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Golden Rice and the Looming GMO Trade Debate: Implication for the Poor

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Golden Rice and the Looming GMO Trade Debate: Implication for the Poor

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ABSTRACT

The first generation of genetically modified crop varieties, currently most widespread in the maize and soybean sectors, sought to increase farmer profitability by improving agronomic traits. The next generation of biotech research is focusing also on breeding for attributes desired by consumers. Although not yet commercially available, a new variety of rice, known as ‘Golden Rice’, has been genetically engineered to contain a higher level of vitamin A. Thus in contrast with the current commercial applications of biotech crops, this new rice variety aims directly at benefiting consumers rather than producers. More specifically, it aims at improving the health of poor people in developing countries who rely on rice as their main staple food (or would be if it was cheaper) and whose diet is nutrient-deficient. This paper analyses empirically the potential economic effects of such an innovation in an environment of heated debates about the risks and benefits of these biotech developments. The emergence of genetically modified foods is generating policy reactions that are delaying the development and adoption of what promises to be a high-payoff technology, particularly for the world’s poor. These policy reactions may lead to trade disputes, in which case the way this GMO issue is addressed in the WTO’s dispute settlement body could have profound implications for poor households in developing countries.

Key words: GMOs, golden rice, rice policy, WTO agreements, consumer preferences

JEL Codes: C68, D58, F13, O3, Q17, Q18

1. Introduction

The use of genetic engineering techniques in agriculture and food production is seen as an exiting and valuable development by many people who welcome the improvements in production efficiency that they offer to farmers and the enhanced nutritional value that is envisioned to benefit consumers. Others, however, are objecting strongly, raising environmental, food safety, and ethical concerns. A majority of people in Western Europe, Japan and Australia, for example, want at least to have labels on products that contain genetically modified organisms (GMOs), while the most extreme opponents want to see genetically modified (GM) crops completely excluded from production and consumption in their country.

The emergence of genetically modified foods has generated a variety of policy reactions in different countries. The most extreme of these could lead to trade disputes in the World Trade Organization (WTO). Regardless of whether developing countries are exporters or importers of agricultural crops, they will be affected by the biotech policies adopted in countries with which they trade – especially if international trade disputes concerning GMOs emerge. The strong consumer skepticism toward genetic engineering in some countries, particularly in Europe, will also define the trading environment in which developing countries must compete. China, for example, found its exports of processed foods to the United Kingdom being restricted in 2000 because they may have contained traces of GM soybean imported by China from the United States. In turn China placed a moratorium both on soybean imports from the US and on the use of GM varieties by its own farmers for food and feed (but not cotton) production.

The use of genetically modified crop varieties is currently most widespread in the maize and soybean sectors. These first-generation GM crops have improved agronomic traits such as resistance to pests and diseases, and tolerance of specific chemical herbicides. The development of plants with such attributes aims at increasing farmer profitability, typically by reducing input requirements and hence costs. Over time, as the adoption of such lower-cost technologies spreads, this outward shift in the supply curve would lower the consumer price of food.

A second generation of GM crops is focusing on breeding for attributes desired by consumers. Although not yet commercially available, a recent example of such biotech research involves a new variety of rice, known as 'Golden Rice', which has been genetically engineered to contain a higher level of beta-carotene in the endosperm of the grain (Ye et al. 2000; Beyer et al, 2002).[1] In contrast to the current commercial applications of biotech crops, this new rice variety aims directly at benefiting consumers rather than producers. More specifically, it aims at improving the health of poor people in developing countries that rely heavily on rice as their main staple food – or would do if it was cheaper (in place of less nutritious staples such as maize and sweet potato). As with the first-generation GM technology that focused on reducing producers' unit costs, the benefits over time will be shared between producers and consumers, and hence between adopting and non-adopting countries – or would be if countries remain open to international trade in these products.

This paper analyses the prospective impacts of countries adopting Golden Rice technology. First, a brief overview of the current status of genetic engineering in agriculture is given, including a discussion of consumer attitudes toward GM food and how the markets have already begun to react hereto. Then the paper elaborates on ways in which the emergence of GMOs is prompting the development of national regulations and international agreements that could raise difficulties and potentially lead to trade disputes in the WTO. Also considered are labeling schemes, as a means of addressing certain consumers' skepticism and their claim of a 'right to know'. The case of Golden Rice is then addressed by discussing similarities and differences with biotech varieties of maize and soybeans that are currently being produced and traded on commercial terms. Some recent empirical simulation results of possible benefits of Golden Rice are then presented and reviewed. The paper concludes by drawing out implications of the analysis for the WTO and developing countries.

2. Current status of genetic engineering in agriculture[2]

Genetic engineering techniques and their applications have developed rapidly since the introduction of the first genetically modified plants in the 1980s. In the year 2001 genetically modified crops occupied 53 million hectares of land – a considerable expansion from 1.7 million hectares in 1996 (James 1997, 1999, 2000, 2001). Cultivation of transgenic crops has so far been most widespread in the production of soybeans and maize, accounting for 63% and 11% of total transgenic crop area in 2001, respectively. Cotton and canola (rapeseed) made up much of the rest, with only small areas devoted so far to GM linseed, cantalope, papaya, potato, squash, sugarbeet, tobacco and tomato.

[1] Beta-carotene does not occur naturally in the endosperm of rice, hence the need for genetic modification (Bouis 2000).
[2] Sections 2 and 3 of this paper draw on the authors' earlier work in this field. See e.g. Nielsen and Anderson (2001a,b) and Nielsen, Thierfelder and Robinson (2001).

The United States holds almost three-fourths of the total crop area devoted to genetically modified crops. Other major GM-producers are Argentina, Canada and China. Up till now the vast majority of global transgenic crops have been grown in industrial countries, but the recent uptake of GM crops has been most rapid in developing countries. Of the 11% increase in transgenic crop plantings between 1999 and 2000, 84% of this was in developing countries. Hence, the proportion of transgenic crops grown in developing countries increased from 14% in 1997 to 24% in 2000 (James 2001).

Continued expansion in the use of transgenic crops will depend in part on the benefits obtained by farmers cultivating transgenic instead of conventional crops relative to the higher cost for transgenic seeds. So far the improvements have been not so much in increased yields per hectare of the crops but rather by reducing costs of production (OECD 1999). That is, genetic engineering in agriculture has mainly been used to modify crops so that they have improved agronomic traits such as tolerance of specific chemical herbicides and resistance to pests and diseases (James 2001). The development of transgenic plants with enhanced agronomic traits aims at increasing farmer profitability, typically by increasing factor productivity.

Genetic modification can also be used to improve the final quality characteristics of a product to the benefit of the final consumer, perhaps via the food processing industry or livestock producers. Such traits may include enhanced nutritional content, improved durability and better processing characteristics. This type of crop will in many cases sell at a higher market price to the extent consumers perceive it as a different, better-quality product. Most of these types of modification are still in the research pipeline.

One such GM crop – vitamin A enhanced rice, known as Golden Rice – is in an advanced stage of being developed for commercial use in China (as well as being worked on at the international Rice Research Institute in the Philippines). It has the potential of alleviating vitamin A deficiency problems in many developing countries. This could have profound implications in developing countries, especially among the poor where Vitamin A Deficiency (VAD) is a major problem. It is estimated that up to 0.5 million VA-deficient children go blind every year. VAD also weakens the immune system, thereby increasing the incidence and severity of infectious diseases and infant mortality rates. For adults, the implications can be serious too, especially for pregnant and lactating women. Nearly 0.6 million women die from childbirth-related causes each year, many of them from complications which could be reduced through better provision of VA (Sommer and West 1996). Needless to say these problems are greatest among the poorest households in developing countries (Zimmermann and Qaim 2002).

Consumer acceptance or rejection

A factor that is at least as important in determining the extent of continued expansion of transgenic crop plantings and the development and adoption of new GM varieties is consumer attitudes. Certain very strong and vocal consumer groups in developed countries are particularly skeptical about the use of GMOs in food production and demand non-GM varieties be kept separate from GM varieties.

The apparent lack of direct consumer benefits from the current generation of GM foods has not helped foster consumer confidence in GM foods. Consumer concerns over GMOs relate to ethics, in addition to food safety and environmental concerns. Many consumers, particularly in Europe, do not accept the argument that genetic engineering is simply an extension of traditional plant breeding. They find it immoral to interfere with the genetic structure of species. On food safety, the typical issue raised relates to potential allergenic risks such as in the case of Brazil nut traces in GM soybeans. The environmental concerns relate to potentially harmful effects on non-target species, pollen drift, and the development of resistance. Furthermore, consumers demand a 'right to know' about food production methods in general, and about the use of genetic engineering in particular.

Segregated GM and non-GM markets

The sharp reaction against genetic engineering by some consumers has already initiated the creation of differentiated marketing systems for GM and non-GM maize and soybeans (e.g., in the United States). Consumer attitudes will be an important determinant for the profitability and hence the viability of markets for non-GM varieties in the longer term. For commercial producers it is a matter of assessing the benefits and costs of gaining access to niche markets for non-GM crops relative to the benefits of perhaps lower production costs associated with cultivating GM crops. Furthermore, many consumers are not only critical of the use of genetic engineering techniques in the production of bulk commodities such as soybeans and cereal grains. They are also concerned about GM ingredients in animal feed and processed foods. To the extent that consumers are in fact willing to pay the additional costs of having these preferences, identity preservation systems will develop so that these demands can also be satisfied.

Producers in some countries may benefit from the establishment of segregated agricultural markets for GM and non-GM products, depending on three factors: (a) the strength of opposition toward GM products in important markets (be they domestic or foreign), (b) the costs of segregating product throughout the supply chain, and (c) the difference in productivity between GM and non-GM production. In principle these countries may choose to grow GM crops for (domestic or foreign) markets where consumers are indifferent as to GMO content, and to supply GMO-free products to markets where consumers are willing to pay a premium for this characteristic. Such a market development would be analogous to the niche markets that have developed over recent decades for organic foods.

The demand for non-GM varieties could very well expand rapidly. Maize and soybeans are used as ingredients in a wide range of processed foods as well as in animal feed products. Hence food processing industries and livestock producers need to consider the consequences of their input choices both in terms of domestic and foreign demand. The European demand for certified non-GM animal feed soared in 2001 after supermarkets agreed to pay a premium to keep their concerned consumers happy (Reuters 2001a). The demand for non-GM soy meal, for example, is being satisfied by imports from Brazil, which has declared itself a non-GM agricultural producer. After the US, Brazil is the world's second largest producer of soybeans.

Current methods of testing a food product for possible GMO content are not completely reliable. Heating genetically modified maize, for example, eliminates the genetically modified proteins. This renders current testing methods unsatisfactory if the information demanded by consumers is whether or not genetic engineering techniques have been used at any stage in the production process. Therefore, in order to provide consumers with the choice of purchasing guaranteed non-GM foods, the principles of identity preservation (IP) must be followed throughout the food marketing system. IP systems are well known from existing specialty markets (e.g. high-oil maize), but are also applied to a greater or lesser extent for almost all traded agricultural products. After classification has taken place, the subsequent handling, storage and processing systems must ensure that the identity of the product is retained throughout the supply chain – as far and as detailed as the final user or the regulatory authorities require (see Buckwell et al. (1999) for a more detailed discussion of the economics of IP systems). Identity preservation systems to enable reliable labeling of food can be costly, however, and more so the more stages of processing or intermediate input use a crop product goes through before final consumption. An early European survey suggests full traceability could add 6-17% to the farm gate cost of different crops (European Commission 2000), although subsequent analyses indicate that the impost is likely to be somewhat lower particularly after the initial setup costs have been met.

3. What is the GMO trade debate about?

As the use of genetic engineering moves into its second generation and increasingly provides quality-enhanced foods (e.g. better nutritional content, improved durability), consumer attitudes toward GMOs may change. Nevertheless, as long as environmental and food safety consequences remain uncertain there will be some consumers who wish to avoid GMOs altogether. Sheldon (2001) asserts that the public concerns voiced in Europe are mainly a popular movement rather than an explicit attempt to introduce barriers to trade: consumers feel that they are bearing heavy risks while capturing few benefits. Will a successful Golden Rice story carry more weight in the minds of well-to-do European consumers? To help answer that question, we consider first the wide array of approaches to national regulation of GMOs and then some international responses.

National regulations

The differences in approaches to GMO regulation are most stark between the US and the EU, and they have the potential to have a significant impact on trade both between them and with third countries. Because of that, trade in agricultural biotech products could easily become a controversial issue within the World Trade Organization (WTO). The US might accuse the EU of using this issue as an excuse for replacing farm price-support policies, which are being phased down following the Uruguay Round Agreement on Agriculture, with technical barriers to trade using consumer concerns as an excuse. Reuters quoted the US Agriculture Secretary as having said that it would be difficult for the US to accept the EU's recent proposal on labeling of genetically modified foods (based on a tight system of tracing and labeling products at every step ‘from farm to fork’) as not trade distorting.[3] The possibility of challenging the proposal at the WTO was mentioned explicitly.

The resistance to GMO production and use triggered in October 1998 the imposition of a *de facto* moratorium on the authorization of new releases of GMOs in the European Union (EU), pending stricter regulation in this areas. The European Commission has now proposed a very strict approval, traceability and labeling policy for GMOs, which is expected to be accepted by all 15 EU member states for implementation in late 2002 or in 2003. Hence, the EU is now commencing the tough job of trying to get all 15 EU members to agree to lift the three-year moratorium. By contrast, the permit procedure in the United States is far simpler and faster (see e.g. Nelson et al. 1999). With regard to genetically modified foods, the United States Food and Drug Administration (FDA) does not distinguish between foods produced from genetically modified crops and foods produced from crops developed by other technologies. This means that genetically engineered foods and food ingredients must meet the same safety standards as other food products (Food and Drug Administration 1995).

There are also marked differences in national labeling requirements. The US Food and Drug Administration does not require labeling of GM foods *per se*, but only if the transgenic food is substantially different from its conventional counterpart. The EU, by contrast, requires labeling of all foodstuffs, additives and flavors containing 1% or more genetically modified material (Regulations 1139/98 and 49/2000). Individual countries within the EU have added further requirements (OECD 2000).

Numerous non-European countries, including some developing countries, have also enacted GMO consumer legislation. Japan, Australia and New Zealand have introduced mandatory labeling for all foods containing GMOs. Many developing countries also are beginning to develop regulations related to genetically engineered products. Operational field-testing regulations have, for example, been implemented in Argentina, Brazil, Mexico, Chile, Costa Rica, Cuba, India, the Philippines and Thailand.

International trade agreements

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[3] Reuters (2001b). It is not only the Americans that find the EU proposal costly. The Food Standards Agency of the UK is clearly worried that the Commission's proposals are unenforceable, impractical and unaffordable, and that they will not

The Cartagena Protocol on Biosafety

Given the different attitudes and national approaches to regulation of genetically modified products, future trade disputes are a distinct possibility. The Cartagena Protocol on Biosafety (finalized in Montreal on 29 January 2000 as a part of the 1992 Convention on Biological Diversity) may have added to that likelihood. The Biosafety Protocol has the objective of ensuring safe transboundary movement of living modified organisms resulting from modern biotechnology. If ratified by the parliaments of 50 signatories, the Protocol will not only reconfirm the rights of ratifying countries to set their own domestic regulations but also allow each country to decide whether and under what conditions it will accept imports of GM products for release into the environment (for example, as planted seeds). This condoning of import restrictions appears also to apply to GMOs intended as food, feed or for processing.[4] Importantly, the Protocol stipulates that lack of scientific evidence regarding potential adverse effects of GMOs on biodiversity, taking into account also the risks to human health, need not prevent a ratifying country from taking action to restrict the import of such organisms in order to reduce perceived risks (UNEP 2000). In essence, this reflects an acceptance of the guiding influence of the precautionary principle, that is, "better safe than sorry".[5] The Protocol requires that GMOs intended for intentional introduction into the environment or for contained use must be clearly identified as living modified organisms; but modified organisms intended for direct use as food or feed,

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necessarily provide consumers with the information they demand (see Agra Europe, 5 October 2001).

[4] Details concerning the latter products are still to be decided, however, pending the findings of the FAO/WHO Codex Alimentarius Commission's Ad Hoc Intergovernmental Task Force on Foods Derived from Biotechnology. There is uncertainty because while the Protocol relates to biosafety rather than human safety, the phrase "… taking into account effects on human health …" survived the drafting process. The Codex Task Force was due to report within four years of its creation in June 1999, but its progress has been slower than anticipated.

[5] The precautionary principle implies that considerations of human health and the environment rank higher than possible economic benefits in circumstances where there is uncertainty about the outcome.

or for further processing, just require a label stating that the product "may contain" such organisms. No labeling requirements for processed foods such as cooking oil or meal were established by the Protocol.

The WTO agreements and transgenic products

An important aspect of the Biosafety Protocol that is unclear and hence open to various interpretations concerns its relationship with the WTO agreements. The text states that the "Protocol shall not be interpreted as implying a change in the rights and obligations of a Party under any existing international agreements", but at the same time the Protocol claims that this statement is "not intended to subordinate [the] Protocol to other international agreements" (UNEP 2000 p.1). Certainly the Protocol's objective of protecting and ensuring sustainable use of biological diversity whilst also taking risks to human health into account is not inconsistent with WTO agreements. The WTO acknowledges the need of member states to apply and enforce trade-restricting measures in order to protect human, animal or plant health and life as well as public morals. That right for a country to set its own environmental and food safety regulations at the national level is provided for in Article XX of the GATT. But the key goal of the WTO is to achieve efficient use of the world's resources by reducing barriers to international trade. For that reason WTO members also have agreed to not use unduly trade-restrictive measures to achieve environmental or food safety goals. More than that, such measures must be consistent with the key principles of the WTO: non-discrimination among member states, 'national treatment' of imports once having entered the domestic market, and transparent customs procedures. Whether the current WTO agreements prove to be in conflict with the rights to restrict trade in living modified organisms apparently provided for in the Biosafety Protocol, only time – and possibly legal proceedings via the WTO's Dispute Settlement Body – will tell.

Members of the WTO also have trade obligations under other WTO agreements that restrict the extent to which trade measures can be used against GMOs. More specifically related to food safety and animal and plant health are the Agreement on Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT). These agreements allow member states to impose certain restrictions on trade if the purpose of the measure is to protect human, animal or plant life and health. The TBT agreement also covers technical measures aimed at protecting the environment and other objectives. At the same time the agreements aim at ensuring that applied measures and technical regulations are no more trade-restrictive than necessary to fulfill the stated objectives.

Both the SPS and TBT agreements encourage the use of international standards, guidelines and recommendations where they exist, such as in the realms of the Codex Alimentarius (the FAO's international food standards body). Currently there are no international standards for genetically modified products,[6] although the Biosafety Protocol explicitly notes that signatories "shall consider the need for and modalities of developing standards with regard to the identification, handling, packaging and transport practices, in consultation with other relevant international bodies." (UNEP 2000 p. 10, Article 18.3.) International harmonization of regulatory approval procedures for genetically modified products is currently under discussion in several forums including the FAO and OECD. The establishment of international standards for the production, regulation and labeling of these products may be helpful as a way of reducing future trade disputes among developed countries – but could impose onerous compliance costs on poorer GM-exporting countries.

[6] However, the Codex Committee on Food Labelling is currently considering the adoption of an international standard on GMO labelling.

Under the SPS agreement a country may apply higher than international standards *only* if these can be justified by appropriate scientific risk assessments. In other words, while the SPS agreement explicitly allows member states to set their own standards for food safety and animal and plant health, it requires that measures be based on scientific risk assessments in a consistent way across commodities. The TBT agreement is more flexible because member states can decide that international standards are inappropriate for a number of other reasons, such as national security interests (GATT Article XXI). Hence it is of key importance to determine by which WTO agreement a given trade measure is covered. The SPS agreement covers food safety measures and animal and plant health standards regardless of whether or not these are technical requirements. The TBT agreement, on the other hand, covers all technical regulations, voluntary standards and compliance procedures, except when these are sanitary and phytosanitary measures as defined in the SPS agreement (WTO 1998a).

The SPS agreement's scientific requirement is important because it is more objective than the TBT agreement's criteria for determining what is a justifiable trade restriction and what is hidden protectionism. On the other hand, the SPS agreement may be inadequate for legally justifying restrictions introduced on the basis of some vocal groups' opposition to GM foods. Official disputes about trade in genetically modified products have not yet materialized[7], but experience from earlier WTO dispute settlement cases comparable to the GMO debate give an indication as to how the existing rules may be applied. The SPS agreement was used, for example, in the beef hormone dispute between

[7] Thailand did formally object to Egypt's ban on GM imports in the latter half of 2000, but the matter was settled without going to the trouble of setting up a Dispute Settlement panel at the WTO. It objected not to Egypt's right to impose a ban, but rather to the fact that Thai exports were singled out for exclusion. The US threatened to take the EU to WTO dispute

the US and the EU (WTO 1998). In short, the EU import ban on meat and meat products from hormone-fed livestock was found to be in conflict with the EU's WTO obligations, the main argument being that the EU could not present documented scientific risk assessment of the alleged health risk to justify the ban.

Scientific evidence is not always sufficient for governments to make policy decisions, or it may simply be unavailable. In such cases, Article 5.7 of the SPS agreement allows WTO member states to take precautionary measures based on available pertinent information. At the same time, members are obliged to seek additional information so that a more objective evaluation of the risks related to the relevant product or process can be made within a reasonable period of time. The precautionary principle is an understandable approach to uncertainties about genetically modified products, but there is a risk that when used in connection with internationally traded products, it can be captured by import-competing groups seeking protection against any new technology-driven competition from abroad. It may thus be extremely difficult to assess whether a measure is there for precautionary reasons or simply as a form of hidden protectionism. For this reason, attention will focus acutely on how the provisions of the Biosafety Protocol – the most explicit acceptance of the use of the precautionary principle in an international trade agreement relating to food products to date – are interpreted given current WTO commitments.

The existing trade agreements deal with regulations and standards concerning not just products but also production processes and methods *if but only if they affect the characteristics or safety of the product*

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settlement in early 2003, but postponed that action in the hope of securing France and Germany’s approval in the UN Security Council for military action against Iraq.

itself: Standards for production processes that do *not* affect the final product are not covered by the existing agreements. In relation to genetically engineered products, if the process itself were to alter the final product in such a way that there are adverse environmental or health effects associated with consumption, use or disposal of the product, restricting trade in this product need not violate existing WTO rules, ceteris paribus. However, if genetic engineering only concerns the production process and not the final characteristics of a transgenic product, domestic regulations that restrict the use of this method of production cannot be used to restrict imports of products produced by this method simply because the importing country finds it unacceptable by its own environmental, ethical or other norms.[8]

This discussion leads back to the role of scientific evidence. Some would argue that genetically modified products are different from conventional products *regardless* of whether this can be verified scientifically in the final product. One of the priorities of the European Commission in the next WTO round of multilateral trade negotiations is to obtain a clarification of the role of non-product-related processes and production methods within the WTO (European Commission 1999). If trade restrictions based on production methods are allowed, this could lead to the inclusion of a long list of non-tariff barriers, and not only in relation to biotechnology products.

Labeling of foods in relation to international trade is normally covered by the TBT agreement unless the label relates directly to food safety, in which case it is covered by the SPS agreement. Only labeling programs that concern production processes affecting the final product would be covered by the existing TBT agreement. Determining whether or not a genetic modification affects the final product

[8] This product/process distinction became (and has remained) prominent at the WTO as a result of the famous tuna-dolphin case in the early 1990s. The general issue continues to be hotly debated. See, for example, the recent paper by Howse and

will probably have to be done on a case-by-case basis. Where labeling programs are not encompassed by the TBT agreement, which potentially may be the case for many transgenic products, the other agreements of the WTO will be applicable without exceptions (Tietje 1997). GATT Article III concerning non-discrimination, for example, stipulates that member states may not discriminate between otherwise like goods on the basis of their country of origin. A key issue using this Article will be the interpretation of the concept of ‘like goods’ and whether the presence of genetically modified material is ‘sufficient’ to differentiate products. Article III seeks to avoid measures that are based on a false differentiation of products.

In short, the emergence of GMOs in agricultural and food production introduces several new and contentious issues to be dealt with by the WTO membership and ultimately its Dispute Settlement Body (DSB). The DSB has not yet been able to resolve the dispute over the EU’s ban on imports of beef produced with growth hormones (WTO 1998), so it is difficult to see how it will be able to do any better with the far more complex issue of GM products should the EU choose to ban their importation too – particularly now that there is a Biosafety Protocol on the table condoning the use of the precautionary principle and suggesting scientific evidence need not prevent importing countries from restricting GM trade. Mandatory labeling requirements of all GMO-inclusive products including processed foods such as the proposal of the European Commission will probably not violate existing WTO rules as long as they do not discriminate between foreign and domestic goods. Such requirements will add significantly to trade costs, however, and are triggering threats of challenges at the WTO (e.g., from the US – see footnote 7 above).

Regan (2000).

A major international trade dispute concerning GMOs could prove very harmful to agricultural-exporting countries, in particular those countries that are highly dependent on exporting to Western Europe. Even if these countries were fortunate enough to benefit from the new technology in producing for their own consumption, they might risk having their products refused at the European borders solely because they are genetically modified. A market-based segregation of agricultural production into GMO-inclusive and GMO-free varieties, on the other hand, would allow for a broader choice of production methods, particularly if GMO-free products carry a price premium. This would, however, require the imposition of comprehensive testing, certification and labeling systems that can satisfy the requirements of importing countries. Such systems may prove to be very demanding financially and in terms of technical expertise, especially for developing countries. Furthermore, for the label to be meaningful abroad for exported GM-free products, multilateral agreement on that threshold would be needed.

4. Golden Rice in the context of international trade

The above discussion reveals that there are a number of potentially contentious issues relating to trade in genetically modified foods. Whether or not these issues develop into actual trade disputes only time will tell. However, if they do, there is a risk that the second generation of GM foods, that have the potential of benefiting consumers directly, may never materialize. Perhaps the most important of these is Golden Rice, which has been developed specifically to combat vitamin A deficiencies.

As already mentioned, optimists view Golden Rice as having the potential of improving the lives of millions of the poorest people in the world. Judging by the current intake of vitamin A and beta-carotene, Robertson et al. (2001) assert that Golden Rice could significantly boost total intake, and recommend Golden Rice as a vitamin A intervention strategy for Asia especially due to rice's unique position as the main food staple in Asia. Robertson et al. (2001) do, however, mention five unresolved issues: (i) it is uncertain how much vitamin A can in fact be delivered through Golden Rice, (ii) consumer acceptance is uncertain[9], (iii) success of Golden Rice depends in part on expanding nutritional education, (iv) potential food safety concerns need to be resolved, and (v) the costs of supplying Golden Rice may be high because there will be higher seed costs as well as costs related to keeping Golden Rice production and marketing channels separate from other rice channels. The authors conclude that Golden Rice is probably best seen as a supplementary strategy for addressing nutrition problems in developing countries. Whether Golden Rice can play even that more limited role depends on the extent to which the technology *per se* gets caught up in the very polarized debate at the international level.

What makes Golden Rice different?

To date, the discussion about GMOs in an international trade context has focused on the two main GM crops, maize and soybeans, and how trade in these commodities would be affected by policy choices in regions hostile to this biotechnology, Western Europe being the strongest opponent. Nielsen and Anderson (2001b), for example, examine the consequences of a Western European ban against imports

[9] The acceptance of new rice varieties (particularly in Asia) is paramount to their success. Consumer preferences for specific rice varieties are very sensitive and depend on their taste, color and cooking properties.

of GM commodities and of a more market-oriented policy solution based on labeling. The findings are that an import ban would be very costly to the Western European region itself given its relatively strong dependence on imports of especially soybeans (but also maize) from regions that are enthusiastic adopters of GM varieties.

Nevertheless, several GM varieties are judged as being safe for both the environment and consumers, even in Europe. The most recent policy developments therefore point in the direction of choosing labeling as the preferred solution, acknowledging that some consumers want to be able to avoid GMOs altogether. Nielsen, Thierfelder and Robinson (2001) analyze the consequences of such consumer attitudes to GMOs in a framework in which the entire food processing chain – from primary crops through livestock feed to processed foods – is segregated into GM and non-GM lines of production supported by labeling and traceability schemes. The results from that empirical analysis show that increasing consumer aversion toward GMOs will have substantial effects on trade, production and prices not only for the crop sectors that benefit directly from the new technology, but also for the sectors that use these crops as inputs (for example, in livestock production).

Clearly, the impact that biotech policies and consumer attitudes will have on the production and trade of crops that are potentially subject to genetic modification in different countries depends on a number of factors. First of all, the ease with which crops are genetically modified varies by crop. To date the technique has been successfully applied to maize and soybeans, for example, but the process is apparently more complex for wheat. Second, the effect on production and possibly also on trade may depend on whether the aim of the modification is to improve the agronomic attributes of the crop or to enhance its nutritional value. Third, the impact of other countries' policies and their consumers' attitudes towards GMOs will depend on how traded the crop in question is and between which countries. Finally, the spillover effects on the rest of the economy will depend on whether the crop in question is consumed directly, whether it is used primarily as animal feed, or whether it is used mainly as an input to the food processing industry.

A number of aspects separate the Golden Rice case from the maize and soybean cases. From a staple food perspective rice is of vital importance to many developing countries - particularly those in Asia - and only of marginal importance to developed countries. More than 95% of world rice production and consumption takes place in developing countries, with 90% produced and consumed in Asia (FAOSTAT 2001). By contrast, the US and the EU are two of the major producers and traders of maize and soybeans. Judging by the history of international trade disputes to date, the GMO trade debate is likely to be confined to the controversies between these two particular WTO members. Nonetheless, that debate inevitably will have some spillover effects on developing countries. This is already evident in China's unwillingness to date to contemplate approving the release of GM rice, as it was in its decision in 1995 to cease growing GM tobacco because of strong opposition by tobacco imports in the US and elsewhere (Huang et al. 2002). More broadly, it is affecting the willingness of the private sector and the international donor community to support GMO food research and development.

Another major difference that distinguishes the discussion of Golden Rice in an international trade context from the discussion to date is that rice is primarily consumed in the country where it is produced, with only a small share of total rice production entering the international market. Over the period 1961-99 the average shares of production exported have been 18% for wheat, 14% for maize, but only 4.6% for rice (FAOSTAT 2001). On its own, the latter figure suggests that policies concerning the introduction of genetically modified rice varieties, be they vitamin-A enhanced Golden Rice, pest-resistant rice or herbicide-tolerant rice, will be primarily domestic. Even so, there are some countries where rice exports make up a substantial part of total sales and where potential trade disputes relating to genetic engineering as such could be directly harmful. Rice exports are concentrated in the hands of just a few large exporting nations. The six largest rice exporters in 1999 were Thailand, Vietnam, China, the USA, India and Pakistan (in that order in volume terms). The importance of rice exports is very different for these exporters. For the two largest rice producers - China and India - international trade is a residual market (2% and 3% of production, respectively), while for Thailand, Vietnam, Pakistan and the US very substantial shares of production are sold on foreign markets (45%, 22%, 35% and 45%, respectively, in 1999 (FAOSTAT 2001)). Hence for the latter countries the choice regarding GM versus non-GM varieties will be important, depending on their trading partners.

In the cases of maize and soybean, two of the major traders involved are the United States (mainly as an exporter) and the European Union (mainly as an importer). Particularly in the case of soybean, there are interests at stake on both sides of the equation. The US soybean producers export a large share of their produce, and a substantial part is destined for the EU market. On the import side, the EU is fairly dependent on imported soybean products and a substantial part is sourced from the United States. Hence potential disputes on this front would be harmful to both traders. In the case of maize, however, there is somewhat more space for the EU to increase its own production and/or to source imports from non-GMO countries. Likewise, the maize export pattern of the United States is more diverse and so there would be a possibility of diverting trade away from GMO-skeptical consumers in the EU.

In the case of international rice trade, the most important export markets for Thai rice are Indonesia and Malaysia. Thailand also exports rice to large African nations such as Nigeria, Senegal and South Africa. Thai rice competes with US rice in certain high-quality markets such as the European Union, the Middle East and South Africa, and with Vietnam, India, Pakistan and Myanmar in intermediate and low-quality markets (Nielsen 2002). Given that Thailand already has experience in exporting premium-quality specialty rice to high-income markets such as the EU, there is scope for ensuring that this rice is non-GM.

For Vietnam, the most important markets are Indonesia, Malaysia and the Philippines. Sales to Iraq, Iran and Cuba are also important to Vietnamese rice exports as are former political ties to Eastern Europe. None of these current importers seem to be particularly concerned about GM products but, if Vietnam is to compete with Thailand in selected higher-income markets in the future, there may be a reason for its farmers also to focus on developing non-GM varieties.

Over the past few years, China has been a major rice competitor with Vietnam. China exports mainly to Indonesia, the Philippines and Malaysia, just like Vietnam. China also exports to politically sensitive countries such as Cuba and Iraq. The country's communist history is also evident in the rice export pattern. In contrast with Vietnam, however, China has managed to gain access to the Japanese market after the Uruguay Round Agreement on Agriculture minimum access requirements were put in place in 1995.

India exports both low-quality milled rice to developing countries such as Bangladesh as well as premium-quality basmati rice to higher-income countries. Basmati rice markets for India are the

Middle East, the EU and the United States. Russia, South Africa, Sub-Saharan Africa and the Middle East are major purchasers of non-basmati rice. Like India, Pakistan exports both high-quality basmati rice to high-income markets as well as lower-quality rice to developing countries, mainly in Africa, where it competes with Thailand, Vietnam and China. So, just like Thailand, it seems that India and Pakistan will fare well if they can manage both GM and non-GM varieties.

A final issue to raise when comparing rice on the one hand, and maize and soybean on the other, is that rice is almost exclusively used for human consumption. According to FAOSTAT (2001) only 3% of total production is used for animal feed. Also, rice does not get used much in producing other processed foods, unlike soybean products. Maize and soybean are used to a much larger extent as animal feed. Hence there will be differences with respect to the spillover effects on other sectors of the economy, and on the cost of addressing consumers' right to know if a product contains GMOs.

Golden Rice may open the door to other GM rice varieties

Since Golden Rice is the first major example of a genetically modified food that aims directly at improving consumer nutrition, and more specifically the nutrition of poor people in the world's developing countries, a natural question is whether this can pave the way for other GM foods. One might anticipate that people in developing countries would adopt a more positive stance toward GMOs than people in rich countries precisely because one of the first GM crops they encounter provides them with direct nutritional benefits.

The acceptance of Golden Rice might open the door to accepting other useful GM rice varieties. Other GM rice varieties aim at addressing agronomic problems such as the control of weeds. Currently rice producers use herbicides, crop rotation, flooding and tilling as the main instrument of combating weeds. By using herbicide resistant varieties there is scope for using land and water more efficiently and thereby reducing the need for these and other inputs. Another useful rice variety is virus-resistant rice. In Africa, for example, the yellow mottle virus causes substantial crop losses. In both Asia and Africa nematodes cause large yield losses. These pests are often combated using environmentally harmful chemicals, and so the development of virus-resistant rice varieties could solve part of this problem. Consumer acceptance of such varieties in developing countries will depend, however, on their taste, color and cooking properties because, as discussed by e.g. Latham (1998), consumer preferences for specific types and qualities of rice are crucial in Asian economies.

5. Quantifying the gains from Golden Rice

There are several dimensions to the task of quantifying the economic gains from the adoption of GM rice. One is the productivity growth it offers farmers, in terms of fewer inputs being required per unit of output. Huang et al. (2002) suggest these could amount to as much as a 7% saving, but to be conservative we assume below that primary factor and intermediate input productivity improves by 5%.[10] Another dimension is the increase in demand that might be expected for Golden Rice because of its improved nutritional attribute. That is not modelled here because it requires segregating the world's

[10] Our shock is uniform across all inputs and primary factors. Huang et al. (2002) fine tune that somewhat in their analysis for just China by specifying slightly differing productivity gains for the use of pesticides, seed and labour.

rice market into GM-free and GM-inclusive rice.[11] And a third dimension is to quantify the economic value of the health benefits that might result from Golden Rice. Results from a recent study o that issue are summarized below.

Prospective gains from rice productivity improvement

On the assumption that rice-consuming developing countries are more tolerant of new GM rice varieties, what impact would a reduction in the cost of producing rice have on global rice markets? This question can be addressed using the same technique as in our earlier analyses of GM maize and soybean (Nielsen and Anderson 2001a,b). The analytical framework used is the global, economy-wide GTAP (Global Trade Analysis Project) model and database.[12] The country aggregation adopted reflects the facts that paddy rice production accounts for up to one-quarter of agricultural production in Asia and one-fifth in Sub-Saharan Africa, but is negligible in other regions.

The results in Table 1 show the implications under current policies of introducing genetically modified paddy rice which is assumed to increase primary factor and intermediate input productivity by 5%. The regions that are assumed to have access to this technology are North America, the Southern Cone

[11] Two recent empirical studies that so segregate the markets are Stone at al. (2002) where grains are treated as a group, and Jackson and Anderson (2003) where just soybean and maize markets are analysed.

[12] The GTAP model is a multi-regional, static applied general equilibrium model based on neo-classical microeconomic theory (Hertel 1997). Markets are characterised by perfect competition, the technology of the profit-maximizing producers exhibit constant returns to scale, and substitution between intermediate inputs is possible. The behaviour of the utility-maximising consumers is captured in a non-homothetic private demand system. Capital and labour are perfectly mobile between sectors, whilst the total supply of factors of production is fixed within each region. Land is limited to use in the primary agricultural sectors, and shifts among these are determined by transformation elasticities. International trade is described by an Armington specification (Armington 1969), which means that products are differentiated by country of origin. This enables a specification of the bilateral trade flows rather than simply net trade. Macro closure of the model is achieved by ensuring equilibrium between global savings and investment. The model's 1995 database provides a

countries of Latin America, China, South Korea, Taiwan, Southeast Asia, India and the Rest of South Asia. (Sub-Saharan Africa is assumed to lack the infrastructure to be among the first adoptors of this technology.) In this scenario it is assumed consumers are indifferent between GM-free and GM-inclusive rice.

That assumed technology boost would cause Chinese and Indian paddy rice production to increase by just 0.3% and the Rest of South Asia's by even less, while the increase is around 2% for North America and Southeast Asia even though all regions experience the same assumed productivity increase. These differences are partly explained by the structures of intermediate use of paddy rice: 27% of paddy rice production in China is used to feed livestock and only about half of paddy rice production is further processed, whereas in Southeast Asia paddy rice is not used as livestock feed and almost all is processed. Chinese consumers spend an equal share of total food expenditure on processed and unprocessed rice, whereas consumers in Southeast Asia almost exclusively purchase processed rice while those in South Asia consume mostly unprocessed rice, according to the GTAP database. These different degrees of processing mean that the increased productivity in paddy rice production in Southeast Asia can result in much higher value-added than an identical increase in paddy rice productivity in China or South Asia. Moreover, India and Southeast Asia are major exporters of rice, so a foreign market for their increased production exists to the extent that demand for rice is price elastic -- and the average price of processed rice on world markets declines by about 3%. The domestic price of paddy rice within both East and South Asia declines by more -- about 6-7%. As a net exporter of rice, non-adopting Sub-Saharan Africa in this scenario has to face a lower export price as a consequence of

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comprehensive description of the structures of the individual economies and the commodity and services trade between them (McDougall et al. 1998).

increased competition from GM-adopting, rice-exporting countries. This leads to a marked decline in Sub-Saharan African exports and a rise in the region's imports of rice.

In terms of economic welfare, the world economy is estimated to be better off by US$6.2 billion per year in 1995 dollars because of such a technology shock, assuming it has no external effects (Table 2).[13] Western Europe gains mostly because resources move out of producing highly protected rice there. The only regions in that table to lose are the US and Australia, and their loss is trivial. The welfare decomposition reveals that the reason for the loss is that the deterioration in their terms of trade, because of the fall in international rice prices, outweighs the gain from productivity growth in this crop (due to the minor importance of rice to both countries). All of Asia's adopting regions gain substantially, and Asia's developing countries as a group capture all but one-sixth of the global gains. All gain from the technological improvement by similar amounts, but Southeast Asia gains less overall because more resources are attracted to its relatively assisted rice sector.

Clearly, this is another 'green revolution' for Asia (and potentially other regions including Sub-Saharan Africa should they adopt the technology), even if the gains were to be confined to cost savings for rice producers. But if in fact the gains extend also to health benefits for undernourished rice consumers, how much would that add to the $6 billion global gain per year reported above? No global studies of that are yet available, but a recent country study hints at the orders of magnitude that could be involved.

[13] If South Asia did not adopt the new GM technology, the global gains would be reduced to $4.5billion p.a. The reason we have not used the model to evaluate the effects of introducing Golden Rice is that we have no way of guessing what the consumer responses to it would be, whereas the productivity shock assumed to be associated with input-reducing rice

Prospective gains from improved health for Golden Rice consumers

In an innovative analysis Zimmermann and Qaim (2002) estimate the potential economic value of the health benefits of Golden Rice for the Philippines. They do so by estimating the direct savings in health costs associated with Vitamin A Deficiency (leaving aside indirect savings such as for families caring for a blind family menber). That is done by examining its impact on disability-adjusted life years (DALYs), based on Murray and Lopez (1996), and using the World Bank (1994) estimate of each year being worth US$1,000 in terms of lost income and the willingness to pay for health services. Impacts on children and well as pregnant and lactating women are evaluated, and a pessimistic and an optimistic scenario are presented. The aggregate benefit is estimated to range between $23 and $137 million per year, or between 0.03% and 0.18% of GDP. If that were to be representative of what could be achieved in all East and South Asian developing countries, then for the region as a whole those health benefits would amount to between $0.8 and $4.5 billion per year. This is a very substantial addition to the $5.3 billion gain shown in Table 2 for that region from the assumed productivity gain associated with GM rice.

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varieties is based on the actual savings that have been generated in the cases of GM maize and soybean and the field-trial results in China for GM rice.

6. Conclusion: implications for the WTO and developing countries

The introduction of Golden Rice would not be without controversy, but for countries choosing to adopt they are mainly of a domestic nature if those countries are less than 100% rice self-sufficient. Among the issues such countries would need to grapple with are domestic consumer acceptance, evaluation of potential environmental and food safety risks, and the establishment of appropriate regulatory frameworks to deal with biosafety risks, intellectual property rights, etc.

However, for countries that are or would become net exporters of rice, GM technology may pose greater challenges from an international trade perspective. Even though the above empirical simulation results suggest such varieties have the potential to bring much-needed welfare gains to developing economies, an important issue for a rice-exporting country would be to evaluate the consumer attitudes towards GMOs in its export markets and to be well aware of any rice trade policies (e.g. labeling and segregation requirements) affecting GM varieties. For developing countries that are dependent on exporting to countries where there are clear preferences against GM products (e.g. the European Union and Japan), there may be scope for the development of segregated GM and non-GM rice markets. Then the main challenge would be to establish completely segregated lines of production and marketing. Consumers' willingness-to-pay for the non-GM characteristic, the costs of segregation, and any productivity differences between GM and non-GM varieties would together determine the economic viability of such action.

A prior challenge for WTO members, however, is to avert a trade dispute of international dimensions because the EU and the US, for example, disagree on appropriate approaches to regulating GM trade.[14] Averting such a dispute is especially important for the world's rice-based economies, to reduce the risk that this could delay the introduction of beneficial GM rice varieties in developing countries. In other words, the "gold" of genetically modified rice might be lost in an international trade dispute about genetically engineered foods in general. Missing out on the Golden Rice variety would mean a lost chance of improving the health of poor people in rice-consuming developing countries. And that in turn could mean they miss out on other GM rice varieties being developed and adopted, and hence on a chance of enhancing the international competitiveness of poor farmers in developing countries more generally.

[14] For more on the challenges for the WTO of the GM revolution, see Perdikis et al. (2001), and Isaac and Kerr (2003).

References

Armington, P.A. (1969) 'A Theory of Demand for Products Distinguished by Place of Production'. *IMF Staff Papers* 16: 159-178.

Beyer, P., S. Al-Babili, X. Ye, P. Lucca, P. Schaub, R. Welsch and I. Potrykus (2002) 'Golden Rice: Introducing the Beta-Catotene Biosynthesis Pathway into Rice Endosperm by Genetic Engineering to Defeat Vitamin A Deficiency', *Journal of Nutrition* 132: 506-10.

Bouis, H.E. (2000) 'The Role of Biotechnology for Food Consumers in Developing Countries', pp. 189-213 in *Agricultural Biotechnology in Developing Countries: Towards Optimizing the Benefits for the Poor*, edited by M. Qaim, A.F. Krattiger and J. Von Braun, Dortrecht: Kluwer.

Buckwell, Allan, Graham Brookes and Dylan Bradley (1999) *Economics of Identity Preservation for Genetically Modified Crops*. Final report of a study for Food Biotechnology Communications Initiative (FBCI). With contributions from Peter Barfoot, Stefan Tangermann and Jan Blom.

European Commission (2000) *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector: A Synthesis*. Working Document, DG-Agriculture, Brussels: European Commission, August.

European Commission (1999) *The EU Approach to the Millennium Round: Communication from the Commission to the Council and to the European Parliament*. Note for the 133 Committee. MD: 400/99.

FAOSTAT (2001) *FAOSTAT Agriculture Data*, www.fao.org, Accessed September 2001.

Food and Drug Administration (1995) *FDA's Policy for Foods Developed by Biotechnology. Emerging Technologies – Biotechnology*. Washington, D.C.: FDA.

Hertel, Thomas W. (1997) (ed.) *Global Trade Analysis: Modeling and Applications*. Cambridge and New York: Cambridge University Press.

Howse, Robert and Donald Regan (2000) 'The Product/Process Distinction -- An Illusory Basis for Disciplining Unilateralism in Trade Policy.' mimeo, University of Michigan Law School, Ann Arbor, January.

Huang, Jikun, Ruifa Hu, Hans van Meijl and Frank van Tongeren (2002) 'Biotechnology Boosts to Crop Productivity in China: Trade and Welfare Implications', mimeo, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing.

Isaac, Grant E. and Wiliam A. Kerr (2003) 'Genetically Modified Organisms and Trade Rules: Identifying Important Challenges for the WTO', *The World Economy* 26(1): 29-42, January.

Jackson, Lee Ann and Kym Anderson (2003) 'Why Are US and EU Policies Toward GMOs so Different?', Paper presented to the AARES Annual Conference, Perth, 11-14 February.

James, Clive (1997) *Global Status of Transgenic Crops in 1997*. ISAAA Briefs No.5. International Service for the Acquisition of Agri-biotech Applications. Ithaca, NY.

James, Clive (1999) *Global Status of Commercialized Transgenic Crops: 1999*. ISAAA Briefs No.12, Preview. International Service for the Acquisition of Agri-biotech Applications. Ithaca, NY.

James, Clive (2000) *Global Status of Commercialized Transgenic Crops: 2000*, ISAAA Brief No. 21, Preview, International Service for the Acquisition of Agri-biotech Applications. Ithaca, NY.

James, Clive (2001) *Global Status of Commercialized Transgenic Crops: 2001*, ISAAA Brief No. 18, Preview, International Service for the Acquisition of Agri-biotech Applications. Ithaca, NY.

Latham, A.J.H. (1998) *Rice: The Primary Commodity*, London: Routledge.

McDougall, Robert A., Aziz Elbehri and Truong P. Truong (1998) (eds.) *Global Trade, Assistance, and Protection: The GTAP 4 Data Base*. Center for Global Trade Analysis, Purdue University, West Lafayette.

Murray, C.J.L. and A.D. Lopez (eds.)(1996), *The Global Burden of Disease, Vols. I and II*, Cambridge MA: Harvard University Press for the Harvard School of Public Health on behalf of the WHO and World Bank.

Nelson, Gerald C., Timothy Josling, David Bullock, Laurian Unnevehr, Mark Rosegrant and Lowell Hill (1999) *The Economics and Politics of Genetically Modified Organisms: Implications for WTO 2000*. With J. Babinard, C. Cunningham, A. De Pinto and E.I. Nitsi. Bulletin 809. College of Agricultural, Consumer and Environmental Sciences, University of Illinois at Urbana-Champaign, November.

Nielsen, Chantal Pohl (2002) 'Vietnam in the International Rice Market: Facing an Obstacle Course of Trade Barriers and Domestic Support Policies'. Working Paper. Danish Institute of Agricultural and Fisheries Economics (SJFI), Copenhagen.

Nielsen, Chantal Pohl and Kym Anderson (2001a) 'Global Market Effects of Alternative European Responses to GMOs' *Weltwirtschaftliches Archiv* 137(2): 320-346.

Nielsen, Chantal Pohl and Kym Anderson (2001b) 'GMOs, Trade Policy, and Welfare in Rich and Poor Countries', in *Quantifying the Impact of Technical Barriers to Trade: Can it be Done?* edited by K. Maskus and J. Wilson, Ann Arbor: University of Michigan Press.

Nielsen, Chantal Pohl, Karen Thierfelder and Sherman Robinson (2001) 'Consumer Attitudes Towards Genetically Modified Foods: The Modelling of Preference Changes'. Working Paper No. 1/01. Danish Institute of Agricultural and Fisheries Economics (SJFI), Copenhagen.

OECD (1999) *Modern Biotechnology and Agricultural Markets: A Discussion of Selected Issues and the Impact on Supply and Markets.* Directorate for Food, Agriculture and Fisheries. Committee for Agriculture. AGR/CA/APM/CFS/MD(2000)2, Paris: OECD.

Perdikis, Nicholas, William A. Kerr and Jill E. Hobbs (2001) 'Reforming the WTO to Diffuse Potential Trade Conflicts in Genetically Modified Goods', *The World Economy* 24(3): 579-98, March.

Reuters (2001a) "Demand surges for non-GMO animal feed in Europe" 8 October.

Reuters (2001b) "U.S. sees EU GMO labeling rules as impeding trade" 10 October.

Robertson, Richard, Laurian Unnevehr and David Dawe (2001) 'Golden Rice: What Role Could It Play in Alleviation of Vitamin A Deficiency', paper presented at the 5th International Conference on "Biotechnology, Science and Modern Agriculture: a New Industry at the Dawn of the Century". Ravello, Italy, June.

Sheldon, Ian (2001) 'Regulation of biotechnology: Will we ever "freely" trade GMOs?' Paper presented at the 77th EAAE Seminar entitled "International Agricultural Trade: Old and New Challenges, Helsinki, Finland, 17-18 August.

Sommer, A. and K.P. West Jr. (1996) *Vitamin A Deficiency: Health, Survival, and Vision,* London and New York: Oxford University Press.

Stone, Susan, Anna Matysek, and Andrew Dolling (2002) *Modelling Possible Impacts of GM Crops on Australian Trade*. Staff Research Paper. Canberra: Productivity Commission.

Tietje, Christian (1997) 'Voluntary Eco-Labelling Programmes and Questions of State Responsibility in the WTO/GATT Legal System'. *Journal of World Trade* 31(1): 123-158.

UNEP (2000) *Cartagena Protocol on Biosafety to the Convention on Biological Diversity* http://www.biodiv.org/biosafe/biosafety-protocol.htm

World Bank (1994) *Enriching Lives: Overcoming Vitamin and Mineral Malnutrition in Developing Countries.* Washington, DC: World Bank.

WTO (1998) *EC Measures Concerning Meat and Meat Products (Hormones). Report of the Appellate Body*. WT/DS26/AB/R. WT/DS48/AB/R AB-1997-4. Geneva: WTO.

Ye, X., S. Al-Babili, A. Kolti, J. Zhang, P. Lucca, P. Beyer and I. Potrykus (2000), 'Engineering the Provitamin A (Beta-Carotene) Biosynthetic Pathway into (Carotenoid-Free) Rice Endosperm', *Science* 287: 303-05.

Zimmermann, R. and M. Qaim (2002), ’Projecting the Benefits of Golden Rice in the Philippines’, ZEF-Discussion Papers on Development Policy No. 51, Center for Development Research (ZEF), Bonn, September.

Table 1. Effects on production, domestic prices and trade of selected regions adopting GM rice (percentage changes)[a]

	North America[c]	China[c]	Southeast Asia[c]	India[c]	Rest of South Asia[c]	Western Europe	Sub-Saharan Africa
Production							
Paddy rice	1.8	0.3	2.0	0.3	0.1	-11.5	-0.3
Processed rice	-5.2	0.3	2.4	6.8	-3.1	-1.5	-3.7
Domestic prices							
Paddy rice	-5.5	-6.0	-6.7	-7.2	-7.1	-0.9	-0.1
Processed rice	-0.3	-2.7	-4.5	-3.9	-1.8	-0.4	-0.2
Exports[b]							
Paddy rice	10.8	33.6	22.5	28.8	31.7	-23.7	-25.9
Processed rice	-10.2	4.1	10.7	6.8	-5.2	-3.9	-11.6
Imports[b]							
Paddy rice	-0.9	-0.1	-8.9	-25.5	-22.4	-0.3	22.2
Processed rice	9.2	5.5	-5.4	4.4	-1.6	0.0	8.0

[a] For space reasons, other regions are omitted from this table.
[b] Includes intra-regional trade.
[c] GM rice-adopting region.

Source: Authors' GTAP model results.

Table 2. Effects on economic welfare of selected regions adopting GM rice

	Equivalent Variation (EV) US$ million pa	Decomposition of welfare results, contribution of (US$ million): Allocative Efficiency Effects	Terms of Trade effects	Technical Change
North America	-30	8	-126	76
Western Europe	295	284	14	0
Australia/New Zealand	-38	1	-39	0
Japan	144	67	82	0
South Korea+Taiwan	1321	112	81	1122
China	1715	226	24	1489
Southeast Asia	804	-232	-87	1120
India	1178	140	-46	1088
Rest of South Asia	389	53	5	328
Sub-Saharan Africa	21	5	15	0
Other developing and transition economies	422	101	77	241
WORLD	6220	765	0	5466

Source: Authors' GTAP model results.

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