the remaining farmers.

Figure 1 shows that most of the farmers (56%) received their first information about HTS from the seed companies. In contrast, the INTA, farmers' organizations, and other institutions played only a minor role in bringing initial information to the farmers.

Table 1 shows the influence of information sources on the decision to plant HTS. Seed companies are the most important information source for *early* adopters, whereas personal contact with other farmers is the most important information source for *late* adopters. As we saw previously (Figure 1), the INTA, farmers' organizations, and others play a minor role in the decision process of HTS adoption. Except for the influence of seed companies, no difference between early and late adopters exists for these items.

Table 2 presents the reasons for HTS adoption. The expectations of HTSs to facilitate crop management and to lower herbicide costs are the most important points for both early and late adopters. Moreover, the expected combination of HTS and no-till farming is an important

reason for adoption. The importance of this combination is also underlined by the fact that all farmers in the sample adopted no-till farming. Another important issue for the adoption of HTS is the security to sell products without any problems. This is even more pronounced for the group of late adopters. The late adopters indicate that this issue is more important than it is to the early adopters. The expectation to increase yields by adopting HTS is higher for the early adopters than for the late adopters. Smaller expectations of yield increases might be a result of observations of early adopters' farms and contact with early adopters. The importance of observing the advantages of HTS on the neighbors' field is higher for late adopters. Early adopters, however, are not influenced by the observed results of field trials in this case. The fact that HTS adoption enables double cropping is less important for the adoption decision than the combination with no-till farming. Rising land-rent prices are only important for the adoption decision of late adopters. Moreover, farmers evaluated on-farm environmental impacts of HT soybean adoption as very positive (results not shown).

Some of the reasons for HTS adoption are highly correlated. A positive and significant correlation is found between the expected combination of HTS and no-till farming and the expected effects of HTS on the facilitation of wheat-soy double cropping. Furthermore, significant correlations are found between the facilitation of crop management and reducing herbicide costs, as well as between the observations of HTS advantages on neighbors' fields and rising land-rent prices.

Table 3 shows that there is no difference between early and late adopters with regard to farmers' age and

Table 4. Binary logistic regression results: Odds ratio estimates.

Variable	Odds ratio estimates
Log farm size in 1996	7.22**
I expected increasing yields	3.98**
Rising prices for land rent	0.32**
I expected facilitated wheat-soybean double cropping	2.87**
Constant	1.16e-08**

Note: All variables given in Table 2 and 3 are used in the binary logistic regression. Moreover, the 1996 land tenure is taken into account. In a stepwise variable selection, variables enter and are removed from the model assuming a 0.05 level of significance.

**Odds ratios are significantly smaller and larger than 1, respectively, at the 0.05 level. Generalized coefficient of determination (Nagelkerke, 1991): 0.78. 96% of correct predictions.

experience. However, early adopters tend to have a higher level of education than late adopters. The farm size seems to be an important characteristic that separates early and late adopters of HTS. Early adopters cropped on average 1,084 ha, whereas the average farm size of late adopters was 316 ha in 1996.

In 1996, the proportion of owned land to cropped land (i.e., land tenure) of the farmers was on average 55%. Moreover, 88% of the farmers indicated farming as their primary occupation in 1996. Land tenure did not change over time from 1996 to 2007. In contrast, a primary occupation in agriculture in 2007, indicated by 96% of the farmers, is higher than in 1996. This accompanies an increasing trend in farm size from 1996 to 2007. The total sample average farm size increased from 562 ha in 1996 to 784 ha in 2007. Both the average farm size increase and the change in primary occupation from 1996 to 2007 are significant at the 5% level. No difference between early and late adopters exists in land tenure and primary occupation.

For the binary logistic regression, the variable 'Farm Size' in 1996 is transformed using its logarithm in order to derive a symmetric distribution of this variable and to improve the estimation procedure. The new variable is abbreviated as 'Log Farm Size in 1996.' The stepwise variable selection[2] indicates four variables that significantly contribute to the binary response variable 'Adop-

tion Time' (1 for early and 0 for late adopters) as presented in Table 4.

It shows that the log of farm size in 1996, the expectation to increase yields, the expectation to facilitate wheat-soy double cropping, and the rising prices for land rent have remained in the model. All other variables do not significantly contribute to the binary response variable for adoption time in the logistic regression. The reason for the exclusion of the latter variables from the model is twofold. First, the effects of some variables are overlapping due to high multicollinearity. For instance, the high correlation between the expected combination of HTS and no-till farming and the expectation to facilitate wheat-soy double cropping within the reasons for HTS adoption cause only the latter variable to enter the model.[3] Thus, even though some variables show significant differences between early and late adopters in the descriptive analysis (Tables 2 and 3), they cannot further improve the model if other variables are included. Second, some variables are not included in the model because they are not correlated with the binary response variable 'Adoption Time' and are thus not important for the classification of farmers in early and late adopters. In our analysis, the odds are the ratio of the probability that a farmer is an early adopter and the probability that he is a late adopter.

The odds ratio estimate from binary logistic regression shows that a one-unit increase in the item "I expected increasing yields" as a reason for HTS adoption leads to a 3.98-fold increase in the odds that a farmer is an early adopter. A one-unit increase in the item "I expected facilitated wheat-soybean double cropping" as a reason for HTS adoption leads to a 2.87-fold increase these odds. In contrast, a one-unit increase in the item "rising prices for land rent" as a reason for HTS adoption leads to a 3.13-fold (1/0.32) decrease of the odds that a farmer is an early adopter. Due to the logarithm transformation of the farm size variable, the interpretation of the odds ratio estimate changes as follows: a 1% increase in the 1996 farm size leads to a 7.22-fold increase in the odds that a farmer is an early adopter.

Discussion and Conclusion

The adoption process of herbicide tolerant soybeans in Argentina after their introduction in 1996 has been rapid. Nearly the entire current soybean production has

---

2. *Moreover, a principal component logistic regression was applied to identify the most important questionnaire items that explain the adoption time. The results are in line with those presented here.*

3. *In the final model, no multicollinearity problems exist as these independent variables all have variance inflation factors below 1.5.*

switched to HT traits. Previous research identified that drivers such as good economic performance and the special legal framework (e.g., weak intellectual property rights) supported this rapid adoption process in Argentina. Using a survey-based analysis, we focused on the identification of crucial factors that determine the adoption pattern, such as those factors that separate early and late adopters. Moreover, we studied the role of seed companies in the rapid adoption process of HTS in the Argentinean subdivisions in Pergamino and in Salto in the northeast of the Buenos Aires province. All of the interviewed farmers adopted HTS by 2007. Thirty-two percent of these farmers adopted HTS in 1996 and are defined as early adopters, whereas the remaining farmers form the late adopters' group.

Multinational seed companies have been important for the development of GM crops in Argentina, as the vast majority of GM crop field trials in Argentina are conducted by these companies and not by governmental institutions or universities (Trigo & Cap, 2003). Qaim and Traxler (2005) argued that, even though the intellectual property rights for HTS are weak in Argentina and seed prices are thus lower than in the United States, the *sheer size* of the sector attracts seed companies. Our results show that seed companies also played an important role in the adoption process. Most farmers indicated seed companies as the first source of information on GM crops. Moreover, seed companies have influenced farmers' decision on HTS adoption much more than farmers' organizations or public research institutions. The direct contact of the seed companies to Argentinean farmers has been a successful strategy for a rapid and widespread adoption of HTS. However, farmers' organizations and research institutions had only small effects on farmers' adoption decision. In contrast, the influence of research institutions had been much larger in Delaware where most farmers indicated that universities are as important information sources for adoption decisions (Bernard et al., 2004). By strengthening the information flow from research and governmental institutions to farmers, these institutions can improve their ability to assist farmers' with future structural change.

The expected combination of HTS and no-till adoption, the expectation of facilitated crop management, and reduced herbicide costs have been indicated by the surveyed farmers as the most important reasons for HTS adoption. These items have the highest mean response, as presented in Table 2. These results are in line with survey results of soybean farmers in South Dakota by Schütte et al. (2004), which show that the improved effectiveness of weed control and the reduced herbicide

costs were the most important preferences of farmers with regard to HT plants. Moreover, farmers indicated that the security to sell products is an important item for adoption. Expected effects of HTS on the facilitation of wheat-soy double cropping and on yield increases have been less important for the adoption decision. The latter is consistent with very small effects of HTS on yield levels pointed out by Qaim and Traxler (2005) and Qaim and Zilberman (2003). The perceived advantages on other fields have been rated as unimportant to the adoption decision. The "learning from neighbors" effect (Foster & Rosenzweig, 1995) has nevertheless been important for the adoption process. Late adopters perceived cost reductions, easier crop management, and the security of the market for GM crops from their neighbors, which reinforced rapid diffusion of the HT technology in Argentina.

Moreover rising land rental prices have been rated as not decisive for the adoption decision. However, the results of a binary logistic regression show that differences in the expectations for increasing yields and for the facilitation of wheat-soy double cropping, as well as rising land rental prices, are suitable items to classify farmers with respect to their adoption time. The expectation of higher soybean yields and the facilitation of wheat-soy double cropping can be attributed to the farmers that adopted HTS in 1996. In contrast, late adopters have faced higher land rental prices. The latter might indicate the existence of a technological treadmill as described, for instance, by Kalaitzandonakes (1999) for GM crops. Increased demand for crop land due to economic benefits for HTS adopters might crowd out non-adopters via increasing rental prices. Bernard et al. (2004) argues that this effect leads to a reinforcement of the adoption process. Moreover, farm size is an important variable to explain the adoption time. The larger the farm size in 1996, the higher the probability that the farm is an early adopter. This contrasts the results of Hategekimana and Trant (2002) for Canada. They identified, in particular, small farms as early adopters of HTS. However, Fernandez-Cornejo et al. (2001) show that the effect of farm size is more important at the innovator stage. The more the technology diffuses, the more the effect of farm size decreases. No significant relationship between adoption time and farmers' characteristics such as age, experience, or education has been identified in our analysis by the applied binary logistic regression. The latter contrasts the results of other studies (e.g., Alexander et al., 2003; Fernandez-Cornejo & McBride, 2002; Marra et al., 2001), where early adoption of HTS was associated with a higher level of education. How-

ever, Bernard et al. (2004) argued that insignificance of education, age, or experience could be the result of identical information sources that the farmer relied on. Our analysis suggest that farmers relied to a large extent on information provided by the seed companies. This holds for all farmers within the sample, as no relationship between the influence of information sources (Table 1) and any item of farmers' characteristics (Table 3) is found.

Our results further suggest a trend to more professional soybean farming among the interviewed farmers. Compared to 1996, the average farm size increased roughly 40% by 2007. Moreover, the proportion of farmers that indicated farming as their primary occupation increased from 88% to 96% by 2007. This is consistent with the results of Bernard et al. (2004) for farmers in Delaware that expanded their farm acreage after HTS adoption. Moreover, the latter analysis shows similar trends in the rapid adoption of no-till farming after HTS adoption, as indicated by our survey. However, the trends of increased farm acreage and increased shares of no-till farming in Argentinean soybean farming cannot be fully attributed to the adoption of HTS. There has been a trend of increasing agricultural production in general and increasing soybean production in particular in Argentina since the early 1990s (Trigo & Cap, 2003). Moreover, the no-till planting area in Argentina increased due to price reductions for farming and no-till equipment since the early 1990s (Trigo & Cap, 2003). Thus, the lack of a baseline, caused by a steady modification of agricultural production factors, hampers the attribution of observed changes in crop management practice to the adoption of HTS (Champion et al., 2003; Senior & Dale, 2002).

In conclusion, our study suggests that seed companies played a major role in the adoption and diffusion process of herbicide tolerant soybean traits in Argentina by providing the initial information about HTS to the farmers that they were influential for farmers' adoption decisions. Our results furthermore emphasize that major changes in crop management practices took place in Argentinean soybean production within the last decade. All farmers within our sample switched to GM soybean traits and no-till farming since 1996. This was accompanied with an increasing trend in farm size and increased primary occupation in agriculture. We find the expected cost reductions and easier crop management as major drivers of farmers' adoption decision toward HTS. Moreover, farmers rated the security to sell GM products and the positive interaction of the introduction of no-till farming with HTS as important reasons for their

adoption decision. As the adoption of generically modified soybean traits is a dynamic process, the given answers by the farmers in our study might be influenced by mostly positive experience from a retrospective view. Therefore, further research should carry out surveys at different stages of an adoption process.

References

Alexander, C., Fernandez-Cornejo, J., & Goodhue, R.E. (2003, October). *Farmers' adoption of genetically modified varieties with input traits* (Giannini Foundation Research Report 347). University of California. Available on the World Wide Web: http://ageconsearch.umn.edu/bitstream/11928/1/rr030347.pdf.

Anderson, K., & Jackson, L.A. (2003). Why are US and EU policies toward GMOs so different? *AgBioForum*, *6*(3), 95-100. Available on the World Wide Web: http://www.agbioforum.org.

Bernard, J.C., Pesek, J.D., & Fan, C. (2004). Delaware farmers' adoption of GE soybeans in a time of uncertain US adoption. *Agribusiness*, *20*(1), 81-94.

Brookes, G., & Barfoot, P. (2006). Global impact of biotech crops: Socio-economic and environmental effects in the first ten years of commercial use. *AgBioForum*, *9*(3), 139-151. Available on the World Wide Web: http://www.agbioforum.org.

Champion, G.T., May, M.J., Bennett, S., Brooks, D.R., Clark, S.J., et al. (2003). Crop management and agronomic context of the farm scale evaluations of genetically modified herbicide-tolerant crops. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1439), 1801-1818.

Chimmiri, N., Tudor, K.W., & Spaulding, A.D. (2006). An analysis of McLean County, Illinois farmers' perceptions of genetically modified crops. *AgBioForum*, *9*(3), 152-165. Available on the World Wide Web: http://www.agbioforum.org.

Chudnovsky, D. (2007). Argentina: Adopting RR soy, economic liberalization, global markets and socio-economic consequences. In S. Fukuda-Parr (Ed.), *The gene revolution GM crops and unequal development* (pp. 85-103). London: Earthscan Publications Ltd.

Cook, A.J., & Fairweather, J.R. (2003). New Zealand farmer and grower intentions to use gene technology: Results from a resurvey. *AgBioForum*, *6*(3), 120-127. Available on the World Wide Web: http://www.agbioforum.org.

Curtis, K.R., McCluskey, J.J., & Wahl, T.I. (2004). Consumer acceptance of genetically modified food products in the developing world. *AgBioForum*, *7*(1&2), 70-75. Available on the World Wide Web: http://www.agbioforum.org.

Fernandez-Cornejo, J., & McBride, W.D. (2002, May). *Adoption of bioengineered crops* (Agricultural Economic Report No. 810). Washington, DC: US Department of Agriculture (USDA). Available on the World Wide Web: http://www.ers.usda.gov/publications/aer810/.

Fernandez-Cornejo, J., Daberkow, S., & McBride, W.D. (2001). Decomposing the size effect on the adoption of innovations: Agrobiotechnology and precision agriculture. *AgBioForum*, *4*(2), 124-136. Available on the World Wide Web: http://www.agbioforum.org.

Foster, A.D., & Rosenzweig, M.R. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy*, *103*(6), 1176-1209.

Graef, F., Stachow, U., Werner, A., & Schütte, G. (2007). Agricultural practice changes with cultivating genetically modified herbicide-tolerant oilseed rape. *Agricultural Systems*, *94*(2), 111–118.

Hategekimana, B., & Trant, M. (2002). Adoption and diffusion of new technology in agriculture: Genetically modified corn and soybeans. *Canadian Journal of Agricultural Economics*, *50*(4), 357–371.

Kalaitzandonakes, N. (1999). A farm level perspective on agrobiotechnology: How much value and for whom? *AgBioForum*, *2*(1), 61-64. Available on the World Wide Web: http://www.agbioforum.org.

Kolady, D.E., & Lesser, W. (2006). Who adopts what kind of technologies? The case of Bt eggplant in India. *AgBioForum*, *9*(2), 94-103. Available on the World Wide Web: http://www.agbioforum.org.

La Dirección Provincial de Estadística, Ministerio de Economía, la Provincia de Buenos Aires [The Provincial Department of Statistics, Ministry of the Economy, Buenos Aires Province]. (2002). *Censo nacional agropecuario*. Buenos Aires, Argentina: Author.

Marra, M.C., Hubbell, B.J., & Carlson, G.A. (2001). Information quality, technology depreciation, and Bt cotton adoption in the southeast. *Journal of Agricultural and Resource Economics*, *26*(1), 158-175.

Nagelkerke, N.J.D. (1991). A note on a general definition of the coefficient of determination. *Biometrika*, *78*(3), 691-692.

Novoselova, T.A., Meuwissen, M.P.M., & Huirne, R.B.M. (2007). Adoption of GM technology in livestock production chains: An integrating framework. *Trends in Food Science & Technology*, *18*(4), 175-188.

Qaim, M., & Traxler, G. (2005). Roundup Ready soybeans in Argentina: Farm level and aggregate welfare effects. *Agricultural Economics*, *32*(1), 73-86.

Qaim, M., & Zilberman, D. (2003). Yield effects of genetically modified crops in developing countries. *Science*, *299*(5608), 900-902.

Sanvido, O., Romeis, J., & Bigler, F. (2007). Ecological impacts of genetically modified crops: Ten years of field research and commercial cultivation. *Advances in Biochemical Engineering/Biotechnology*, *107*, 235-78.

SAS. (2004). *SAS/STAT 9.1 user's guide*. Cary, NC: SAS Institute Inc.

Schütte, G., Stachow, U., & Werner, A. (2004). *Agronomic and environmental aspects of the cultivation of transgenic herbicide resistant plants* (TEXTE series 11/04). Berlin: Federal Environmental Agency. Available on the World Wide Web: http://www.umweltdaten.de/publikationen/fpdf-l/2636.pdf.

Senior, I.J., & Dale, P.J. (2002). Herbicide-tolerant crops in agriculture: Oilseed rape as a case study. *Plant Breeding*, *121*(2), 97-101.

Squire, G.R., Brooks, D.R., Bohan, D.A., Champion, G.T., Daniels, R.E., et al. (2003). On the rationale and interpretation of the farm scale evaluations of genetically modified herbicide-tolerant crops. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1439), 1779-1799.

Trigo, E.J., & Cap, E.J. (2003). The impact of the introduction of transgenic crops in Argentinean agriculture. *AgBioForum*, *6*(3), 87-94. Available on the World Wide Web: http://www.agbioforum.org.

Vitta, J.I., Tuesca, D., & Puricelli, E. (2004). Widespread use of glyphosate tolerant soybean and weed community richness in Argentina. *Agriculture, Ecosystems & Environment*, *103*(3), 621-624.

Acknowledgements