Product Differentiation and Trade: An Example From the Beef Sector

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ABSTRACT: This paper examines the trade-liberalization effects in a context of product differentiation. A model where consumers display preferences for various qualities/varieties is compared to a model where goods are considered as "homogeneous", because of the aggregation of the quantities/prices without considering qualities/varieties. In a context of decreasing/constant returns to scale for sellers, it is shown that the welfare with products considered as "homogeneous" is greater than the welfare with products considered as differentiated. We illustrate our work by estimating the impact of an increase in the imports of the Argentine bovine meat on the European bovine meat market.

Keywords: product differentiation, bovine meat demand, international trade, European Union, Argentina.

1. INTRODUCTION

In the trade literature, agricultural products are usually considered as homogeneous products. However this approach can lead to some biases regarding the welfare effects coming from trade liberalization. The main reason for focusing on homogenous goods is the absence of precise data that could detail prices per types of products or qualities, allowing to compute the imperfect substitution among these products.

Actually, monopolistic competition is used to model product differentiation taking into account market structures with increasing returns to scale, which characterize manufactured industries (Spence 1976, Dixit and Stiglitz, 1977, Krugman, 1979 and 1980). However, these models may also introduce biases in terms of welfare evaluations, since the effect of the introduction of a new product abstracts from cross-price effects (equal to zero) with old products. An important hypothesis in monopolistic competition is that each firm produces only one variety. This characteristics is more tailored to industrial products or to services (where varieties matter) than to agricultural products.

In agriculture, a new variety/quality of an agricultural product should be considered as a market segmentation instead of a new-variety creation. Different varieties of an agricultural commodity are generally imperfect substitutes, where the differences in varieties are often tiny in particular for raw materials. In other words, cross-price effects are not negligible among products in spite of qualities/varieties differences. So the analysts must take these effects into account, which differs from monopolistic competition models. Eventually, supply is characterized by decreasing/constant returns to scale and perfect competition appears to be the most suited market structure in the case of agricultural products.

The purpose of this paper is to compare a model of product differentiation with a model aggregating the differentiated products for getting an homogeneous one. Most of the trade literature assert that welfare effects are greater when the market structure involved product differentiation as in monopolistic competition. Our paper shows that this relationship is not straightforward. In particular, in a context of decreasing returns to scale for sellers, it is shown that the welfare with products considered as homogeneous (because of aggregation) is higher than the welfare with products considered as differentiated.

In the second section of this paper, we present a model of two imperfect substitutes products. We then compare welfare effects under different hypotheses on demand parameters. In order to illustrate this issue, the third section presents an empirical case of trade liberalization for the beef market between Argentina and the European Union. The beef market is selected since quality differences matter for consumers. Finally, we conclude on the pertinence of using an adequate model of product differentiation for agricultural products.

2. A SIMPLE MODEL OF PRODUCT DIFFERENTIATION

For simplicity, a model of product differentiation with two imperfect substitutes is introduced. According to market hypotheses, the firms exhibit decreasing returns to scale in their production functions in a context of perfect competition.[1] Anyway, the results we show in this paper are true as much under constant as under decreasing returns to scale. The overall supply curve on the market is $Q_s = \sum_i q_i$, which characterizes the overall supply when products are aggregated[2].

On the demand side, we consider demand functions for two imperfect substitutes.

(1) $$q_1^d = \alpha - \beta p_1 + \delta p_2$$

(2) $$q_2^d = \omega - \varphi p_2 + \psi p_1$$

These demand functions come from the maximization of individual utility subject to budget constraint (Spence, 1976). The positive parameters α and ω are the intercept, β and φ are positive and, the positive δ and ψ capture the substitution between varieties.

Indeed, specific values for demand parameters leads to “well-known” frameworks of product differentiation given by Mussa-Rosen [1978] or Spence [1976]. Table 1 presents the specific values of the demand parameters relative to each model of product differentiation.

Table 1: The models of product differentiation

Spence Product Differentiation Model (1976)	***Mussa and Rosen Vertical Product Differentiation Model (1978)***
$\alpha = \omega > 0$	$\alpha > \omega = 0$

[1] Each firm *i* maximizes its profit $\pi_j = \sum_i p_i q_{ji} - \sum_i \frac{\gamma_{ji}}{2} q_{ji}^2$ with $\gamma_{ji} > 0$, which leads to an individual supply function $q_{ji} = \frac{1}{\gamma_{ji}} p_i$. The supply function of a variety *i* is then $q_i = \sum_j q_{ji} = \frac{1}{\gamma_i} p_i$, with $\gamma_i = \frac{\gamma_{ji}}{J}$ since the *j=1,…,J* sellers have the same technology.

[2] Under constant returns to scale, the price of the aggregated product is a linear combination of individual marginal costs of each variety.

$\varphi>\beta>0$	$0<\delta=\psi\cong\beta<\varphi$
$\delta=\psi>0$	

Spence [1976] introduces product differentiation by assuming that the interaction effect between imperfect substitute products is the same in both demand functions. In their model, Mussa and Rosen [1978] uses a structure of vertical differentiation.

When products are aggregated in the statistical analysis, it means that price differences are overlooked and represented by a price index. For simplifying our analysis, we assume that it corresponds to supply and demand aggregation, where goods are exchanged at the same price. Using the demand specification given by equations (1) and (2), the aggregation leads to the overall demand, which will be a kinky demand curve.

(3) if $\frac{\alpha+(\delta p_2)}{\beta}>p_1=P>\frac{\omega+(\psi p_1)}{\varphi}$ the overall demand function is $Q_d=q_1=\alpha-\beta p_1+\delta p_2$

if $0<P<\frac{\omega+(\psi p_1)}{\varphi}$ the overall demand function is $Q_d=\alpha+\omega-(\beta-\psi+\varphi-\delta)P$

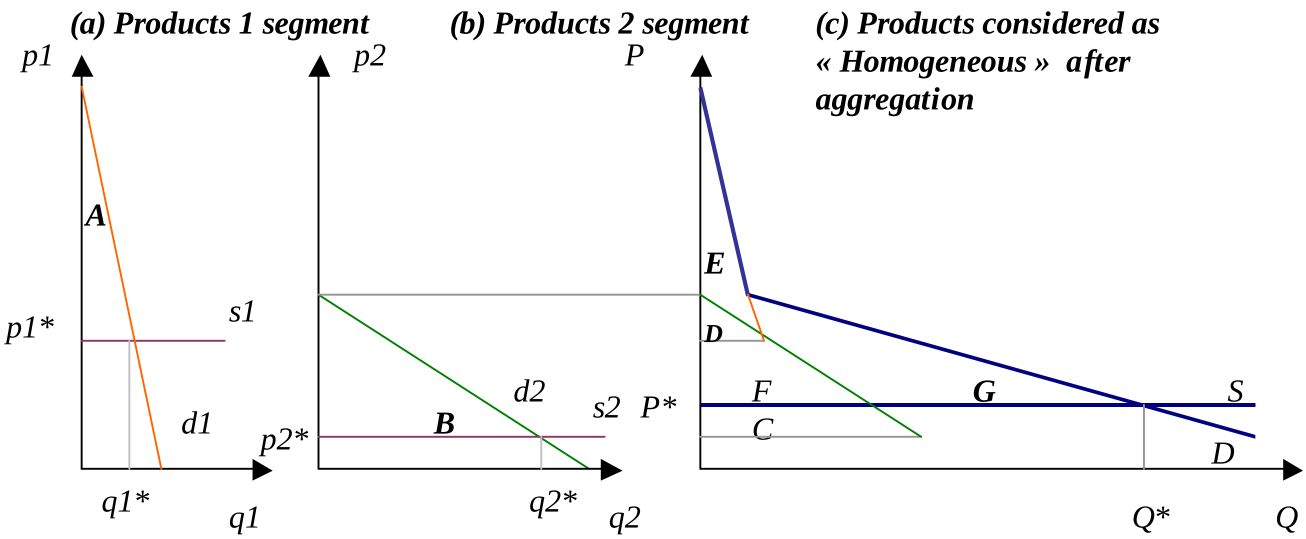
where the intercept $a=\alpha+\omega$, the slope $b=(\beta-\psi)+(\varphi-\delta)$ and P the single price. The aggregated model leads to products considered as "homogeneous" since the price difference is eliminated. The price P in this case comes from the equalization between the overall demand and the supply curve defined above, but under constant returns to scale, where the price equalizes the marginal cost, we assume the “homogeneous” product’s price is:

(4) $$P=\frac{\sum_i p_i q_i}{\sum_i q_i}$$

Market clearing under both configurations, namely the model integrating product differentiation and the "homogeneous" model abstracting from price differences, leads to the equilibrium price, the quantity supplied and the surpluses detailed in appendix.

Analysing welfare effects, we represent the welfare under the product differentiation model (figure (a) and (b)) and the aggregated product model (figure (c)) considering constant returns to scale for simplicity (Figure 1). The X-axis represents the quantity, *q*, and the Y-axis the price, *p*. Recall that for the previous simulations, we assumed prices equal marginal cost for each quality product and for the aggregated product the price is equal to equation (4). The demands are graphed according to equations (1), (2) and (3) in each one of the next graphs.

Figure 1: Equilibrium and welfare under both configurations



When product differentiation is taken into account, the welfare is represented by the area A for products 1 on figure (a) and by the area B for products 2 on figure (b). By considering figures (a) and (b), the overall welfare is given by areas A+B for the product differentiation model. The aggregated product model shows a welfare represented by areas E+D+F+G. The specificities of the supply functions allow us to write A=D+E and B=D+F+C. Consequently, the welfare comparison between both types of approaches leads to the comparison of the area G and C+D. Then, depending on assumptions on the value of the parameters of the demand function G may be greater, equal or smaller than C+D. Clearly under the figure 1, the area G is larger than the area C+D, which means than the welfare under the "homogeneous" approach is greater than the welfare under the product differentiation model, namely *Wh/Wd*>1.

In order to compare welfares, we consider the models of product differentiation under Spence [1976] and Mussa and Rosen [1978] hypotheses and the aggregated product model. Concerning supply hypotheses, we assume decreasing returns to scale for the first calculations, where the supply parameter γ_i is taken equal to one for both segments (i=1,2), which is relevant for the bovine meat market (see the section 3 for details). For the second series of welfare calculations we assume constant returns to scale and we will compare the results between models.

About parameters $\alpha,\beta,\delta,\varphi,\omega,\psi$ we will assume Spence and Mussa and Rosen hypotheses for some of them, and the parameters which denote cross and own-price effects will vary for the analysis.

The ratio *Wh/Wd* helps us to determine the relationship between welfares under the aggregated product model denoted *Wh*, and under the product differentiation model (Spence or Mussa and Rosen hypotheses), denoted *Wd*. A ratio *Wh/Wd*>1 means that the welfare with an “homogenous” product model is larger than the welfare with differentiated products.
Table 2 presents the results with different values of parameters under Spence and Mussa and Rosen hypotheses. The ratio of welfares also depend on the parameters values.

Table 2: Simulation Results

Models	Parameters Hypotheses						Ratio Wh/Wd under decreasing returns	Ratio Wh/Wd under constant returns
	α	β	δ	ω	φ	ψ		
Spence Model 1976	10	0.1	0	10	5	0	1.036712	1.0217
		0.5					1.10163	1.15625
		1					1.051775	1.5555
		3					0.419	16
		4.5					0.16	2.4
	10	3	0.1	10	5	0.1	0.4	31.3203
			0.5			0.5	0.37	53.37
			1			1	0.32	4.5
			2			2	0.2286	1.6
Mussa and Rosen Model 1978	10	0.1	0.099	0	1	0.099	1.00712	1.00695
			0.09			0.09	1.00853	1.00698
			0.05			0.05	1.07336	1.00702
			0.01			0.01	1.01936	1.00696
			0.001			0.001	1.02039	1.00693
	10	0.1	0.09	0	0.9	0.09	1.00049	1.00611
					0.5		0.947384	1.00313
					0.2		0.850557	1.00092

For the Spence specification, we assume that $\varphi=5$ (fixed parameter), $\alpha=\omega$, $\psi=\delta$ and $\beta<\varphi$, to show the difference between high and low quality demand functions. The parameters subject to variations are β and δ. The calculation results under decreasing returns to scale show us that the ratio of welfares *Wh/Wd* is greater than 1 only if there aren’t cross-price effects and if the difference between the parameters of direct (β,φ) effects is maximized.

Under constant returns to scale, the calculation results show a *Wh/Wd* >1 for all cases considered.
Under the Spence specification, the relationship between welfares is ambiguous. The ratio of welfares will be greater than 1 under constant returns to scale, but under decreasing returns to scale, this conclusion is only supported if there is no interaction effect and if the difference between the direct effects is considerable.
For the Mussa and Rosen model, we assume that $\alpha>0$, $\omega=0$, $\beta\cong\psi=\delta$ and $\beta<\varphi<0$. The parameters φ and δ vary. The calculation results show the importance of the difference

between β and φ to have Wh/Wd>1. Under decreasing returns to scale, the relationship between welfares is ambiguous too. The smaller the difference between β and φ, the smaller the ratio of welfare. The ratio of welfare is greater than 1 for close (but non-equals[3]) parameters representing the interaction (δ and ψ) and the direct (β) effect in the demand function. Otherwise, under constant returns to scale, the ratio *Wh/Wd* is always greater than 1 as for the Spence model calculations.

These results clearly demonstrate that welfare, under a two differentiated products model, could have been overestimated in the trade literature. Product differentiation models could lead to welfare estimations smaller than in the homogeneous case due to the assumption of decreasing or constant returns to scale. Moreover, this result also depends on the magnitude of the cross-price and own-price effects in the demand functions and the relationship between them.

[3] Mussa and Rosen (1978) hypotheses about parameters demand ($\beta = \psi = \delta$) complicate welfare calculation, that's the reason why we assume $\beta \cong \psi = \delta$.

3. NUMERICAL EXAMPLE : Beef trade between Argentina and European Union.

In this section, we present a quite simple application of our model of product differentiation for agricultural products. We aim at illustrating our welfare's relationships, by a case study on the bovine meat trade between Argentina and the European Union.

We first calibrate our generic models, the first one with two imperfect substitutes products and the second one with an aggregated product using the GAMS software. Then, we simulate a trade liberalization in bovine meat market between Argentina and European Union. In the case of two imperfect substitutes goods, we suppose two origins of bovine meat (Argentina and EU) and we assume also two different varieties of bovine (high quality bovine meat and low quality bovine meat). Let j represents the origin and i the quality. Under the aggregated product model, we consider no differences in origins nor in qualities.

For this purpose we have used the European statistics on bovine meat market (consumption and domestic production) from Ofival[4] and the bovine meat statistics on tariff and trade from COMEXT[5] and TARIC[6] data bases. The choice of demand elasticities (own-price and cross-price) was more delicate.

Indeed, estimates of own and cross-price elasticity of bovine meat demand vary widely in the literature. Schroeder, Marsh and Mintert [2000] display a review of selected studies estimating bovine meat demand with time-series data. Estimates range between -0.28 and -0.85 most falling between -0.40 and -0.70. Their own estimate of bovine meat demand own-price elasticity is equal to -0.608. They conclude that demand for bovine meat is inelastic and that as consumer incomes rise bovine meat demand will remain inelastic especially for high quality cuts that have few substitutes.

Lusk et al. [2001] have calculated price elasticities for meat demand. Two types of bovine meat are modeled, "Choice beef" which could be considered as high quality bovine meat (hq) and "Select beef" as low quality (lq). Choice and Select beef have own-price elasticities (hqhq, lqlq) of demand equal to -0.43 and -0.63 and cross-price elasticities (hqlq, lqhq) of 0.196 and 0.269 respectively.

[4] OFIVAL is the French Inter-professional Office for Meat and Breeding.
[5] COMEXT is the European database for trade.
[6] TARIC is the database on integrated tariff of the European Community.

Van Eeno, Peterson and Purcell [2000] summarize the estimates from Tvedt and al. [2000][7] of own-price elasticities of beef meat demand in different parts of the world (namely, US, Japan, Mexico, Korea, New Zealand and Rest of the World). These estimates range from -1.840 to -0.036 and from -1.816 to 0.005 for respectively high (hqhq) and low (lqlq) quality meat. Cross-price elasticities range from 0.026 to 0.757 and from 0.005 to 1.292 for respectively hqlq and lqhq. For USA only; these elasticities are -0.774 for hqhq, -1.816 for lqlq, 0.728 for hqlq and 1.292 for lqhq. These result contrast with the precedent in the order of magnitude but they lead to some similar conclusions. High-quality is more elastic than low-quality meat demand and the demand for low-quality meat is more responsive to the price of high-quality meat than the contrary. However the demand for bovine meat is more price elastic in the latter case than in the former.

The literature about European bovine meat market shows great differences between own-price elasticities from a European country to another. For Great Britain, Tiffin and Tiffin [1999] find an own-price elasticity of demand for bovine meat equal to –1.642 , while Fousekis and Revell [2002] estimate is –0.49. In Spain, Laajimi and Albisu [1997] find an own-price elasticity close to unity (-0.97), and these authors compare their estimations with Garcia and Albisu [1995] ones, which show a more inelastic bovine meat demand (-0.66). In Norway, Rickertsen [1996] estimate an uncompensated demand price elasticity for bovine meat demand of –0.87.

Because of these differences in demand elasticities it is difficult to state an arbitrary value for price elasticities in the bovine meat demand. We then decide to simulate two extreme situations. In the first one, we have considered the elasticities of Lusk et al.[2001] and in the second one, we have used the elasticities of Tvedt [2000] of the USA case. Changing the values of elasticities, we modify the values of the demand parameters and we can estimate welfare sensitivity to a tariff reduction in a product under different assumptions (with two imperfect substitute products or with an “homogenous” product). This is a good illustrative example because bovine meat bears differentiated tariffs at the entry of the EU according to the quality of the meat.

We simulate a tariff reduction using our models (imperfect substitute product model and aggregated product model) without restrictions on the demand parameters. In table 3, we

[7] Tvedt, D., M. Reed, A. Maligaya, and B. Bobst. *Elasticities in World Meat Markets.* Agricultural Economics Research Report Series No. 55. University of Kentucky, 1991.

underline the relationship between the welfares in these two cases, before and after a tariff reduction.

First, we present the results of a 10% reduction in each tariff (tariff of the low-quality meat, tariff of high quality meat, and the tariff of the homogeneous product called bovine meat). The results show that, the greater the elasticities (cross-price and own-price), the greater the welfare ratio[8].

We then estimate the consequences of a tariff reduction under Spence [1976] and Mussa and Rosen [1978] demand parameters hypotheses. For the model with Mussa an Rosen parameters restriction we assume $\varepsilon_{12}=\varepsilon_{21}=\varepsilon_{22}$ and the Spence parameter restriction are only $\varepsilon_{12}=\varepsilon_{21}$. Our unrestricted model presents intermediates results between Mussa and Rosen ‘s and Spence’s.

The ratio Wh/Wd is always greater than 1 for all models (restricted and unrestricted models). The results show that under Tvedt elasticities Wh/Wd is equal to 1.046 and under Lusk et al. elasticities the Wh/Wd is1.037, except for the Mussa and Rosen hypotheses where the welfare ratio is greater after than before the tariff reduction (1.048 under Tvedt elasticities and 1.038 under Lusk et al. elasticities) . Using the Tvedt elasticities, differences in welfare measures between the “homogeneous” case and the “differentiated” cases are larger than considering the Lusk et al. elasticities. The conclusion is still the same, “the greater the elasticities, the greater the welfare ratio”.

Then, we show the results of simulating a 10%-tariff reduction on the aggregated product tariff and a 20% tariff reduction on only one bovine meat quality. The same relationships described in the paragraph above are true for these two particular cases. But, comparing welfare results between the last two cases, we see that a tariff reduction on low-quality bovine meat trade would bring a greater welfare than reducing high-quality bovine meat tariff. It

[8] This conclusion is supported too for welfare variation terms. For example, we observe a surplus gain for consumers and a surplus loss European producers under Lusk et al. elasticities and the losses for both, consumers and European producers, under Tvedt elasticities. The values of elasticities have the same impact on the Argentinean producer's surplus variation as we obtain the same results in all cases (17% surplus variation under Tvedt elasticities and 11% surplus variation under Lusk et al. elasticities). The explanation is always the same: “the greater the elasticities, the greater the welfare variation”. Concerning the aggregated product case we find smaller welfare variations than under the two imperfect substitutes product cases.

seems straightforward, because t2 (European tariff of low-quality bovine meat) is greater than t1 (European tariff of high-quality bovine meat), so t2 represents the biggest constraint in the bovine meat trade between Argentina and EU.

Table 3: Welfare Variation after a Tariff Reduction

	Basic Model: Import Tariff Reduction (10%)		***Basic Model: Import Tariff Reduction (-10% t et -20%t1)***		***Basic Model: Import Tariff Reduction (-10%t,-20%t2)***	
	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities
Wh/Wd before tariff reduction	1.046	1.037	1.046	1.037	1.046	1.037
Wh/Wd after tariff reduction	1.046	1.037	1.046	1.037	1.046	1.037
	Spence Model: Import Tariff Reduction (10%)		***Spence Model: Import Tariff Reduction (-10% t et -20%t1)***		***Spence Model: Import Tariff Reduction (-10%t,-20%t2)***	
	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities
Wh/Wd before tariff reduction	1.046	1.037	1.046	1.037	1.046	1.037
Wh/Wd after tariff reduction	1.046	1.037	1.046	1.037	1.045	1.037
	Mussa and Rosen Model: Import Tariff Reduction (10%)		***Mussa and Rosen Model: Import Tariff Reduction (-10% t et -20%t1)***		***Mussa and Rosen Model: Import Tariff Reduction (-10%t,-20%t2)***	
	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities	Tvedt (2000) elasticities	Lusk et al. (2001) elasticities
Wh/Wd before tariff reduction	1.046	1.037	1.046	1.037	1.046	1.037
Wh/Wd after tariff reduction	1.048	1.038	1.048	1.037	1.049	1.038

4. CONCLUSION

Literature on trade asserts that welfare is always greater in a model of product differentiation under monopolistic competition than in an homogeneous product model.

In our paper, we justify the necessity of introducing product differentiation in agricultural good markets, but always keeping some basic characteristics of these markets (decreasing/constant return to scale, perfect competition, many producers of many varieties and many consumers for all varieties).

Under these hypotheses, we have compared welfare effects under an aggregated product model and an imperfect substitute products model. We have proved that this relationship between these two cases is not straightforward. The ambiguity of the results depends on supply hypotheses (constant our decreasinfg returns to scale) and on demand parameters (own-price and cross-price demand elasticities). The greater the elasticities, the greater the welfare difference between an aggregated product model and two differentiated products model (ratio Wh/Wd). Our simulation results show that a tariff reduction leads to a greater welfare under the "homogeneous" product model than under the imperfect substitute products model.

It is important to differentiate between varieties/qualities in agricultural goods in order to compute welfare effects correctly, avoiding calculation biases. An agricultural product generally shows elasticities of demand which aren't negligible (own-price and cross-price demand elasticities). If we consider agricultural product as an aggregated product, we omit interaction effects between varieties of the same product and we can over or under-estimate welfare effects.

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APPENDIX

PART A: Ideal Model

Expression of equilibrium price, quantity and surpluses.

We consider no import tariff that affects the supply functions, and we assume the existence of decreasing returns to scale for production functions, then the supply function are $q_i = p_i$ where $t_i = 0$ and $\gamma_i = 1$.

Considering product differentiation case, the prices and quantities at equilibrium are:

$$p_1^* = -\frac{\alpha + \alpha\varphi + \delta\omega}{-1 - \beta - \varphi - \beta\varphi + \delta\psi}$$

$$p_2^* = -\frac{-\alpha\psi - \omega - \beta\omega}{1 + \beta + \varphi + \beta\varphi - \delta\psi}$$

$$q_1^* = \frac{\alpha + \alpha\varphi + \delta\omega}{1 + \beta + \varphi + \beta\varphi - \delta\psi}$$

$$q_2^* = \frac{\alpha\psi + \omega + \beta\omega}{1 + \beta + \varphi + \beta\varphi - \delta\psi}$$

The consumer and producer surplus of each variety and the total welfare were calculated using these expressions:

$$CS=\int_{p_1^*}^{\frac{\alpha+\delta p_2^*}{\beta}}(\alpha-\beta p_1+\delta p_2^*)dp_1+\int_{p_2^*}^{\frac{\omega+\psi p_1^*}{\varphi}}(\omega-\varphi p_2+\psi p_1^*)dp_2=\frac{(\alpha^2(\varphi+2\varphi^2+\varphi^3+\beta\psi^2)+2\alpha(\delta\varphi(1+\varphi)+\beta(1+\beta)\psi)\omega+(\beta+2\beta^2+\beta^3+\delta^2\varphi)\omega^2)}{(2\beta\varphi(1+\beta+\varphi+\beta\varphi-\delta\psi)^2)}$$

$$PS_1=\int_0^{p_1^*}(p_1)dp_1=\frac{(\alpha+\alpha\varphi+\delta\omega)^2}{2(1+\beta+\varphi+\beta\varphi-\delta\psi)^2}$$

$$PS_2=\int_0^{p_2^*}(p_2)dp_2=\frac{(\alpha\psi+\omega+\beta\omega)^2}{2(1+\beta+\varphi+\beta\varphi-\delta\psi)^2}$$

$$W=CS+\sum_i PS_i=\frac{(\alpha(1+\varphi)((1+\beta)\varphi+(1+\beta)\varphi^2+\beta\psi^2)+2\alpha(1+\beta)(1+\varphi)(\delta\varphi+\beta\psi)\omega+(1+\beta)(\delta^2\varphi+\beta(1+\varphi)+\beta^2(1+\varphi))\omega^2)}{(2\beta\varphi(1+\beta+\varphi+\beta\varphi-\delta\psi)^2)}$$

Now, we consider the aggregated product model under perfect competition. The expressions of price, quantity and surpluses are:

$$p^*=\frac{\alpha+\omega}{2+\beta-\delta+\varphi-\psi}$$

$$q^*=\frac{\alpha+\omega}{1+2\beta-2\delta+2\varphi-2\psi}$$

$$CS=\int_{\frac{\omega+\psi p_1^*}{\varphi}}^{\frac{\alpha+\delta p_2^*}{\beta}}(\alpha-\beta p+\delta p_2^*)dp+\int_{p^*}^{\frac{\omega+\psi p_1^*}{\varphi}}[(\alpha+\omega)-(\beta-\delta+\varphi-\psi)p]dp$$

$$PS=\int_0^{p^*}\left(\frac{p}{2}\right)dp$$

$$W=CS+PS$$

PART B: Introducing an import tariff

Now, we introduce an ad-valorem import tariff in the supply functions ($q_i=\frac{p}{(1+t_i)*\gamma_i}$, where $t_i\geq 0$ depending on the case and $\gamma_i=1$). The prices and quantities at equilibrium will be:

$$p_1{*}=-\frac{\omega}{\psi}+\frac{(\alpha\psi-\omega(-\beta-\frac{1_1}{1+t_1}))(-\varphi-\frac{1}{1+t_2})}{\psi(\delta\psi-(-\beta-\frac{1}{1+t_1})(-\varphi-\frac{1}{1+t_2}))}$$

$$p_2{*}=-\frac{\alpha\psi-\omega(-\beta-\frac{1}{1+t_1})}{\delta\psi-(-\beta-\frac{1}{1+t_1})(-\varphi-\frac{1}{1+t_2})}$$

$$q_1{*}=\frac{\alpha+\alpha\varphi+\delta\omega+(\alpha\varphi+\delta\omega)t_2}{1+\beta+\varphi+\beta\varphi-\delta\psi+(\varphi+\beta\varphi-\delta\psi)t_2+t_1(\beta+\beta\varphi-\delta\psi+(\beta\varphi-\delta\psi)t_2)}$$

$$q_2{*}=\frac{\alpha\psi+\omega+\beta\omega+(\alpha\psi+\beta\omega)t_1}{1+\beta+\varphi+\beta\varphi-\delta\psi+(\varphi+\beta\varphi-\delta\psi)t_2+t_{11}(\beta+\beta\varphi-\delta\psi+(\beta\varphi-\delta\psi)t_2)}$$

Including the tariff effects, the consumer and producers surplus and the total welfare present these forms.

$$CS=\int_{p_1^*}^{\frac{\alpha+\delta p_2^*}{\beta}}(\alpha-\beta p_1+\delta p_2^*)dp_1+\int_{p_2^*}^{\frac{\omega+\psi p_1^*}{\varphi}}(\omega-\varphi p_2+\psi p_1^*)dp_2$$

$$PS_1=\int_0^{p_1^*}\left(\frac{p_1}{1+t_1}\right)dp_1$$

$$PS_2=\int_0^{p_2^*}\left(\frac{p_2}{1+t_2}\right)dp_2$$

$$W=CS+\sum_i PS_i$$