# How to Estimate Technical Barrier to Trade When There Is No Trade

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**Abstract:** We derive a novel approach to estimate the tariff equivalent of a prohibitive Technical Barrier to Trade (TBT) based on Wales and Woodland's Kuhn-Tucker approach to corner solutions in consumer choice. The approach identifies the nonredundant component of a prohibitive trade barrier and overcomes the lack of observed trade flow and data. It also accounts for differentiated goods by place of origin. We apply the derived random utility model to world trade of Australian, New Zealand, and other apples to identify the tariff equivalent of prohibitive trade barriers Australia has been imposing on imports of New Zealand apples. We estimate the forgone apple trade between the two countries and the implied trade injury imposed by Australia on New Zealand. Welfare analysis suggests that Australia would experience net gains in excess of US$100 millions annually.

**Keywords**: TBT, NTB, Technical barrier to trade, Kuhn-Tucker model, corner solution, New Zealand apples

**JEL Code**: F13, Q17

**Estimate Technical Barrier to Trade When There Is No Trade**

## Introduction

Some countries or regions implement quarantine measures to restrict trade in a product associated with a perceived or actual risk of transferring a pest or disease into their geography. Trade agreements recognize countries' right to set their own standards and regulations on trade in order to protect human, animal or plant health or life. For example, Article 20 of the General Agreement on Tariffs and Trade, and two specific World Trade Organization (WTO) agreements deal with food safety and animal and plant health, and with product standards: the Sanitary and Phytosanitary Measures Agreement and the Technical Barriers to Trade Agreement. However, these agreements require that countries setting their own standards do not discriminate among countries or use this motive as concealed protectionism. The Technical Barriers to Trade Agreement of the WTO was generated to minimize unnecessary obstacles in regulations, standards, and testing and certification procedures. In practice some countries impose stricter than necessary conditions on importing goods to isolate domestic producers from international competition, which lead to protectionist technical barriers to trade. The stricter regulations may lead to questionable impediments to imports that compete with domestic products, in addition to the existing tariff barriers. When the possibility of a disease or pest transmission is very low or threat to food safety is small, these trade impediments often cause welfare losses for importing countries and mercantilist losses (injury in WTO lingo) for exporting countries due to reduced exports. These strict growing, storage, and inspection conditions often result in higher cost of production which in turn leads to a higher price of the importing goods. Sometimes, the price of the importing good is so high due to the demanding conditions that the importing good loses its competitiveness relative to the domestic competing product. The trade barrier becomes prohibitive, that is, no trade takes place. A large empirical literature exist on how to measures TBTs and their effects when imports are positive. For example, the price-wedge approach is often used to estimate the tariff equivalent and trade impact of a TBT by assuming homogeneous consumer preference and perfect substitution of domestic and imported goods (Calvin and Krissoff, 1998; Deardorff and Stern, 1998). Yue, Beghin and Jensen (2006) have developed a new approach to estimate TBT by accounting for imperfect substitution of domestic and imported goods, consumers' home good preference and trade cost and show that the standard price-wedge approach tends to overestimate the trade effect of TBTs. However, the estimation of the tariff equivalent of a TBT is a challenging task when trade flows do not exist because no reference imports exist and because part of the tariff equivalent will be redundant when the TBT is strictly prohibitive. Quantifying the impact of the removal of the TBT is also difficult for the same reasons. There exists some work to predict trade volume using the Tobit model when many trade observations contain zero values. For example, Eaton and Tamura (1994) recommended adopting the threshold Tobit model in which trade volume appears to be positive only when desired trade exceeds some threshold. However, Anderson and van Wincoop (2003) showed that country indicator variables should be included into the gravity model in order to control the multilateral resistance terms. Therefore, most recent studies use linear regression analysis with log(1+trade) as the dependent variable to overcome the problem brought by zero trade flow instead of using the Tobit model (Anderson and van Wincoop, 2004). Ranjan and Tobias (2005) proposed a new Bayesian procedure for estimating a generalized threshold Tobit model to avoid adding unity arbitrarily to the dependent variable to avoid taking the log of zero. The mentioned literature used different ways to deal with zero trade volume, yet none of them are related to the estimation of the tariff equivalent and trade effect of a TBT when trade volume is systematically zero for all observations of bilateral trade between two countries. This problem is likely to arise in the case of trade data for disaggregated sectors or a single commodity.

In this article we derive a novel approach to estimate the tariff equivalent of a prohibitive TBT based on Wales and Woodland's Kuhn-Tucker approach to corner solutions in consumer choice. This method has been successfully applied to random utility model of recreation demand in environmental economics (Phaneuf, Kling and Herriges, 2000)). The latter authors apply the Kuhn-Tucker approach to recreation demand for anglers in the Wisconsin Great Lakes region based on survey of fishing license holders. The random utility model accounts for the fact that consumers do not go to all the recreation areas for fishing. The demands for some sights for some particular consumer are systematically zero due to the higher transportation cost or personal preferences. Our trade approach is similar in spirit. Because of trade costs ( TBT, distance, and tariffs) and/or preferences, some consumers never consume a subset of the importables.

Additionally, we account for consumers' heterogeneous preferences for substitute goods by place of origin. We do so to avoid problems arising from assuming homogeneous goods in the computation of the tariff equivalent of a policy and its effects (Salerian, Davis, and Jomini, 1999; Yue, Beghin, and Jensen, 2006). Imperfect substitution tends to increase the size of the tariff equivalent but decreases the import expansion following the policy elimination. Extensive applied literature shows that consumers have different preferences for close substitute disaggregated food goods from different countries.

Using recent data and the proposed new approach, we provide an investigation of the Australian phytosanitary ban on imports of New Zealand apples because of the alleged risk of introducing fire blight in Australia orchards. We compute the tariff equivalent of this Australian TBT regulation affecting bilateral apple trade between Australian and New Zealand and quantify the impact of removing this TBT policy on welfare and apple trade flows.

The New Zealand-Australia apple dispute has lasted for more than 80 years without being effectively resolved. As explained later the ban has been replaced by a set of prohibitive standards making it impossible to export apples from New Zealand to Australia. A related case between Japan and the United States was resolved in summer 2005 though a WTO dispute settlement body with rulings requiring Japan to remove its fire blight regulations because they were not science based and constituted protectionism (WTO, 2005). These WTO rulings have great potential to boost the case of New-Zealand against the Australian fire blight regulations which in essence or also protectionist. Mature fruit that are shown symptomless are not effective carriers of fire blight and do not require extensive procedure dictated by the Australian regulations (WTO, 2005).

The next section introduces the Kuhn-Tucker model and the derivation of the system of equations to be empirical estimated to recover preference parameters and the tariff equivalent of measure of the TBT on prices. Then data and estimation results are presented. Welfare computations follow. Policy implications are discussed in the conclusion section.

**Conceptual model for the econometric estimation of the prohibitive TBT**

Suppose consumers in country *i* maximize utility subject a budget constraint or

$$\underset{x,AOG}{Max} U_i(x, AOG, I, y; \delta, \eta, \varepsilon, \Omega) = \sum_{j=1}^{M} \psi_{ij}(\eta, \delta_j, \varepsilon_j, y_i) \ln(x_j + \Omega) + AOG$$

$$s.t. \quad \{(p + \gamma * d)(1 + t + TBT)\}' x + AOG \le I \qquad (1)$$

$$AOG \ge 0$$
$$x \ge 0,$$

Where $\psi_{ij}(\eta, \delta_j, \varepsilon_j, y_i) = \exp(\eta \cdot y_i + \delta_j + \varepsilon_j)$ represents consumers' preference for product *j* with different attributes, $y_i$ is socio-demographic information of consumers in country *i*, $\delta_j$ is the preference for attributes of product *j* (country of origin, for example); $x = (x_1, \cdots, x_M)'$ is a vector of consumer goods; $p = (p_1, \cdots, p_M)'$ is the vector of associated prices; $t = (t_1, \cdots, t_M)'$ is the vector of tariff imposed in each country on importing goods; and $TBT = (TBT_1, \cdots, TBT_M)'$ is a vector of tariff equivalent of TBT policies faced by products in any given country. For domestic and imported products *j* in countries without technical barrier to trade imposed, then the tariff equivalent is set to zero, or $TBT_j$ =0. Vector $d = (d_1, \cdots, d_M)'$ represent distances between the exporting and importing countries; $\Omega$ is the common taste parameter for quality attributes; $\gamma$ is the unit rate of transportation cost and other fees from exporting countries to importing countries; here since we focus the study on apples, for simplicity we assume the unit rate to be the same even though the apples are from different countries. Vector

$\varepsilon = (\varepsilon_1, \cdots, \varepsilon_M)'$ is a vector of random components capturing preference variation; *I* is the income of the representative consumer and *AOG* denotes consumption of all other goods, which is the numéraire good.

The corresponding first order necessary and sufficient conditions Kuhn-Tucker conditions are

$$U_j(x, y; \delta, \eta, \Omega, \varepsilon) = \frac{\partial U(x, AOG, I, y; \delta, \eta, \varepsilon, \Omega)}{\partial x_j} \leq \lambda(p_j + \gamma * d_j)(1 + t_j + TBT_j), x_j \geq 0, \quad (2)$$

$$x_j[U_j(x, y; \delta, \eta, \Omega, \varepsilon) - \lambda(p_j + \gamma * d_j)(1 + t_j + TBT_j)] = 0, \; j = 1, \cdots, M \quad (3)$$

$$U_{AOG}(x, y; \delta, \eta, \Omega, \varepsilon) = \frac{\partial U(x, AOG, I, y; \delta, \eta, \varepsilon, \Omega)}{\partial AOG} \leq \lambda, \; AOG \geq 0$$

(4)

$$AOG[U_{AOG}(x, y; \delta, \eta, \Omega, \varepsilon) - \lambda] = 0 \quad (5)$$

Where $\lambda$ is the marginal utility of income. Suppose the consumption of the numéraire good is positive, $AOG > 0$, we have $\lambda = U_{AOG}(x, y; \delta, \eta, \Omega, \varepsilon) = 1$. Therefore, (2) becomes

$$U_j(x, y; \delta, \eta, \Omega, \varepsilon) \leq (p_j + \gamma * d_j)(1 + t_j + TBT_j), x_j \geq 0, \quad (6)$$

Specifically, when $x_j > 0$,

$$U_j(x, y; \delta, \eta, \Omega, \varepsilon) = (p_j + \gamma * d_j)(1 + t_j + TBT_j), \quad (7)$$

and when $x_j = 0$,

$$U_j(x, y; \delta, \eta, \Omega, \varepsilon) \leq (p_j + \gamma * d_j)(1 + t_j + TBT_j) \quad (8)$$

And

$$U_j(x, y; \delta, \eta, \Omega, \varepsilon) = \frac{\psi_{ij}(\eta, \delta_j, \varepsilon_j, y_i)}{x_j + \Omega} = \frac{\exp(\eta \cdot y_i + \delta_j + \varepsilon_j)}{x_j + \Omega} \quad (9)$$

The specification of the utility function in (1) lead to

$$\varepsilon_j \leq g_j(x, y, p, d, t; TBT, \delta, \Omega, \gamma, \eta) = \ln\left[(p_j + \gamma * d_j)(1 + t_j + TBT_j)(x_j + \Omega)\right] - \delta_j - \eta y_i \quad (10)$$

When $x_j > 0$, $\varepsilon_j = g_j(x, y, p, d, t; TBT, \delta, \Omega, \gamma, \eta)$ and when $x_j = 0$,

$\varepsilon_j \leq g_j(x, y, p, d, t; TBT, \delta, \Omega, \gamma, \eta)$.

Assuming the $\varepsilon_j$'s are identical, independent, and follow standard normal distribution, the log-likelihood function is

$$l = \sum_{i=1}^{K} \ln \Phi(g_i) + \sum_{i=K+1}^{M} \ln \phi(g_i) + \ln|J|, \quad (11)$$

Where, $\Phi$ is the cumulative density function of standard normal distribution, $\phi$ is the density function of standard normal distribution, and $|J|$ is the determinant of the Jacobian transformation. The parameters to be estimated are $TBT, \delta, \gamma$, $\eta$ and $\Omega$. Maximum likelihood estimation is applied to estimate these parameters.

We apply this model to the case of the Australian ban on New Zealand apples. To keep the problem manageable, we group apples into 3 types: Australian apples ($x_{AU}$), New Zealand apples ($x_{NZ}$) and all other apples ($x_{Other}$). This grouping allows us to identify the relative preferences between Australian and New Zealand apples and the TBT affecting the potential flow of New Zealand apples to Australia.

**Welfare analysis approach**

Following the econometric estimation of the TBT, welfare analysis will be conducted to investigate the welfare implication of eliminating the TBT. For welfare analysis, we use the usual Equivalent Variation (EV) measure of the consumer's welfare, with $EV = e(\tilde{p}^0, u^1) - m^0$, with $\tilde{p} = (p_{AU}, p_{NZ}, p_{Other})$ and superscripts 0 and 1 indicating initial and new prices.

Australian apple producers face welfare losses with the introduction of New Zealand apples that would follow the elimination of the TBT. This elimination will affect the Australian apples' supply and associated producer surplus, which we use to gauge producer welfare. We use a small displacement model to determine the price of domestic (Australian) apples and eventually infer the impact of removing the TBT barrier on imports and domestic (Australian) market equilibrium. Let $S_{AU}$ be the domestic retail supply of Australian apples, which is an increasing function of domestic apple price and exogenous parameter $\lambda$.

$$S_{AU}(p_{AU}, \lambda) = \lambda p_{AU}^{\varepsilon_S}. \qquad (12)$$

Parameter $\varepsilon_S$ represents the own-price elasticity of the domestic (Australian) apple supply. Decreases in parameter $\lambda$ would reflect upward shifts in supply if contamination occurs and induces an increase in the cost of production. Equilibrium domestic price $p_{AU}$ and quantity are determined by market equilibrium condition, or

$$S_{AU}(p_{AU}^e, \lambda) = X_{AU}(p_{AU}^e, p_{NZ}, p_{Other}). \qquad (13)$$

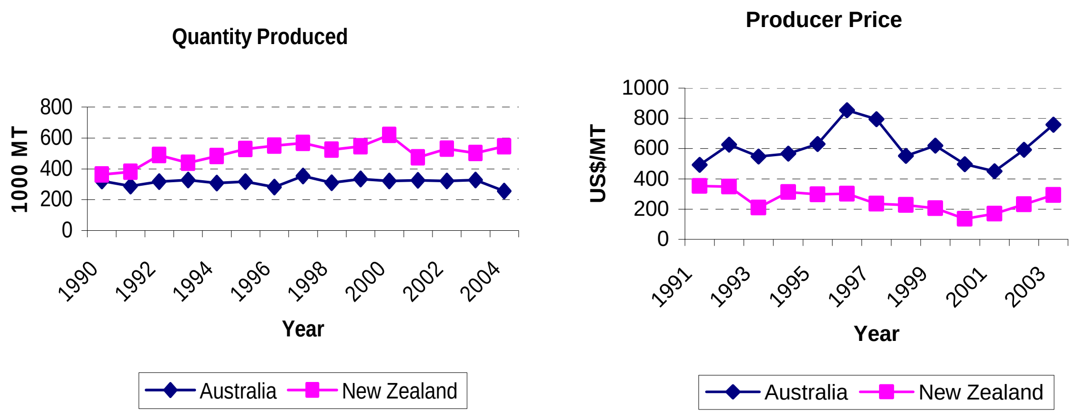
The aggregate demand $X_{AU}(p_{AU}^e, p_{NZ}, p_{Other})$ for Australian apples is the per capita demand for Australian apples by Australian consumers derived from the first order conditions of the utility maximization multiplied by population.

With the elimination of the TBT, the internal price of New Zealand apples in Australia, $p_{NZ}$, decreases whereas the internal price of Australian apples, $p_{AU}$, will fall if there is no risk of contamination from the increased imports. The domestic demand for Australian apple declines with the change in $p_{NZ}$ . Then the domestic market adjusts at a lower price such that demand equals supply. Imports of New Zealand apple expand as the direct effect of the decrease in the New Zealand price is larger than the feedback effect of the lower Australian domestic price, by stability. If fire blight contamination occurs, the price of Australian domestic apples may not decrease as the domestic supply shifts upward to reflect the increased cost from contamination.

The Australian domestic apple equilibrium quantity is further reduced by the disease contamination. Imports increase. For simplicity, we assume away feedback effects from apple suppliers into the income of the representative consumer. We turn next to our investigation of the Australian–New Zealand apple dispute starting with some key stylized
facts on the dispute.

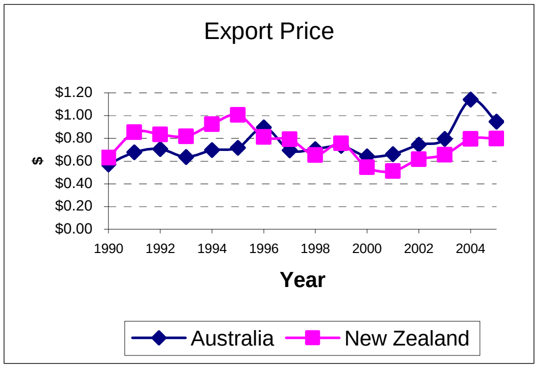
**The competitiveness of Australian and New Zealand Apple Industries**

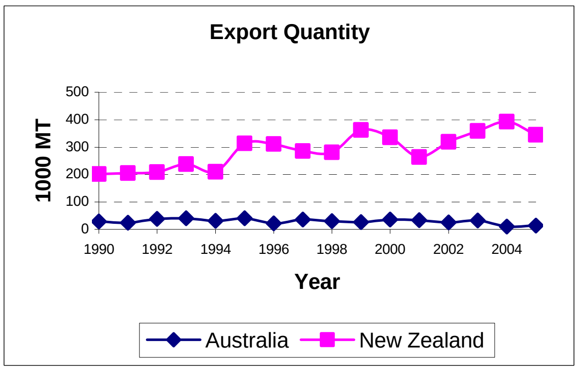
Based on 1996-2000 world apple competitive rankings provided by World Apple Report (2000), New Zealand apples' overall competitiveness ranked 1st followed by Chile's and Netherlands'. Australian apples did not make it into the top ten. In terms of production efficiency, New Zealand ranked 2nd, while again Australia was again not included in the top ten most competitive countries. New Zealand ranked the 2nd in terms of inputs and infrastructure competitiveness, while Australia's ranking was the 8th. In terms of finance and markets competitiveness, New Zealand ranked first, but Australia only ranked 9th. New Zealand exports about 55 percent of its total crop, which is higher than other significant export competitors (McKenna and Murray, 2002). The consensus view among apple market specialists is that New Zealand apple industry's overall competitiveness is a lot higher than the Australian apple industry (Dixon and Hewett, 2000). New Zealand produces more and better apples at a lower cost than Australia does, as shown in Figure 1 and Figure 2.




Data source: Food and Agriculture Organization of the United Nations
**Figure 1. Australia and New Zealand Apple Quantity Produced and Producer Price**

Figure 2 shows the export price and export quantity of Australian and New Zealand apples. From the figure we can see that New Zealand apple export is a lot higher than that of Australian apples. On average, New Zealand apple export is about ten times of that of Australian apples. The difference between New Zealand apple export quantities and Australian apple export quantities over the years is motivated by the difference in prices and the difference in consumers' preferences for apples from different origin. The New Zealand apple industry succeeded in the worldwide competition because it emphasizes on providing high quality products (Ministry of Agriculture and Forestry, New Zealand).




Data source: UN Comtrade

**Figure 2. Export Price and Quantity of Australian and New Zealand apples**

Despite the high quality and relative low cost of New Zealand apples, Australian has prohibited importation of New Zealand apples since 1921 to protect Australia from fire blight, which is claimed to be absent in Australia. In 1919, fire blight was discovered in Auckland, New Zealand. Two years later, Australia banned the imports of New Zealand apples. In 1983, Australia and New Zealand have set up the Australia-New Zealand Closer Economic Relations Trade Agreement. Under this agreement, the elimination of all tariffs and quantitative restrictions was achieved in 1990 with apples as one of the most notable exceptions.

Between 1986 and 1995, New Zealand has repeatedly applied to export apples to Australia but the applications were declined. In 1997, Australia released its Pest Risk Analysis regarding the apple imports from New Zealand. In the same year, New Zealand observed fire blight in Melbourne Royal Botanic Gardens. In 1998, Australian Quarantine and Inspection Service (AQIS) released draft risk assessment refusing imports of New Zealand apples. One year later, in 1999, New Zealand requested a review of available risk management options for apple exports from New Zealand. In 2000, the Australian Department of Agriculture, Fisheries and Forestry proposed to allow importing New Zealand apples but imposed the world's strictest bio-security conditions. In 2001, AQIS recommended lifting the 80-year ban but this recommendation was rejected by the Australian Senate Rural Affairs Committee. In 2004, the Australian Department of Agriculture, Fisheries and Forestry released import risk analysis and recommended admitting apple imports from New Zealand subject to stringent controls. In 2006, the final risk assessment by Australia allowed importing New Zealand apples into every state except Western Australia. But the New Zealand ministers and apple growers condemned that the conditions set by Australia were not materially changed and conditions to meet were so strict that few of the apple growers would afford to export to Australia. The conditions include orchard inspections of fire blight symptoms in New Zealand, the utilization of disinfection treatments in packing houses and auditing with the involvement of the Australian Quarantine and Inspection Service. New Zealand ministers and growers thought this move ignored the scientifically-based argument and was effectively a trade barrier. The ministers said no options had been ruled out including taking this case to the WTO Dispute Settlement Body (Agra Euro Weekly, 2006).

**Econometric Estimation**[1]

The random utility framework is applied to the Australian import ban on New Zealand apples. The three types of apples considered are differentiated by subscript j (*j*=*AU*, *NZ* and *Other*). They are Australian apples ( $x_{AU}$ ), New Zealand apples ( $x_{NZ}$ ) and apples from other countries ( $x_{Other}$ ).The *x*'s are per capita consumption of different apples. To estimate the TBT brought by the strict conditions imposed by Australia on New Zealand apples we incorporate 38 countries' consumers as representative consumers such as US, Canada, Asian countries such as Singapore, Bangladesh, China, India, Malaysia, Indonesia, Philippines, Sri Lanka, Thailand, and Australia, New Zealand and so on. The countries and years are listed in Table 1.

**Table 1. Countries and years**

| Country | Years |
|---|---|
| Australia | 1990-2005 |
| Bangladesh | 1991-2004 |
| Barbados | 1998-2005 |
| Belgium | 2000-2004 |
| Brunei Darussalam | 1992-1998, 2001-2003 |
| Cambodia | 2000-2004 |
| Canada | 1991, 1993, 1995-2005 |
| China | 1993-1996, 1998-2005 |
| Denmark | 1990-1992, 1994-1995, 1997, 2000, 2002-2004 |
| Finland | 1990-1995, 1998-2002 |
| France | 1995-2005 |
| French Polynesia | 1996-2005 |
| Germany | 1991-2005 |
| India | 1999-2005 |
| Indonesia | 1990-2005 |
| Ireland | 1992-1994, 1997-1998, 2001-2004 |

[1] The estimation results are tentative. An updated version of estimation is in progress with consumer surplus as the welfare measure. The current EV measure uses the restriction $\sum_{j=1}^{M}\psi_{ij}(\eta,\delta_j,\varepsilon_j,y_i)=1$, with the expenditure form of $e(p,u)=\Omega\sum_j p_j + u\prod_j\left(\frac{p_j}{\psi_{ij}(\eta,\delta_j,\varepsilon_j,y_i)}\right)^{\psi_{ij}(\eta,\delta_j,\varepsilon_j,y_i)}$.

| | |
|---|---|
| Italy | 1994-2005 |
| Kiribati | 1995-1997, 2005 |
| Malaysia | 1990-2005 |
| Maldives | 1998-2005 |
| Mauritius | 1993-2005 |
| Mexico | 1992-2005 |
| Netherlands | 1992-2005 |
| New Zealand | 1990-2005 |
| Norway | 1993-2005 |
| Philippines | 1996-2005 |
| Portugal | 1999-2005 |
| Russian Federation | 1996-2005 |
| Saudi Arabia | 1991-2005 |
| Seychelles | 1995-2005 |
| Spain | 1990-2005 |
| Sri Lanka | 1990-1994, 1999-2005 |
| Sweden | 1992-2005 |
| Switzerland | 1990, 1992, 1994, 1997-2005 |
| Thailand | 1990-1991, 1993-2004 |
| Trinidad and Tobago | 1999-2000, 2004-2005 |
| USA | 1991-2005 |
| United Kingdom | 1993-2005 |

Panel data (time, countries) are collected to estimate the model. Since panel data are used we need to capture the individual country effects. We do so by including per capita GDP ( $y_i$ ) in the utility function to see how consumers in different countries differ in their marginal utility of income as captured by parameter $\eta$ in equation (10).

Population and export quantities and prices come from the United Nations' Comtrade database. The prices for Australian apples ( $p_{AU}$ ) and New Zealand apples ( $p_{NZ}$ ) are Free On Board (FOB) prices not including international transportation fee and insurance. The latter are explicitly accounted for through cost associated with distance. The corresponding unit fee (dollar per kilometer per kilogram) is going to be estimated ( $\gamma$ ). The distances (*d*) between exporting and importing countries are sea distance via the

Suez canal in kilometers (Hengeveld, 1999). The importing prices for all other apples are CIF prices ( $p_{Other}$ ). The tariff rates are obtained from World Trade Organization online tariff rate schedules. All together we have 413 observations.

The optimization method used in maximum likelihood estimation is Nelder and Mead method, which is proved to be a robust method (Nelder and Mead, 1965). The program is complied in R version 2.4.1. The estimation results are shown in Table 2.

**Table 2. Estimation Results of Maximum Likelihood Estimation**

| Parameters | Estimate (Unit) | P-value |
|---|---|---|
| *TBT* | 0.70 | 0.012 |
| $\delta_{NZ}$ | -1.62 | <0.001 |
| $\delta_{AU}$ | -2.26 | <0.001 |
| $\delta_{Other}$ | 0.42 | <0.001 |
| $\gamma$ | $7.42*10^{-5}$ (\$/(km*kg)) | <0.001 |
| $\eta$ | $3.85*10^{-5}$ | <0.001 |
| $\Omega$ | 0.09 | <0.001 |

All parameters estimated have expected signs and are statistically different from zero at a 5% critical level or less. From the estimation results we can see that all the estimate of the parameters are significant. The TBT Australia imposes on New Zealand apples is on average about 70% of the FOB price inclusive of transportation cost. Estimated parameter $\hat{\delta}_{NZ}$ is greater than $\hat{\delta}_{AU}$ , which indicate the representative consumer prefer New Zealand apples to Australian apples. This result is in line with Dixon and Hewett (2000) who show that New Zealand apples are regarded as having premium quality, and explains why the total quantities of New Zealand apples exported to the world have been higher than those of Australian apples over years. The average unit fee for international transportation and insurance is estimated to be $7.42*10^{-5}$/(km*kg). This is comparable to an earlier study by Calvin, Krissoff and Foster (2005) about apple transportation fee from the US to Japan. Estimated parameter $\hat{\eta}$ measures how consumers' preference for apples varies by country as characterized by their income. It indirectly measures how the marginal utility of income changes as income increases. The positive $\hat{\eta}$ indicates that the marginal utility of one dollar decreases as income increases. This is because as stated in the conceptual model part of the paper, we can use the first order condition (2) and equation (9) to obtain

$$\frac{\exp(\eta \cdot y_i + \delta_j + \varepsilon_j)}{x_j + \Omega} \le \lambda(p_j + \gamma * d_j)(1 + t_j + TBT_j), x_j \ge 0 \,. \qquad (14)$$

Eventually we have

$$\frac{\exp(\delta_j + \varepsilon_j)}{x_j + \Omega} \le \exp(-\eta \cdot y_i)\lambda(p_j + \gamma * d_j)(1 + t_j + TBT_j), x_j \ge 0, \quad \text{leading to} \qquad (15)$$

$$\frac{\exp(\delta_j + \varepsilon_j)}{x_j + \Omega} \le \overline{\lambda}(p_j + \gamma * d_j)(1 + t_j + TBT_j), x_j \ge 0, \qquad (16)$$

Where $\overline{\lambda} = \exp(-\eta \cdot y_i)\lambda = \exp(-\eta \cdot y_i)$ measures how the marginal utility of one dollar differs in different countries. Since the estimated $\hat{\eta}$ is found to be positive, it implies that in higher income country the marginal utility brought by one dollar is lower.

The estimated tariff equivalent of the TBT Australia has been imposing on New Zealand apples is 70% of the FOB price of New Zealand apples inclusive of international transportation and insurance fee. The dollar value of *TBT* (in specific tariff form) changes across years as apple price change. Table 3 shows the dollar value of *TBT* from year 2003 to year 2005. The average of the specific *TBT* across the three years is $0.62/kg.

**Table 3. Dollar value of TBT across years**

| Year | $p_{NZ}$ | $d$ | *TBT* | *TBT*($/kg) |
|---|---|---|---|---|

| | (\$/kg) | (km) | | |
|---|---|---|---|---|
| 2003 | 0.62 | 2676 | 70% | 0.57 |
| 2004 | 0.66 | 2676 | 70% | 0.60 |
| 2005 | 0.80 | 2676 | 70% | 0.70 |

Next we calculate the implications of removing the Australian TBT in terms of Australian imports of New Zealand apples and the associated social welfare. Since Australian imports of New Zealand fresh apples have been zero over the years due to the import ban, the increase in imports is simply the Australian consumers' optimal consumption quantity of New Zealand apples by maximizing their utility function. The increasing amounts in imports across year 2003 to year 2005 are shown in Table 4. By eliminating *TBT*, Australian imports of New Zealand apples would increase substantially, between $111.70 \times 10^3$ MT and $134.20 \times 10^3$ MT across the three years. The average increasing import amount of New Zealand apples is $112 \times 10^3$ MT. The dollar amount of this trade expansion provide a measure of the trade "injury" caused by Australia to New Zealand and is listed in the third column of Table 3. It ranges from 69.25 million dollars to 107.36 million dollars over the three years.

**Table 4. Changes in Australian imports of New Zealand apples after the TBT removal**

| Year | Increase in Australian Import of NZ apples ($10^3$ MT) | Increase in Export Revenue of NZ apples (million \$) |
|---|---|---|
| 2003 | 111.70 | 69.25 |
| 2004 | 120.00 | 79.20 |
| 2005 | 134.20 | 107.36 |

Changes in welfare arising from the elimination of *TBT* vary depending on the chosen assumption on the transmission of disease associated with the introduction of New Zealand apples. The elimination of *TBT* leads to increase of imports of New

Zealand apples, which would increase the social welfare from consuming apples other things being held constant. In the case of no disease transmission the introduction of New Zealand apples lowers the price of Australian domestic apples through competition because the lower price of New Zealand apples and the relative small transportation fee due to the close distance between the two countries. The producers' welfare decreases. But because of the lower price of apples consumers will be better off. The total social welfare change depends on the relative value of consumers' welfare and producers' welfare but with net expected gains as long as terms of trade effects are moderate. But in the case of with disease transmission, the Australian domestic supply will further decrease due to the damage brought by fire blight contamination of Australian orchards. This will further jeopardize producers' interest. Table 5 gives the welfare implications of eliminating the TBT between year 2003 and 2005 in the no-disease transmission case. Following Arthur (2006) we assume short and medium term supply elasticity of apples to be 0.3.

**Table 5. Welfare changes by elimination of TBT without disease transmission**

| Year | $p_{NZ}$ ($/kg) | Tariff | *TBT* | *EV (million $)* | *Loss of Producer Surplus (million $)* | *Net Welfare*[a] *(million $)* |
|---|---|---|---|---|---|---|
| 2003 | 0.62 | 2% | 70% | 112.84 | 17.05 | 97.61 |
| 2004 | 0.66 | 2% | 70% | 130.83 | 24.56 | 108.33 |
| 2005 | 0.80 | 2% | 70% | 142.02 | 17.80 | 126.90 |

[a] the net welfare is the *EV* + change of tariff revenue-loss of Producer Surplus.

EV and producer surplus are shown in the fifth and sixth columns of Table 5. And the net welfare changes following the removal of *TBT* is shown in the last column of Table 5. Not surprisingly, *EV* is far larger than the loss of producer surplus. And the net social welfare are positive across the years. Therefore, it's optimal for Australian government to eliminate the TBT.

Following Yue, Beghin and Jensen (2006) and Arthur (2006), we assume that production of apples would decrease by a fixed proportion of 20%, if there was fire blight contamination of Australian orchards.  This estimate comes from the Queensland Government's Department of Primary Industries and Fisheries. Transmission of disease implies an upward shift of Australian domestic supply of apples because the variable cost of producing apples has increased. Table 6 shows the welfare implications with disease transmission.

**Table 6. Welfare changes by elimination of TBT when there is disease transmission**

| Year | $p_{NZ}$ ($/kg) | Tariff | *TBT* | *EV (million $)* | *Loss of Producer Surplus (million $)* | *Net Welfare (million $)* |
|---|---|---|---|---|---|---|
| 2003 | 0.62 | 2% | 70% | 108.07 | 17.21 | 92.69 |
| 2004 | 0.66 | 2% | 70% | 125.25 | 24.77 | 102.54 |
| 2005 | 0.80 | 2% | 70% | 139.65 | 17.90 | 124.43 |

From Table 5 we see that when there is disease transmission *EV* is lower compared with the case when there is no disease transmission and the loss of producer surplus increases. But the net welfare through the years are still positive of close magnitude, which indicates that it's optimal to eliminate TBT even if there is a possibility of disease transmission. The TBT prevents Australian consumers from enjoying the higher quality of New Zealand apples and the lower prices of both domestic and New Zealand apples. This is true even if the disease could be transmitted, resulting in further decreases in domestic production, since the gains to consumers far outweigh the loss to producers. If we incorporate the welfare of both New Zealand and Australia, "global" social welfare would be enhanced further by the elimination of the TBT.

**Conclusion**

We applied the Wales and Woodland approach to corner solutions in consumption decisions to prohibitive trade barriers. The random utility model is applied to trade flows consumed and sometime not consumed by international consumers depending on trade costs associated with the importable goods and consumer preferences. TBT policies, transportation costs and tariff are incorporated in the measurement of trade costs. Their influence is recovered in the estimation of Kuhn-Tucker conditions coming from maximizing utility. We recover the non redundant component of the tariff equivalent of TBT policies that are prohibitive and inherently partly redundant. We apply the approach to trade restrictions some countries still impose via prohibitive standards and regulations on imports of certain products to protect domestic growers. We fill a gap in the TBT literature by providing an explicit way to overcome both the redundant component of a prohibitive TBT policy and the lack of observed bilateral trade flow. This article bridges this important gap in the literature.

The rigorous investigation of the Australia–New Zealand apple dispute validates the approach. More importantly, our research raises important policy implications. The results strongly suggest that consumers prefer New Zealand apples to Australian apples, which confirms previous findings on premium quality of New Zealand apples. An important implication of our analysis of the New Zealand-Australia apple dispute is that the increase in New Zealand apple imports by Australia would be quite high, following the elimination of the Australian TBT policy. We provide an estimate of the injury New Zealand could claim in a WTO dispute with Australia in terms of forgone apple exports to the latter country. Incidentally this figure is of the same order of magnitude as the estimated injury the United States claimed in its WTO dispute against Japan (US$143 millions), but slightly smaller.

Last, preliminary welfare analysis shows that it is optimal for Australia to eliminate its TBT policy on New Zealand apples imports even in the case of a significant fire blight contamination as Australian consumers' gains would largely outweigh producers' losses. These welfare measures will be refined in subsequent versions of this paper.

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