Chapter 4
Benefits to Producers and Society

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4.1 Introduction

Most studies conducted to date about the adoption and impacts of genetically modified organisms (GMOs) have examined the direct, on-farm benefits to producers (Qaim 2009; Smale et al 2009; Pontifical Academy of Sciences 2010; Potrykus and Ammann 2010; Areal et al. 2012). To estimate on-farm benefits, applied researchers have most often relied on farm data collected through survey interviews to test hypotheses about changes in yield, use of labour and other inputs, costs and returns. The same data can be aggregated to represent benefits to a sector and to society.

Researchers have also used estimates of net profits per hectare from survey data, trial data or data obtained from companies to estimate overall returns to producers (for a complete discussion, see Smyth et al., forthcoming). Benefits to society have been generally estimated via the well-known economic surplus approach or the Global Trade Analysis Project (GTAP) and similar approaches that consider market supply and demand for a specific sector or for the economy as a whole. Use of trade analysis reflects the interest of decision-makers in understanding whether a specific country stands to gain from the potential adoption of GMOs. Researchers have also modified the economic surplus approach to address issues such as temporary monopoly conferred to innovators through intellectual property, heterogeneity among producers, uncertainty and the postponement of benefit flows due to regulatory processes. Benefits to society are often expressed as the size and distribution of economic benefits accruing to producers, consumers and innovators.

This chapter discusses methods and approaches used to evaluate benefits to producers and society, and their limitations and implications for national and

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international regulatory environments. Studies examining producer and societal benefits are more relevant to formal technology evaluation processes than the environmental and/or the food/seed risk assessment procedures used in biosafety regulatory processes. This is largely because very few aspects related to the measurement of benefits to producers and to society are directly related to risk considerations. Some exceptions to this state of regulatory and decision-making affairs may be the financial or production risks connected to market and post-release environments.

4.2 Methodologies

A fundamental distinction concerns ex ante as compared to ex post analyses. Methods described here can be used in either. Ex ante impact assessment refers to analysis that estimates the potential impact of the adoption and diffusion of a GM innovation. Practitioners customarily perform ex ante analysis to evaluate competing project options and allocate resources based on a priority setting exercise. In an ex ante analysis, the researcher proposes plausible values for key parameters in the model chosen.

In contrast, ex post impact assessment refers to analysis that evaluates past performance and achievements. This is an after-the-fact analysis that examines use of inputs and seeks to provide information to policy-makers. In an ex post analysis, the researcher collects data on key parameters from primary or secondary sources. The probability of success, adoption rates and information about production performance are known, elicited from experts, or can be estimated from different sources.

One critical issue of ex post (and to a certain degree ex ante) analysis is making the appropriate comparison between the scenarios that depict conditions 'with' and 'without' the innovation (the counterfactual). Agronomic and other life sciences experiments customarily deal with the counterfactual by comparing a group of individuals (plants, persons) that received the proposed treatment (a treatment group) with a group that did not (a control group). In the case of quasi-experimental, economic impact studies conducted among farmers, it is not feasible to identify the control group. We observe those farmers who received a treatment (adopted a technology) after they adopted, and those who did not, but we cannot observe adopters had they not adopted. Adopters and non-adopters are likely to differ in important ways. Similarly, the researcher cannot observe the prices and quantities that would have prevailed had technical change not occurred. The next best solution is to use information available for the conventional (older) technology. The researcher estimates 'without-innovation' prices and quantities using formulas derived from the system of supply and demand equations.

We group analytical approaches into three distinct sub-categories, according to their objectives: (1) cost/benefit analysis, (2) partial and general equilibrium analysis, and (3) regulatory impact assessment.

4.2.1 Cost/Benefit and Net Present Value Methods

The purpose of Cost/Benefit Analysis (CBA) is to evaluate the consequences of decisions using consistent procedures. Often the literature distinguishes two types of CBA. The financial approach considers only cash costs and benefits, and is typically used by private firms and individuals. The decision rule is simply that a project is undertaken as long as benefits exceed costs. This decision rule is equivalent to positing that net benefits are greater than or equal to zero. The second, or economic approach, adds the cost of alternatives (opportunity cost) and external influences on society. Alternative costs are customarily valued using 'shadow prices', which include all the cost incurred by society in order to supply a good in a specific market.

To reflect the time value of money, researchers discount the flow of future net benefits using the appropriate discount factor or interest rate. Discounting is a way to estimate the present value of benefits and costs realized during the course of adoption and use of a technology. The process of discounting assumes that money spent today is more valuable than money spent in the future because today's money can be invested, generating income until it is spent in the future. In addition, discounting assumes that most people prefer to consume now rather than later.

The net present value (NPV) is the sum of the discounted stream of annual net benefits. All costs necessary to bring the project into existence are considered. An alternative measurement is the internal rate of return (IRR), which is simply the rate of interest which, when applied to discount the stream of net benefits, equates the NPV to zero. The analyst compares the IRR to an existing benchmark rate of interest, usually the prevailing bank-lending rate. If the IRR is greater than the benchmark rate of return, the project is accepted.

4.2.2 Partial and General Equilibrium Analysis

Partial and general equilibrium analysis—including economic surplus approaches—seeks to estimate net additional benefits to the economy due to the adoption of an innovation. The economic surplus methodology is based on the principle that supply and demand for a particular good reaches an equilibrium point. Equilibrium represents the combination of prices and quantities at which the quantity demanded by individuals exactly equals the amount supplied by producers. Changes in the equilibrium quantity and price occur because of external shocks to the system of supply and demand functions (e.g. introduction of a biotechnology innovation). In particular, a technology innovation may cause a per-unit cost reduction (increase) or equivalently, more (less) output produced with the same amount of inputs.

Economic surplus is composed of consumer and producer surplus, both measured as changes with respect to a counterfactual. Change in consumer surplus arises when adoption of the technology causes a shift in supply and a decrease in product price, and is calculated by multiplying the price change by the quantity of the good consumed. Change in producer surplus results from the increase in benefits

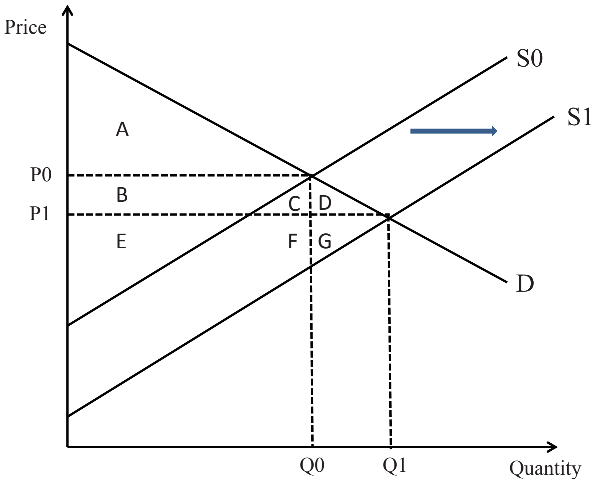

Fig. 4.1 Producer and consumer surplus changes due to supply shift. Notes: (1) Consumer surplus is the area below the demand curve and above the price. Producer surplus is the area above the supply curve and below the price. (2) Prior to the shift in supply from *S*0 to *S*1, producer surplus was areas $B+E$. After the supply shift, producer surplus is area $E+F+G$. Change in producer surplus is thus $F+G-B$. Consumer surplus before the shift was A. After the supply shift it is $A+B+C+D$. Change in consumer surplus is $B+C+D$

associated with increased output or decreased cost of production. Benefits to society are estimated as the sum of producer, consumer and innovator surplus and changes in deadweight losses. Figure 4.1 shows changes in producer and consumer surplus and deadweight losses due to a change in demand or supply.

This is a well-established methodology in economics literature and has been shown to provide valuable contributions to impact assessment efforts. When there are other impacts beyond the sector, researchers can use multi-market approaches. Impacts may be 'horizontal' in the sense that the adoption affects two or more commodity markets, or 'vertical', meaning that effects are transmitted among output and input markets.

Researchers initiate the estimation procedure of economic surplus by deciding on the type of model to use. A decision on the model type will also include decisions about the type of functions (linear vs curvilinear) and the type of supply or demand shift (parallel or pivotal). If there is a need to have preliminary estimations, procedures using a parallel shift and linear functions are handy. At this point, researchers must also consider whether there is data that is sufficient and of strong-enough quality for an econometric analysis.

Impact assessment practitioners choose from among several techniques to estimate economic surplus. The main advantage of econometric techniques is that these enable the researcher to test hypotheses about the parameters in the model with statistics. The mathematical programming method obviates the need for extensive data, but requires extensive knowledge about the processes and production characteristics of the innovation and has the disadvantage that it is hard to judge the robustness of the model.

The quasi-rent approach provides an expedient and simple means to measure economic surplus. However, it is significantly close to economic surplus only when the change in supply or demand is small, and the elasticity of supply is unitary. If the innovation under study departs from these narrow assumptions, quasi-rents and economic surplus will diverge. Equilibrium displacement models have a stronger theoretical basis, are relatively expedient to use and also enable the researcher to explore a range of policy questions. Minimal data is required and this is provided from the existing literature. However, because equilibrium displacement models are based on linear functions and parallel shifts, they may not be suitable for all problems encountered by practitioners.

General equilibrium analysis (GEA) is a technique used when the technology under study affects a large number of sectors in the economy, directly or indirectly. GEA is grounded on the principle that structural equations describe not only the stock of resources but also resource flows, processes and linkages among them. The impact of regulation can therefore be estimated by formulating the appropriate expected effects relative to the baseline model. Input/output models, linear programming models and computable general equilibrium models are GEA tools. For more details on partial and general equilibrium analysis, the reader is directed to Chap. 15 (Market Access and Trade).

4.2.3 Regulatory Impacts Assessment

Regulation can introduce costs and benefits that affect producers and society as a whole. Examples of studies in which these are measured, and the tools to measure them, are few. If the CBA (described above in general terms) is oriented towards estimating the regulation's impact on the private sector, or a representative firm, it is also known as a business impact methodology. If the CBA is based on examination of estimated or true budgets, then it is known as a budgetary analysis. Cost Effectiveness (CE) is a special case of CBA which can be used when benefits of a regulation cannot be easily estimated and when the regulatory policy sets specific target objectives. The CE of a regulatory policy is estimated by dividing the regulation's annual costs by the physical units described by the regulatory objective. For example, if the explicit objective of a biosafety regulation is to reach a pre-determined level of safety, then the cost of implementing the regulation is determined for this level of safety. The CE method does not identify an optimal regulatory level but can be used to compare alternative regulatory policy options. Additionally, CE does not preclude the selection of regulatory policy options exclusively on the basis of having 'the least-cost' option.[1]

Direct compliance cost (DCC) is the simplest means of assessing regulatory impacts. DCC equates the social cost of implementing a regulation to the sum of all

[1] This method is also used in the food security and medical literature where it may be inappropriate to quantify the value of human life. Typically, the CE method is the ratio of outcome (life saved, years of life saved) to the cost of achieving the outcome. Most common CE method is the Quality Life Adjusted Years (QALYs).

analytical procedures necessary to meet the regulation by a representative institution or private firms. In the case of private firms, DCC tends to overestimate the true value of the social cost of regulation because it ignores possible substitutions or changes in the production system. Moreover, analysts using DCC do not take into consideration the changes in capital or labour investments by private firms that result from implementing a biosafety regulation. This approach may approximate true social costs when expected changes in prices and quantities are small and there are few indirect effects.

4.3 Critical Assessment

Most practitioners agree that socio-economic impact assessment is not an end in itself but rather a way to identify and choose among innovation alternatives. Impact assessment can empower scientists and policy-makers by providing them with estimates of the potential costs and benefits associated with innovations, and in some cases, pinpointing ways to enhance overall benefits and reduce social costs.

However, these estimates should be considered with caution because they are by nature, speculative. Even in ex post analysis, some parameters and variables will be subject to some bias and measurement error, although not all error is systematic and bias may not alter qualitative findings (e.g. the relative rank of innovation options). In most cases, care should be taken in extrapolating or generalizing from one study context to another.

4.3.1 Cost/Benefit and Net Present Value Methods

Cost/Benefit and partial budget approaches are deceptively simple. In fact, considerable care must be used in applying them. For example, because of the costs of survey implementation, most early studies conducted in developing countries reported only gross margins. As compared to net margins, gross margins include the costs of intermediate inputs but exclude costs of labour and land. This was a shortcoming given that some crop-trait combinations, such as herbicide tolerance, are specifically designed to influence labour costs.

Partial budgets treat only one farm activity at a time. Even where farmers are fully commercialized, the net impact of adoption on whole-farm production and resource use cannot be deduced from a partial budget. Cross-activity impacts have rarely been systematically investigated in studies of GM crops, particularly in developing countries.

Partial budgets are also of limited utility in situations with missing or imperfect markets, such as in the case of subsistence food crops in many developing economies. In those cases, the effective prices that influence farmer decision-making depend on the characteristics of individual households and their access to markets, ranging between the consumer and producer price for the food crop. This can be addressed by employing sensitivity analysis based on the price range between the consumer and producer price.

Finally, risk and uncertainty have been considered explicitly in only a few of these studies. Stochastic analysis, Monte Carlo simulations and real option models can be utilized to introduce risk and uncertainty into CBA and partial budget analysis. Given the consistent evidence of outcome variability in the literature, examining the statistical distributions of impact variables (yields, costs, profits), in addition to average impacts, seems fundamental for future work.

4.3.2 Partial and General Equilibrium Analysis

The assumptions behind the partial and general equilibrium—including economic surplus approaches—most closely depict an industry with commercially oriented farmers who buy and sell in well-organized markets and grow their crops under relatively homogeneous conditions. This depiction is quite useful for portraying farmers in developed economies but unrealistic for most farmers in developing economies, and particularly those who produce staple food crops.

The quality of the underlying data is crucial for results validity. Generally, reliable cross-sectional, time-series data to support sector analyses of GM crops are not yet available in developing economies. At present, such data are probably too costly to assemble, maintain and disseminate publicly given the information infrastructure found in most of these countries.

One way researchers have compensated for the lack of large cross-sectional, time-series data has been to expand existing data from both primary and secondary sources using stochastic simulations and real option models, as mentioned above. These tools assume special significance when technologies are developed by farmers in heterogeneous production environments for uncertain markets, where location and year-specific effects on productivity can generate large coefficients of variation in model parameters, including farm profits, adoption rates and prices. If the number of input suppliers is small or markets must be segregated, risk and uncertainty in the market channel may be somewhat higher in the case of GM crops relative to other new crop varieties.

As the most used method to date is the economic surplus approach, additional information about the most common specific methods used under this approach is provided in Table 4.1 This table is useful when choosing between different options. For a more complete discussion of the different economic surplus methods, see Alston et al. (1995) and Alston and Pardey (2001).

The evaluation criteria to choose the appropriate methodology are expediency, available resources, data availability and quality, and the type of research or policy question to be answered. For example, the quasi-rent, standard surplus models and the equilibrium displacement models (EMDs) are very expedient, with little data required, and require relatively few resources to implement. However, the quasi-rent approach can only be thought of as a first approximation to check results from other economic surplus models. The EMDs can model policy implications readily; however, they require the researcher to have advanced knowledge of economic concepts and methods, as well as extensive knowledge of the policy implications in hand.

Table 4.1 Advantages and disadvantages of economic surplus estimation approaches

Estimation approach	Advantages	Disadvantages
Standard models	Very little data required Simple models Most data found in the literature	May be inflexible Linear models may not be appropriate for some production processes
Econometric	Ability to test statistically hypotheses about parameters Possibility of addressing some data problems	Large amount of good quality data required
Equilibrium Displacement Models (EDM)	Ability to model explicit economic and policy considerations Very little data required Data available in the literature	Linear models may not be appropriate for some production processes
Linear programming	Very little data required	Extensive production (engineering) knowledge required In most cases unable to statistically test hypotheses about parameters
Quasi-rent approaches	Expedient Relatively little data required	Converges to standard models of economic surplus only when cost or yield changes are small and when the elasticity of supply is unitary

4.3.3 Regulatory Impact Assessment

Studies about the impacts of regulations on research and development (R&D) and innovation in developed and developing economies have become more frequent. Given the salience of issues related to regulatory impact assessment issues such as supply channel performance, and industrial organization in the development and diffusion of GM crops, quantitative analyses of these issues are particularly needed. In addition, policy issues such as effects on health and the environment have not been adequately addressed. One explanation for the rarity of such studies is that these topics may be less amenable to analysis with conventional, applied research methods. Health and environmental analyses typically require interdisciplinary research design and analysis.

4.3.4 Overarching Issues

4.3.4.1 Developing Economies

Generally speaking, applied researchers must adapt their tools to the empirical context in which they conduct their analysis. This is also true when analyzing the impact of technology adoption on farmers in developing economies. As described in

Tripp (2000), such farmers typically work on small landholdings, and depend on a few key commodities, livestock or aquatic resources for food consumption and sale. Many of these are remote areas, where farmers have poor access to many goods and services, and particularly, modern farm inputs and related information. Smallholder farmers are often cash constrained unless they are linked to markets through farm credit or producer associations.

4.3.4.2 Data Problems

Data are the most critical ingredient in the above assessments. However, historical data series of prices and quantities supplied and demanded are often not available in developing economies. This limits the possibility of time-series econometric analysis. Differences in data collection procedures and definitions also limit the possibility of cross-national and regional comparisons. Survey data collected through interviews with farmers in developing countries, discussions related to various types of bias and ways to address them can be found in studies assembled by Smale and Falck-Zepeda (2012).

4.4 International Arena

The international experience with inclusion of socio-economic issues of benefits to producers and society in biosafety decision-making is relatively weak. Argentina (a non-party to the Cartagena Protocol on Biosafety) has a mandatory process that assesses economic consequence on exports and producer competitiveness. Brazil and Mexico allow the environmental and food/feed risk assessment to proceed. If any socio-economic issue is raised, a third party is then commissioned with a study. India and China do not have a formal requirement in their legislation/policy, but both have conducted socio-economic studies considering benefits to producers or society with different degrees of impact.

4.5 Administrative Consequences

Society can gain knowledge and information of technology impacts on producers and society. Inclusion of socio-economic considerations (SECs) focused on producers and society, especially as a result of thorough assessment studies, can help identify valuable technologies and discard those which are unacceptable for society. Assessment studies can help stakeholders take advantage of the benefits from such technologies by identifying limiting issues relevant to technology deployment and adoption. Furthermore, society can learn much about the multiple feedbacks and links between technology, science, R&D and the users' context in an innovation setting.

Inclusion of studies examining benefits to producers and society can increase regulatory costs of compliance with biosafety and/or technology approval regulations. Conducting socio-economic assessments will unequivocally increase implementation costs. In fact, the more complex and broader the portfolio of issues in an assessment, the more expensive a specific study will be to any developer and to government itself as it leads to a more complex regulatory process. An economic study examining impacts on biodiversity and long-term sociological and anthropological issues on producers will be far more complex (and expensive) to implement than one focused on a very specific topic (e.g. impact of exports/trade or impact on small-scale producers).

The likelihood of asymmetric impact on public sector R&D and public goods also increases. This scenario is particularly crucial to the public sector in developing countries that are likely to develop technologies of a public good nature. In fact, the introduction of additional regulatory hurdles can impact national and international public investments in R&D, which in turn may impact technology flows by causing a reduction in the number of potential technologies available to producers and society. This may be a result of additional regulatory complexity, cost implications and/or uncertainty. Bayer et al. (2010) have shown delays can have a significant impact on the net benefits from the potential adoption of GM crops in the Philippines. This research illustrated that even small delays of three years compared to the baseline can significantly decrease net benefits to producers. Increases in cost of compliance had a very small effect on net benefits. Inclusion of socio-economic studies will increase the cost of compliance and if not done in a careful manner and in close coordination with other assessments processes, they may increase the amount of time necessary to complete a biosafety regulatory assessment process.

Perhaps a more important impact of the inclusion of socio-economics into decision-making is the introduction of additional uncertainty into the process. A workable regulatory system can be defined as one where all elements of society are able to define, describe and trust the process and its outcome. Society actors can thus judge the system based on transparency, participation ability, predictability and robustness and cost and time efficiency. For example, developers (public or private sector) with predictable regulatory systems can attach a value on outcome by projecting potential gains by producers and consumers, and add the respective probabilities of success into their decision-making process. If developers cannot attach such probabilities due to an unpredictable or uncertain process and thus cannot attach success probabilities and calculate potential benefits, the likelihood is that they will not make investments in such jurisdiction.

4.6 Summary/Synthesis

- Sound estimates of the benefits and costs of innovations to producers, consumers and society as a whole are important because this information can be used by decision-makers to improve innovation systems.

- There is an array of approaches used by applied economists to estimate these costs and benefits; no approach is superior, each method has advantages and disadvantages, and the choice of approach depends on the nature of the innovation, the empirical context of the study, its feasibility, data requirements, the research budget, parameter uncertainty and relevance to the socio-economic context.
- A number of issues related to sampling, measurement and parameter variability should be carefully addressed by practitioners.
- Limitations and the applicability of methods are particularly acute when examining costs and benefits in developing agricultural economies. Approaches have been recommended in the literature.
- While there is no 'best' practice, applied researchers should attempt to follow good practice. Practitioners are encouraged to describe the challenges met during study implementation if these may affect study outcomes, and report how they were addressed.

References

Alston JM, Norton GW, Pardey PG (1995) Science under scarcity: principles and practice for agricultural research evaluation and priority setting. Cornell University Press, Ithaca

Alston JM, Pardey PG (2001) Attribution and other problems in assessing the returns to agricultural R & D. Agric Econ 25:141–152

Areal FJ, Riesgo L, Rodriguez-Cerezo E (2012) Economic and agronomic impact of commercialized GM crops: a meta-analysis. J Agric Sci. CJO2012 doi:10.1017/S0021859612000111. Accessed Dec 2012

Bayer, J. C., G. W. Norton, and J. B. Falck-Zepeda. (2010). Cost of compliance with biotechnology regulation in the Philippines: Implications for developing countries. *AgBioForum* 13(1): 53-62. Available online at http://www.agbioforum.org/v13n1/v13n1a04-norton.htm

Falck-Zepeda JB, Traxler G, Nelson RG (2000) Surplus distribution from the introduction of a biotechnology innovation. Am J Agric Econ 82(May 2000):360–369

Demont M, Tollens E (2001) Uncertainties of estimating the welfare effects of agricultural biotechnologies in the European Union. Working Paper Number 58, Department of Agricultural and Environmental Economics, Katholieke Universiteit, Leuven

Falck-Zepeda J, Sanders A, Rogelio Trabanino C, Batallas-Huacon R (2012) Caught between scylla and charybdis: impact estimation issues from the early adoption of GM maize in Honduras. AgBioForum 15(2):138–151. http://www.agbioforum.org

Hofs JL, Fok M, Vaissayre M (2006) Impact of Bt cotton adoption on pesticide use by smallholders: a 2-year survey in Makhatini Flats (South Africa). Crop Prot 25(9):984–988

Huang J, Hu R, Fan C et al (2002) Bt cotton benefits, costs, and impacts in China. AgBioForum 5(4):153–166. http://www.agbioforum.org

National Academy of Sciences of the United States (2000) Transgenic plants and world agriculture. National Academy Press, Washington, DC

Pemsl D, Waibel H, Orphal J (2004) A methodology to assess the profitability of Bt-cotton: case study results from the state of Karnataka, India. Crop Prot 23(12):1249–1257

Pemsl D, Waibel H, Gutierrez AP (2005) Why do some Bt-cotton farmers in China continue to use high levels of pesticides? Int J Agric Sustain 3(1):44–56

Pontifical Academy of Sciences (2001) Science and the future of mankind: science for man and man for science. http://www.casinapioiv.va/content/dam/accademia/pdf/sv99.pdf. Accessed Dec 2012

Potrykus I, Ammann K (eds) (2010) Proceedings of a Study Week of the Pontifical Academy of Sciences New Biotechnology 27(5):445–718

Qaim M (2009) The economics of genetically modified crops. Ann Rev Resour Econ 1:665–694

Smale M, Falck-Zepeda J (eds) (2012) Farmers and researchers discovering biotech crops: experiences measuring economic impacts among new adopters. AgBioForum Special Issue 151(1):7–33

Smale M, Zambrano P, Gruère G et al (2009) Impacts of transgenic crops in developing countries during the first decade: approaches, findings, and future directions. IFPRI Food Policy Review 10. International Food Policy Research Institute, Washington, DC

Smyth SJ, Phillips PWB, Castle D (eds) (forthcoming) Handbook on agriculture, biotechnology and development. Edward Elgar Publishing, Cheltenham

Tripp R (2000) Can biotechnology reach the poor? The adequacy of seed and information delivery. Paper presented at the 4th International Conference on the Economics of Agricultural Biotechnology, Ravello, Italy, 24–28 August 2000