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Mandatory Labelling or Import Ban?: Two-Country Trade with Biotechnology Products

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Abstract

This paper examines trade and welfare effects of biotechnology. While biotechnology lowers production costs, it also lowers perceived quality of products. Without labelling, consumers cannot distinguish between biotechnology and conventional products. In a simple general equilibrium model of two-country trade, it is shown that when a biotechnology product is invented in one country, the importing country may lose from trade under free trade without labelling. The importing country can be better off by requiring labelling for the biotechnology product. If labelling cost is high, however, the importing country may prefer to ban the import of the biotechnology product.

Keywords: biotechnology; genetically modified organisms; mandatory labelling; import ban; credence goods.

JEL classification: F10; L15; Q16; Q17; Q18.

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1 Introduction

International trade disputes on trade in agricultural and food products have increasingly been caused by advances in biotechnology. The dispute on genetically modified organisms (GMOs) is such an example.[1] The dispute on hormone-treated beef between the European Union (EU) and the United States (US) is another example.[2] Import ban and mandatory labelling are typical trade measures for dealing with these biotechnology products.

The differences among countries in technology level in biotechnology and in consumers' attitudes toward biotechnology products seem to be part of the main causes of trade disputes. The US is the current world leader in biotechnology. European countries and Japan are still far behind the US despite their efforts.[3] On the other hand, consumer surveys show that North American consumers tend to be more tolerant toward biotechnology products, while European consumers tend to be more concerned about these products.[4]

Biotechnology products have some specific features. First, many of the currently available biotechnology products are aimed at reducing production costs. Second, some consumers perceive these products as being of lower quality because of their potential negative impacts on human health and on the environment.[5] Third, these products are *credence goods* in the terminology of Darby and Karni (1973). That is, consumers cannot know whether a product is biotechnologically modified or not even after consuming it.[6]

Given these features of biotechnology products, one may wonder how countries are affected by an innovation in biotechnology in one country through international trade. In order to examine this issue, I construct a general equilibrium model in which the economy

[1] Exporting countries of GMOs, such as the United States, argue against mandatory labelling imposed by importing countries, such as the European Union and Japan.

[2] The EU banned the import of US beef supplemented with growth promoting hormones. The US appealed to the World Trade Organisation (WTO). The WTO ruled against the EU in 1997, because the import ban was not based on scientific grounds. See Bureau *et al.* (1998) and Vogel (1995, Chapter 5) for details.

[3] In recent years the US has filed 53.7 per cent of patents for biotechnology, while the EU shares 32.6 per cent and Japan shares only 7.7 per cent (Paillotin, 1998).

[4] For example, Hoban (1997) reports that surveys show differences among countries in consumers' willingness to buy biotechnology products. While about three-quarters of the US and Canadian respondents are willing to buy biotechnology products (US: 73%; Canada: 74%), only 22% of Austrian and 30% of German respondents are willing to buy these products. In many European countries, about 50 to 60% of respondents answered they are willing to buy these products.

[5] For example, Kerr (1999) provides detailed discussion on features of genetic modification. Chataway and Assouline (1998) discuss in detail potential environmental risks of GMOs.

[6] In this sense, credence goods are distinguished from *experience goods* whose quality consumers can know only after they consume these goods (Nelson, 1970).

consists of two sectors: food and manufacturing. The manufacturing sector is taken as the numeraire. In the food sector, there are a large number of competitive firms that engage in production of final good and a large number of competitive firms that provide an intermediate good to the final good firms. There is also one firm that engages in research and development to supply a biotechnology-derived intermediate good. There are two types of consumers: concerned and unconcerned. Concerned consumers perceive biotechnology food as a lower quality product. Unconcerned consumers do not perceive any quality difference between biotechnology and conventional food. The government decides whether to regulate the marketing of the biotechnology food either by requiring mandatory labelling or by banning it. There are two countries: home and foreign. I consider the case where a biotechnology product is invented in the foreign country.

The main results are as follows: Since the model is Ricardian, the pattern of trade is rather straightforward. That is, at least one country specializes and which country specializes depends on the relative demand. When trade takes place without labelling, neither country produces conventional food. By imposing mandatory labelling of biotechnology food, the home country domestically produces and consumes conventional food. With regard to welfare effects of trade, the foreign country gains from trade, regardless of trade with or without labelling. By contrast, the home country may lose from trade if trade takes place without labelling. The home country is more likely to lose from trade if the home consumers are more concerned about negative effects of biotechnology food. The home country can be better off by imposing mandatory labelling if the home consumers are highly concerned about biotechnology food and labelling cost is not so high. This mandatory labelling lowers foreign welfare. If the home consumers are highly concerned about biotechnology food but labelling cost is very expensive, then the home country prefers a ban on the import of biotechnology food rather than labelling. The import ban hurts the foreign country more severely than labelling does.

In the trade policy literature, while several papers have examined trade policies for products with unknown quality,[7] labelling has been rather ignored. Moreover, most of the existing papers examine trade policies for *experience goods* (Nelson, 1970) and few papers have examined those for *credence goods*. An exception is Bond (1984), who examines trade

[7]See, for example, Donnenfeld *et al.* (1985), Grossman and Horn (1988), and Bagwell and Staiger (1989).

and welfare effects of labelling as well as tariffs for products with unobservable qualities. This paper is different from his in some respects. First, since he assumes fixed supply of goods, a high quality good is supplied even under asymmetric information. In my case, by contrast, due to adverse selection only a low quality good is supplied under asymmetric information. Second, since he examines costless labelling, there is no trade-off between information and labelling cost. By contrast, since I explicitly consider labelling cost, labelling is not always better than asymmetric information. In the agricultural economics literature, welfare effects of labelling for biotechnology products have been examined by several works including Bureau *et al.* (1998) and Gainsford and Lau (2000). None of these papers, however, have fully analyzed patterns of trade and welfare effects of trade in a general equilibrium framework. In the literature of the economics of information, most of the papers that have investigated the issue of credence goods have focused on expert services for credence goods and ignored the role of labelling.[8] An exception is Marette *et al.* (2000). In the context of product safety, they investigate, among other things, effects of labelling for credence goods. Trade effects of labelling, however, are not examined.

The remainder of the paper proceeds as follows. Section 2 sets up the model. Section 3 analyzes the autarky equilibrium with and without biotechnology products. Section 4 examines trade and welfare effects of biotechnology products. Section 5 concludes.

2 The Basic Model

In this section I set up a simple general equilibrium model with two final goods (x and z), one primary factor (labour), and two intermediate goods (s_1 and s_2).

2.1 Production

There are two final goods denoted by x and z. Labour is the only primary factor of production, but an intermediate good is also used for the production of x. Good z, or *manufacturing good*, is treated as the numeraire and hence the units are chosen in such a way that one unit of labour produces one unit of good z, i.e., $z = l_z$, where l_z is the amount of labour employed for the production of good z. Set price of z be one.

[8] See, for example, Wolinsky (1995) and Emons (1997, 2001).

Production of good x, or *food*, uses labour and intermediate goods as inputs. Potentially two intermediate goods are available: non-genetically modified organism (non-GMO), s_1, and genetically modified organism (GMO), s_2. In order to distinguish products produced by these two different intermediate goods, call the non-GM food (non-GMF) as x_1 and the GM food (GMF) as x_2. The non-GM technology is embodied in s_1 and is represented by $x_1 = f(s_1, l_{x_1})$. The GM technology is embodied in s_2 and is represented by $x_2 = g(s_2, l_{x_2})$. Both $f(\cdot, \cdot)$ and $g(\cdot, \cdot)$ are constant returns to scale (CRS) and l_{x_i} is the amount of labour employed for the production of x_i. The GM technology is superior in the sense that $f(s, l) < g(s, l), \forall (s, l)$. Following Moschini and Lapan (1997), in order to measure s_2 in the same physical units as s_1 I assume

$$g(s, l) = f(\lambda s, l), \qquad \forall (s, l), \quad \lambda > 1. \tag{1}$$

That is, the technological innovation is of a type of its own input augmenting.[9]

Competitive firms produce s_1 using labour as an input: $l_1 = \kappa s_1$, where l_1 is the labour employed for the production of s_1. An innovating firm produces s_2 using labour as an input: $l_2 = \kappa s_2 + \eta$, where l_2 is the labour employed for the production of s_2 and η is the labour required for inventing s_2. The innovation is protected by intellectual property rights (IPRs), such as patents. For simplicity, I assume that the innovating firm does not directly engage in production of the final good. I also rule out the possibility of licensing the GM technology. I also assume that the final good producing firms are perfectly competitive and that the market structure is not affected by the introduction of the GM technology. It then turns out that the model exhibits a Ricardian nature.

2.2 Utility and demand

There are L consumers, who are divided into two types: unconcerned (U) and concerned (C) consumers. U consumers perceive GMF as the same quality as non-GMF, whose utility is given by $u^U(x_1, x_2, z) = (x_1 + x_2)^\beta z^{1-\beta}$, where $\beta \in (0, 1)$. C consumers, on the other hand, perceive GMF as a lower quality product, compared to non-GMF, because of its potential negative effects on human health. A C consumer's utility is given by $u^C(x_1, x_2, z; \alpha) = (x_1 + \alpha x_2)^\beta z^{1-\beta}$, where $\alpha \in [0, 1]$ measures how she perceives quality of GMF. The share of C consumers is $\theta \in [0, 1]$. Each consumer is endowed with one

[9] This is not a crucial assumption. Other types of innovation are also analyzed in a similar way.

unit of labour. For simplicity, I assume that the innovating firm's profits, if any, are transferred to consumers in a lump-sum way. From the consumer's utility maximization problem, if GMF and non-GMF are offered at different prices, a U consumer chooses the cheaper product. A C consumer's choice, on the other hand, depends on the value of α and the price ratio of the two products. Let p_i be price of x_i. If $\alpha < p_2/p_1$, a C consumer chooses non-GMF, and vice versa. Total demands for x and z are respectively given by $X^D = \beta IL/p$ and $Z^D = (1-\beta)IL$, where I is income.

2.3 The government

The government may impose mandatory labelling of GMF or prohibit the marketing of GMF, if necessary. Because food is a *credence* good, consumers cannot distinguish GMF from non-GMF without labelling. I assume that mandatory labelling is the only credible way to disclose information on whether a product is GMF or non-GMF.[10]

Labelling is costly. Under mandatory labelling of GMF, each producer of good x_2 has to sort and test his own products. I assume that under mandatory labelling $\tau > 1$ units of food must be produced in order to deliver one unit of food to consumers. In other words, when the producer price of good x is p, the consumer price of x is given by τp.[11] I also assume that labelling is required for both GMF and non-GMF if GMF is domestically produced. The reason is that when both products are produced in one country, there is a chance that two products are mixed up at some production stage. Thus, non-GMF also needs to be tested to verify the absence of GMF.[12] If GMF is not domestically produced, however, domestically produced food does not need to be labelled.

3 Autarky Equilibrium

Consider two countries: home and foreign. Foreign variables are indicated by an asterisk ($*$). I assume that the total number of consumers is the same in the two countries, i.e.,

[10] Individual firms may provide voluntary labelling. In fact, non-GMF producers *do* have an incentive to provide voluntary labelling. However, since food is a credence good and there are a large number of competitive firms that produce non-GMF, private labelling by non-GMF firms is unlikely to be credible. For detailed discussion on credibility of voluntary labelling, see, for example, Bureau *et al.* (1998) and Rege (2000). I briefly discuss implications of voluntary labelling in section 5.

[11] This idea is the same as the "iceberg" transportation costs. See, for example, Krugman (1980).

[12] Even if non-GMF is labelled, GMF still has to be labelled. This may be because other GMOs that are not permitted to sell in the home country are also produced.

$L = L^*$. I consider the case in which GMO is invented in the foreign country.

3.1 The home country: Autarky without GMO

In the home country, only the non-GM technology is available. Total production of good x is then given by $X = f(s_1, l_{x_1})$. The unit cost function is given by $c^1(r_1, w)$, where r_1 is the price of s_1 and w is wage. By Shephard's Lemma, input demands are given by $l_{x_1} = Xc^1_w(r_1, w)$ and $s_1 = Xc^1_r(r_1, w)$, where $c^1_w(r_1, w) \equiv \partial c^1/\partial w$ and so on. Then, under full employment it holds that $X = (L - Z)/\bar{\mu}$, where $\bar{\mu} \equiv c^1_w(r_1, w) + \kappa c^1_r(r_1, w) = c^1_w(\kappa, 1) + \kappa c^1_r(\kappa, 1)$.[13] As long as good z is produced, $w = 1$. Hence, $r_1 = \kappa w = \kappa$. In equilibrium, the price of x is given by $p^A = c^1(r_1, w) = w\bar{\mu} = \bar{\mu}$. Then, it holds that $Z = l_z = (1 - \beta)L$ and $X = \beta L/\bar{\mu}$. A consumer's indirect utility is then given by

$$V^i(p^A, I^A) = \frac{B}{\bar{\mu}^\beta}, \qquad i = C, U, \tag{2}$$

where $B \equiv \beta^\beta(1 - \beta)^{1-\beta}$. Note that each consumer's income is $I^A = w = 1$.

3.2 The foreign country: Autarky with GMO

I now turn to the foreign country, where GMO is available. I assume that parameters are so that the foreign government allows unlabelled marketing of GMF. When a firm in the food sector uses s^*_1, its unit cost function is $c^1(r^*_1, w^*)$, while it is $c^2(r^*_2, w^*)$ when the firm uses s^*_2. From Eq. (1), it holds that $c^2(r^*_2, w^*) = c^1(r^*_2/\lambda, w^*)$. Then, $c^1(r^*_1, w^*) \geq c^2(r^*_2, w^*)$ for $r^*_2 \leq \lambda r^*_1$. The derived demand for s^*_2 is then given by

$$s^{*D}_2(r^*_2, w^*) = \begin{cases} X^{*D}(c^2(r^*_2, w^*))c^2_r(r^*_2, w^*) \equiv s^{*M}_2(r^*_2, w^*) & \text{if } r^*_2 < \lambda r^*_1, \\ \in [0, s^{*M}_2(r^*_2, w^*)] & \text{if } r^*_2 = \lambda r^*_1, \\ 0 & \text{if } r^*_2 > \lambda r^*_1. \end{cases}$$

The innovating firm's profits are given by $\pi^*_M = (r^*_2 - \kappa w^*)\, s^{*D}_2(r^*_2, w^*) - w^*\eta$. Define $r^{*M}_2(w^*) = \arg\max_{r^*_2} \left\{(r^*_2 - \kappa w^*)\, s^{*D}_2(r^*_2, w^*)\right\}$. The innovating firm chooses $r^*_2 = \min\{\lambda r^*_1, r^{*M}_2(w^*)\}$. In either case, all x producers adopt s^*_2 (Moschini and Lapan, 1997). Thus, all food supplied in the foreign market is GMF. Here, I focus on the case where

[13] Note that zero profit condition yields $r_1 = \kappa w$ and that both $c^1_w(r_1, w)$ and $c^1_r(r_1, w)$ are homogeneous of degree zero.

$\lambda r_1^* > r_2^{*M}(w^*)$.[14] It then can be written as $r_2^{*M}(w^*) = \sigma\lambda r_1^*$, where $\sigma < 1$.[15]

Total production of x is $X^* = f(\lambda s_2^*, l_{x_2}^*)$ and the unit cost function of good x is $c^1(r_2^*/\lambda, w^*)$. The full employment condition yields $X^* = (L - Z^* - \eta)/\hat{\mu}(\sigma)$, where $\hat{\mu}(\sigma) \equiv c_w^1(\sigma\kappa, 1) + \kappa c_r^1(\sigma\kappa, 1) < \bar{\mu}$. The price of x in autarky is given by $p^{*A} = c^1(\sigma^1\kappa, 1) < \hat{\mu}(\sigma^1) < p^A$, where σ^1 is the value of σ in autarky. Thus, the price of x is lower in the foreign country than in the home country. Good x is then relatively more produced and consumed in the foreign country than in the home country. It holds that $Z^* = l_z^* = (1-\beta)I^*L$ and $X^* = \beta I^*L/p^{*A}$. U and C consumers' indirect utilities are given by

$$V^{*U}(p^{*A}, I^{*A}) = \frac{BI^{*A}}{(p^{*A})^\beta}, \tag{3}$$

$$V^{*C}(p^{*A}, I^{*A}; \alpha^*) = \frac{\alpha^{*\beta}BI^{*A}}{(p^{*A})^\beta}, \tag{4}$$

respectively, where $I^{*A} = w^* + \pi_M^{*A}/L \geq 1$.

4 Trade between Two Countries

Consider now trade between the two countries. Trade takes place in both final goods and intermediate goods. Labour is internationally immovable. When s_2^* is imported, it is subject to the domestic safety test, which increases production cost of x_2.[16] Thus, in order to deliver one unit of s_2^* to the home country, the foreign country must export $\xi > 1$ unit of s_2^*. I also assume that even taking importing cost into account the unit cost of x_2 for the home firms is lower than that of x_1, i.e., $c^1(\xi\sigma\kappa, 1) < c^1(\kappa, 1) = \bar{\mu}$.

I first examine the case of free trade without mandatory labelling. I then examine the case where the home country imposes mandatory labelling of GMF.

4.1 Free trade without mandatory labelling

When trade is liberalized without labelling, consumers in either country cannot distinguish between GMF and non-GMF and hence a common world price must be given to food. As

[14] This is a case of *drastic* innovation in the terminology of Arrow (1962). I assume that at $r_2^* = r_2^{*M}(w^*)$ the monopolist's net profits are non-negative. The case in which $\lambda r_1^* \leq r_2^{*M}(w^*)$ is not interesting. In that case, $r_2^* = \lambda r_1^*$ and hence the price of food in unchanged after GMO is invented.

[15] Note that as long as consumers' total expenditure on x_2 is constant at βI^*L and $w^* = 1$, $r_2^{*M}(w^*)$ is fixed at some value and hence σ is also fixed. After opening up to trade, however, since the demand for food changes, the derived demand for s_2^* will also change. Since σ reflects the innovating firm's price decision, it will also change after opening up to trade.

[16] This may be because the use of s_2^* in production process may have some negative effects on the local environment.

in autarky, the foreign food producers produce only GMF after trade is liberalized. The home food producers, on the other hand, have no incentive to produce non-GMF under free trade without labelling, because the price of food is lower than the unit cost of x_1. It is obvious that the foreign country has a comparative advantage in food production. The pattern of trade is rather straightforward, since the model is Ricardian.

Proposition 1 *Under free trade without mandatory labelling of GMF, when GMO is invented in the foreign country, the home country always exports the numeraire and the foreign country always exports GMF. Moreover, if the demand for food is very strong, the foreign country also exports GMO.*

(Proofs of propositions are presented in the Appendix.)

As is usual in Ricardian models, at least one country specializes and which country specializes depends on how strong the world demand for food is. Note that neither country produces non-GMF. GMF completely dominates the world food market.

4.2 Trade with home mandatory labelling of GMF

I now turn to the case where mandatory labelling of GMF is imposed. With mandatory labelling, price of x_1 and x_2 can be different in the home country. In the foreign country, on the other hand, a common price must be given to x_1 and x_2 since there is no labelling in the foreign market.[17] Let p^* be the producer price of x_2 under trade with home labelling. Then, the consumer price of x_2 in the home country is at τp^*.[18] Let p_1 be the consumer price of x_1 in the home country under trade with home labelling. Since the imported x_1 from the foreign country must be labelled, the producer price in the foreign country is at p_1/τ. The domestically produced x_1 may or may not be labelled, depending on whether or not GMF is produced in the home country. There are two cases to consider.

The first case is that the world demand for GMF is not very strong. In this case, since the foreign country can meet all the world demand for GMF, the home country does

[17]Note that the policy choice of the foreign government is not affected by the policy choice of the home government.

[18]The innovating firm may set the price of s_2 strategically in order to attract the home C consumers. I rule out this case by assuming that the innovating firm's profits are higher when it charges the monopoly price r_2^{*M} than when it charges the strategic price r_2^{*S}. That is, $\pi_M^*(r_2^{*M}) > \pi_M^*(r_2^{*S})$, where r_2^{*S} is defined as the price of s_2 at which $\tau p^* = \alpha p_1$ holds, i.e., the home C consumers are indifferent between x_1 and x_2.

not produce GMF. Thus, x_1 produced in the home country does not need to be labelled. Thanks to mandatory labelling, the home firms have an incentive to supply x_1. In fact, only the home firms supply x_1 in equilibrium. The pattern of trade is then as follows:

Proposition 2 *Under trade with the home country requiring mandatory labelling of GMF, if the world demand for GMF is not very strong, (i) The home country produces both non-GMF (and non-GMO) and the numeraire and exports the numeraire, and (ii) The foreign country either specializes in GMF (and GMO) or is diversified to produce GMF (and GMO) and the numeraire. In either case, the foreign country exports GMF.*

Note that non-GMO s_1 is exclusively supplied by the home firms. Since neither country has cost advantage in s_1, international trade in s_1 does not provide any economic gain.

The second case is that the world demand for GMF is very strong. Since the world demand for GMF exceeds the foreign country's supply capacity, the home country also produces GMF in equilibrium. Thus, x_1 produced in the home country must also be labelled. In equilibrium, x_1 is produced only in the home country, while x_2 is produced in both countries. The pattern of trade is as follows:

Proposition 3 *Under trade with the home country requiring mandatory labelling of GMF, if the world demand for GMF is very strong, (i) The home country produces non-GMF (and non-GMO), GMF, and the numeraire, and exports the numeraire, and (ii) The foreign country specializes in GMF (and GMO) and exports GMF and GMO.*

Note that while the home country can import s_2 and domestically produce x_2, it has a comparative disadvantage in the production of x_2. Thus, the home country imports x_2 as well as s_2. Note also that as in the first case, s_1 and x_1 are produced only in the home country and non-traded.

4.3 Labelling or import ban?: Normative analysis of trade

I now examine welfare effects of trade between the two countries with and without home labelling of GMF. Since there is more than one type of consumers in each country, welfare effects are evaluated on the basis of the *Potential Pareto Principle*, or *Kaldor Compensation Principle*, unless all consumers agree on the ordering of social states.[19] That is, even

[19]The *Potential Pareto Principle*, which was proposed by Kaldor (1939), provides a complete ordering of social states without requiring interpersonal comparison of well-being. State x is said to be a *Potential Pareto Improvement (PPI)* on

though either type of consumers were worse off by moving, for example, from autarky to free trade without labelling, the country would be judged to gain from trade without labelling if it is possible to make free trade at least as good as autarky for all consumers and strictly better than autarky for some consumers by making *hypothetical* lump-sum transfers among consumers. Note that when all consumers agree on the ordering of social states, the ordinary Pareto efficiency criterion can be applied.

I first look at welfare effects of trade in the foreign country. Compared with autarky, it is shown that foreign consumers are all better off under free trade without labelling. The reasons are as follows: Firstly, the foreign country experiences the standard gain from trade. Secondly, the foreign country earns rents to innovation of GMO. Thirdly, there is no quality effect because foreign consumers all consume GMF both before and after opening up to trade. Finally, the foreign country benefits from the informational asymmetry. That is, the home consumers who would consume non-GMF if information on whether a product is GMF or non-GMF were available are also forced to consume GMF under free trade without labelling. This raises further the price of GMF.

If the home country imposes mandatory labelling, the foreign country still gains from trade, compared with autarky. Both types of consumers are better off under trade with home labelling. This is because the foreign country still experiences the standard gain from trade and earns rents to innovation. Compared with free trade without labelling, however, the foreign country suffers from home labelling mainly because the foreign country loses benefits of informational asymmetry. Moreover, labelling cost lowers further the home country's demand for GMF. The following proposition is thus obtained:

Proposition 4 *When GMO is invented in the foreign country, the foreign country always gains from trade. Foreign welfare is higher under free trade without labelling than under trade with the home country imposing mandatory labelling of GMF.*

An implication of the proposition is that mandatory labelling of GMF imposed by the

state y if and only if there exists another state z, which can be reached from x with an appropriate set of transfers between gainers and losers, such that z is an ordinary Pareto improvement over y, even if in fact these transfers will not take place. The traditional gains-from-trade theorem is based on this principle (see, e.g., Samuelson (1939, 1962) and Kemp (1962)). Grandmont and McFadden (1972) analyze the *actual* lump-sum compensation mechanism that ensures gains from trade. More recent literature on the gains-from-trade theorem with many consumers explores non-lump-sum compensation that ensures gains from trade. See, e.g., Dixit and Norman (1980 Chapter 3, 1986) and Kemp and Wan (1986).

importing country hurts the exporting country of GMF, compared with free trade. It is, however, better than an import ban of GMF.

I next analyze welfare effects of trade in the home country and policy choice by the home government. When trade is liberalized without labelling, the home U consumers are better off because they have access to cheaper imported food. This is a positive *price effect*. While C consumers also enjoys the positive price effect, they may be worse off because there is also a negative *quality effect* due to GMF imports. If the negative quality effect experienced by C consumers dominates the positive price effect, the home country loses from trade. Welfare effects under trade with labelling, on the other hand, depend on the strength of the world demand for GMF. When the world demand for GMF is not very strong, C consumers are not affected by liberalizing trade since $p_1 = p^A$. The home country thus gains from trade with labelling if and only if U consumers are better off under trade with labelling. When the world demand for GMF is very strong, C consumers are strictly worse off under trade with labelling because $p_1 = \tau\bar{\mu} > p^A$. Thus, in order for the home country to gain from trade with labelling, C consumers need to be compensated.

A comparison between trade with and without labelling again depends on the strength of the world demand for GMF. When the world demand for GMF is not very strong, by imposing mandatory labelling C consumers experience a positive quality effect because they can consume non-GMF under trade with labelling. They also experience a negative price effect because the price of x_1 under trade with labelling is higher than that of x under trade without labelling, i.e., $p_1 > p^T$. C consumers prefer trade with labelling if and only if $p^T > \alpha\bar{\mu}$. U consumers also experience a price effect. The sign of the price effect, however, can be positive or negative, depending on the case. The typical case would be that U consumers prefer trade without labelling. It happens if and only if $p^T < \tau p^*$. Then, compared with free trade without labelling, the home country is better off by imposing mandatory labelling of GMF if the quality effect experienced by C consumers dominates the price effect experienced by both C and U consumers. When the world demand for GMF is very strong, since the prices of both x_1 and x_2 under trade with labelling are higher than those in the previous case, the (negative) price effect for both types of consumers are stronger. Thus, the following proposition is obtained:

Proposition 5 *The home government imposes mandatory labelling of GMF if*

$$
\begin{aligned}
(p^T)^\beta &> \theta\,(\alpha\bar{\mu})^\beta + (1-\theta)\,(\tau p^*)^\beta\,, \quad \textit{and} && (5)\\
\tau &< \bar{\mu}/p^*, && (6)
\end{aligned}
$$

when the world demand for GMF is not very strong and if

$$
\begin{aligned}
(p^T)^\beta &> \theta\,(\alpha\tau\bar{\mu})^\beta + (1-\theta)\,(\tau p^*)^\beta\,, \quad \textit{and} && (7)\\
\tau^\beta &< \frac{\bar{\mu}^\beta}{\theta\bar{\mu}^\beta + (1-\theta)(p^*)^\beta}, && (8)
\end{aligned}
$$

when the world demand for GMF is very strong. If

$$\phi < (p^T/\bar{\mu})^\beta \tag{9}$$

holds, where $\phi \equiv 1 - \theta(1-\alpha^\beta)$, and if (6) ((8) when the world demand for GMF is very strong) is violated, the home government rather imposes an import ban on GMF.

An intuitive explanation of the proposition is as follows: As the home country is more concerned about GMF (i.e., α is lower and θ is higher) and cost of labelling is lower (i.e., τ is lower), the home government is more likely to choose mandatory labelling of GMF. This is because as τ is lower, U consumers are more likely to be better off by liberalizing trade with labelling. Moreover, when α is lower and θ is higher in addition to a lower τ, the quality effect due to labelling on C consumers dominates the price effect of labelling on both C and U consumers, compared to free trade without labelling. When the home country is highly concerned about GMF (i.e., ϕ is low) but cost of labelling is high (i.e., τ is high), on the other hand, the home government rather imposes an import ban on GMF. This is because as ϕ is smaller the negative quality effect is more likely to dominate the positive price effect under free trade without labelling. Moreover, as τ is higher, U consumers are more likely to be worse off under trade with labelling.

Note that if the world demand for GMF is very strong, the home government is more likely to impose an import ban and less likely to impose mandatory labelling.

5 Conclusions

This paper has examined trade and welfare effects of biotechnology that lowers production cost but also lowers perceived quality of product. The main purpose was to study recent international disputes on trade in biotechnology products, such as genetically modified organisms (GMOs). It has been shown that the country in which a biotechnology product is invented exports the biotechnology product because biotechnology confers comparative advantage on the country. The exporting country always gains from trade. The importing country of the biotechnology product, on the other hand, may lose from trade. This is because biotechnology provides both a positive price effect and a negative quality effect to the importing country. Without labelling, consumers cannot distinguish between biotechnology and conventional products and hence they are forced to consume the biotechnology product even if they preferred to consume the conventional one. Under free trade without labelling, neither country produces the conventional product and hence the biotechnology product completely dominates the market in both countries. As the importing country's consumers are more concerned about the negative effects of the biotechnology product, the importing country is more likely to lose from trade.

Imposing mandatory labelling of the biotechnology product can be a remedy for this problem. When labelling is costly, the cost of labelling must be sufficiently low in order for mandatory labelling to be an effective remedy. Since mandatory labelling imposed by the importing country necessarily hurts the exporting country, the result in this paper explains why mandatory labelling causes international trade dispute.

In terms of the regulation for the import of the biotechnology product, labelling is not always preferred to an import ban from the importing country's point of view. If the domestic consumers are highly concerned about the biotechnology product and if labelling cost is very expensive, then the importing country may put a ban on the import of the biotechnology product. From the exporting country's point of view, however, the import ban hurts the exporting country more severely than labelling does.

In this paper, I assumed that voluntary labelling by individual firms has no credibility. The assumption would be reasonable for a large number of competitive firms. In the real world, however, firms often provide labelling voluntarily. As I have argued in footnote 10, it can be shown that the producers of the conventional product *do* have an incentive to provide voluntary labelling. Then, if the credibility of voluntary labelling is sufficiently high, the importing country may not have to impose mandatory labelling because voluntary labelling will disclose information in the *laissez-faire* economy. This implies that with credible voluntary labelling the importing country is less likely to lose from trade. However, if the domestic consumers are highly concerned about the biotechnology product and if the cost of labelling is sufficiently high, the importing country may be better off by imposing an import ban on the biotechnology product.[20] This is because the importing country incurs very high labelling costs to separate the products under free trade. The import ban would be a cheaper means to separate the products.

A Appendix: Proofs of Propositions

A.1 Proof of Proposition 1

Let p^T be the price of x under free trade. For a given σ, the foreign supply of x_2 is infinitely elastic at $p^T = c^1(\sigma\kappa, 1)$ and the home supply of x_2 is infinitely elastic at $p^T = c^1(\xi\sigma\kappa, 1)$, where $c^1(\sigma\kappa, 1) < c^1(\xi\sigma\kappa, 1)$.[21] Then, if $p^T < c^1(\xi\sigma\kappa, 1)$, x_2 is produced only in the foreign country. The home country must specialize in z and export z. At $p^T = c^1(\sigma\kappa, 1)$ the foreign country is diversified to produce x_2 and z, while for $p^T > c^1(\sigma\kappa, 1)$ it specializes in x_2. This is because at $p^T = c^1(\sigma\kappa, 1)$, $w^* = 1$ in both x and z sectors. For $p^T > c^1(\sigma\kappa, 1)$, $w^* > 1$ in the x sector, while $w^* = 1$ in the z sector. At $p^T = c^1(\xi\sigma\kappa, 1)$, the home country is diversified to produce x_2 and z, while the foreign country must specialize in x_2. In that case, the home country must export z and import s_2. It also imports x_2. When the foreign country specializes in x_2, the total output of x_2 is given by $X = (L-\eta)/\hat{\mu}(\sigma)$. The world demand for x is given by $X^{WD} = \beta L(I + I^*)/p$. Then, if $X^{WD} < (L - \eta)/\hat{\mu}(\sigma)$ at $p^T = c^1(\sigma\kappa, 1)$, or $\beta < (L-\eta)c^1(\sigma\kappa, 1)/\{\hat{\mu}(\sigma)L(1+I^*)\}$, the foreign country is diversified. If $\beta > (L-\eta)c^1(\xi\sigma\kappa, 1)/\{\hat{\mu}(\sigma)L(1+I^*)\}$, the foreign country is specialized and the home country is diversified. *Q.E.D.*

A.2 Proof of Proposition 2

The world demand for x_2 is given by $X_2^{WD} = (1-\theta)\beta LI/(\tau p^*) + \beta LI^*/p^*$. The foreign country's capacity of supplying x_2 is given by $X = (L - \eta)/\hat{\mu}(\sigma)$. The home firms in the

[20] Note that under voluntary labelling the price of the conventional product rather than that of the biotechnology product is affected by labelling cost.

[21] Note that since the innovating firm faces the derived demand for s_2^* which is different from that in autarky, the value of σ will be different from that in autarky.

x sector have an incentive to produce x_2 if $p^* \geq c^1(\xi\sigma\kappa, 1)$. Thus, if $X_2^{WD} < (L-\eta)/\hat{\mu}(\sigma)$ at $p^* = c^1(\xi\sigma\kappa, 1)$, or $\beta < (L-\eta)\tau c^1(\xi\sigma\kappa, 1)/\{\hat{\mu}(\sigma)L(1-\theta+\tau I^*)\}$, x_2 is not produced in the home country in equilibrium. Suppose this is the case. Then, if $X_2^{WD} < (L-\eta)/\hat{\mu}(\sigma)$ at $p^* = c^1(\sigma\kappa, 1)$, or $\beta < (L-\eta)\tau c^1(\sigma\kappa, 1)/\{\hat{\mu}(\sigma)L(1-\theta+\tau I^*)\}$, the foreign country is diversified to produce x_2 and z. Otherwise, it specializes in x_2.

The world demand for x_1, on the other hand, is given by $X_1^{WD} = \theta\beta LI/p_1$. The home supply of x_1 is infinitely elastic at $p_1 = \bar{\mu} = c^1(\kappa, 1)$. The foreign supply of x_1 is infinitely elastic at $p_1 = \tau\bar{\mu}$. Since X_1^{WD} never exceeds the home demand for x in autaky, the equilibrium price of x_1 must be $p_1 = \bar{\mu}$ and hence x_1 is produced only in the home country. The home country must also produce z and export z. It imports x_2. *Q.E.D.*

A.3 Proof of Proposition 3

Suppose that $\beta > (L-\eta)\tau c^1(\xi\sigma\kappa, 1)/\{\hat{\mu}(\sigma)L(1-\theta+\tau I^*)\}$, so that x_2 is produced in the home country as well as in the foreign country in equilibrium. The foreign country must specialize in x_2 and export s_2. It also exports x_2. The home supply of x_1 is infinitely elastic at $p_1 = \tau\bar{\mu}$. The foreign supply of x_1, on the other hand, is infinitely elastic at $p_1 = \tau w^*\bar{\mu}$, where $w^* \geq 1$. Since the demand for x_1 never exceeds the home demand for x in autaky, x_1 is produced only in the home country and $p_1 = \tau\bar{\mu}$. The home country must also produce z and export z. *Q.E.D.*

A.4 Proof of Proposition 4

Foreign U and C consumers' indirect utilities in autarky are given by Eqs. (3) and (4), respectively. Under free trade without labelling, U and C consumers' indirect utilities are respectively given by

$$V^{*U}(p^T, I^{*T}) = \frac{BI^{*T}}{(p^T)^\beta} \quad \text{and} \tag{A.1}$$

$$V^{*C}(p^T, I^{*T}; \alpha^*) = \frac{\alpha^{*\beta}BI^{*T}}{(p^T)^\beta}. \tag{A.2}$$

It holds that $p^T > p^{*A}$. The wage and the innovating firm's profits are weakly higher under trade without labelling than in autarky, i.e., $w^{*T} \geq 1$ and $\pi_M^{*T} \geq \pi_M^{*A}$. Then, the standard terms of trade effect and an increase in income together imply that each type of consumer is better off under free trade without labelling. Similarly, foreign U and C consumers' indirect utilities under trade with home labelling are respectively given by

$$V^{*U}(p^*, I^{*L}) = \frac{BI^{*L}}{(p^*)^\beta} \quad \text{and} \tag{A.3}$$

$$V^{*C}(p^*, I^{*L}; \alpha^*) = \frac{\alpha^{*\beta}BI^{*L}}{(p^*)^\beta}. \tag{A.4}$$

It holds that $p^* > p^{*A}$. The wage and the innovating firm's profits are weakly higher under trade with labelling than in autarky, i.e., $w^{*L} \geq 1$ and $\pi_M^{*L} \geq \pi_M^{*A}$. It is then shown that each type of consumer is better off under trade with labelling. Finally, compare Eqs. (A.1) and (A.2) with Eqs. (A.3) and (A.4). I have $p^T \geq p^*$, $w^{*T} \geq w^{*L}$, and $\pi_M^{*T} \geq \pi_M^{*L}$. It is easily shown that each consumer is better off under trade without labelling. *Q.E.D.*

A.5 Proof of Proposition 5

Home consumer's indirect utility in autarky is given by Eq. (2). Under free trade without labelling, U and C consumers' indirect utilities are respectively given by $V^U(p^T, I^T) = B/(p^T)^\beta$ and $V^C(p^T, I^T; \alpha) = \alpha^\beta B/(p^T)^\beta$. Hold $V^U(p^A, I^A + T^A) = V^U(p^T, I^T)$ and have $V^C(p^A, I^A - (1-\theta)T^A/\theta) > V^C(p^T, I^T; \alpha)$, where $T^A = \{(\bar{\mu})^\beta - (p^T)^\beta\}/(p^T)^\beta$ is a (hypothetical) per-capita lump-sum transfer between U and C consumers, to yield (9). Note that (9) also ensures $V^U(p^T, I^T - \theta\hat{T}^T/(1-\theta)) < V^U(p^A, I^A)$ with $V^C(p^T, I^T + \hat{T}^T; \alpha) = V^C(p^A, I^A)$, where $\hat{T}^T = \{(p^T)^\beta - (\alpha\bar{\mu})^\beta\}/(\alpha\bar{\mu})^\beta$.

Under trade with labelling, home U and C consumers' indirect utilities are respectively given by $V^U(p_1, p^*, I^L; \tau) = B/(\tau p^*)^\beta$ and $V^C(p_1, p^*, I^L) = B/(p_1)^\beta$. When the world demand for GMF is not very strong, it is obvious that C consumers are indifferent and that U consumers are better off under trade with labelling if (6) holds. When the world demand for GMF is very strong, on the other hand, hold $V^C(p_1, p^*, I^L + \hat{T}^L) = V^C(p^A, I^A)$ and have $V^U(p_1, p^*, I^L - \theta\hat{T}^L/(1-\theta); \tau) > V^U(p^A, I^A)$, where $\hat{T}^L = \tau^\beta - 1$, to yield (8). It also ensures $V^C(p^A, I^A - (1-\theta)\hat{T}^A/\theta) < V^C(p_1, p^*, I^L)$ with $V^U(p^A, I^A + \hat{T}^A) = V^U(p_1, p^*, I^L; \tau)$, where $\hat{T}^A = \{(\bar{\mu})^\beta - (\tau p^*)^\beta\}/(\tau p^*)^\beta$. As for the comparison with the case of free trade without labelling, when the world demand for GMF is not very strong, hold $V^U(p_1, p^*, I^L + T^L; \tau) = V^U(p^T, I^T)$ and have $V^C(p_1, p^*, I^L - (1-\theta)T^L/\theta) > V^C(p^T, I^T; \alpha)$, where $T^L = \{(\tau p^*)^\beta - (p^T)^\beta\}/(p^T)^\beta$, to yield (5). It also ensures $V^U(p^T, I^T - \theta\tilde{T}^T/(1-\theta)) < V^U(p_1, p^*, I^L)$ with $V^C(p^T, I^T + \tilde{T}^T; \alpha) = V^C(p_1, p^*, I^L)$, where $\tilde{T}^T = \{(p^T)^\beta -$

$(\alpha\bar{\mu})^{\beta}\}/(\alpha\bar{\mu})^{\beta}$. When the world demand for GMF is very strong, since the price of non-GMF is $p_1 = \tau\bar{\mu}$ rather than $p_1 = \bar{\mu}$, replace $\bar{\mu}$ in (5) by $\tau\bar{\mu}$ to derive (7). *Q.E.D.*

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