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REVISITING BARRIERS TO TRADE: DO FOREGONE HEALTH BENEFITS MATTER?

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Introduction

After over more than six decades of broad-based multilateral trade liberalization under the General Agreement on Tariffs and Trade (GATT), and subsequently the World Trade Organization (WTO), trade in agricultural products is still constrained by high barriers to market access for imports. These barriers consist of both traditional tariffs and a plethora of non-tariff barriers. Until the Uruguay Round (1986-1994) of GATT negotiations, trade in agricultural products was largely exempt from multilateral disciplines pertaining to market access due to *waivers* granted in the early years of the GATT. While the conclusion of the Uruguay Round brought the rules of trade for agricultural products within the general WTO framework, tariff concessions were few, and in the end significant improvements in market access were largely thwarted by *dirty tarifficaction* and the continued widespread use of non-tariff barriers. Many members of the WTO continue to show little enthusiasm for the liberalization of market access for agricultural products.

As a result of the continued reticence of some countries to liberalize their agricultural markets, no agreement has been reached in the Doha Round negotiations that began in 2001 – market access for agricultural products remains a major stumbling block to completion of the round (Gifford et al., 2008). Even if the Doha Round were to succeed, what has arisen thus far in the negotiations shows only limited *ambition*. It seems that the traditional approach to liberalizing market access may not be able to deliver much progress, and those interested in securing better access should explore alternative means to accomplish their goals.

While the state of international market access may be relatively static, the agri-food sector is exhibiting considerable innovativeness and dynamism – the move to genetic modification of some plants, the expansion in biofuel production, ongoing improvements in *cold chain* capacity in food supply chains and the arrival of a growing range of *functional foods* – those that provide health benefits beyond those arising from those associated with nutrition, to name only a few. Rising consumer incomes have led to more value added and processing being incorporated in the food people buy and a decline in the proportion of meals eaten at home. As a result, there is a greater opportunity to engage in product differentiation in the food sector. The trade barriers in the agricultural sector largely reflect the period when international movements were largely commodity-based meaning that product differentiation was difficult and farmers in one country were competing directly with farmers in another country.

While significant progress on liberalizing market access in agriculture has proved allusive over the last half century, the imposition of new barriers has been more difficult. As with other tariffs, agricultural tariffs have long been *bound* and the creation of new tariffs largely prohibited. Certainly, some new non-tariff barriers have been put in place and the process of tariffication and the establishment of tariff rate quotas that arose from the Uruguay Round led to increases in barriers to access, but, for the most part, the barriers to agricultural trade have been long standing.

Given the changing nature of agri-food products and trade – and the apparent inability to garner significant liberalization in multilateral negotiations – the question arises as to whether trade barriers put in place decades ago are still appropriate. Are there situations where the decision to impose barriers to trade need to be revisited? This implies a piecemeal approach to trade liberalization. Of course, countries always have the right to unilaterally lower their trade barriers. One suspects that there is a great deal of inertia in trade policy making once trade barriers are imposed. Thus, the question becomes, when should policy makers revisit the decision to impose trade barriers?

Except under particular market configurations (e.g. optimum tariff strategies for large countries), trade restrictions are welfare reducing (Gaisford and Hester, 2007). As policy makers are willing to impose trade barriers, this suggests that they must give implicit, if not explicit, weightings to the benefits (received or forgone) by various market participants. In a simple example, if the benefits forgone by consumers from the imposition of a trade barrier are three times the value of the benefits received by producers, when policy makers chose to impose the barrier then they must, at a minimum, give a weighting to producers welfare that is three times that which they give to consumers welfare. Of course, it may be that the actual weighting given to producer's welfare is four or five times that which they give to consumers. The *tipping point* where the marginal weighted utility of consumers is equal to the marginal weighted utility of producers, as evaluated by policy makers, is not transparent. It is, however, clear that there must be some implicit tipping point where a policy decision would be reversed.

If the benefits forgone from the existence of a trade barrier were to increase significantly, or the benefits reaped decreased significantly (or some combination of the two) then the tipping point might be reached and policy makers might wish to revisit their decision. It is clear that policy makers require additional information upon which to base their decisions.

One of the areas where agri-food products are evolving, and where there may have been an increase in the benefits forgone when trade barriers are in place, is functional foods. Functional foods provide consumers with health benefits in excess of the value provided by the food's nutrition. In some cases, foods have been improved or enhanced to provide the new health benefits; in other cases research has found new health benefits in previously existing products. As the barriers to trade in food products were put in place when only the nutritional value of the food was known, there will be additional benefits forgone. As yet, there are no separate tariff lines for functional food variants of traditional products – and creating new tariff lines is a long and complicated process (Kerr and Loppacher, 2005).

This paper has two objectives: (1) to provide a preliminary investigation into how the additional benefits expected from functional foods can be incorporated into trade models and; (2) to provide case studies to examine whether the increased benefits forgone are of sufficient magnitude to cause policy makers to revisit the decision to impose trade barriers. While the latter is subjective, if the results of the empirical analysis produce what appear to be trivial changes in the benefits forgone, then it might be concluded that this is not an appropriate avenue for further research. Given that we do not know of any other attempts to incorporate health benefits into trade models, this is an important first step.

Functional Foods

New types of foods designed to promote health or to reduce the risk of diseases have been recognized as *functional foods* since the 1990s (Niva and Mäkelä, 2007). These new products are designed to meet specific health concerns by assisting disease prevention and helping to promote health. In addition to new products which are designed to be health-enhancing, a number of traditional and familiar foods are also now considered functional foods as new health benefits have been recently discovered (Hasler, 2000). For example, at the annual Frontiers in Cancer Prevention Research conference in Seattle 2004, it was pointed out that *an apple a day* may be an effective approach to cancer prevention (Davis, 2004). Eggs have proved to be an excellent dietary source of many essential (e.g., protein/choline) and non-essential (e.g., lutein/zeaxanthin) elements that promote optimal health (Hasler, 2000).

Consumers are increasingly interested in combining their diet decision with the promotion of health benefits. As a result, functional food products represent a value-added growth opportunity for the agri-food industry around the world. According to Euromonitor International (2006), the world market for functional foods has grown by more than 50 percent in the last 5 years. The United States, Japan and Europe are major global markets, contributing over 90 percent of total sales (Kotilainen et al., 2006). Healthy food (natural and organic foods, functional foods and lesser evil foods[1]) sales in the United States reached US $102 billion in 2004. Among them, functional foods accounted for 20 per cent of total US healthy food sales (excluding food service). The sales of functional and fortified foods were expected to reach US $59.87 billion in 2009 (Sloan, 2006).

Japan is the second-largest market in the world for functional products after the US (JETRO, 2006). The Japanese market is valued between US $4 billion and US $15 billion annually (SWMI, 2002). The functional food market in Europe is expected to grow quickly — by as much as 16 percent annually — reaching an approximate value US $15 billion (SWMI, 2002). Canada can be an internationally competitive producer of a range of functional foods. The small size of the Canadian market, however, suggests that the success of the functional foods industry will depend, to a considerable degree, on access to foreign markets (Yeung et al., 2007).

Valuing Health Benefits

Correct valuation of risks to human health is essential to health, safety, and the environment (Berger et al., 1987). A number of broad-based economic approaches to

[1] Lesser-evil foods are manufactured by removing unwanted substances including fat, calories, preservatives, caffeine, alcohol, salt, etc. from their originally state (NBJ,2008).

estimating health benefits have been developed including; cost-illness analysis, cost-effectiveness analyses, cost-utility analyses and cost-benefit analyses; while partial economic evaluations depend on cost analyses, cost-comparison studies and cost-outcome descriptions (Higgins and Green, 2008). Traditionally, measuring the benefits of improved health has been based on avoidance of the damage that occurs as a result of contracting disease (Berger et al., 1987). One of the simplest and most straightforward approaches to estimate the medical costs avoided based on health improvements is the cost-of-illness (COI) model (EPA, 1991). Cost of illness studies were first used in the late 1950s and early 1960s and have been used extensively since that time (Cooper and Rice, 1976). They are most common in the medical literature. The basic idea in COI studies is to estimate the maximum economic costs that could potentially be saved or gained if a disease were to be lessened or eradicated (Segel, 2006). The cost of illness is measured by the sum of the direct costs for prevention, detection and treatment from health care and the indirect costs or loss due to disability (morbidity) and premature death (mortality) (Cooper and Rice, 1976). COI studies are valuable because they provide informative evidence for policy makers (Segel, 2006).

The COI approach has been used to evaluate the benefits of functional foods. For example, Malla et al. (2007) valued the potential health benefits of *trans* fat-free canola oil by using the COI model. In their paper, a COI model is adapted to estimate the impact of a change in dietary fat intake on coronary heart disease (CHD) costs in Canada. Their results have shown that the potential health-care or cost of illness savings in Canada from healthier *trans* fat-free oils are important. The authors suggest valuing health improvements through food industry innovations is a subject worthy of further study (Malla et al., 2007). In this paper we adapt this approach to assist in the estimation of the foregone benefits of retaining trade barriers.[2]

Trade Policy Trade Offs

A comparative-static partial equilibrium trade model (Gaisford and Kerr, 2001) is illustrated in Figure 1. D is the domestic demand curve for a particular product. As the price of the product, P, rises, consumers will not be willing to purchase the same quantity as at the lower price. Consequently, the quantity demanded, Q, declines and the demand curve is negatively sloped. For supply, as the price, P, rises, production becomes more profitable and the output supplied by producers increases. Thus, the quantity supplied, Q, increases, leading to a positively sloped supply curve, S (Gaisford and Kerr, 2001). Without the opportunity to engage in international trade, the equilibrium price is determined where the total domestic supply of the commodity

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[2] There are, however, weaknesses associated with the use of cost-of-illness studies. As a basic and straightforward method, a COI model may overlook additional information that could be used to better value the impact. Opportunity costs, for example, should be considered in a health evaluation to obtain the optimal solution for the allocation of resources (Donaldson and Narayan, 1998). Another example is the difficulty associated with measuring the utility foregone by consumers in a COI model compared to a contingent valuation (CV) model. Based on a survey of willingness-to-pay or willingness-to accept among responders, a CV model is superior in valuating non-market attributed which give people utility. Without taking into account the loss in utility to individuals, the COI model may underestimate the true cost of illness. Furthermore, instead of establishing a relationship between costs and benefits, the static COI model simply tabulates the two concepts and adds them together to establish the net total cost (Roux and Donaldson, 2004). Without the appropriate information and a comprehensive treatment, COI studies are likely to be sub-optimal in determining how resources are to be allocated (Drummond, 1992.).

is equal to the total domestic demand. At this point, E, the market clears at P_E because the quantity being supplied by firms, Q^E is exactly equal to the quantity of the commodity being demanded by consumers.

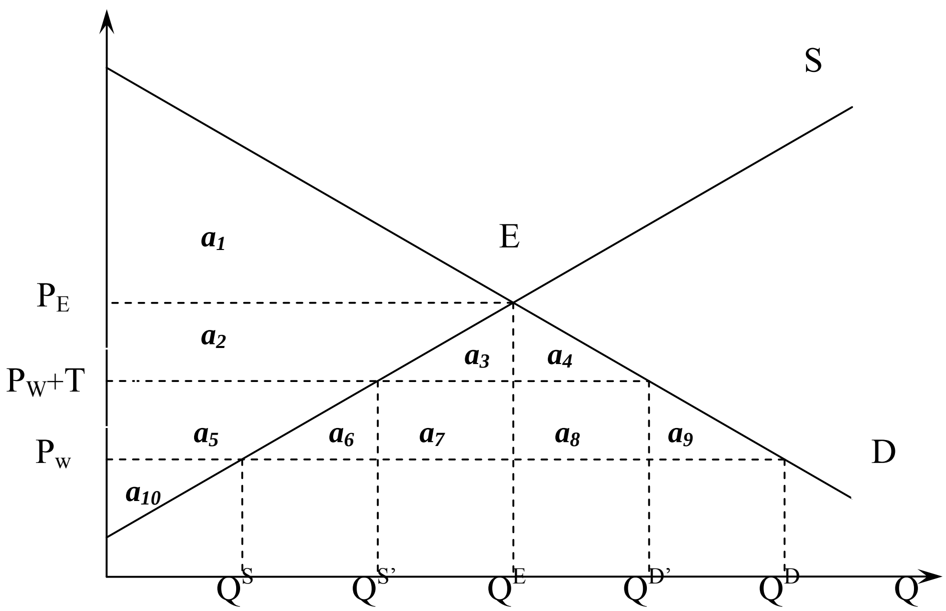


Figure 1: The Basic Trade Model

In Figure 1 in the autarky case, consumer surplus is represented by area $\boldsymbol{a_1}$ which is a triangle above the domestic price and below the demand curve. Producer surplus is area $\boldsymbol{a_2}+\boldsymbol{a_5}+\boldsymbol{a_{10}}$, a triangle below the domestic price and above the supply curve. Combined, the consumer surplus and the producer surplus, make up the total surplus or the welfare arising in this market.

Now assume the opportunity to engage in international trade in this product arises. The price consumers and producers face in the international markets is P_w — the world price. In this case, P_w is the price at which imports can be obtained in the international market, $P_w < P_E$. Assuming transport and transaction costs associated with international shipments are sufficiently small to ignore, the domestic price will decline until it is equal to the world price. At Pw, domestic consumers are willing to purchase Q^D while domestic producers are only willing to supply Q^S. The difference between demand and supply at Pw is filled by imports. The import quantity is shown as $(Q^D$-$Q^S)$. Consumer surplus is $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ which is a triangle above the world price and below the demand curve. Producer surplus is area $\boldsymbol{a}_{10}$. Total welfare is $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{10}}$ and greater than under autarky (i.e. $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_5} + \boldsymbol{a_{10}}$). Thus, trade is welfare enhancing.

If Pw is too low for some producers to make normal profit, they may lobby for protection from imports. Political decision makers may wish to supply protection. Protection could be provided through the imposition of a tariff (tax) on imports. After the tariff, T, is imposed, the domestic price rises from P_w to $(P_w + T)$. At price $(P_w +$

T), domestic firms are willing to produce additional quantity because they must now compete with imports priced at (P_w + T) instead of with imports priced at P_w. The supply expands from Q^S to $Q^{S'}$. However, the higher price leads to a reduction in consumption from Q^D to $Q^{D'}$. Thus, imports decrease to ($Q^{D'}$- $Q^{S'}$).

After imposing the tariff, total welfare also changes. The higher domestic price leads to an increase in producer surplus but a loss in consumer surplus. At price (P_w + T), the consumer surplus shrinks from area $a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8 + a_9$ to area $a_1 + a_2 + a_3 + a_4$ and producer surplus increase from area a_{10} to area $a_5 + a_{10}$. The tariff causes a loss of consumer surplus equal to $a_5 + a_6 + a_7 + a_8 + a_9$ for a gain in producers surplus of a_5 . If the objective of the protection policy was to increase producer surplus by a_5, decision makers must weigh the benefits received by producers more heavily than benefits forgone by consumers. In this case, we assume that the revenue received by government is not a motivation in the decision to provide protection. This is a reasonable assumption for most modern market economies where tariffs receipts are a relatively trivial source of revenue[3]. In the case of functional foods, the trade restricting policies may not be tariffs[4]. Thus, the protection is assumed to have been granted on the basis of a weighting of consumer and producer benefits only. Let us denote η as the ratio giving decision makers' weighting of the changes in consumer surplus and producer surplus arising from the imposition of a protectionist policy.

[3] This may not be the case for some developing countries and the analysis would have to incorporate tax revenues for those countries. We ignore these cases.
[4] It is assumed that the rents available from the imposition of non-tariff barriers do not influence policy makers' decisions.

$$\eta = \frac{\Delta \text{consumer surplus}}{\Delta \text{producer surplus}}$$

Compared to the situation before the tariff, consumers suffer a loss of area $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ and producer gain area $\boldsymbol{a_5}$. Thus,

$$\eta = \frac{\Delta \text{consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_5 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_9}{\boldsymbol{a}_5}$$, Which is larger than 1.

In order to clarify the effects before and after the granting of protection, let us simply assume η = 3 for this specific situation. When η =3, the loss for consumers arising from the higher price is three times larger than the gain by producers. Political decision makers must assign at least three times the weight to producer benefits than they assign to consumer benefits. Given that the tariff was imposed, a weight of three is the minimum weight they could have used in their decision, although a higher weighting may have been possible. While political decision makers may not explicitly make these weighed tradeoffs, they must do it implicitly with some *rule of thumb*. The change in trade policy turns out to be welfare reducing for the domestic economy (Gaisford and Kerr, 2001). If the situation in the market changes such that η rises, a case might be made for decision makers to re-evaluate their decisions.

Trade Barriers and Functional Foods – Four Cases

This paper focuses on the trade policy effects when new products with health improving attributes — functional foods — become available in markets with pre-existing restrictions on trade in place. While the trade barrier in place could be a tariff, non-tariff barriers are also common in agriculture (Hobbs, 2007). Food products normally face two broad types of non-tariff barriers. One set of non-tariff barriers acts like an import ban — prevents any imports. Other non-tariff barriers raise the cost of exporting so that imports still take place, but at lower levels — the effect is similar to a tariff (Kerr, 2007).

Figure 2 illustrates the differential effects of a ban compared to an increase in costs as a result of an import regulation. Before any import regulation is put into place, domestic consumers and producers face P_w, a world price in the international market. At P_w, domestic demand from consumers is Q^D while domestic supply is Q^S. The difference between demand and supply at Pw leads to imports. The import quantity is shown as (Q^D- Q^S). However, when there are non-tariff barriers pertaining to imports, the market will be constrained. If the non-tariff barrier acts like an import ban, it prevents any imports. There is only domestic production sold in the market and imports at P_w cannot take place. The market will clear at $P_{E.}$ The equilibrium quantity is Q^E. Thus, equilibrium will be reached at $P_{E,}$ a higher price than P_w.

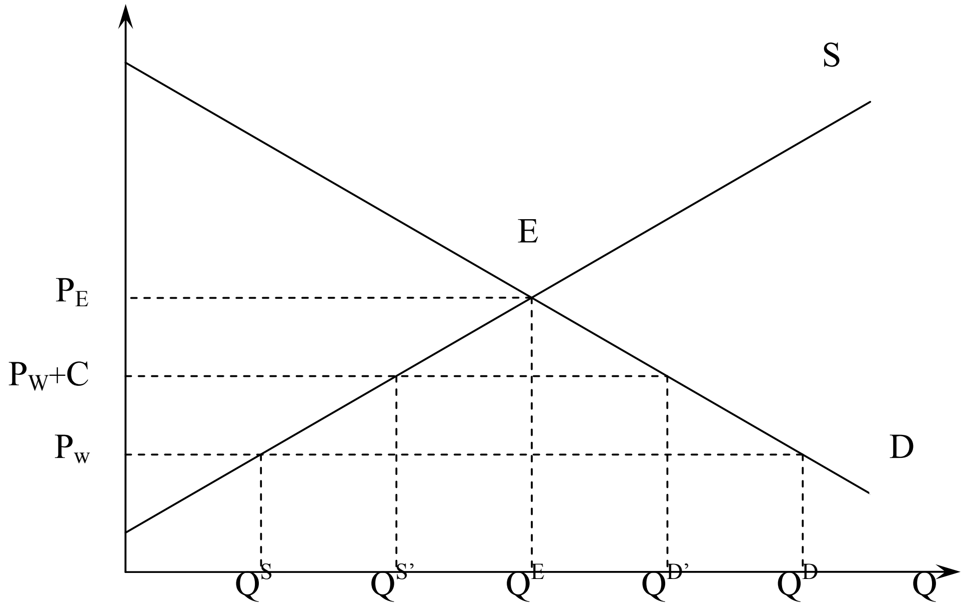


Figure 2: Non-tariff barriers effects

Non-tariff barriers can also raise the cost of exporting. In such a case, the domestic price will increase from P_w to $(P_w + C)$ - where C is the additional cost increase faced by the exporter in satisfying the importing country's requirements. At $(P_w + C)$, import quantity shrinks to $(Q^{D'} - Q^{S'})$.

In order to gain market access, exporters may have to satisfy cost increasing regulations of importing countries. An example might be testing to ensure that imports are free of a drug residue. These regulations may be unduly odorous and thus provide economic protection — they are a disguised protectionist measure. Thus, there are additional costs incurred in the process of production when firms in the exporting country wish to export their products. If there are different requirements for testing and proof of scientific evidence, the importing country may refuse to accept foreign credentials or scientific procedures and the importer's regulations are equivalent to an import ban.

The welfare effects of a trade restriction also vary depending on whether or not the new functional food can be provided domestically in the importing market. Therefore, four different cases pertaining to import restrictions on functional foods can be examined. These four cases fall into two categories: *trade policy* and *ability to produce*. Within *trade policy*, the focus is on the trade barrier faced by exporters. The barrier is either equivalent to an import ban or a cost increasing regulation[5]. Under *ability to produce*, functional foods are divided by the ability to acquire the new

[5] Tariffs are treated as part of the latter category.

products from domestic producers as well as imports (domestic production or imports) or solely from imports (imports only).

Table 1 outlines the four cases under different trade policy and production constraints. Case 1 and Case 3 are based on the same trade policy but different assumptions regarding the ability to produce. Products in Case 1 can be supplied by domestic producers and obtained from the international market. On the other hand, for Case 3, the functional food version of the product can only be acquired from the international market. In Case 2 and Case 4 the supply choices are the same as above but the market is constrained by the more restrictive policy such that imports are effectively banned.

Table 1: Four Cases for trade policy and the supply of functional foods

Supply of Functional foods \ Trade Policy	Cost increasing regulation	Import prohibition
Domestic production or imports	Case 1	Case 2
Imports only	Case 3	Case 4

Case 1

For Case 1, there are both domestic sellers and an international source of supply for a new functional food. Figure 3 shows the domestic market of the new functional food. D^M is the demand curve for a pre-existing product that does not have health enhancing attributes, product M. There is a domestic supply curve S^M for product M. At P_w, the world price for M, consumers are willing to purchase Q^{DM} and producers will only supply Q^{SM}. Imports would be (Q^{DM}- Q^{SM}). If a cost increasing import restriction has been put in place that raises costs so that the *landed price* equals (P_w + C) — cost increasing regulation (or equivalent tariff) — imports will fall to ($Q^{DM'}$- $Q^{SM'}$).

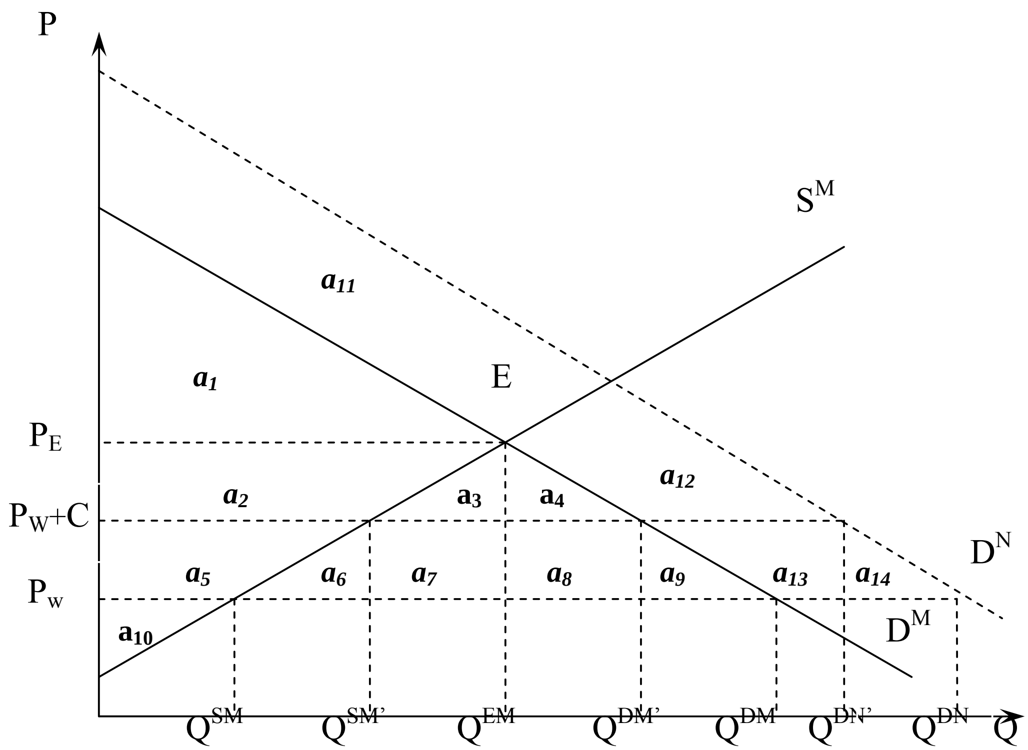


Figure 3: Case 1 — domestic and import supply, cost increasing regulation

The cost increasing policy will alter welfare in the market. Without the regulation, the consumer surplus is area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$. Producer surplus is shown as area $\boldsymbol{a_{10}}$. After trade policy is implemented, consumer surplus decreased to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4}$. Consumers suffer a loss of area $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ in consumer surplus because of the higher price. On the other hand, producer surplus increases to an area $\boldsymbol{a_5} + \boldsymbol{a_{10}}$ — a change equal to $\boldsymbol{a_5}$. The relative weighing ratio is

$$\eta^{M} = \frac{\Delta \text{ consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_5 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_9}{\boldsymbol{a}_5}$$

Now assume a new health enhancing functional food version of product M, denoted product N, comes onto the market. In order to simplify the exposition, we make three assumptions. First, we assume the new product, N, can be produced at the same cost as product M by both domestic and foreign suppliers. Second, product N can be represented by the same demand curve as product M and that the new health attribute does not change the slope of the demand curve in a meaningful way.[6] Thirdly, from the perspective of consumers, more people are willing to buy the new health enhancing product N at the same price. Therefore, demand increases shifting out the demand curve from D^M to D^N. As the additional demand can be accommodated by

[6] It is possible that the slope of demand curve for product N will be changed due to a change in consumers' perception of the product. As no information is available on how the slope may have changed, a parallel shift in demand is assumed.

acquiring additional imports at (P_w + C), there is no change in price. Thus there is no change in domestic producer surplus.

The new product, N, faces the original world price P_w and distorted landed price (P_w + C), the same as with product M. With the new demand curve, consumers receive more surplus than that from product M. With no trade restriction, consumer surplus changes from area $a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8 + a_9$ to area $a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8 + a_9 + a_{11} + a_{12} + a_{13} + a_{14}$ an increased benefit of area $a_{11} + a_{12} + a_{13} + a_{14}$. After the cost increasing trade policy is applied, new world price (P_w + C) leads to a decline in consumer surplus to area $a_1 + a_2 + a_3 + a_4 + a_{11} + a_{12}$. Therefore, the cost increasing policy generates a loss in consumer welfare of area $a_5 + a_6 + a_7 + a_8 + a_9 + a_{13} + a_{14}$. In addition to the direct consumer benefits from functional foods which arise in this market, there may be savings in health care costs[7] for the government as a result of the consumption of the functional food. We assume for the moment that these cost savings are a positive constant denoted HCS[8]. The relative weighting ratio is now at least

$$\eta^N = \frac{\Delta \text{consumer surplus} + \text{HCS}}{\Delta \text{producer surplus}} = \frac{\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_9 + \mathbf{a}_{13} + \mathbf{a}_{14} + \text{HCS}}{\mathbf{a}_5}$$

Therefore, $\eta^N > \eta^M$;

$$\frac{a_5 + a_6 + a_7 + a_8 + a_9 + a_{13} + a_{14} + \text{HCS}}{a_5} . > \frac{a_5 + a_6 + a_7 + a_8 + a_9}{a_5}$$

7 Health care costs include direct health care cost such as inpatient care cost and out patient care cost as well as indirect health care costs such as a loss in productivity and the provision of informal care.

8 This assumption will be relaxed at a later stage.

As a result, policy makers may wish to revisit their decision to impose a trade barrier.

Case 2

For Case 2, there still exist both domestic producers and international sources of supply for a new functional food. However, the new functional food, N, faces a regulatory trade barrier that is equivalent to an import ban.

Figure 4 illustrates the domestic market when a new functional food enters the marketplace. As in Case 1, D^M is the demand curve for a pre-existing product that does not have health enhancing attributes, product M. S^M is the domestic supply curve for product M. At P_w, the world price for M, consumers are willing to purchase Q^{DM} and producers will only supply Q^{SM}. Imports would be (Q^{DM}- Q^{SM}). The consumer surplus is area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$ and the producer surplus is area $\boldsymbol{a_9}$. If there is an import ban imposed on product M, the price will rise to P^E_M and the quantity consumed will be Q^{EM}. Therefore, the consumer surplus will decrease to area $\boldsymbol{a_1} + \boldsymbol{a_2}$ –a reduction of $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$. Producer surplus increases to area $\boldsymbol{a_5} + \boldsymbol{a_9}$ with an increase equal to area $\boldsymbol{a_5}$.

The relative weighting ratio is

$$\eta^M = \frac{\Delta \text{consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_5 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \boldsymbol{a}_8}{\boldsymbol{a}_5}$$

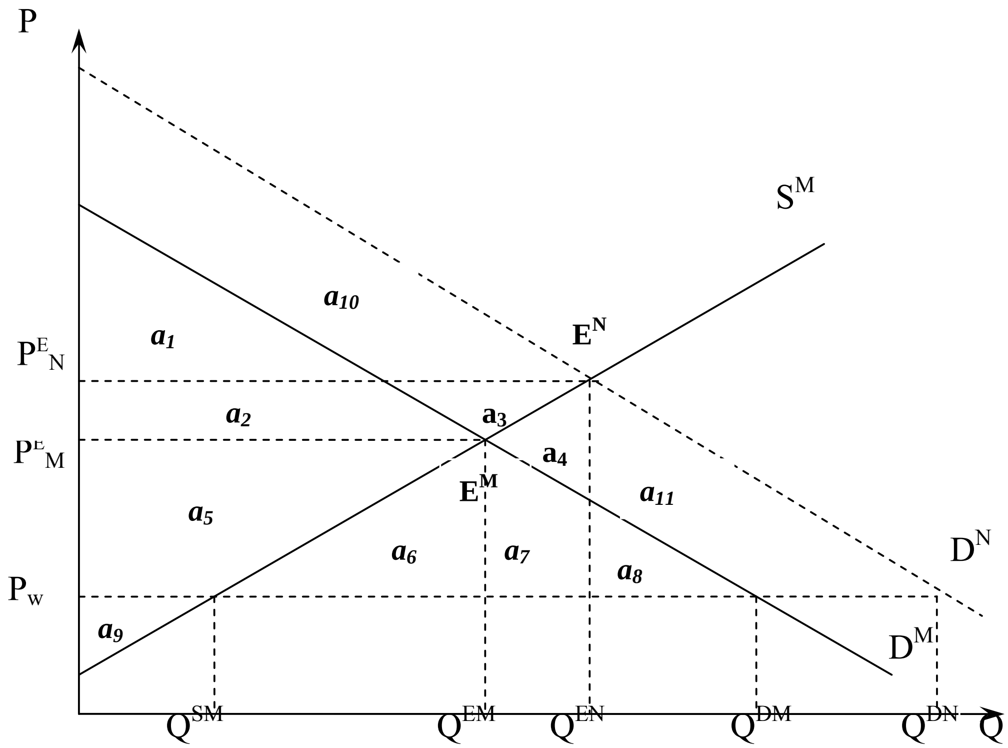


Figure 4: Case 2 — domestic and import supply, trade prohibiting regulation

Now product N — a new health enhancing version of traditional food — arrives in the market. Our two assumptions still hold: (1) The new version product, N, can be produced at the same cost as product M by both domestic and foreign suppliers and; (2) more consumers are willing to buy the new health enhancing product N at the same price. Therefore, the new health enhancing functional food, N, shifts demand curve out to D^N. Product N faces the same world price as product M. At P_w, the consumer surplus increases to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{10}} + \boldsymbol{a_{11}}$. As the world price is unchanged and the supply curve is not altered, domestic producer surplus remain equal to area $\boldsymbol{a_9}$.

With the import ban in place, the domestic price rises to P^E_N and the quantity consumed equals to Q^{EN}. At P^E_N, consumer surplus decreases to area $\boldsymbol{a_1} + \boldsymbol{a_{10}}$. Consumers suffer a loss of area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{11}}$ in consumer surplus because of the higher price. On the other hand, new producer surplus increases to a area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_5} + \boldsymbol{a_9}$ — a change equal to $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_5}$. Again, there may also be a health cost savings — HCS. The relative weighting ratio is

$$\eta^N = \frac{\Delta \text{ consumer surplus} + \text{HCS}}{\Delta \text{ producer surplus}} = \frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_{11} + \text{HCS}}{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_5}$$

Thus,

$$\eta^N = \frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_{11} + \text{HCS}}{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_5}$$

$$\eta^M = \frac{\Delta \text{ consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_5 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \boldsymbol{a}_8}{\boldsymbol{a}_5}$$

It is an empirical question whether $\eta^{N} > \eta^{M}$ or $\eta^{N} < \eta^{M}$ or $\eta^{N} = \eta^{M}$ due to the different producer surplus change in the denominator of our weighting ration formula. It is possible that $\eta^{N} > \eta^{M}$. So, policy makers may wish to reconsider the imposing import ban after the introduction of the health-enhancing functional food.

Case 3

For Case 3, there is only an international supply for a new functional food. Figure 5 shows the domestic market of both conventional product and the new functional food version of the products. Before the new innovative product enters into the market, the situation for the original product M is the same as in Case 1. D^{M} is the demand curve for a pre-existing product M and the supply curve S^{M} for product M. At P_{w}, the world price for M, imports would be the difference between what consumers are willing to purchase, Q^{DM}, and what producers will supply, Q^{SM}, that is $(Q^{DM} - Q^{SM})$. If a cost increasing import restriction has been put in place that raises costs so that the *landed price* equals $(P_{w} + C)$, imports will fall to $(Q^{DM'} - Q^{SM'})$.

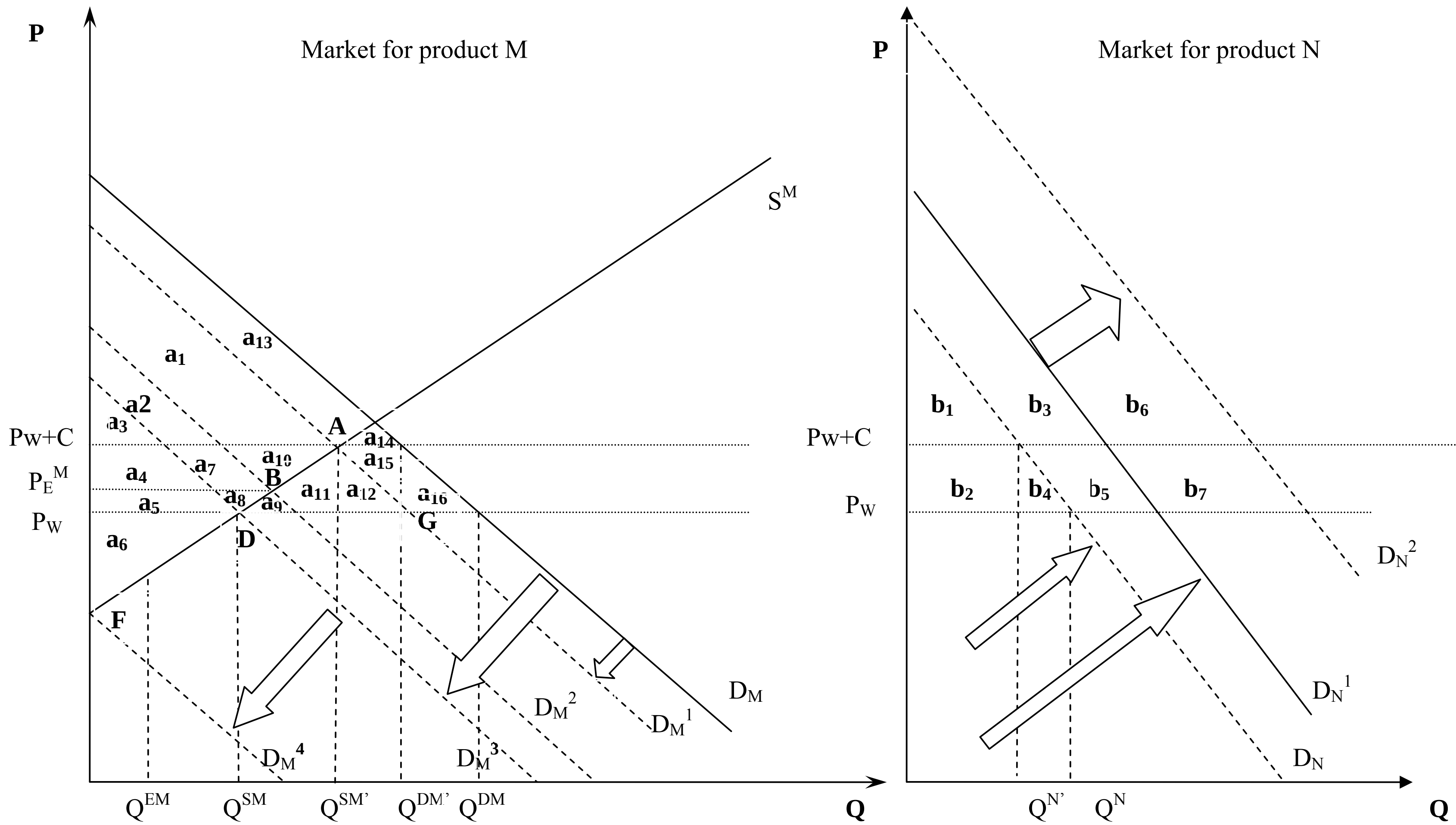


Figure 5: Case 3 —import supply only, cost increasing regulation

The cost increasing policy will change the welfare in the market. Without the regulation in place, the consumer surplus is area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{10}} + \boldsymbol{a_{11}} + \boldsymbol{a_{12}} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}} + \boldsymbol{a_{15}} + \boldsymbol{a_{16}}$ and producer surplus is area $\boldsymbol{a_6}$. However, after trade policy is implemented, consumer surplus decreased to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}}$ with a loss of area $\boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{10}} + \boldsymbol{a_{11}} + \boldsymbol{a_{12}} + \boldsymbol{a_{15}} + \boldsymbol{a_{16}}$. In contrast, producer surplus increases to area $\boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{10}}$ — a gain equal to $\boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{10}}$. The relative weighting ratio is

$$\eta^{M} = \frac{\Delta \text{consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_9 + \boldsymbol{a}_{10} + \boldsymbol{a}_{11} + \boldsymbol{a}_{12} + \boldsymbol{a}_{15} + \boldsymbol{a}_{16}}{\boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_{10}}$$

Now assume the new version of product M — a health enhancing functional food N — comes onto the market but can only be sourced from imports. Our assumptions: (1) new product, N, can be produced at the same cost as M by foreign suppliers and, (2) product N can be represented by a demand curve that has the same slope as product M. (3) more people are willing to buy the new health enhancing product N at the same price, still apply here.

To begin with, product M and N are facing the same world price at P_w with no trade barrier. At any price above P_w, no consumers are willing to purchase product M. Based on the assumptions, consumers switch to the market for N, which shifts the demand curve from D_M to D_M^1 in the market for M. This unambiguous switch to product N will continue until curve D_M reaches D_M^3. The difference between demand curve D_M and D_M^3 leads to a separate market for N. In the market for N in Figure 5, we take D_N^1 for the demand curve of product N when the demand for product M is D_M^3. Once the demand curve for M shifts further to the left of D_M^3, product M's price will be less than Pw and some consumers will choose to continue to consume it. This means that the rate at which consumers are switching to product N slows. The further to the left the demand curve for M moves, the larger the price advantage for product M and the more attractive product M will be to consumers. An equilibrium may well be reached somewhere between point D and F in Figure 5. If the demand curve for M reaches D_M^4, no firms are willing to supply product M. At point F, the market for M no longer exists and all consumers have moved to the market for N.

When there is a cost increasing restriction in place, the demand will again shift inward as consumers switch to the more desirable product, N. When demand for M reaches D_M^1, point A in Figure 5, product M and N both face price (Pw + C). The difference between demand curve D_M and D_M^1 leads to demand curve D_N for product N in the separate market for N.

As the demand curve moves beyond point A, the demand curve of M still shifts inward because consumers might be more interested in the new version of the product with functional attributes. However, it is possible that domestic producers can supply product M at a lower price than (Pw + C). Therefore, some consumers may stay in the market for M because it is lower priced than N. Let's suppose the price of M declined to P_E^M, where D_M^2 equals S^M. Point B, may be an equilibrium if no more consumers are willing to switch to product N. As more consumers switch from M to N, the demand curve for N shifts out from D_N in Figure 5. Finally, the demand curve in market for M could reach D_M^4 and the demand curve in market for N will move to D_N^2 in Figure 5. At point F, there is no supply for product M and consumers will all have switched to the market for N.

As the demand changes are dynamic, we calculate the welfare of both consumers and producers based on minimum changes at point A and for the maximum change, point F. In both markets together, consumers receive more surplus than that arising from only product M being in the market — N gives more utility per unit than M. At point G, without a trade barrier, consumer surplus equal area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{10}} + \boldsymbol{a_{11}} + \boldsymbol{a_{12}} + \boldsymbol{b_1} + \boldsymbol{b_2} + \boldsymbol{b_4}$. However, after the cost increasing trade policy is applied, at point A, new world price (Pw + C) leads to a consumer surplus change equal to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{b_1}$ with a loss in consumer welfare of area $\boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{10}} + \boldsymbol{a_{11}} + \boldsymbol{a_{12}} + \boldsymbol{b_2}$. The change in producer surplus remains $\boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{10}}$.

The relative weighting ratio is now at least

$$\eta^{NA} = \frac{\Delta\,\text{consumer surplus} + \text{HCS}}{\Delta\text{producer surplus}} = \frac{\boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_9 + \boldsymbol{a}_{10} + \boldsymbol{a}_{11} + \boldsymbol{a}_{12} + \boldsymbol{b}_2 + \text{HCS}}{\boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_{10}}$$

Since

$$\eta^{M} = \frac{\Delta\,\text{consumer surplus}}{\Delta\text{producer surplus}} = \frac{\boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_9 + \boldsymbol{a}_{10} + \boldsymbol{a}_{11} + \boldsymbol{a}_{12} + \boldsymbol{a}_{15} + \boldsymbol{a}_{16}}{\boldsymbol{a}_4 + \boldsymbol{a}_5 + \boldsymbol{a}_7 + \boldsymbol{a}_8 + \boldsymbol{a}_{10}},$$

where only product M is available in the domestic market.

Noticing that ($a_4 + a_5 + a_7 + a_8 + a_9 + a_{10} + a_{11} + a_{12}$) is a term common to both η^{NA} and η^{M}. Therefore, $\eta^{NA} > \eta^{M}$ if $b_2 + HCS > a_{15} + a_{16}$;

$$\frac{a_4 + a_5 + a_7 + a_8 + a_9 + a_{10} + a_{11} + a_{12} + b_2 + HCS}{a_4 + a_5 + a_7 + a_8 + a_{10}} > \frac{a_4 + a_5 + a_7 + a_8 + a_9 + a_{10} + a_{11} + a_{12} + a_{15} + a_{16}}{a_4 + a_5 + a_7 + a_8 + a_{10}}$$

As a result, political decision makers may wish to reconsider their decision to impose a trade barrier which adds to the cost of imports.

At point F in Figure 5, without a trade barrier, the demand in market for product N has shifted to D_N^2 and consumer surplus equals area $b_1 + b_2 + b_3 + b_4 + b_5 + b_6 + b_7$ However after the cost increasing trade policy is applied, new world price (Pw + C) moves consumer surplus to area $b_1 + b_3 + b_6$ with a loss in consumer welfare of area $b_2 + b_4 + b_5 + b_7$. One the producer side, at point G, the producer surplus is a_6 before any policy applied. After the cost increasing regulation is implemented, at point A, the producer surplus is equal to $a_4 + a_5 + a_6 + a_7 + a_8 + a_{10}$ with a gain of $a_4 + a_5 + a_7 + a_8 + a_{10}$. Nevertheless, the producer surplus is decreasing with the movement of the demand curve for M. When the demand curve for M moves from D_M to D_M^2, that is from point A to point B, the producer surplus changes to $a_5 + a_6 + a_8$ with a reduction of $a_4 + a_7 + a_{10}$. Compared to the producer surplus before product N entered into the market, calculated as a_6, however, producers still gain $a_5 + a_8$ if there is no trade restriction existing in the market. Once the demand curve shifts to point D, the producer surplus returns to a_6 which is exactly the same as when only product M was available in the market without any trade restriction.

Thus, producers do not receive any benefits from the trade restriction policy at point D. From Point D to Point F, the producers lose surplus from the arrival of the new good in the market. The price increasing policy provides no benefit to producers after point D is reached, and consumers suffer a loss in surplus because of the cost increasing regulation. Thus, the policy has no merit and should be abandoned.

Case 4

In Case 4, while there is domestic capacity to supply the conventional version of product, no domestic capacity to supply the new functional food exists. The new products can only be acquired from the international market. However, the new functional food can't be acquired from aboard because of an import policy that is equivalent to a ban.

Figure 6 give us an insight into the domestic market before and after the introduction of a new functional food product. As in the previous cases, D^M represents the demand curve for a pre-existing product that does not have health enhancing attributes, product M. S^M is the supply curve for product M. At P_w, the world price for M, consumers will purchase Q^{DM} and producers are only willing to supply Q^{SM}. The difference between demand and supply would be (Q^{DM}- Q^{SM}) for imports. Thus, the consumer surplus is area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4}$ and the producer surplus is area $\boldsymbol{a_5}$. As in Case 2, if there is a import ban imposed on the product M, both consumers and producers will reach the new equilibrium E^M with $P^E_{M,}$ a higher price than P_w, and quantity Q^{EM}. Therefore, the consumer surplus will decrease to area $\boldsymbol{a_1}$ with a reduction of $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4}$. Producer surplus changes to area $\boldsymbol{a_2} + \boldsymbol{a_5}$ with an increase of area $\boldsymbol{a_2}$.

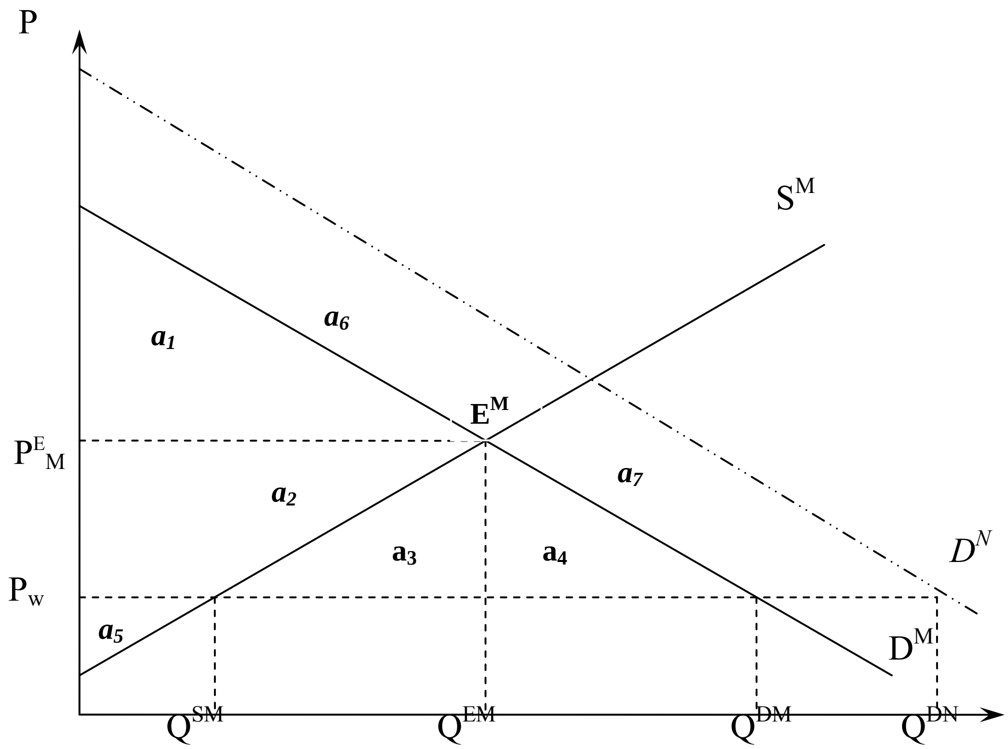


Figure 6: Case 4 —import supply only, trade prohibiting regulation

The relative weighting ratio is

$$\eta^{M} = \frac{\Delta \text{ consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4}{\boldsymbol{a}_2}$$

If the new health-enhancing product N can be introduced into the domestic market successful through imports, there will be a demand shift from the original demand curve D^M to D^N. From our previous assumption, product N can be produced at the same world price as product M. So, at P_w, there is larger demand, Q^{DN}, for the new product. However, in this case, there is no domestic production of product N that can be supplied to the consumers. Thus, total imports are equal to total demand Q^{DN}. The consumer surplus expands to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_6} + \boldsymbol{a_7}$.

However, in Case 4, we assume there exists an import regulation that still acts like a ban, thus allowing none of product N into the market. The demand for product N cannot be supplied by the international producers. Thus, the new demand curve, D^N, does not apply under an import ban. The domestic market has to move back to the previous situation with the product in an autarky market.

We assume there is no supply of the old product M from foreign market — the exporter no longer produces product M. Thus, consumers and producers return to the domestic price $P^E{}_M$. At the autarky equilibrium point, consumer surplus decreases to area $\boldsymbol{a_1}$, a reduction of area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_6} + \boldsymbol{a_7}$ and the producer surplus is area $\boldsymbol{a_2} + \boldsymbol{a_5}$. There would also be a health care savings equal to HCS. Therefore, the relative weighting is

$$\eta^{N} = \frac{\Delta \text{consumer surplus} + \text{HCS}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \text{HCS}}{\boldsymbol{a}_2}$$

Since

$$\eta^{M} = \frac{\Delta \text{consumer surplus}}{\Delta \text{producer surplus}} = \frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4}{\boldsymbol{a}_2}$$

Thus, $\eta^{N} > \eta^{M}$.

$$\frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4 + \boldsymbol{a}_6 + \boldsymbol{a}_7 + \text{HCS}}{\boldsymbol{a}_2} > \frac{\boldsymbol{a}_2 + \boldsymbol{a}_3 + \boldsymbol{a}_4}{\boldsymbol{a}_2}$$

Therefore, political decision makers may wish to change their trade inhibiting policy.

Incorporating Health Care Costs

In each case, we assumed that the HCS is constant. However, savings in health care costs for the government is not likely to be a constant. In most cases, it is likely to be some function of the consumption of the particular functional food. For our analysis, in each case the HCS that would arise from the remove of the trade barrier is a function of the increased consumption of product N. That is,

$$\text{HCS} = f(\Delta Q^{N}),$$

where ΔQ^{N} is the difference between the consumption of N with a trade barrier and that which arises without the trade barrier.

HCS will be different depending on each case given the different trade situations illustrated above. In Case 1, there are both domestic sellers and an international source of supply for functional food N. The cost increasing regulation increases the import price from P_w to $(P_w + C)$ which leads to a reduction in the demand of product N. Thus, the difference between the consumption of N with a trade barrier and that of without a trade barrier is measured by the quantity change along the demand curve D^N from $(P_w + C)$ to P_w.

$$HCS^1 = f(\Delta Q^N) = f(Q^{DN} - Q^{DN'})$$

In Case 2, product N faces both domestic and international supply but with a regulatory trade barrier that is equivalent to an import ban. The import ban allows no supply for product N from the international market. Thus, the difference between the consumption of N with a trade barrier and that without the trade barrier is measured by the quantity change on the demand curve D^N from Pw to P^E_M.

$$HCS^2 = f(\Delta Q^N) = f(Q^{DN} - Q^{EN})$$

In Case 3, there is only an international supply for functional food N. Like Case 1, the cost increasing regulation makes the import price P_w increase to $(P_w + C)$ which leads to a reduction in the demand of product N. Thus, the difference between the consumption of N with a trade barrier and that without the trade barrier is measured by the quantity change along the demand curve D^N from $(P_w + C)$ to Pw. As the figure in Case 3 is dynamic, the change in consumption of the product N, which based on the shift of demand curve D^N , can take on a range of values.

$$HCS^3 = f(\Delta Q^N) = f(\Delta Q^N) \geq f(Q^N - Q^{N'})$$

In Case 4, there is no domestic capacity to supply the functional food N. However, product N cannot be acquired from abroad because of an import policy that is equivalent to a ban. Before the import ban, the consumption of N is based on imports only and the import quantity is equivalent to domestic demand which is Q^{DN}.

With the import ban in place, the imports of product N do not take place. Therefore, there is no consumption of product N. The change in the consumption of product N is just equal to Q^{DN}.

$$HCS^4 = f(\Delta Q^N) = f(Q^{DN} - 0)$$

This section has developed a partial equilibrium model to examine the effects of the introduction of functional foods that provided consumers with positive health benefits when pre-existing trade restrictions are in place. While undertaking empirical investigations for examples of each of the four cases would have been desirable given the different results they predict, limits on time and resources allowed for investigations of only two of the cases. As the objective of this investigation is only to determine whether incorporating health benefits into international trade models is worthy of further study, limiting the investigation to only two cases is not major constraint. In what follows, two cases are developed using trade restrictions on canola oil. The first study involves the Chinese tariff on canola oil and is an example of Case 1. The second study examines the market for canola oil in the United Kingdom where market access is blocked by the European Union's import ban on genetically modified products – an example based on Case 2 developed above.

Barriers to Canola Oil in China

Over time, consumers have responded to new scientific information related to food consumption by switching their purchases to products with healthier or less harmful components (Malla et al., 2007). Recently, the relationship between consumption of *trans* fatty acids (TFA) and associated heart disease has become a *hot topic* with the public. Coronary heart disease (CHD) refers to the failure of the coronary circulation system to supply adequate blood to the heart muscle and surrounding tissue. Over 451,000 Americans die of coronary heart disease every year (AHA, 2008a). In the United Kingdom, over 100,000 deaths annually are attributed to coronary heart disease (BHF, 2007). Scientific studies suggest that consumption of *trans* fat will increase the risk of CHD. The Food and Drug Administration (FDA) in the United States ruled that the reporting of *trans* fat levels had to be added to the Nutrition Facts Panel on food labels starting from January 1, 2006. Identifying saturated fat, *trans* fat, and cholesterol on the food label provides consumers with information so that food choices that help reduce the risk of CHD can be made. The revised label was expected to be helpful to people who are concerned about high blood cholesterol and heart disease (FDA, 2003).

This section provides a Chinese case study to examine the potential welfare benefits forgone from the existence of trade barriers when a selected product becomes a functional food. First, the chapter gives a detailed overview of the connection between *trans* fat and health. Further, the selected product — canola oil is introduced from two aspects — its functional attributes to reduce the risk of CHD and its international trade status. Following this introduction, the empirical case study of Chinese canola oil is examined according to Case 1 in the framework developed above. The forgone benefits of functional canola oil in China arising from the trade barriers — a tariff — are calculated.

Trans fat and Health

Trans fat (also known as *trans* fatty acids) is a specific type of fat formed when liquid oils are processed into solid fats like shortening and hard margarine. However, a small amount of *trans* fat is naturally occurring, primarily in selected animal-based foods. The majority of *trans* fat comes from adding hydrogen to vegetable oil through a process called hydrogenation. *Trans* fats are more solid than oil but less likely to spoil. In processed foods, *trans* fat helps food keep fresh, extends the self life and gives products a less greasy feel (MFMER, 2006).

Animal-based fats were once the only *trans* fats consumed, but by far the largest amount of *trans* fat are formed during the partial hydrogenation of vegetable oils, a process that converts vegetable oils into semisolid fats for use in the food industry (Mozaffarian et al., 2006).

The consumption of *trans* fatty acids raises the levels of low-density lipoprotein (LDL) cholesterol[9], so called *bad cholesterol* and reduces levels of high-density lipoprotein (HDL) cholesterol[10], so called *good cholesterol*. *Trans* fats alter the ratio between LDL and HDL by increasing the ratio HDL in total

[9] LDL (bad) cholesterol could lead to heart attack or stroke by forming clots in the inner walls of the arteries and blocking the way to feeding the heart and brain (AHA, 2008b).
[10] High levels of HDL (more than 40 mg/dL) protect against heart attack by carrying cholesterol away from the arteries to the liver, where it is passed from the body (AHA, 2008b).

cholesterol[11]. The latter is a powerful predictor of the risk of CHD (Stampfer et al, 1991). A study published in the *New England Journal of Medicine* reported that *trans* fat is linked to a 93 percent rise in the risk of cardiovascular disease. The research also revealed that replacing of 2% of *trans* fat consumed with monounsaturated fat (MUFA) that are derived from plant sources such as canola, peanuts and olives could reduce heart disease risk by 53 percent (Lam, 2002).

Conventional canola oil and soybean oil require hydrogenation to make them stable. Hydrogenation is the process that turns fats into *trans* fat. New technology, however, gives canola oil a very high degree of stability, eliminating the need for hydrogenation (Malla et al., 2007). At present, there are two types of canola oil: commodity and high-oleic. The former is sold directly to consumers; the latter is characterized by high stability which is newer and sold almost exclusively to food processing companies and food service operations. Both oils have the same low level of saturated fat and positive health attributes (Canola Council of Canada, 2008a).

The FDA (2006b) states that:

> Limited and not conclusive scientific evidence suggests that eating about 1½ tablespoons (19 grams) of canola oil daily may reduce the risk of coronary heart disease due to the unsaturated fat content in canola oil. (n.p.)

Thus, Canola oil is seen as a healthier alternative to a number of important vegetable oils due to its *trans* fat-free and very low, or even zero, saturated fat but

[11] The total cholesterol to HDL cholesterol ratio is obtained by dividing the total cholesterol value by the value of the HDL cholesterol. High ratios (High total cholesterol and low HDL cholesterol) indicate higher risks of heart attacks (Kinosian et al., 1994).

high—almost 60%—monounsaturated oil content and beneficial omega-3 fatty acids profile. Saturated fat has been linked to rising levels of bad LDL cholesterol in the blood and increased risk of CHD. Monounsaturated fat is helpful in reducing the risk of coronary heart disease and controlling blood glucose by lowering bad LDL cholesterol in the blood. Omega-3 fats are essential for a healthy daily diet and it helps protect against heart attacks and strokes. Thus, canola oil might be a better choice for avoiding *trans* fat in deep fried and baked foods and is becoming a popular oil of choice in restaurants and commercial food products (Canola Council of Canada, 2008b).

The Chinese Vegetable Oil Market

The market for vegetable oils is growing across Asia as a result of expanding populations and rising incomes. China's population growth rate is approximately 8.6 million people per year. Further, gross domestic product (GDP) in China has been growing at an annual rate in excess of 10 percent. Per-capita GDP in China is approximately US$7,600 on a purchasing power parity basis (AAFC, 2007). According to the China State Administration of Grain[12], total vegetable oil imports reached 8.5Mt in 2006-2007, accounting for 18 percent of global imports of vegetable oils. However, the annual consumption of vegetable oils increased to 23.4Mt, meaning only 15.14Mt are being supplied domestically. The consumption of canola oil is 4.34 Mt and domestic production only supplies 4.01 Mt at the

[12] State Administration of Grain can be accessed at: http://www.grain.gov.cn

existing price level (USDA, 2008). As a result, approximately 0.33 Mt of canola oil are imported. This is approximately to 15% of the world canola oil imports.

Prior to joining the WTO, China had an import management control system for vegetable oils. A tariff rate quota (TRQ) restricted the amount of vegetable oils that could be imported. All imports up to the quantity limit known as the *TRQ-quota* were subject to a low *within-quota tariff* of 9 percent, while any additional imports were subject to a higher *above-quota tariff* ranging between 19.9 percent and 52.4 percent (Xu and Wang, 2006). From 2006, however, China removed all of the import management restrictions on vegetable oils as part of its WTO accession commitments. However, there still a flat tariff of 9 percent on imports of vegetable oils.

In Case 1 developed above, there are both domestic producers and an international source of supply for a new functional food. China's current import regime is consistent with the assumptions of Case 1. In the China case study, canola oil is a new functional food. Given the constraints on Chinese production and processing capacity, imports of canola oil are required. However, the existing tariff level acts as a trade barrier on imports. The protection benefits producers at the expense of consumers. This tariff was put in place prior to the health benefits of canola becoming apparent. Given that the social costs can be expected to rise as the health benefits become known, the Chinese government may wish to revisit having a tariff on canola oil.

Canola oil is the final consumer product from which the health benefit is derived. Of course, canola oilseed is the major traded product. Since the focus of this thesis is on the forgone benefits of *trans* fat free canola oil from existing trade barriers, the calculations will not address trade in canola oilseed directly because oilseeds are semi-finished products that need further processing into oil and meal. The import data used in the Chinese case study are estimated through domestic production and consumption for oil – they are net oil import quantities. The benefits received by consumers and health care cost savings are derived from oil consumed by those living in China.[13]

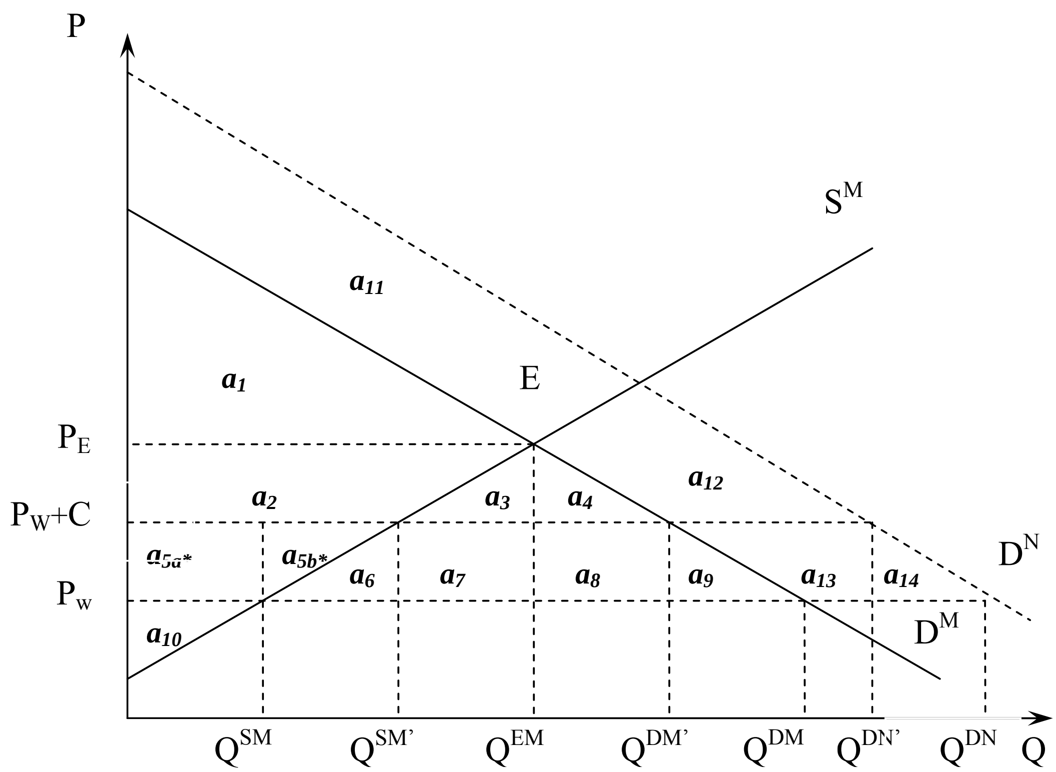
Stage One – Calculation of Trade Effects

In Figure 7, D^{M} is the demand curve for canola oil before people realize the health benefits it provided. There is a supply curve S^{M} for canola oil. At P_w, the world price for canola oil, consumers are willing to purchase Q^{DM} and domestic producers will only supply Q^{SM}. Imports would be (Q^{DM}- Q^{SM}). However, an import tariff at 9 percent is in place in China. It raises the domestic price above the world price so that the new domestic price equals (P_w + C). Imports will fall to ($Q^{DM'}$- $Q^{SM'}$).

Without the tariff, the consumer surplus is area $\boldsymbol{a_1}$ +$\boldsymbol{a_2}$ + $\boldsymbol{a_3}$ + $\boldsymbol{a_4}$ + $\boldsymbol{a_5}$ + $\boldsymbol{a_6}$ + $\boldsymbol{a_7}$ + $\boldsymbol{a_8}$ + $\boldsymbol{a_9}$. Producer surplus is area $\boldsymbol{a_{10}}$. After the tariff is implemented, consumer surplus decreased to area $\boldsymbol{a_1}$ +$\boldsymbol{a_2}$ + $\boldsymbol{a_3}$ + $\boldsymbol{a_4}$. Consumers suffer a loss of area $\boldsymbol{a_5}$ + $\boldsymbol{a_6}$ +

[13] If one wished to calculate the benefits for exporters, the proportion of trade arising from oil imports and seed imports that would be processed into oil would have to be considered. As there is a degree of tariff escalation in Chinese tariffs, using the tariff on oil may overestimate the trade benefit to some degree.

$\boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ in consumer surplus because of the higher price. On the other hand, producer surplus increases to an area $\boldsymbol{a_5} + \boldsymbol{a_{10}}$ — a change equal to $\boldsymbol{a_5}$.



* In order to calculate the area, $\boldsymbol{a_5}$ is divided into $\boldsymbol{a_{5a}}$ and $\boldsymbol{a_{5b}}$.

Figure 7: Chinese Case Study — domestic and import supply with tariff in China

As canola oil can now be seen as a functional food in the Chinese food market due to health enhancing attributes that are newly recognized by the public, more people are willing to purchase canola oil. Alternatively, consumers are willing to pay a premium for a higher quality (health enhancing) product. Hence, demand increases from D^M to D^N. As the additional demand can be accommodated by acquiring additional imports at (P_w + C), there is no change in price. Thus, there is no change in domestic producer surplus.

With the new demand curve, consumers receive more surplus than before. With no tariff, consumer surplus changes from area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{11}} + \boldsymbol{a_{12}} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}}$, an increased benefit of area $\boldsymbol{a_{11}} + \boldsymbol{a_{12}} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}}$. After the tariff is applied, new world price (P_w + C) leads to a decline in consumer surplus to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_{11}} + \boldsymbol{a_{12}}$. Therefore, the tariff generates a loss in consumer welfare of area $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}}$.

Thus, without new health information regarding canola oil, the direct welfare changes arising from the tariff are areas $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ — the decrease in consumer surplus — and $\boldsymbol{a_5}$ — the increase in producers surplus. Both $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9}$ and $\boldsymbol{a_5}$ are trapezoid areas that can be divided into rectangles and triangles for the calculation of their values; assuming that over the relevant ranges, the supply and demand functions are linear. After health enhancing attributes of canola oil having been accepted, the trade change for consumer is area $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}}$ while the increase in producer surplus remains $\boldsymbol{a_5}$. Area $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{13}} + \boldsymbol{a_{14}}$ can be divided into rectangle $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_9} + \boldsymbol{a_{13}}$ and triangle $\boldsymbol{a_{14}}$. Combined with the data from Table 2, the calculations and resultant values can be found in Table 3. The data sources are provided in Table 2.[14]

[14] A detailed discussion of the data can be found in Zhang (2009).

Table 2: Data for the canola/rapeseed oil market in China (2006-2007) [a]

Total consumption (Mt) - $Q^{DM'}$	4.343 [b]	
Domestic supply (Mt) - $Q^{SM'}$	4.013 [c]	
Supply elasticity - ε^S	0.32 [d]	
Demand elasticity - ε^D	-0.20 [e]	
World price($ US dollar/tonne) – P_w	852 [f]	
Tariff rate	9% [g]	
tariff cost ($ US dollar/tonne) – C	76.68 [h]	
Total consumption (Mt) without tariff - Q^{DM}	4.415 [i]	
Domestic supply (Mt) without tariff – Q^{SM}	3.907 [j]	
Price increase rate [k]	Base	20%
	High	50%
	Medium	40%
	Low	10%
Increased domestic consumption (Mt) - $(Q^{DN} - Q^{DM})$ [l]	Base	0.883
	High	2.207
	Medium	1.776
	Low	0.441

[a] 2006-2007 is from October, 2006 to September, 2007.

[b] Source: United States Department of Agriculture (USDA), Foreign Agricultural Service, July 2008.

[c] Source: USDA, Foreign Agricultural Service, July 2008.

[d] Note: it is a short-term supply elasticity for national rapeseed supply. (Source: Shen, 2007)

[e] Note: it is a direct price elasticity for oilseed oil demand. (Source: Meilke et al., 2001)

[f] Average price from October, 2006 to September, 2007. Rotterdam CIF, Any Origin, Oil World. Source: USDA, Foreign Agricultural Service, July 2008.

[g] Source: China Customs..

[h] Cost - C = P_W * 9%.

[i] Q^{DM} is calculated from following steps using demand elasticity:

$$\varepsilon^D = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{DM} - Q^{DM'})}{P_W - (P_W + C)} * \frac{P_W + C}{Q^{DM'}} = \frac{(Q^{DM} - Q^{DM'})}{(-C)} * \frac{P_W + C}{Q^{DM'}}$$

$$Q^{DM} = \varepsilon^D * (-C) * \frac{Q^{DM'}}{P_W + C} + Q^{DM'}$$

$$= (-0.20) * (-76.68) * \frac{4.343}{852 + 76.68} + 4.343$$

$$= 4.415 \text{ (Mt)}$$

[j] Q^{SM} is calculated from following steps using supply elasticity:

$$\varepsilon^S = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{SM'} - Q^{SM})}{(P_W + C) - P_W} * \frac{P_W + C}{Q^{DM'}} = \frac{(Q^{SM'} - Q^{SM})}{C} * \frac{(P_W + C)}{Q^{DM'}}$$

$$Q^{SM} = Q^{SM'} - (\varepsilon^S * C * \frac{Q^{SM'}}{P_W + C})$$

$$= 4.013 - (0.32 * 76.68 * \frac{4.013}{852 + 76.68})$$

$$= 3.907 \text{ (Mt)}$$

[k] Demand shift rate is estimated from current reports and studies regarding to China's functional food market. For details, see section A1.1 in Appendix 1.

[l] (Q^{DN}- Q^{DM}) = demand shift rate* (Q^{DM})

Table 3: Trade effects in the Chinese Case study

<table>
<tr><td></td><td colspan="2">$a_5+a_6+a_7+a_8+a_9$</td><td colspan="2">a_5</td><td colspan="3">$a_5+a_6+a_7+a_8+a_9+a_{13}+a_{14}$</td></tr>
<tr><td></td><td>Rectangle $a_5+a_6+a_7+a_8$</td><td>Triangle a_9</td><td>Rectangle a_{5a}</td><td>Triangle a_{5b}</td><td>Trapezoid $a_5+a_6+a_7+a_8+a_9$</td><td colspan="2">Parallelogram $a_{13}+a_{14}$</td></tr>
<tr><td>Formula</td><td>$Q^{DM'}* C$</td><td>$1/2*(Q^{DM} - Q^{DM'})* C$</td><td>$Q^{SM} * C$</td><td>$1/2*(Q^{SM'} – Q^{SM})* C$</td><td></td><td colspan="2">$(Q^{DN} - Q^{DM})* C$</td></tr>
<tr><td rowspan="4">Calcu- lation</td><td rowspan="4">4.343 * 76.68</td><td rowspan="4">1/2*(4.415- 4.343)* 76.68</td><td rowspan="4">3.907 * 76.68</td><td rowspan="4">1/2*(4.013- 3.907)* 76.68</td><td rowspan="4"></td><td>Base</td><td>0.883* 76.68</td></tr>
<tr><td>High</td><td>2.207* 76.68</td></tr>
<tr><td>Medium</td><td>1.776* 76.68</td></tr>
<tr><td>Low</td><td>0.441* 76.68</td></tr>
<tr><td rowspan="8">Result (Million$)</td><td rowspan="4">333.021</td><td rowspan="4">2.750</td><td rowspan="4">299.589</td><td rowspan="4">4.064</td><td rowspan="4">335.771</td><td>Base</td><td>67.704</td></tr>
<tr><td>High</td><td>169.26</td></tr>
<tr><td>Medium</td><td>135.408</td></tr>
<tr><td>Low</td><td>33.893</td></tr>
<tr><td colspan="2" rowspan="4">335.771</td><td colspan="2" rowspan="4">303.653</td><td>Base</td><td colspan="2">403.475</td></tr>
<tr><td>High</td><td colspan="2">505.031</td></tr>
<tr><td>Medium</td><td colspan="2">471.179</td></tr>
<tr><td>Low</td><td colspan="2">369.664</td></tr>
</table>

Table 3 shows all the calculations and results for the trade effects of canola oil.[15] With the 9 percent tariff on imports of canola oil in China, consumers suffer a loss of US$335.8 million in consumer surplus (area $a_5 + a_6 + a_7 + a_8 + a_9$) because of the higher landed price. On the other hand, producers gain US$303.7 million in producer surplus (area a_5).

After health information regarding canola oil becomes well-known to Chinese consumers, consumers' loss increases, but producer gain remains constant. For the four levels of demand shift assumed under the sensitivity analysis in appendix 1, a US$403.5 million in the base case level, a US$505 million in high level, a US$471.2 million in medium level and a US$369.7 million loss in low level in consumer surplus change (area $a_5 + a_6 + a_7 + a_8 + a_9 + a_{13} + a_{14}$) have been estimated (see Table 3). At the base case level of demand shift, for example, consumers suffer a US$403.5 million reduction in consumer surplus because of the increased consumption of canola oil. This loss increase is approximately 20 percent compared to the former US$335.8 million consumer surplus change. For the high level there is approximately a 50 percent increase compared to the previous situation. Even at lower levels, increased consumption of healthy canola oil leads to a much greater loss in consumer surplus than when the health benefit was unknown. As expected, the results of trade effects indicate that the tariff generates a larger loss in consumer welfare than the gain on the producer side. The loss becomes even larger after the increased consumption of canola oil with health attributes are taken into consideration.

Stage Two – Estimating the Potential Health Care Cost Savings for the Chinese Case Study

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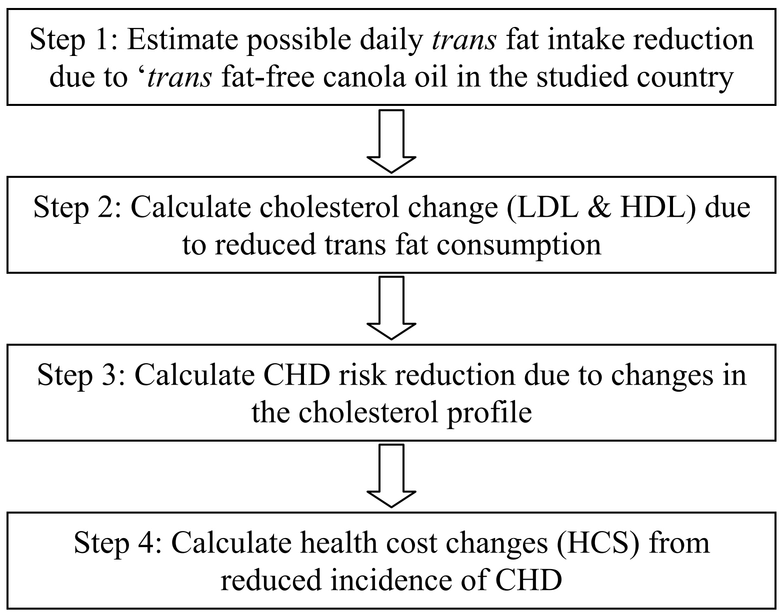
[15] A sensitivity analysis was performed on supply and demand elasticities and the results were found not to be particularly dependant on the values used. Details of the sensitivity analysis can be found in Zhang (2009).

The model developed by Malla et al. (2007) is adapted to estimate the potential health benefit and related medical cost savings in China arising from the consumption of more healthy *trans* fat-free canola oil. They use a variation on the COI approach to estimate the impact of a change in dietary fat intake on CHD costs in Canada. Their method involves four distinct steps – see Figure 8. The calculation will start from the *trans* fat intake reduction caused by the substitution of a *trans* fat-free canola oil for other vegetable oils to the effect of reduced cholesterol levels on the incidence of CHD in the studied country and from there to the relationship between CHD and medical costs savings. Following Malla et al. (2007), it is assumed that a 1 percent drop in the incidence of the disease in the long run will result in a 1 percent decrease in the COI.

Figure 8: Steps in a COI analysis



(Source: Malla et al., 2007)

Step 1: Estimate possible daily *trans* fat intake reduction due to '*trans* fat-free canola oil in China

In step 1, a total *trans* fat consumption (intake) per day is estimated using available studies. Due to different diets and eating habits, calculations and results vary among countries.

In China, there is no database for TFA consumption. Generally in China, the total fatty acids in the daily diet come from natural fatty acids in food and from vegetable based cooking oils that contain very low TFA. On average, the Chinese diet leads to a lower intake of shortening oil when compared to diets in North America and Europe. In China, however, the growth of fat intake has been dramatic; increasing 2.7 times from 33g/person/day to 90 g/person/day in the space of a few years (FAO, 2006). With rising incomes and the opening of the economy, Chinese dietary tastes are broadening. The dietary structure is changing from traditional oriental cooking towards diverse dining. North American and European food, and fast food in particular, is becoming increasingly popular. While no studies on fat consumption in China could be found, the TFA intake of the daily diet in China is increasing due to rising shortening oil consumption, especially among young people.

While no studies on *trans* fat consumption in mainland China could be found, a study on *trans* fats in locally available foods conducted jointly by the Centre for Food Safety (CFS) and the Consumer Council (CC) in Hong Kong, China is available. The study tested a total of 80 products which, for the most part, use hydrogenated vegetable oils (shortening oil, salad oil and margarine) in their production. Samples included (i) bakery products (including breads, cakes, egg tarts, chicken pies and batter-made food such as egg rolls, waffles and egg puffs); (ii) deep fried foods (including French fries, fried chicken, pork chops, fritters and pastries); and (iii) butter and margarine/margarine-like spreads. The study found that *trans* fats levels varied considerably among similar food products. For example, *trans* fats levels in 23 bread samples ranged from zero to 1.8 g/100 g. *Trans* fats levels in 11 butter-made products ranged from zero to 1.0 g/100 g. For the 14 fried products, there was also a wide range of *trans* fats levels from 0.034 to 0.38 g/100 g. These results suggest that it is possible to reduce *trans* fats levels in food products (CFS, 2007).

Following the CFS (2007) study, a total *trans* fat consumption (intake) per day in daily food sources can be estimated. The estimated average consumption used in the case study on China is 1.99 g, including 0.54 g/day from baked goods and 0.03 g/day from butter-made products, 0.03 g/day from fried products and 0.39g/day from margarine/ margarine like spreads [16].

[16]The main TFA intake in China is assumed from the above categories - baking, butter-made fried products and margarine/margarine like spreads. The average calculation method was used for TFA intake in each category. For details, see Section A2.1 in Appendix 2.

Table 4: *Trans* fatty intake reduction in China due to *trans*-fat-free canola oil

	Base	High	Medium	Low
Total TFA intake daily (g) in sample foods [a]	1.99	1.99	1.99	1.99
Assumed TFA reduction (%) in sample foods [b]	20	50	40	10
Total TFA reduction (g) in sample foods [c]	0.40	0.99	0.79	0.20

[a] The Total TFA intake daily (g) in sample foods is calculated in Section A3.1 in Appendix 3.

[b] TFA reduction (%) in sample foods is assumed to have four levels from high, medium, and base to low. These four levels indicate the percentage of vegetable oils found in daily food consumption that is assumed to be replaced by *trans* fat-free canola oil. The TFA reduction ratio guarantees the subsequent calculations focus solely on the health care cost savings for a certain group of people who consumed trans fat-free canola/rapeseed oil rather than other vegetable oils.

[c] The total TFA reduction = The Total TFA intake daily (g) * Assume TFA reduction (%)

From Table 4, the effect of *trans* fat-free canola oil substitution can be seen. Using sensitivity analysis, the estimation assumes four level of substitution from base (20%), high (50%), medium (40%) and low (10%). The resulting reductions in *trans* fat consumption are 0.40 g (Base), 0.99 g (High), 0.79 g (Medium) and 0.20 g (Low) daily in China.

<u>Step 2: Calculate cholesterol change (LDL & HDL) due to reduced *trans* fat consumption</u>

According to Malla et al. (2007), a number of studies have measured the effects of TFA consumption on LDL, HDL, and total cholesterol levels using controlled diets. Following Malla's conclusion, in step 2, the assumption is made that for every 1 g reduction in TFA, total cholesterol will reduced by 1.55 percent.

<u>Step 3: Calculate CHD risk reduction due to changes in cholesterol profile</u>

Drawing on the conclusions of the US National Cholesterol Education's Expert Panel (Expert Panel, 1988), the assumption can be made that there is a 2 percent reduction in the risk of CHD for every 1 percent reduction in cholesterol levels for the medium, base and low cases, while for the high level a 3 percent reduction in CHD risk is assumed (Malla et al., 2007).

<u>Step 4: Calculate health cost changes from reduced incidence of CHD</u>

The final step in the analysis (step 4) is to calculate the potential health-care cost savings from *trans* fat-free canola oil.

According to the World Health Organization (WHO), globally, cardiovascular diseases were the number one cause of death in the past and remain so currently. An estimated 17.5 million people died from cardiovascular disease in 2005, which accounts for 30 percent of all global deaths. By 2015, an estimated 20 million people will die from cardiovascular disease (mainly from heart attacks and strokes) if current trends continue (WHO, n.d.). In China, the annual deaths due to cardiovascular disease are about 3 million, accounting for 45 percent of total deaths in the population (NCCD, 2005).

Treatment of cardiovascular-related diseases is also a major cost in China. In a Chinese government cardiovascular report, it was estimated that in 2003, the direct cardiovascular disease expense[17] accounted for 16.13 percent (RMB 92.6 billion, approximate US $13.2 billion[18]) of total health care costs. According to the prediction in the report, CHD costs have increased at an average annual growth rate of 12.83 percent over the last 10 years. Currently, CHD costs are ranked in the second place in the total medical expense in China. The overall health care costs for CHD is approximately RMB 26.4 billion (US $3.85 billion) with RMB 13.3 billion (US $1.94 billion) for outpatient care[19] and RMB 13.1billion (US $1.91 billion) for inpatient care (NCCD, 2005). Due to absence of indirect health care costs data for China, the health care costs for CHD calculated for this case study are limited to only the direct health care costs including outpatient and inpatient care costs.

In order to simplify the calculation, the estimated cost of illness savings under *trans* fat-free vegetable oil substitution are limited to savings only from cardiovascular disease. Other possible health improvements from reduced consumption of TFA are not considered in this case study. Following Malla et al. (2007), a 1:1 ratio is assumed between reduced CHD risks and health-care cost savings for first three levels; thus, the related costs will be decreased by 1 percent if CHD is reduced by 1 percent. For the low

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[17] Direct costs of CHD represent the value of resources spent that could have been used for other purposes in the absence of illness (e.g., hospital expenditures, drug expenditures, medical care, and research) (Malla et al, 2007).
[18] I use USD: CNY = 1:6.86, based on the current market foreign exchange rate (2:00pm, July 7, 2008). These exchange rates apply for all exchange calculations between US dollar and Chinese Yuan in this thesis.
[19] Outpatient care includes outpatient care, emergency medical treatment and medications.

level, it is assumed that for every percentage reduction in CHD, cost will only be reduced by half a percent (Malla et al., 2007). The calculation for health care savings concentrate solely on the expansion quantities in the market due to trade liberalization, a HCS rate (%) is introduced into the last step calculation (For details, see section A2.2.1 in appendix 2).

In Table 5, the total change in annual CHD cost due to *trans* fat-free canola oil substitution is calculated. A range of scenarios are calculated given the incomplete nature of the data on HCS. These scenarios are based on Malla et al. (2007).

The base case estimation assumes that 20 percent of the hydrogenated vegetable oils market is replaced by *trans* fat-free vegetable oils, leading to a 0.40g daily *trans* fat intake reduction in China. With the assumed 1:2 cholesterol to CHD risk ratio it provides a saving of about US $0.79 million in health-care and medical costs annually in China.

Table 5: Potential health care savings estimated in China

	Base	High	Medium	Low
TC change due to 1 g TFA reduction daily(%)[a]	1.55	1.55	1.55	1.55
Daily TFA reduction (g)	0.40	0.99	0.79	0.20
Total change in TC (%)[b]	0.62	1.53	1.22	0.31
TC to CHD ratio [c]	2.0	3.0	2.0	2.0
Change in CHD (%)[d]	1.24	4.60	2.45	0.62
Change in CHD (%) to change in cost (%)	1 : 1	1 : 1	1 : 1	1 : 0.5
Total annual CHD cost($ million US dollars) [e]	3850	3850	3850	3850
Total change in annual CHD cost due to TFA reduction in daily diet ($ million US dollars) [f]	48	177	94	12
Health Care Savings (HCS) rate [g]	1.66%	1.65%	1.66%	1.66%
Final HCS ($ million US dollars) [h]	0.79	2.92	1.56	0.20

[a] Total Cholesterol (TC) change is rated at 1.55: 1 due to 1 g of TFA reduction.

[b] Total change in TC (%) = TC change due to 1 g TFA reduction daily(%) * Daily TFA reduction (g)

[c] The relationship between total cholesterol and CHD is 1:2 based on Expert Panel (1988). For the 1:3 ratio is used for high level estimation which assumed to be the long-term ratio. (Source: Malla et al., 2007)

[d] Change in CHD (%) = total change in TC (%) * TC to CHD ratio

[e] Source: NCCD (2005).

[f] Total change in CHD cost = total annual CHD cost * Change in CHD(%) * Change in CHD (%) to change in cost (%) ratio

[g] See Section A2.2.1 in Appendix 2 for details.

[h] HCS = Total change in annual CHD cost * HCS rate (%)

The high level assumption is based on an optimistic perspective that *trans* fat-free vegetable oils cover a 50 percent market share in hydrogenated vegetable oils such as the shortening and the salad oil, accounting for a 0.99g *trans* fat intake reduction daily in China. With the assumption that every percentage change in total cholesterol leads to a 3 percent change in CHD and 1:1 ratio between the incidence of CHD and the resulting costs to society, high level estimation results in a saving of about US $2.92 million in Chinese health care costs.

For medium estimate, *trans* fat-free vegetable oil is assumed to substitute 40 percent of the hydrogenated vegetable oils market, which together results in a 0.79g *trans* fat intake reduction daily in China. Given a smaller ratio with every percentage change in cholesterol level which lead to a 2 percent reduction in CHD, this results in a saving of about US $1.56 million in health care costs annually in China based on an assumed 1:1 ratio between the incidence of CHD and the resulting costs to society.

The low scenario demonstrates potential health-care cost savings under very conservative assumptions. *Trans* fat-free oils are assumed to reach only a 10 percent market share in the hydrogenated vegetable oils market. There is a 0.20g *trans* fat intake reduction daily in China. Besides, a reduced ratio with 1:0.5 is applied between CHD change and health-care costs instead of the former 1:1 ratio. Although every step is extremely conservative, the low scenario still suggests a potential reduction of about US $0.2 million in health-care and medical costs annually in China.

Stage Three – Determine the Final Ratios for the Chinese Case Study

Putting a tariff in place changes total welfare. If the objective of the protection policy was to increase producer surplus, decision makers must weigh the benefits of producers more heavily than benefits of consumers. As derived above, the ratio η will be applied here to show decision makers' weighting of the changes in consumer surplus and producer surplus as well as the health cost savings arising from the imposition of a tariff on canola oil imports in China. Table 6 shows the calculations undertaken to derive the ratios used in the comparison. From the table, the ratios for canola oil are calculated based on the results from the previous sections. In summary, in the absence of the information pertaining to the health benefits from canola, η^{M}=1.11. With the health benefits, this ratio rises to 1.33 in the base case, 1.67 in the high case, 1.56 in the medium case and 1.22 in the low case.

Considering health benefits and health care cost savings on canola, the weighting ratio is considerably larger than before the health benefits of canola oil became known. At the base level with 20 percent TFA reduction in daily *trans* fat intake, the loss for consumers arising from the higher price is nearly one and a half times larger than the gain by producers. The high and medium levels even show over one and a half times weight given to producer benefits relative to consumer benefits. At the low level, consumers still lose more than the gain for producers. Therefore, from a welfare perspective, political decision makers may wish to re-evaluate their decisions on the import policy towards canola.

Table 6: Final Ratio Calculation for the Chinese Case Study

η^{M}	$\eta^{M} = \frac{\Delta\text{ consumer surplus}}{\Delta\text{producer surplus}} = \frac{\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_9}{\mathbf{a}_5} = \frac{335.77}{303.65}$		***1.11***
η^{N}	Base	$\eta^{N} = \frac{\Delta\text{ consumer surplus} + \text{HCS}}{\Delta\text{producer surplus}}$ $= \frac{(\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_9 + \mathbf{a}_{13} + \mathbf{a}_{14})^{\text{Base}} + \text{HCS(Base)}}{\mathbf{a}_5}$ $= \frac{403.475 + 0.79}{303.65}$	***1.33***
	High	$\eta^{N} = \frac{\Delta\text{ consumersurplus} + \text{HCS}}{\Delta\text{producersurplus}}$ $= \frac{(\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_9 + \mathbf{a}_{13} + \mathbf{a}_{14})^{\text{High}} + \text{HCS(High)}}{\mathbf{a}_5}$ $= \frac{505.031 + 2.92}{303.65}$	***1.67***
	Medium	$\eta^{N} = \frac{\Delta\text{ consumersurplus} + \text{HCS}}{\Delta\text{producersurplus}}$ $= \frac{(\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_9 + \mathbf{a}_{13} + \mathbf{a}_{14})^{\text{Medium}} + \text{HCS(Med)}}{\mathbf{a}_5}$ $= \frac{471.179 + 1.56}{303.65}$	***1.56***
	Low	$\eta^{N} = \frac{\Delta\text{ consumersurplus} + \text{HCS}}{\Delta\text{producersurplus}}$ $= \frac{(\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_9 + \mathbf{a}_{13} + \mathbf{a}_{14})^{\text{Low}} + \text{HCS(Low)}}{\mathbf{a}_5}$ $= \frac{369.664 + 0.2}{303.65}$	***1.22***

The Effect of the EU Import Ban on Canola for the United Kingdom

The UK case study examines the potential welfare benefits forgone from the existence of trade an import ban when canola oil becomes a functional food. First, the GMO import ban is discussed. Following this introduction, the empirical case study of canola oil in the UK is examined as an example of Case 2 in the framework developed above. The forgone benefits of functional canola oil in UK arising from the GMO ban are then calculated.

The Import Ban on GMOs

In recent years, the vegetable oil market in the EU has changed dramatically and is now strongly driven by the demand for biodiesel. As a result, there is competition between vegetable oil used as an input to biodiesel and for human consumption (Bendz, 2007; Gunstone, 2001).

While the domestic market is expanding rapidly, the import market for canola oil is heavily constrained. The EU has had community-wide legislation on genetically modified organisms (GMOs) since 1998. Before being placed on the market, GMOs must first undergo a very strict assessment process. If approved, they must be labeled and managed in accordance with strict product traceability requirements (EUROPA, n.d.). The majority of products that use genetic modification technology in their production, especially imported products, could not enter into the market because of a stringent science-based assessment and a lengthy approval process. GMOs are a contentious political issue in the EU, which delayed the establishment of an expeditious approval mechanism and continues to inhibit approvals (Phillips, 2006).

Europeans preferred the name oilseed rape, rape oil, or rapeseed oil to the name canola. One unique difference, however, is that Europe does not permit the making of canola oil from genetically modified plants (VitaminsDiary, n.d.). European farmers are prevented by law from growing genetically modified rapeseed. However, over the period since 1995 about 80 percent of the canola grown in Canada has now been modified using biotechnology to make it tolerant to some herbicides (Canola Council of Canada, 2008c). Thus, Canadian canola is currently banned from the European food market as the GM varieties of canola have not been approved for import into the EU and there is no segregation of GM and non-GM canola in the post-harvest supply chain (Smyth et al., 2006). Australia was the only major exporter of non-GM canola to the EU, but Australia is now adopting GM canola at a rapid rate.

In the face of pressure from major GM grain exporting countries, the EU has made some concessions on the imports of GM products. In late 2004, some GM grain varieties were approved but imports of the most important varieties of GM canola are still not allowed (Foster and French, 2007). In 2006, the European Commission announced that three oilseed rapes known as Ms8, Rf3 and Ms8xRf3 that are genetically modified for tolerance to the herbicide glufosinate-ammonium are authorized to be placed on the EU market. These oilseed rapes are allowed to be imported but only for processing into animal feed or for industrial purposes, not for cultivation (EUROPA, 2007). They cannot be imported if destined for the human food supply channel. Thus, the EU market including the UK is effectively closed to canola imports that can enhance human health.

The UK Rapeseed Oil Market

Both domestic producers and international sources of supply are assumed for a new functional food in Case 2 of the framework developed above. In Case 2, the new functional food faces a regulatory trade barrier that is equivalent to an import ban. Canola oil from Canada suffers from a GMO import ban which prevents market access to the U.K and, hence, is a suitable example for a case study under the assumptions contained in Case 2[20].

The European Union is a major producer of rapeseed. In the past, it has been a net exporter of rapeseed products. The EU's net exports have declined in recent years and the EU is now becoming a net importer of both rapeseed and rapeseed oil due to strong demand for it as an input to biodiesel production (Foster and French, 2007). However, the increased imports of rapeseed and rapeseed oil are still small relative to the large domestic production — approximately 5 percent of domestic production in 2006 (see Table 7). Further, the EU has diverted more than three million tonnes, or 60 percent, of its rapeseed oil production to biodiesel production (Business Times, 2008). More than half of the imports went to biodiesel production in order to satisfy mandated increased utilization of this new transport fuel. Thus, the remaining imports of rapeseed oil for food use from other countries only cover a tiny portion of the domestic market for rapeseed oil consumption. Thus, it is assumed for the purpose of

[20] The assumption being made is that any small remaining quantities of non-GM imports of canola provided from Australia can be safely ignored.

this case study that the EU, and hence the UK, are closed to cheaper international sources of canola oil.

With its *trans* fat-free health enhancing attributes, it is assumed that canola oil as a functional food will have increased in popularity in the EU market if consumers have access to the functional product. However, since the EU has established very strict laws governing the import of GM canola, opportunities in promoting health benefits may be lost while GM canola imports are prohibited. Hence, in the UK case study, imports of rapeseed oil from countries outside the EU are assumed to be to be zero in order to better capture the foregone benefits arising from the GMO ban.

Table 7: EU - supply and disposal of rapeseed oil (Kt)

	2002-2003	2003-2004	2004-2005	2005-2006
Opening Stocks	320	315	152	200
Production	4353	4339	5365	5945
Imports	7	33	38	335
Total supply	4680	4687	5555	6480
Domestic Consumption	4115	4392	5365	5945
Exports	250	143	125	75
Closing stocks	315	152	200	190

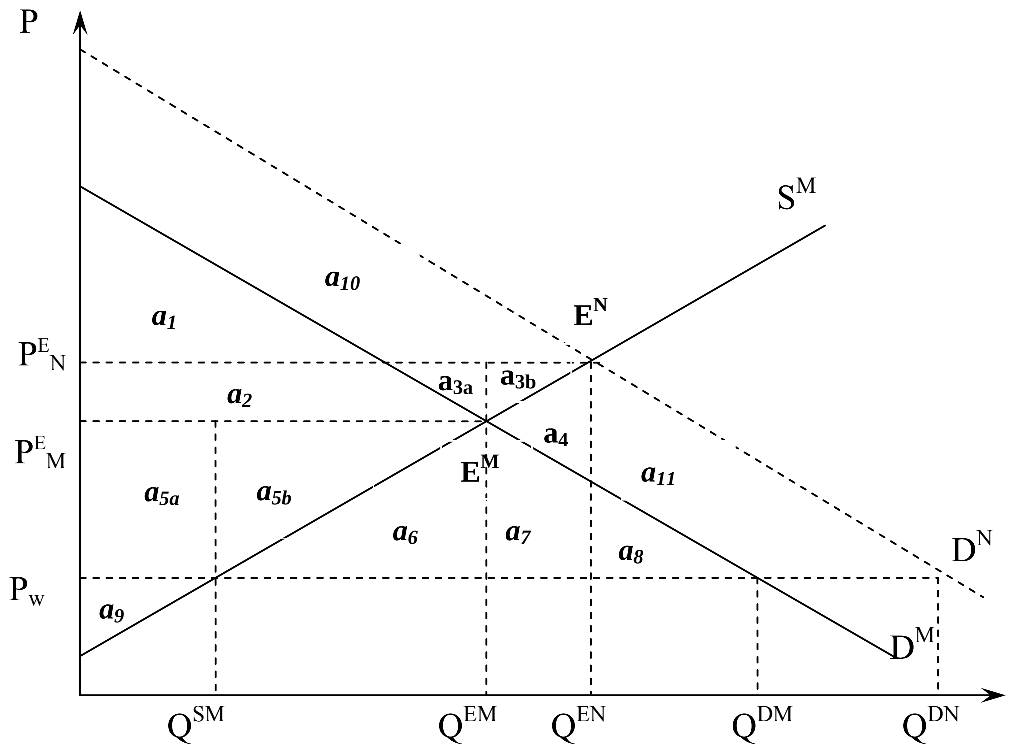
Source: US Department of Agriculture (2006).

Stage One – Calculation of Trade Effects

In Figure 9, D^M is the demand curve of canola oil in the UK market prior to the health improvement benefits becoming apparent. There is also a supply curve S^M for canola oil. At Pw, the world price for canola oil, consumers are willing to purchase Q^{DM} and domestic producers will only supply Q^{SM}. Imports would be (Q^{DM}- Q^{SM}). However, there is a GMO ban in the UK imposed on the import of canola oil for human consumption. Therefore, it raises the price to P^E_M and the quantity consumed will be Q^{EM}.[21]

Without the GMO import ban, the consumer surplus is area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$. Producer surplus is area $\boldsymbol{a_9}$[22]. After the GMO import ban is implemented, consumer surplus decreases to area $\boldsymbol{a_1} + \boldsymbol{a_2}$ with a reduction of $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$. Producer surplus increases to area $\boldsymbol{a_5} + \boldsymbol{a_9}$ with an increase equal to area $\boldsymbol{a_5}$.

[21] Note we are assuming that the S^M curve includes any transfers within the EU's single market.
[22] Given that S^M includes within EU transfers, the estimates of producer surplus may exceed the value of producer surplus that accrues to British producers.



* For calculation purposes, a_5 is divided into a_{5a} and a_{5b} . a_3 is divided into a_{3a} and a_{3b}.

Figure 9: Case 2 — domestic and import supply, trade prohibiting regulation in the UK

Canola oil can now be viewed as a functional food in the food market in the UK. As a result, more people are willing to buy canola oil given its newly recognized health enhancing attributes — only recognized after the GM import ban was put in place. In addition, consumers are expected to be willing to pay at least the same price or a premium for higher quality (health enhancing) canola. Therefore, the increased consumption of new health enhancing canola oil shifts the demand curve out to D^N. Faced with the same world price at P_w, the consumer surplus increases to area $\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{10}} + \boldsymbol{a_{11}}$. As the world price is unchanged and the supply curve is not altered, domestic producer surplus remain equal to area $\boldsymbol{a_9}$.

With the import ban in place, however, no imports of canola oil exist in the domestic market in the UK. Hence, the domestic price P^E_M rises to P^E_N and the quantity consumed equals Q^{EN} with the increased demand. With higher price P^E_N, consumer surplus decreases to area $\boldsymbol{a_1} + \boldsymbol{a_{10}}$. Consumers suffer a loss of area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{11}}$ in surplus because of the higher price. On the other hand, producer surplus increases to area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_5} + \boldsymbol{a_9}$ — a change equal to $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_5}$.

Thus, before any new health information on canola oil was received, the trade changes are areas $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$ — the decrease in consumer surplus and $\boldsymbol{a_5}$ — the increase in producers surplus. Both $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$ and $\boldsymbol{a_5}$ are trapezoid areas that can be divided into rectangles and triangles for the calculation of their values[23]. After the health enhancing attributes of canola oil having been recognized by the consumers,

[23] Assuming, of course, linear supply and demand curves.

the trade change is area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{11}}$ in consumer surplus and $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_5}$ in producer surplus. Area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{11}}$ can be divided into rectangle $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7}$ and triangle $\boldsymbol{a_8} + \boldsymbol{a_{11}}$. Area $\boldsymbol{a_2} + \boldsymbol{a_3}$ can be divided as rectangle $\boldsymbol{a_2} + \boldsymbol{a_{3a}}$ and triangle $\boldsymbol{a_{3b}}$. Combined with the data from Table 8, the calculations and resultant values can be found in Table 9.

Table 8: Data for canola oil market in the UK (2006) [a]

Total domestic consumption/supply (Mt) – Q^{EN} [b]	0.63 [c]	
Supply elasticity - ε^S	0.84 [d]	
Demand elasticity - ε^D	-0.50 [e]	
Average world price($ US dollars/tonne) - Pw	553 [f]	
Current domestic price($ US dollars/tonne) – P_N^E	983 [g]	
Domestic demand (Mt) without GMOs ban- Q^{DN}	0.77 [h]	
Domestic supply (Mt) without GMOs ban - Q^{SM}	0.40 [i]	
Demand increasing rate [j]	Base	30%
	High	50%
	Medium	40%
	Low	20%
Original domestic consumption (Mt) at P_M^E - Q^{EM} [k]	Base	0.48
	High	0.42
	Medium	0.45
	Low	0.525
Original price before demand shifts– P_M^E ($ US dollar/tonne) [l]	Base	704
	High	593
	Medium	649
	Low	788
domestic consumption (Mt) at Pw - Q^{DM} [m]	Base	0.53

	High	0.43
	Medium	0.48
	Low	0.60

[a] All the data period is based on year 2006.

[b] Different from the Chinese case study in the chapter 4, rapeseed oil has been well-known for its *trans* fat-free and other health enhancing benefits in the UK market for over 10 years. Thus, it is assumed that the total domestic consumption/supply of rapeseed oil is Q^{EN}. That means the demand curve D^M has already been shifted to D^N in the current market. The initial price for the purpose of calculation is, hence, P_N^E.

[c] Source: FEDIOL(2006).

[d] Note: it is a oilseed area response elasticity for oilseed oil supply. (Source: Meilke et al, 2001)

[e] Note: it is a direct price elasticity for oilseed oil demand. (Source: Meilke et al, 2001) See

[f] Average Pw is based on period from 87/88 to 05/06. Source: USDA (1999) and USDA (2008).

[g] Raw vegetable oil price in Netherlands and Germany. Source: Horváth (2006).

(Origin: 162,663 HUF. Convert to US $ 982 based on 1:0.006042 (HUF: USD) currency rate. Source: Yahoo Finance, Sept 27th , 2008.)

[h] Q^{DN} is calculated from the following steps using demand elasticity:

$$\varepsilon^D = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{EN} - Q^{DN})}{P^E{}_N - P_W} * \frac{P^E{}_N}{Q^{EN}}$$

$$Q^{DN} = Q^{EN} - \varepsilon^D * Q^{EN} * \frac{(P^E{}_N - P_W)}{P^E{}_N}$$

$$= 0.63 - (-0.50) * 0.63 * \frac{(983 - 553)}{983}$$

$$= 0.77 \text{ (Mt)}$$

[i] Q^{SM} is calculated from following steps using supply elasticity:

$$\varepsilon^S = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{EN} - Q^{SM})}{P^E{}_N - P_W} * \frac{P^E{}_N}{Q^{EN}},$$

$$Q^{SM} = Q^{EM} - (\varepsilon^S * (P^E{}_N - P_W) * \frac{Q^{EN}}{P^E{}_N})$$

$$= 0.63 - (0.84 * (983 - 553) * \frac{0.63}{983})$$

$= 0.4$ (Mt)

[j]. Demand increases are estimated from current reports and studies regarding to the UK's functional food market. For details, see Appendix 1.2.

[k] $Q^{EM} = Q^{EN} / (1 + \text{Demand increasing rate})$

[l] P_M^E is calculated from following steps using supply elasticity:

$$\varepsilon^S = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{EN} - Q^{EM})}{P^E{}_N - P^E{}_M} * \frac{P^E{}_N}{Q^{EN}}$$

$$P^E{}_M = P^E{}_N - \frac{(Q^{EN} - Q^{EM}) * P^E{}_N}{\varepsilon^S * Q^{EN}}$$

[m] Q^{DM} is calculated from following steps using demand elasticity:

$$\varepsilon^D = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{EM} - Q^{DM})}{P^E{}_M - P_W} * \frac{P^E{}_M}{Q^{EM}}$$

$$Q^{DM} = Q^{EM} - (\varepsilon^D * (P^E{}_M - P_W) * \frac{Q^{EM}}{P^E{}_M})$$

Table 9: Trade effects calculation in the UK Case study

		$a_5 + a_6 + a_7 + a_8$		a_5		$a_2 + a_3 + a_5$			$a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8 + a_{11}$	
		Rectangle $a_5 + a_6$	Triangle $a_7 + a_8$	Rectangle a_{5a}	Triangle a_{5b}	Rectangle $a_2 + a_{3a}$	Triangle a_{3b}	a_5	Rectangle $a_2 + a_3 + a_4 + a_5 + a_6 + a_7$	Triangle $a_8 + a_{11}$
Formula		$Q^{EM'} * (P_M^E - P_W)$	$1/2*(Q^D_M - Q^{EM})*(P_M^E - P_W)$	$Q^{SM} * (P_M^E - P_W)$	$1/2*(Q^E_M - Q^{SM})*(P_M^E - P_W)$	$Q^{EM} * (P_N^E - P_M^E)$	$1/2*(Q^{EN} - Q^{EM})*(P_N^E - P_M^E)$		$Q^{EN} * (P_N^E - P_W)$	$1/2*(Q^{DN} - Q^{EN})*(P_N^E - P_W)$
Result (Million$)	Base	72.48	3.78	60.4	6.04	133.92	20.93	66.44	270.9	30.1
	High	16.8	0.2	16	0.4	163.8	40.95	16.4		
	Med	43.2	1.44	38.4	2.4	150.3	30.06	40.8		
	Low	123.38	9.4	94	14.69	102.38	10.24	108.69		
	Base	76.26		66.44		221.29			301	
	High	17		16.4		221.15				
	Med	44.64		40.8		221.16				
	Low	132.78		108.69		221.31				

Table 9 shows all the calculations and results for the trade effects of canola oil.[24] With a GMO ban on imports of canola oil in the UK, consumers suffer losses ranging from US$17 million to US$133 million at our different levels for consumer surplus change (area $\boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8}$). On the other hand, producers gain US$16.4 million to US$108.7 million in producer surplus change (area $\boldsymbol{a_5}$).

After health information regarding canola oil becomes well-known to the public, consumers' loss increases relative to producers' gain. A US$301 million loss in consumer surplus (area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_4} + \boldsymbol{a_5} + \boldsymbol{a_6} + \boldsymbol{a_7} + \boldsymbol{a_8} + \boldsymbol{a_{11}}$) has been calculated (see Table 9). Without sufficient imports, increased consumption of canola oil raised the domestic market price leading to the loss in consumer surplus. This loss is increased substantially compared to former loss in consumer surplus at the four different levels. Even at base levels with the US$221 million gain in producer surplus, the increased consumption of healthy canola/rapeseed oil leads to a greater loss in consumer surplus than when the health benefit was unknown. Although the producer surplus also increased (area $\boldsymbol{a_2} + \boldsymbol{a_3} + \boldsymbol{a_5}$), the comparative increase is less than the decline in consumer surplus.

Stage Two – Estimating the Potential Health Care Cost Savings for the UK Case Study

The model developed by Malla et al. (2007) is adapted to estimate the potential health benefit and related medical cost savings arising from the consumption of more healthy *trans* fat-free canola oil in the UK. The calculations involve four steps.

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[24] A sensitivity analysis was performed on supply and demand elasticities and the results were found not to be particularly dependant on the values used. Details of the sensitivity analysis can be found in Zhang (2009).

Step 1: Estimate possible daily *trans* fat intake reduction due to '*trans* fat-free canola oil in the UK

In step 1, a total *trans* fat consumption (intake) per day is estimated using available studies. Hulshof et al. (1999) studied the intake of fatty acids in Western Europe. They found that in the United Kingdom, the main sources of TFA were partially hydrogenated oils and fats which contribute 35 percent of the intake of total *trans* fatty acids in the diet. Of these, margarines, spreads, frying and cooking fats and oils contributed at least 31 percent TFA in the diet. The study further revealed that a total daily intake of individual *trans* fatty acids among 11 fatty acid isomers from selected food sources per day is 40.92g in the UK.[25]

The effect of *trans* fat-free canola oil substitution can be seen in Table 10. Using sensitivity analysis, the estimation assumes four level of substitution from base (20%), high (50%), medium (40%) and low (10%). The resulting reductions in daily *trans* fat consumption are 0.89 g (Base), 2.22g (High), 1.78 g (Medium) and 0.44 g (Low) in the UK.

[25] 11 fatty acid isomers are $C_{14:1t9}$ (0.11 g methylesters/day), C16 :1t9 (0.18 g methylesters/day), $C_{18:1t}$ (2.00 g methylesters/day), $C_{18:2t}$ (0.28g methylesters/day), $C_{18:3t}$+$C_{20:1}$ (0.17g methylesters/day), $C_{20:2t11,14}$ (0.02 g methylesters/day), $C_{22:1t}$ (0.06 g methylesters/day), $C_{18:1c9}$ (19.3 g methylesters/day), $C_{18:2c9,12}$ (11.4 g methylesters/day), $C1_{8:3c9,12,15}$ (1.4 g methylesters/day), $C_{18:0}$ (6.0 g methylesters/day).
Source: Hulshof et al. (1999).

Table 10: *Trans* fatty intake reduction in the UK due to *trans*-fat-free canola oil

	base	High	medium	Low
Total daily TFA (intake) per person (g) [a]	40.92	40.92	40.92	40.92
Contribution rate (%) [b]	10.85	10.85	10.85	10.85
TFA intake due to hydrogenated oils consumption [c]	4.44	4.44	4.44	4.44
Assume TFA reduction (%) [d]	20	50	40	10
Total TFA reduction (g) [e]	0.89	2.22	1.78	0.44

[a] Source: Hulshof et al. (1999).

[b] According to Hulshof et al. (1999), the main sources of TFA were partially hydrogenated oils and fats which contribute 35 percent of the intake of total trans fatty acids in the diet. Of these, margarines, spreads, frying and cooking fats and oils contributed at least 31 percent TFA in the diet. Thus, a contribution rate is applied to reveal total TFA intake due to hydrogenated oils consumptions. Contribution rate (%) is calculated from the product of 35% times 31%.

[c] TFA intake due to hydrogenated oils consumptions = Contribution rate * total TFA (intake) per day

[d] TFA reduction (%) in sample foods is assumed have four levels from base, high, medium to low. These four levels indicates the percentage of vegetable oils found in daily food consumption that is assumed to be substituted by *trans* fat-free canola oil. The TFA reduction ratio guarantees the subsequent calculations focus solely on the health care cost savings for a certain group of people who consumed trans fat-free canola/rapeseed oil rather than other vegetable oils.

[e] The total TFA reduction = The Total TFA intake daily (g) * Assume TFA reduction (%).

Step 2: Calculate cholesterol change (LDL & HDL) due to reduced *trans* fat consumption

According to Malla et al. (2007), a number of studies have measured the effects of TFA consumption on LDL, HDL, and total cholesterol levels using controlled diets. Following Malla's conclusion, in step 2, the assumption is made that for every 1 g reduction in TFA, total cholesterol will reduced by 1.55 percent.

Step 3: Calculate CHD risk reduction due to changes in cholesterol profile

Drawing on the conclusions of the US National Cholesterol Education's Expert Panel (Expert Panel, 1988), the assumption can be made that there is a 2 percent reduction in the risk of CHD for every 1 percent reduction in cholesterol levels for the medium, base and low cases, while for the high level a 3 percent reduction in CHD risk is assumed (Malla et al., 2007).

Step 4: Calculate cost changes from reduced incidence of CHD

The final step in the analysis is to calculate the potential health-care cost savings from *trans* fat-free canola oil in the UK. Each year cardiovascular disease causes over 4.3 million deaths in Europe and over 2.0 million deaths in the European Union which accounts for nearly half of all deaths (Allender et al., 2008a). Cardiovascular disease (CVD) leads to larger economic and human costs for Europe.

From European cardiovascular disease statistics provided by European Heart Network, CVD costs the health systems of the EU about € 110 billion (US$172.7 billion)[26] in 2006, which represents around 10 percent of the total health care expenditure across the EU (Allender et al., 2008a). Further, production losses from CVD deaths and illness are also considered into the overall CVD costs leading to a cost of € 192 billion (US$301.44 billion) a year. CHD accounts for one-quarter of these overall costs (Allender et al., 2008a). In the United Kingdom, the total costs of CHD are approximate £9.0 billion (US$17.82 billion)[27] in 2006. Of the total cost of CHD to the UK, around 36% is due to direct health care cost, 43% to productivity losses, and 21% to the informal care of people with CHD (Allender et al., 2008b).

In order to simplify the calculations, the estimated cost of illness savings under *trans* fat-free vegetable oil substitution are limited to savings only from cardiovascular disease. Any other possible health improvements from reduced consumption of TFA are not considered in this study. Following Malla et al. (2007), a 1:1 ratio is assumed between reduced CHD risks and health-care cost savings for the first three levels; thus, the related costs will be decreased by 1 percent if CHD is reduced by 1 percent. For the low level, it is assumed that for every percentage reduction in CHD, cost will only be reduced by half a percent (Malla et al., 2007). The health care savings are limited to the opportunities for increased consumption arising from trade liberalization, a HCS rate (%) is introduced into the last calculation step (For details, see section A2.2.2 in appendix 2).

[26] I use EUR: USD = 1:1.57, based on the current market foreign exchange rate (2:00pm, July 7, 2008).
[27] I use GBP: USD = 1:1.98, based on the current market foreign exchange rate (average, July 7, 2008).

Table 11: Potential annual health-care savings estimated in the U.K

	Base	High	Medium	Low
TC change due to 1 g TFA reduction daily (%)[a]	-1.55	-1.55	-1.55	-1.55
Daily TFA reduction	0.89	2.22	1.78	0.44
Total change in TC (%)[b]	1.38	3.44	2.76	0.68
TC to CHD ratio [c]	2.0	3.0	2.0	2.0
Change in CHD (%)[d]	2.76	10.32	5.52	1.36
CHD to cost ratio	1.0	1.0	1.0	0.5
Total annual CHD cost (million U.S dollars) [e]	17820	17820	17820	17820
Total change in annual CHD cost due to TFA reduction in daily diet (million US dollars) [f]	492	1839	984	121
Health Care Savings (HCS) rate [g]	22%	22%	22%	22%
Final HCS (million US dollars) [h]	108.24	404.58	216.48	26.62

[a] Total Cholesterol (TC) change is rated at 1.55: 1 due to 1 g of TFA reduction.

[b] Total change in TC (%) = TC change due to 1 g TFA reduction daily(%) * Daily TFA reduction (g)

[c] The relationship between total cholesterol and CHD is 1:2 based on Expert Panel (1988). For the 1:3 ratio is used for high level estimation which assumed to be the long-term ratio. (Source: Malla et al., 2007)

[d] Change in CHD (%) = total change in TC (%) * TC to CHD ratio

[e] Source: Allender et al., (2008b).

[f] Total change in CHD cost = total annual CHD cost * Change in CHD(%) * Change in CHD (%) to change in cost (%) ratio

[g] See Section A2.2.2 in Appendix 2 for details.

[h] HCS = Total change in annual CHD cost * HCS rate (%)

In Table 11, the total estimated change in annual CHD cost in the UK due to *trans* fat-free canola/rapeseed oil substitution is calculated. A range of scenarios are calculated given the incomplete nature of the data on HCS based on Malla et al. (2007).

The base estimation assumes that 20 percent of the hydrogenated vegetable oils market are replaced by *trans* fat-free vegetable oils, leading to a 0.40g *trans* fat intake reduction daily in the UK. With the assumed 1:2 cholesterol to CHD risk ratio a saving of US$108 million in health-care costs is generated annually in the UK.

The High level assumption is based on an optimistic perspective that *trans* fat-free vegetable oils cover a 50 percent market share in hydrogenated vegetable oils such as the shortening and the salad oil, accounting for a 0.99g *trans* fat intake reduction daily in the UK. With the assumption that every percentage change in total cholesterol leads to a 3 percent change in CHD and 1:1 ratio between the incidence of CHD and the resulting costs to society, the high level estimation results in a saving of US$405 million in the UK medical costs annually.

For the Medium estimate, *trans* fat-free vegetable oil is assume to substitute for 40 percent of the hydrogenated vegetable oils market, which together results in a 0.79g daily *trans* fat intake reduction individually in the UK. Given that a smaller ratio with every percentage change in cholesterol level which leads to a 2 percent reduction in CHD, this results in a saving of US$216 million in health-care costs annually in the UK based on an assumed 1:1 ratio between the incidence of CHD and the resulting costs to society.

The low scenario demonstrates potential health-care cost savings under very conservative assumptions. *Trans* fat-free oils are assumed to reach only a 10 percent market share in the hydrogenated vegetable oils market. There is a 0.20g *trans* fat intake reduction daily in the UK. Further, a reduced ratio of 1:0.5 is applied between CHD change and health-care costs instead of the former 1:1 correlation. Although every step is extremely conservative, the extreme low scenario still suggests a potential reduction of US$27 million in health-care costs annually in the UK.

Stage Three – Determine the Final Ratios for the UK Case Study

The ratio η which was discussed above is used to indicate the decision makers' weighting of the changes in consumer surplus and producer surplus as well as the health cost savings arising from the imposition of an import ban on canola oil imports in the case of the United Kingdom. Table 12 shows the calculations undertaken to derive the ratios. From the table, the ratios for canola oil are calculated based on the results from the previous sections. In summary, in the absence of the information pertaining to the health benefits from canola oil η^{M} is equal to 1.19 in the base case, 1.05 in the high case, 1.11 in the medium case to 1.26 in the low case. With the health benefits, this ratio rises to 1.78 in the base case, 2.32 in the high case, 2.0 in the medium case to 1.65 in the low case.

The result shows that η^{N} is much larger than η^{M} at all four levels, which is consistent with the Chinese case study. Given the increased demand for canola oil in the UK market, consumers suffer a significant loss due to the higher domestic price caused by the import ban. Adding forgone health benefits and health care cost savings on canola oil into the ratio, the weighting ratio is considerably larger than before the health benefits of canola oil became known. In the High Case with 20 percent TFA reduction in daily *trans* fat intake, the loss for consumers arising from the 30 percent increased demand is more than two times larger than the gain by producers. At the low level, consumers still lose more than one and a half times the gain for producers. Therefore, from a welfare perspective, it is possible political decision makers may wish to re-consider their decisions on the import policy towards canola oil in the UK — and hence to push for reform in the EU.

Table 12: Final Ratio Calculation in the U.K Case Study

	η^{M}	η^{N}
Formula	$\eta^{M} = \frac{\Delta \text{ consumer surplus}}{\Delta \text{producer surplus}} = \frac{(\mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8)}{\mathbf{a}_5}$	$\eta^{N} = \frac{\Delta \text{ consumer surplus} + \text{HCS}}{\Delta \text{producer surplus}} = \frac{(\mathbf{a}_2 + \mathbf{a}_3 + \mathbf{a}_4 + \mathbf{a}_5 + \mathbf{a}_6 + \mathbf{a}_7 + \mathbf{a}_8 + \mathbf{a}_{11}) + \text{HCS}}{\mathbf{a}_2 + \mathbf{a}_3 + \mathbf{a}_5}$
Base	76.26/64.17	$\frac{348.61 + 108.24}{219.02}$
	1.19	***2.09***
High	18/17.1	$\frac{348.61 + 404.58}{216}$
	1.05	***3.49***
Medium	44.44/39.87	$\frac{348.61 + 216.48}{215.22}$
	1.11	***2.63***
Low	132.78/105.16	$\frac{348.61 + 26.62}{217.78}$
	1.26	***1.72***

Conclusions

Restrictions on market access for agricultural products have, for the most part, been in place for a long time – often many decades. Multilateral liberalization of market access for the sector has, historically, shown little progress. Currently, one of the major stumbling blocks to completion of the Doha Round of WTO negotiations is the question of market access for agricultural markets. The market for agricultural products, however, is not static with new products being introduced at a rapid pace. This changing marketplace for agricultural products calls into question whether trade restrictions put in place under entirely different market conditions remain appropriate. While broader questions pertaining to liberalization of market access are caught up in the politics of trade negotiations, countries always have the right to unilaterally remove barriers to market access. The question is, under what circumstances might they want to consider the unilateral option for selected markets?

This paper has examined the question of revisiting the imposition of existing trade barriers in one case of an evolving marketplace – when a traditional food product is altered to provide, or discovered to have, human health benefits that increases their value to consumers. In other words, the food becomes a *functional food*. A functional food has the potential provide direct benefits to consumers as well as indirect benefits to society in the form of health care cost savings. If the trade barrier was put in place prior to these direct and indirect benefits of the food becoming apparent, then they would not have been considered when the decision to impose the trade barrier was taken. In these circumstances, policy makers may wish to revisit a decision to impose a trade barrier.

As we could not find any previous research that considered this question, the objectives of this paper were to formally incorporate direct and indirect health benefits into a trade model and then to undertake two case studies to determine if the changes brought by functional foods are of a sufficient magnitude to justify further research in this area. Our theoretical work examined four cases: (1) A cost increasing trade barrier with domestic production of the functional food; (2) An import ban with domestic production of the functional food; (3) A cost increasing trade barrier without domestic production of the functional food and; (4) An import ban without domestic production of the functional food. The four cases produced effects that differed considerably suggesting that future examinations would have to be undertaken on a case by case basis.

Barriers to market access for canola oil, which has been found to have additional health benefits associated with its consumption, were used for the empirical case studies. China imposes tariffs and produces canola domestically while market access to the United Kingdom is restricted by the European Union's ban on imports of genetically modified organisms. Canola oil is, however, produced in the United Kingdom. The results suggest that, in both cases, a failure to consider health benefits in decisions pertaining to the imposition of trade barriers is a non-trivial matter. While, decision making pertaining to trade policy remains opaque, the results suggest that policy makers might wish to revisit decisions imposing trade barriers in the cases where functional foods are manifest in the marketplace. The results also suggest that this is an avenue of research worth pursuing for trade policy economists.

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APPENDIX 1: CANOLA OIL
SHIFTS IN DEMAND

A1.1 Canola Oil Shift in Demand for China

The trade model developed for functional food markets in this paper is based on two assumptions. First, the new product N, is assumed to be produced at the same cost as product M by both domestic and foreign suppliers. Second, product N can be represented by the same demand curve as product M and that the new health attribute does not change its price elasticity and, hence, there is no change in the slope of demand curve. From the perspective of consumers, more people are willing to buy the new health enhancing product N at the same price. Therefore, demand increases shifting out the demand curve.

Based on these assumptions, in the Chinese case study, canola oil is assumed to benefit from an increase in demand and consumption due to the recent discovery of health giving attributes being associated with canola. Currently in China, however, there are no accurate surveys or reports on consumers' attitudes to canola oil consumption after it became well-known for its *trans* fat-free attribute. Therefore, indirect evidence must be used to reveal the consumers' behaviors towards *trans* fat-free canola oil. In other words, some way of determining the demand shift is needed to undertake calculations for the China case study.

Healthcare Packaging (2007) suggests that functional food product markets are booming in the Asia Pacific because of the trend towards health and wellness. Consumer demands for convenience products and for healthier and functional products show an increasing trend (Taylor and Van Osdol, 2006; Bean, 2006). China's health food industry experienced rapid growth from the late 1980s to the late 1990s, with the fastest increase among the urban higher income population (Kotilainen et al., 2006). China is leading the way in functional food market expansion in the Asia Pacific region. It is reported that the value of sales of functional foods grew by nearly 20 percent in 2005 (Healthcare Packaging, 2007). Continued expansion of the functional foods market in China is predicted with a two-fold or larger growth in per capita spending on functional foods expected between 2004 and 2010 (Benkouider, 2005).

Thus, drawing on the reports and information outlined above, four levels of demand shift are assumed for the Chinese case study calculation. A base level is estimated with a 20 percent increase in demand for canola/rapeseed oil in the Chinese market. A two-fold expansion over the base case is set at 40 percent for the medium level and an even larger increase of 50 percent is assumed for the most optimistic case. Below the base level, a 10 percent shift in demand is assumed.

A1.2 Canola Oil Shift in Demand for the UK

In the UK case study, it is assumed that more people are willing to buy canola oil with newly recognized health enhancing attributes and consumers are willing to pay at least the same price or a premium for higher quality (health enhancing) canola oil. Therefore, the rising interest in new health enhancing canola oil shifts out the demand curve. However, with a GMO import ban, no imports of canola oil exist in the domestic market in the UK. Hence, domestic consumption rises to a new and higher autarky equilibrium.

Canola (or rapeseed0 oil has been the most important vegetable oil produced in the European Union since 1988. In 10 years, EU consumption of vegetable oil has risen 50%, mainly due to increased consumption of rapeseed oil for its health attributes. Currently, rapeseed oil accounts for more than one-third of total European vegetable oil production and remains the largest oil consumed in Europe (MATIF, n.d.).

At present, the competition between food consumption and biofuels usage is becoming a significant driver of the vegetable oils market and for rapeseed oil in particular. Currently, the production capacity for rapeseed is limited in the EU — demand in rapeseed oil already exceeds supply. However, the GMO import ban on rapeseed/canola oil considerably restricts import sources from other countries and further raises the domestic price.

A report from FEDIOL (2006) shows that the consumption of rapeseed oil in the UK market went up 48 percent from 0.43 million tones (Mt) to 0.63 Mt in the last 15 years. This increasing rate has slackened a bit in the last 5 years because of increases in the rapeseed oil price caused by the high competition for oil due to mandated bio-fuel usage. However, rapeseed oil remains the most widely consumed vegetable oil in the UK market, particularly since its health enhancing attributes became well known in the 1990s.

Therefore, the UK case study is consistent with the two major assumptions of the model. First, the consumption of rapeseed oil is increasing due to the health giving attributes of rapeseed oil. Based on the information in FEDIOL (2006), four levels of increased demand are used in the UK's case study calculations. A base level is estimated using a 30 percent increase in the domestic price for canola oil as a functional food in the UK market. A 40 percent change is used for the medium level. An even greater increase of 50 percent is assumed for the most optimistic case. Below the base level, a 15 percent demand increase is assumed for the most conservative case.

APPENDIX 2: ESTIMATION AND CALCULATIONS FOR THE SAVINGS IN HEALTH COSTS

Appendix 2 provides a more detailed estimation and calculation for some important data used in the case study.

A2.1 Estimation of daily *trans* fat intake data in China

While no studies on *trans* fat consumption in mainland China could be found, a study on *trans* fats in locally available foods conducted by the Centre for Food Safety (CFS) and the Consumer Council (CC) in Hong Kong, China is available. However, since results vary among different tested samples, no single estimate is available for the case study. Hence, an average estimate is required. Based on CFS (2007), the average *trans* fat daily intake for four major types of food were calculated.

Combining the total trans fat consumption data from the CFS (2007)'s study, which used samples of 80 varied products, the final calculation of individual daily average trans fat intake is shown in table A2.1. Since the tested sample foods are not a major proportion of the Chinese diet, consumers may or may not choose all of the above four types of foods to include in their diet. Therefore, a 25 percent ratio is assigned to provide a conservative estimate. This ratio results in a total of 1.99g TFA daily intake for Chinese consumers.

Table A 2.1 Estimated *trans* fat consumption in China

	bread samples [a]	butter-made products [b]	fried products [c]	margarine/ margarine like spreads [d]	Total
Total TFA(g) [e]	202.7	3.37	1.59	12.4	220.06
Sample size(piece)	33	25	14	8	80
Average TFA(g) [f]	6.14	0.13	0.11	1.55	7.94
25% intake [g]	1.54	0.03	0.03	0.39	1.99

[a] Bread samples include sliced breads, buns, loaves, croissants and egg tarts.

[b] Butter-made products includes cakes, waffles, egg puffs and egg rolls.

[c] Fried products includes fries, fried chicken and oriental fried food.

[d] margarine/margarine like spreads includes butter and margarine/margarine like spreads.

[e] TFA is calculated from 100g/sample.

[f] Average TFA(g) = Total TFA(g)/ Sample size(piece)

[g] As the above sample foods are not frequently found in the common diet in China, it is assumed that there is only 25 percent chance that people will choose one of above four types foods in their daily diet. This means that 25 percent of total average TFA is the actual dietary intake assumed.

A2.2 Assumed HCS rate (%)

A2.2.1 Assumed HCS rate (%) in Chinese case study

Recall the discussion on health care costs savings (HCS) suggested that they are likely to be some function of the consumption of the particular functional food. Therefore, the HCS that would arise from the removal of the trade barrier is a function of the increased consumption of product N. That is,

HCS = $f(\Delta Q^N)$, where ΔQ^N is the difference between the consumption of N with a trade barrier and that which arises without the trade barrier.

Following the analysis in Figure 7, the difference between the consumption of N with a trade barrier and that which arises without the trade barrier is measured by the quantity change along the demand curve D^N from P_w to $(P_w + C)$. Thus, in the Chinese case study, the HCS would arise from the quantity change, which is a function of the increased consumption of *trans* fat-free canola oil along the new demand curve.

Known as a functional food, *trans* fat-free canola oil is found to provide health enhancing benefits for consumers. However, prior to the scientific evidence discovered on its health enhancing attributes, canola oil has made health contributions to consumers since it was marketed. Therefore, all the people who consumed canola oil benefited from its health enhancing attributes and society received health savings due to reduced risk of CHD. Among the first three steps in section followed in the body of the paper, HCS calculations are based on consumption of canola oil in the entire domestic market, which is quantity $Q^{DN'}$. However, the health care costs savings (HCS) of interest is only those health improvement effect that can be attributed to trade liberalization. That means the HCS calculation should be focused on the quantity change of *trans* fat-free canola oil along the new demand curve. In order to limit the calculation to this group of individuals, a HCS rate is introduced into the last step calculation. The HCS rate is calculated as

HCS rate = $\frac{Q^{DN} - Q^{DN'}}{Q^{DN'}}$ and is provided as a percent change — details can be found in the Table A2.2.

By introducing the HCS rate in the Chinese case study, calculation for health care savings are concentrated on the expansion quantities in the market due to trade liberalization. Therefore, only those health care cost savings attributed to trade liberalization are included when determining the health care savings.

Table A 2.2 HCS rate calculation in Chinese case study

	High (50% demand shift)	Medium (40% demand shift)	Base (20% demand shift)	Low (10% demand shift)
Q^{DN}(Mt) [a]	6.515	6.080	5.212	4.777
$Q^{DN'}$ (Mt) [b]	6.409	5.981	5.127	4.699
$Q^{DN} - Q^{DN'}$(Mt)	0.106	0.099	0.085	0.078
HCS rate (%) = $\frac{Q^{DN} - Q^{DN'}}{Q^{DN'}}$	1.65%	1.66%	1.66%	1.66%

[a] $Q^{DN} = Q^{DM} * (1+ \text{demand shift rate})$

[b] $Q^{DN'}$ is calculated from the following steps using demand elasticity: (Demand elasticity is the same with both demand curves)

$$\varepsilon^D = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(Q^{DN} - Q^{DN'})}{P_W - (P_W + C)} * \frac{P_W + C}{Q^{DN'}} = \frac{(Q^{DN} - Q^{DN'})}{(-C)} * \frac{P_W + C}{Q^{DN'}}$$

$$Q^{DN'} = \frac{Q^{DN} * (P_W + C)}{(P_W + C) + \varepsilon^D * (-C)}$$

where ε^D is -0.20, ($P_w + C$) is 928.68 (US dollar/tonne) and (-C) is -76.68 (US dollar/tonne) from table 4.1 in section 4.3.2.1.

A2.2.2 Assumed HCS rate (%) in the UK case study

A HCS rate is introduced into the last calculation step in the UK case study. The HCS rate is calculated as

$$\text{HCS rate} = \frac{Q^{DN} - Q^{EN}}{Q^{EN}} = \frac{0.77 - 0.63}{0.63} = 22 \text{ percent}$$

Where Q^{DN} is 0.77 Mt and Q^{EN} is 0.63 Mt from Table 8.

By introducing the HCS rate in the UK case study, calculations for health care savings are concentrated on the expansion quantities in the market due to trade liberalization. Therefore, only those health care cost savings attributed to trade liberalization are included when determining the health care savings.