# LINCOLN TRADE AND ENVIRONMENT MODEL-BIOTECHNOLOGY MODULES:

## GENETIC MODIFICATION



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## 1. Brief overview

*Producer impacts*

The current commercial release of first generation GM food affects the production system. The main commercially released GM food crops are herbicide-tolerant (Ht) soybeans and insect-resistant maize, with insect-resistant canola of somewhat less importance (ISAAA, 2003; James, 2001). Thus, nearly all of the current benefits of GM come from the supply side and relate to potential increases in yield and/or reductions in costs (Caswell, et al., 1998; OECD, 2000; USDA, 2000 and 2002).

The impact of GM technology on yield varies by crop type. For herbicide-tolerant (Ht) soybeans, university varietal trials (Benbrook, July 1999) and farmer surveys (Marra, et al., 2002) indicate lower yields in 1997 and 1998, while the USDA (2002) found small yield increases. Data from a 2000 survey of Iowa farms confirms earlier findings of lower yields (Duffy, 2001). Little research has been published on the yield impacts of Ht maize, but Fernandez-Cornejo & Klotz-Ingram (1998, in USDA, 2000) found higher yields. Similarly, little yield research is available for Ht canola, although CEC (2000) cites evidence of mixed impacts. By contrast, maize genetically modified to express an insect toxin from the bacterium *Bt* generally shows yield improvement (Marra, et al., 1998, in USDA, 2000; Duffy, 2001; CEC, 2000). Finally, the use of rbST has increased actual dairy herd productivity, although by less than projected increases (Stefanides & Tauer, 1999; Caswell, et al., 1998)

Several inputs are affected by the adoption of GM crops, including pesticide use, seed costs, and labour and management effort. For pesticides, changes are crop specific. Herbicide-tolerant crops, for example, are generally associated with higher use of glyphosate herbicide (Roundup), but lower use of other herbicides (USDA; 2000; Shoemaker, et al., 2001; Duffy; 2001; CEC, 2000). Whether there is an overall decrease in herbicide use is uncertain, and also depends on how use is measured (USDA, 2002; CEC, 2000; Benbrook, 2001a; Marra, et al., 2002). A different pesticide issue is the effect of *Bt* corn on the use of insecticides, particularly against the European corn borer. Some research suggests that *Bt* corn has led to savings in insecticide costs (Marra, et al., 1998, in USDA, 2000). Other research has found little is any changes in insecticide use in corn (Benbrook, 2001a), and suggests that *Bt* corn is valuable not for savings in insecticide costs, but for protecting farmers' yields (Duffy, 1999 and Furman Selz, 1998, both in CEC, 2000).

Seed costs are higher for GM crops because they require a technology fee. This is largely either found or assumed to be constant across the U.S. (Falck-Zepeda, et al., 2000; Gianessi, et al., 2002; Marra, et al, 2002; Marra, et al., 1998, in Shoemaker, et al., 2001; Gianessi & Carpenter, 2001, in Benbrook, 2001b; Duffy, 2001; CEC, 2000), and to run about $8-$10 per acre for *Bt* corn, for example. However, research by Benbrook (2001b) indicates that the technology fee varies regionally and by corn variety, from a few dollars an acre to as much as US$30 per acre.

Management and labour effort are considered lower for Ht crops, because they make the job of weed management easier. Farmers can use fewer pesticides and have a wider window for their use than with other weed management programmes (USDA, 2002; CEC, 2000; Gianessi, et al., 2002; Benbrook, 2001a; Duffy, 2001). Several studies note this benefit of Ht varieties, but do not try to calculate a value for it. The CEC (2000) reports on research done on GM canola and considers that ease-of-use has been included in the analysis in labour and fuel savings for the GM canola.

The bottom line is the impact of yield and costs changes on net returns. A review of profitability estimates shows that findings are mixed. Ht soybeans have been found to decrease net returns, (Benbrook, 1999), increase net returns (Marra, et al., 1998, in Shoemaker, et al., 2001), or have no effect (Fernandez-Cornejo, et al., 1999, in Shoemaker, et al., 2001; Duffy, 2001; USDA, 2002). It is more difficult to assess the impact on gross margins for *Bt* corn given that it is highly dependent on the level of insect infestation. Again, there are reports of net gains from *Bt* corn (Furman Seltz, 1998, in CEC, 2000; Marra, et al., 1998, in Shoemaker, et al., 2001), net losses (USDA, 2002), and little effect (Duffy, 2001). Net results have also been shown to vary by year, with gains in 1997 and losses in 1998 (Gianessi & Carpenter, in CEC, 2000; Benbrook, 2001b). For Ht corn, the USDA (2002) found improved net farm returns for specialised corn farms. In the case of Ht canola, results are mixed with Fulton & Keyowski (1999) reporting lower returns with GM canola, whereas a study in Alberta in 1999 found both gains and losses (CEC 2000). Marra, et al. (2002) also reported findings of increased profitability from Roundup-Ready canola. Finally, research on the use of rbST has found that profits did not increase (Stefanides & Tauer, 1999; Foltz & Chang, 2002).

One important issue with these estimates of profitability is that the effect of a price differential between GM and non-GM crops is generally not factored into the analyses (e.g., Gianessi, et al., 2002; Duffy, 2001). Much of the research relies on figures from 1997 and 1998 (USDA, 2000 and 2002; Shoemaker, et al., 2001; CEC, 2000; Marra, et al., 2002), and price differentials did not appear until 1999 (CEC, 2000). In that year, premiums of 2% to 6% were reported for non-GM soybeans and maize/corn (Golan, et al., 2000). The assumption of equal prices for both crops may be an accurate portrayal of commodities with supported prices (CEC, 2000; Duffy, 2001), but may not apply to other crops. Thus, these assessments of farm-level profitability do not take into account possible negative consumer reactions to GM food.

*Consumer impacts*

Consumer responses to GM food are important and have not always been positive. As the first wave of commercially released GM crops has only affected production inputs and not enhanced products in ways valuable to consumers, this reaction may not be surprising (CEC, 2000). Moreover, to evaluate GM food ordinary citizens use knowledge of everyday human fallibility and of past behaviour of institutions responsible for the development and regulation of technological innovations and risks (Marris, et al., 2001). These reactions have led to various regulatory and labelling frameworks for GM food, as well as clear positioning by European retailers as providing non-GM food (ANZFA, 2001; CEC, 2000; Phillips & McNeill, 2000).

Studies of consumer attitudes towards GM have been considerable and show that these attitudes vary regionally with, for example, GM being more acceptable in North America than Europe. Studies also conclude that information provision is important in increasing the acceptability of GM, as is the source of that information. However, transgenics and the manipulation of genes in humans and animals have lower acceptability than gene manipulation in plants (Campbell, et al., 2000).

Economic estimates of willingness to pay for non-GM food bear out the results of attitudinal research. Moon & Balasubramanian (2001) found in a contingent valuation survey, for example, that U.S. consumers were willing to pay 37% more and U.K. consumers 56% more to avoid GM food. Choice modelling has found similar results, with sometimes large price differentials between GM and non-GM food that varied by gender and other factors. Thus, James & Burton (2001) found that GM food would have to sell at an average discount of 20% to 47% in Western Australia. Burton, et al. (2001) reported that the group of U.K. respondents most favourably disposed towards GM food would nevertheless be willing to pay a 26% premium to have non-GM products, and other groups were willing to pay much more. Additional evidence of non-GM price premiums comes from auction experiments, which have assessed the willingness to pay for non-GM food, the reaction to different levels of adventitious presence (i.e., co-mingling), and the effects of information provision (Tegene, et al., 2003; Huffman et al. 2001; Rousu et al. 2002). Tegene, et al. (2003), for example, found that U.S. Midwestern consumers discounted 'GM'-labelled products by 14 percent, and reported that their results suggest that mandatory labelling (such as exists in Australia, New Zealand, the European Union, Japan, and South Korea, but not the U.S.) likely reduces demand for GM food products.

Price premiums for non-GM products in international markets began to appear in 1999 (CEC, 2000) with two-tiered pricing structures developing in some markets, such as Japan, Korea, and Europe. The introduction of labelling laws has also encouraged market to source non-GM food, as with the ANZFA laws in Australia and New Zealand (Robertson, 2002). The Tokyo Grain Exchange instituted futures trading in non-GM soybeans in 2000, and these contracts generally trade at a US$0.30 per bushel premium over generic soybean contracts (Parcell, 2002 and 2001).

The results of the market ractions outlined above are that any potential benefits from planting the current commercially released GM crops are further reduced when differential prices are included in the analysis. Even a ten-percent premium for Non-GM products reduces further the incentives to produce GM food. Moreover, if substantial markets begin to ban the use of GM, the negative impacts would be much larger. Of course, it is uncertain how these preferences will develop into the future and whether consumer acceptance will change.

*Trade impacts*

The trade impact of introducing GM has been estimated by several studies. Moschini, et al. (2000) attempt to quantify the effects on production, price and welfare of adoption of roundup ready (RR) soybeans. This study uses a three-region – US, South America and the Rest of the World (ROW) – bilateral partial equilibrium trade model and focuses only on soybeans and soybean products (meal and oil). To model the innovation at the production level, Moschini, et al. (2000) first quantify the per hectare cost, profit and yield effects of RR soybean seed adoption. They then calculate the price effects of quantity changes in the innovator country. The effect of trade polices in their model are assumed to be captured by price differentials between the regions. Finally, Moschini, et al. (2000) quantify the consumer and producer surplus measures of welfare effects of RR adoption in the innovator country and in the other regions. They also provide the welfare effects under the assumption of international technology spill-over from innovator country to other regions. They find that U.S. farmers fare worse when GM technology is made available to others countries and when the technology increases yields as opposed to simply reducing costs.

Nielsen, et al. (2000) analyse the impact of consumers' changing attitude toward genetically modified organisms (GMOs) on world trade patterns, with emphasis on the developing countries. They use a multi-regional computable general equilibrium (CGE) framework that models the bilateral trade among 7 regions: High-Income Austral-Asia, Low-Income Asia, North America, South America, Western Europe, Sub-Saharan Africa and the ROW. Goods are assumed to be imperfect substitutes in the international market.

Nielsen, et al. (2000) allow the GM and non-GM production of maize and soybeans sectors in their model. Initially, they assume an identical production structure in terms of the composition of intermediate input and factor use in the GM and non-GM varieties and also the same structure of exports in terms of destinations for both varieties. The producers and consumers' decision to use GM versus non-GM varieties in their production and final demand respectively is endogenised for maize and soybeans sector. They introduce a 10 % higher level of factor productivity in GM-adopting maize and soybean sectors in all regions as compared with their non-GM counterparts. The factor productivity shocks are introduced in alternative scenarios which differ in terms of the degree to which consumers and producers in high-income regions find GM and non-GM products substitutable. Starting from the perfect substitution case they lower the degree of substitution among GM and non-GM maize and soybeans in production and consumption as the citizens of high-income regions, Western Europe and High-Income Austral-Asia, become more sceptical of the new GM varieties. In the other regions, the citizens are assumed to be indifferent, and hence the two crops remain.

The main findings are that trade diversion becomes significant when the GM-critical regions change their preferences towards Non-GM products. The trade of GM-varieties is found to divert towards GM-favourable markets and Non-GM varieties divert towards GM-critical regions. This is explained as a result of the price differential between GM and Non-GM varieties, which is a consequence of factor productivity differences in the production of these varieties. However, the degree of the price differential and its impact on the supply show differences between the GM-critical and GM-favourable regions. In particular, in GM-favourable regions the prices of the Non-GM varieties declines as well as the price of GM-varieties, due to the high degree of substitution between the two varieties in consumption and to the increased production to supply to GM-critical regions. In the GM-critical regions on the other hand, the price differential impact on the supply of Non-GM goods is minor. Moreover, the high-income regions pay for their preferences largely without affecting the gains in the GM-favourable regions from lower commodity prices.

In a similar work that focuses on production of GM maize and soybean crops, Anderson & Nielsen (2000a) uses a CGE model, GTAP (Global Trade Analysis Project), to quantify the effects on production, prices, trade patterns and welfare of certain countries adopting GM maize and soybean crops[i]. They model three scenarios. First, the GM-adopting sectors experience a one-off increase in total factor productivity (including all primary factors and intermediate inputs) of 5%, thus lowering the supply price of the GM crop Western Europe, Japan, Other Sub-Saharan Africa are assumed to refrain from using or be unable to adopt GM crops in their production systems. In another scenario, the case of a policy and/or consumer response in Western Europe is introduced by banning the imports of maize and soybean products from GM-adopting regions. The distinction between GM-inclusive and Non-GM products is based directly on the country of origin, and labelling costs are ignored. In the third scenario, consumers in Western Europe are assumed to shift their preferences away from imported coarse grain and oilseeds and in favour of domestically produced crops. This scenario involves an exogenous 25% reduction in final consumer and intermediate demand for all imported maize and soybeans.

Anderson & Nielsen (2000a) analyse the impact of policy scenarios on Other High Income economies by showing the change in economic welfare. In the case of GM adoption by other regions (except Western Europe), their findings show that the increase in economic welfare (equivalent variation) of Other High Income group is higher when Western Europe bans the GM imports, compared to 'no policy response' case. The same result also applies when consumer preferences in Western Europe shift towards non-GM varieties and away from GM products. The same results are reported in Anderson & Nielsen (2000b). In addition, they note that the analysis does not account for any increase in welfare European might derive from having access to non-GM products. Furthermore, they note that 'the cost of banning GMO imports in Western Europe amounts to barely US$15 per capita per year – hardly a major impediment to imposing an import ban.' (p. 14). This comment demonstrates the danger of summarising modelling results as welfare changes when dealing with GM food. Without explicating accounting for consumer preferences regarding GM and Non-GM food, it is impossible to calculate welfare changes.

Jackson & Anderson (2003) use a similar GTAP model to estimate intra-national distributive impacts. They model several scenarios, including: increases in productivity enhancements alone and productivity increases with different regulatory and labelling policies. They find that aggregate welfare in North America increases in all model scenarios, but that Australasia gains when other countries ban GM products and lose welfare otherwise. Importantly, they show that European agricultural producers increase their welfare with a ban on GM products, suggesting that pressure for a ban may not be entirely consumer-driven.

Another example of GTAP modelling is a report by the Productivity Commission in Australia (Stone, et al., 2003). The paper assesses the impacts on Australian trade by modelling three main scenarios regarding GM crops : a) an improvement in productivity from GM crops, b) an improvement in productivity plus some consumer resistance to GM and some regulatory costs, and c) a steady-state future with low productivity gains, little consumer resistance, and no regulation. The overall conclusion is that adoption of GM crops will not have a large impact on Australia's trade. The report does however suggest that Australia could lose market share in the long term and therefore export earnings if it does not expand its GM sector.

## 2. Changes in basic behavioral specifics

The LTEM was modified in the present study to quantify the effects of price differential between GM and non-GM varieties of products on agricultural earnings and trade. There are nine countries and 16 agricultural commodities included in the model (see Appendix Table A1 for a list of these). In the LTEM, production in all countries is assumed to be segregated into GM and non-GM components (effectively 28 products are modelled). The GM and non-GM components of a product were assumed to be imperfect substitutes in production and consumption and identical supply, demand, stock and price functions were used for GM and non-GM varieties (similar to the approach used in Nielsen, et al. 2000; Barkley 2002).

The supply response of a GM product was specified as in equation 1. In this equation, the letter $g$ is used to represent the GM component of the product $i$ and subscript $j$ represent substitute commodities. Therefore, supply of a GM product ($qsg_i$) was specified as a function of the supply side shifters ($shf_{qsg}$), producer price of the GM product ($ppg_i$), of the other substitute GM products ($ppg_j$) and of the non-GM component ($pp_i$). A similar functional form and behavioural relationship was also used to reflect the supply response in non-GM product ($qs_i$), equation 2, in which the producer price for GM component ($ppg_i$) also appeared as a substitute product to non-GM component. The own-price elasticity ($ppg_i$) of GM supply was expected to be positive, but the cross-elasticities with respect to the prices of non-GM component ($pp_i$) and other GM products ($ppg_j$) are expected to be negative.

$$qsg_i = \alpha_0 shf_{qsg} ppg_i^{\alpha_1} pp_i^{\alpha_2} \prod_{j=1}^{2} ppg_j^{\alpha_j} \quad 1$$

$$qs_i = \varphi_0 shf_{qs} pp_i^{\varphi_1} ppg_i^{\varphi_2} \prod_{j=1}^{2} pp_j^{\varphi_j} \quad 2$$

The demand in the LTEM was disaggregated into feed, food and processing demand (only food demand is presented below) and the food demand for GM and non-GM varieties were presented in equations 3 and 4. The shifters $shf_{qcg}$ and $shf_{qc}$ in these equations were used to reflect the impact of food demand shifters, such as the changes in consumers' preferences. The food demand for the GM component ($qcg_i$; equation 3) was specified as a function of own-consumer price ($pcg_i$), consumer price of the Non-GM component ($pc_i$), consumer prices of the other GM substitutes ($pcg_i$), per capita real income ($pci$) and population ($pop$). A negative own-price elasticity ($\beta 1$), a positive cross-price elasticity ($\beta 2$) and ($\beta j$), and a positive coefficient on per capita income ($\beta 3$) and population ($\beta 4$) was expected. Similar functional forms and behavioural relationships were also used to reflect the food demand response for non-GM component ($qc_i$), equation 4, in which the consumer price for GM component ($pcg_i$) also appeared as a substitute product in consumption to Non-GM component.

$$qcg_i = \beta_0 shf_{qcg} pcg_i^{\beta_1} pc_i^{\beta_2} pci^{\beta_3} pop^{\beta_4} \prod_{j=1}^{2} pcg_j^{\beta_j} \quad 3$$

$$qc_i = \gamma_0 shf_{qc} pc_i^{\gamma_1} pcg_i^{\gamma_2} pci^{\gamma_3} pop^{\gamma_4} \prod_{j=1}^{2} pc_j^{\gamma_j} \quad 4$$

## References


Anderson, K. and Neilsen, C.P. (2000a). GMOs, food safety and the environment: What role for trade policy and the WTO? Policy discussion paper, No. 0034, Centre for International Economic Research (CIES), September.

Anderson, K. and Neilsen, C.P. (2000b). How will the GMO debate affect the WTO and farm trade reform? Paper prepared for seminars at Massey University, Palmerston North, and the New Zealand Institute for Economic Research, Wellington, 8 & 9 November.

Australia New Zealand Food Authority (2001). Genetically Modified Foods (Brochure). Revised November 2001, downloaded 29 April 2002. http://www.anzfa.gov.au.

Barkley, A.P. (2002). The economic impacts of agricultural biotechnology on international trade, consumers, and producers: The case of corn and soybeans in the USA. Paper presented at the 6th International Consortium on Agricultural Biotechnology Conference, Ravello, Italy, 11–14 July.

Benbrook, C. (2001a). "Do GM crops mean less pesticide use?", *Pesticide Outlook*, October.

Benbrook, C. (2001b). When does it pay to plant *Bt* corn? Farm-level economic impacts of *Bt* corn, 1996-2001. Institute for Agriculture and Trade Policy report, November. http://www.biotech-info.net/Bt_farmlevel_IATP2001.html.

Benbrook, C. (1999). Evidence of the magnitude and consequences of the Roundup-Ready soybean yield drag from university-based varietal trials in 1998. AgBioTech InfoNet Technical Paper Number 1, July. Available at http://www.biotech-info.net/herbicide-tolerance.html.

Burton, M., Rigby, D., Young, T. and James, S. (2001). "Consumer attitudes to genetically modified organisms in food in the UK", *European Review of Agricultural Economics*, *28*(4): 479-498.

Campbell, H., Fitzgerald, R., Saunders, C., and Sivak, L. (2000). Strategic issues for GMOs in primary production: Key economic drivers and emerging issues. CSAFE Discussion Paper #1. Dunedin, New Zealand: Centre for the Study of Agriculture, Food and Environment, University of Otago.

Caswell, M., Fuglie, K., and Klotz, C. (1998). Agricultural biotechnology: An economic perspective. Economic Research Service, U.S. Department of Agriculture, AER No. 687, September.

CEC (2000). *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector.* Commission of the European Communities. Available from http://europa.eu.int/comm/agriculture/public/gmo/fullrep/index.htm.

Dargie, J. (2002). Opening the biotechnology toolbox. *Agriculture21*, Food and Agriculture Organization of the United Nations, January. http://www.fao.org/.

Duffy, M. (2001). Who Benefits from Biotechnology? Paper presented at American Seed Trade Association meeting, December 5 – 7, 2001, Chicago, IL.

Falck-Zepeda, J., G. Traxler, and Nelson, R.G. (2000). "Surplus distribution from the introduction of a biotechnology innovation", *American Journal of Agricultural Economics* 82(2), 360-369.

Foltz, J.D. and Chang, H.H. (2002). "The adoption and profitability of rBST of Connecticut dairy farms", *American Journal Agricultural Economics* 84(4): 1021–32.

Fulton, M. and Keyowski, L. (1999). "The producer benefits of herbicide-resistant canola", *AgBioForum* 2 (2) Spring.

Gianessi, L., Silvers, C., Sankula, S., and Carpenter, J. (2002). Plant biotechnology: Current and potential impact for improving pest management in U.S. agriculture. Washington, D.C.: National Center for Food and Agricultural Policy, June.

Golan, E., Kuchler, F. and Mitchell, L. (2000). Economics of food labelling. U.S. Department of Agriculture, Economic Research Service, AER No. 793, December.

Huffman, W., Shogren, J., Rousu, M., and Tegene, A. (2001). The value to consumers of GM food labels in a market with asymmetric information: Evidence from experimental auctions. Paper presented at the Annual Meeting of the American Agricultural Economics Association, Chicago, Illinois, August.
International Service for the Acquisition of Agri-biotech Applications (ISAAA) (2003). 2002 global GM crop area continues to grow for the sixth consecutive year at a sustained rate of more than 10%. Press release, 16 January. http://www.isaaa.org/.
Jackson, L. & Anderson, K. (2003). Why are US and EU policies toward GMOs so different? Estimating intra-national distributive impacts using GTAP. Paper prepared for the 6th Annual Conference on Global Economic Analysis, 12-14 June.
James, C. (2001). "Global status of commercialised transgenic crops: 2001", *ISAAA Briefs* No. 24: Preview. Ithaca, NY: ISAAA.
James, S. & Burton, M. (2001). Consumer attitudes to GM foods: Some preliminary results from Western Australia. In R. Fraser & J. Taylor (eds.), *Research Profile: Agricultural and Resource Economics at the University of Western Australia in 2001*. Perth: University of Western Australia.
Marra, M., Pardey, P. and Alston, J. (2002). The payoffs to agricultural biotechnology: An assessment of the evidence. Washington, D.C.: International Food Policy Research Institute, January.
Marris, C., Wynne, B., Simmons, P. and Weldon, S. (2001). Public perceptions of agricultural biotechnologies in Europe. Commission of European Committees, December.
Miles, N. (2002). GM contamination spreads in Mexico. BBC News, 9 June. http://news.bbc.co.uk/.
Moon, W. and Balasubramanian, S.K. (2001). Public perceptions and willingness-to-pay a premium for non-GM foods. *AgBioForum, 4* (3&4). http://www.agbioforum.org/.
Moschini, G., Lapan, H. and Sobolevsky, A. (2000). "Roundup Ready Soybeans and Welfare Effects in the Soybean Complex", *Agribusiness*, *16* (1), 33-55.
Nielsen, C.P. and Anderson, K. (2000). Global Market Effects of Adopting Transgenic Rice and Cotton. Mimeo. Centre for International Economic Research (CIES), May.
Nielsen, C.P., Robinson, S. and Thierfelder, K. (2000). Genetic Engineering and Trade: Panacea or Dilemma for Developing Countries? Paper prepared for presentation at the Third Annual Conference on Global Economic Analysis, Melbourne, Australia, June.
OECD (2000). Modern biotechnology and agricultural markets: A discussion of selected issues. Directorate for Food, Agriculture and Fisheries, Committee for Agriculture, September.
Parcell, J. (2002). Emerging IP markets: The Tokyo Grain Exchange non-GMO soybean contract. Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, Missouri, 22-23 April.
Parcell, J. (2001). "An initial look at the Tokyo Grain Exchange non-GMO soybean contract", *Journal of Agribusiness* 19 (1),85-92, Spring.
Phillips, P. and McNeill, H. (2000). "A survey of national labelling policies for GM foods", *AgBioForum*, 3 (4): 219-224. Available from http://www.agbiogforum.org
Robertson, David (7 February 2002). "Marking Time: Australian Rules on Genetically Modified Food Labels Aren't As Tough As They're Made Out To Be", *Far Eastern Economic Review*, 165(5): 41.
Rousu, M., Huffman, W., Shogren, J. and Tegene, A. (2002). Are US consumers tolerant of GM foods? Paper presented at the 6th International Consortium on Agricultural Biotechnology Research Conference, Ravello, Italy, July.
Sanderson, K., Saunders, C.M., Nana, G., Stroombergen, A., Campbell, H., Fairweather, J. and Heinman, A. (2003). Economic Risks and Opportunities from the release of GMOs in NZ. Wellington: Report to the Ministry for the Environment, March.
Schnepf, R., Dohlman, E. and Bolling, C. (2001). Agriculture in Brazil and Argentina:

Developments and prospects for major field crops. Washington, D.C.: Economic Research Service, U.S. Department of Agriculture, WRS-01-3, November.
Shoemaker, R., Harwood, J., Day-Rubenstein, K., Dunshay, T., Heisey, P., Hoffman, L., Klotz-Ingram, C., Lin, W., Mitchell, L., McBride, W. and Fernandez-Cornejo, J. (2001). Economic Issues in Agricultural Biotechnology. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture, Agriculture Information Bulletin No. 762, February.
Stefanides, Z. & Tauer, L. (1999). "The empirical impact of bovine somatotropin on a group of New York dairy farms", *American Journal of Agricultural Economics,* 81 (1), 95-102.
Stone, S., Matysek, A. and Dooling, A. (2002). Modelling possible impacts of GM crops on Australian Trade. Staff Research Paper. Melbourne: Productivity Commission, October.
United States Department of Agriculture (USDA) (2002). Adoption of bioengineered crops. Agricultural Economic Report No. 810.
United States Department of Agriculture (USDA) (2000). Genetically engineered crops for pest management in U.S. agriculture: Farm level effects. Agricultural Economic Report No. 786.

## Appendix

***Table A1: Country and commodity[*] coverage***

| *Countries* | *Commodities* | |
|---|---|---|
| Argentina | Wheat | Raw milk |
| Australia | Coarse grains | Liquid milk |
| Canada | Maize | Butter |
| European Union (15) | Beef and veal | Cheese |
| Japan | Sheepmeat | Whole milk powder |
| Mexico | Oilseeds | Skim milk powder |
| New Zealand | Oilseed meals | |
| United States of America | Oils | |
| Rest of World | Apples | |
| | Kiwifruit | |

[*] Each commodity is included as GM and non-GM components.

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[i] Nielsen & Anderson (2000) also tries to quantify the effects on production, prices, trade patterns and national economic welfare of certain countries adopting GM cotton and rice in another study by employing the same approach used in Anderson & Nielsen (2000a).