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Welfare Measurement Biases and Product Differentiation in Agriculture: An Example from the US Beef Sector

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Abstract

This paper examines the impact of two different model specifications on welfare estimations. A model specification that takes into account product differentiation is compared to a specification where the product differentiation is overlooked. The welfare comparison under both specifications show some biases of aggregation as well as ambiguous results: the welfare under one specification may be larger or lower than the welfare under the alternative assumption. In order to illustrate our theoretical conclusions, we present an application to the US beef market. We show that the welfare, when the product differentiation is taken into account, is smaller than the welfare when the product differentiation is omitted.

Keywords: product differentiation, beef demand, welfare.

1

INTRODUCTION

From the multiplication of varieties for fresh products to the food safety requirements, product differentiation is now widespread in agricultural markets. This empirical fact raises the question of the quantification of consumers' welfare in a context where both quality and variety matter for producers and consumers.

Many empirical models consider agricultural products as homogeneous goods. This is particularly the case in most of the partial equilibrium models that are often used to analyze agricultural markets, for outlooks as well as policy simulations purposes (e.g. the AGLINK model developed by the Organization for Economic Co-operation and Development, the FAPRI model developed by the Food and Agricultural Policy Research Institute). Indeed, the assumption of "homogeneous" goods is generally used due to the lack of detailed information. The availability of data is usually the limiting factor in estimating demand curves or elasticities. In this case, series of prices and quantities for products are very often aggregated without considering quality differences.

However, policy analysis and cost-benefit analysis without enough precision regarding the data are likely to be doomed to failure, since quality/variety matter for issues such as trade, generic advertising, functional food or food safety. Introducing product differentiation in a more precise functional form consists in estimating refined own-price effects (or elasticities) and new cross-price effects (or elasticities) among products.

In this article, we seek to answer the following questions: should we get more precise data for welfare estimations? Are aggregation biases significant when product differentiation is overlooked? A very simple framework is introduced for tackling this issue of product differentiation and the related welfare measure. First, a theoretical comparison of welfare's values is undertaken under two different model specifications. A linear functional form of the demand is considered for specifying the product differentiation model (Spence 1976). The alternative model with products considered as similar or "homogeneous" is built from the previous one via an aggregation of prices and quantities. The comparison of welfare estimations under both specification exhibits an ambiguous result. Depending on the parameter values, the welfare can be lower or larger under either specification.

Then, a calibration of the previous models is realized. For that purpose we have used the elasticities estimated for the US beef market by Lusk et al. (2001). We show that the welfare under the "homogeneous" product specification is greater than the welfare under the product differentiation specification. The welfare is overestimated under the "homogeneous" product specification compared to the product differentiation specification. This result belies the common belief regarding the considerations around product differentiation and it suggests significant biases coming from the absence of precise data. The collection of more precise data regarding the market segmentation is valuable for the analysis, since we show significant differences between both model specifications.

Section 1 presents the different model specifications. Section 2 presents

an empirical case from the US beef market. Section 3 discusses some extensions around this topic. Finally, we conclude about the relevance of using an adequate model of product differentiation and detailed data for agricultural products for welfare measurement.

1 TWO SIMPLE MODEL SPECIFICATIONS

1.1 Product differentiation specification

For simplicity, we introduce a model with two imperfect substitutes that only differ according to the quality. To make the model tractable we use very simple linear demands. We omit the revenue effect because we aim at assessing the impact of introducing Spence hypotheses on welfare measure[1]. The demand for each quality depends on its own price and the price of the substitute. The expression of demands q_i^d for the two substitutes $(i = 1, 2)$ takes the form given by equations 1 and 2.

$$q_1^d = \alpha - \beta p_1 + \delta p_2 \tag{1}$$

$$q_2^d = \omega - \varphi p_2 + \psi p_1 \tag{2}$$

These demand functions come from the maximization of individual quadratic utility subject to budget constraint (Spence 1976, Vives 1999). The positive parameters α and ω are the intercepts, β and φ show the negative slope of the demand functions and, the positive δ and ψ capture the substitution between varieties. The greater δ and ψ values, the greater the substitutability level between qualities. However, the parameter's values of the own-price effect must be greater than the parameter's values of the cross-price effect in order to assure the utility function's concavity (Vives 1999). Specific values for demand parameters lead to well-known frameworks of product differentiation specification (Spence 1976).

For simplicity, we assume that firms exhibit constant returns to scale in their production functions in a context of perfect competition. Prices are equal to the respective marginal costs and welfare is equal to the consumers' surplus. Figure 1 displays the welfare under the product differentiation specification. The X-axis represents the quantity, q_i and the Y-axis the price, p_i. The demands are represented according to equations (1) and (2) in each figure.

When product differentiation is taken into account, the welfare (equal to consumer surplus) is represented by the area A for product 1 and by the area B for product 2 (Figure 1). Considering figure 1, the overall welfare is given by area A+B for the model of product differentiation.

1.2 A "homogeneous" product specification

Many models implicitly consider the absence of product differentiation. Quality differences are overlooked via some aggregation devices when aggregated data are considered. The aggregated price may be approximated

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[1]In order to introduce the revenue effect James & Alston (2002) propose a very useful approach using Cobb-Douglas functions.

Figure 1: *Equilibrium and welfare under the product differentiation specification.*
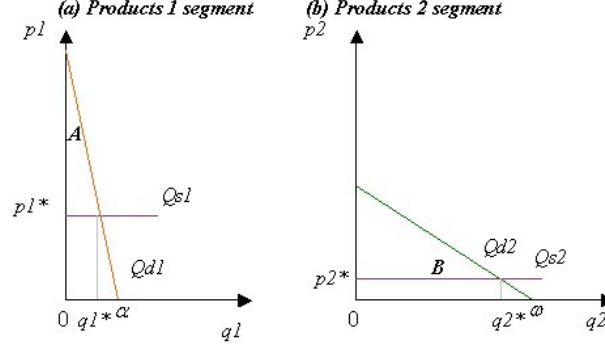
by a unit value where the overall value of the products sold is divided by the overall quantities. With the expressions of equations (1) and (2), the aggregated price may be defined by

$$P = \frac{\sum_i p_i q_i^d}{\sum_i q_i^d} \tag{3}$$

On the demand side, the overall demand function for the product considered as "homogeneous" is :

$$Q_d = a - bP \tag{4}$$

The equilibrium price and quantity for this "homogeneous" product enable to calculate the surplus for welfare measurement. For the analysis of welfare effects, we consider equations (3) and (4) to represent the supply and demand curves. In figure 2, consumer surplus is represented by area C considering the "homogeneous" product specification.

Figure 2: *Equilibrium and welfare under the "homogeneous" product specification.*

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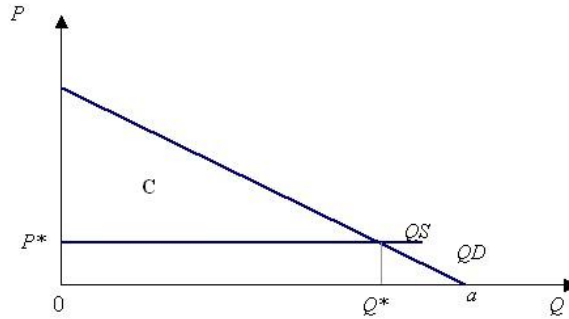
1.3 Welfare Comparison between both specifications

Several assumptions are made for the comparison between both specifications. The aim is to get relevant connections between parameters of equations (1), (2) and (4). As quantities are aggregated for the "homogeneous" market, the first link between the two models are the values of the intercepts. The quantity a (on the X-axis of Figure 2), under the "homogeneous" product specification, is equal to the sum of the quantities α and ω (on the X-axis of Figure 1), under the differentiated product specification, for a price equal to zero. The second link is given by the price of the "homogeneous" product which is presented in equation (3).

In order to compare welfare's values, we made the calculations by considering some restrictions for equations (1) and (2), see (Spence 1976). The parameters which represent the cross-price effect between imperfect substitutes are equals for both demand functions 1 and 2. Table 1 presents the restrictions on demand parameters under the product differentiation specification.

Table 1: *Spence's hypotheses on demand parameters*

Spence Product Differentiation Model (Spence 1976)
$\alpha = \omega > 0$
$\varphi > \beta > 0$
$0 < \delta = \psi < \beta$

We need to define possible values of the parameter b in equation (4). The value of b is hard to predict without any details coming from econometric works. Several configurations for this parameter b are possible regarding the restrictions presented in table 1. Table 2 presents the equilibrium quantities and welfare values (consumers surpluses) for the differentiated product specification and for the "homogeneous" product specification under various values of b.

Table 2: *Welfare under both specifications.*

Product differentiation specification						
$\alpha = \omega$	β	φ	$\delta = \psi$	Wd	t	ΔWd
10	1	1.5	0.5	51.5	0.1	4.34

Homogenous product specification					
a	b	Wh	ΔWh	Wh/Wd	$\Delta Wh/\Delta Wd$
20	$\beta = 1$	146.63	4.88	2.85	1.13
	$\frac{\beta+\varphi}{2} = 1.25$	107.66	4.66	2.09	1.08
	$\varphi = 1.5$	82.03	4.45	1.59	**1.03**
	$\frac{\beta}{2} + \varphi = 2$	50.77	4.01	**0.99**	0.93
	$\beta + \varphi = 2.5$	32.83	4.59	0.64	0.83

The ratio Wh/Wd helps us to determine the relationship between wel-

fare's values under the "homogeneous" product model denoted Wh, and under the model with two imperfect substitutes goods, denoted Wd. A ratio $Wh/Wd > 1$ means that welfare under a homogenous product specification is larger than welfare considering a product differentiation specification. However, as most people are interested in welfare changes we also test the introduction of a 10% tax (t), results are summarized in table 2.

The ratio of welfare's values depends on b value compared to β and φ values. The last column of table 2 presents the results of Wh/Wd for different values of b.

As shown in table 2, the relationship between welfare's values is ambiguous and sensitive to b variations. The results of the calculations show that:

- If b lies between β and φ values ($\beta \leq b \leq \varphi$) then the ratio of welfare will be greater than 1 ($Wh/Wd > 1$).

- The ratio of welfare will be smaller than 1 ($Wh/Wd < 1$) if b is greater than $\frac{\beta}{2} + \varphi$.

- And finally, the ratio of welfare will be approximately equal to 1 ($Wh/Wd \approx 1$) only for b values close to $\frac{\beta}{2} + \varphi$.

The welfare results under different b values show the consequences of different aggregation hypotheses on welfare. Moreover, data aggregation and use of non detailed data may lead to biases in welfare measurement. In terms of welfare variations the results are similar.

These results suggest complex variations in welfare measurement (under or overestimation of welfare) and a possible bias in its calculation (Anderson 1985). The aggregation of data and the omission of product differentiation lead us to a biased welfare analysis. Furthermore, in table 2 the relationship between Wh and Wd depends on the relationship between b, β and φ parameters. Consequently, this relationship is not straightforward, but ambiguous and fragile.

2 APPLICATION TO THE US BEEF MARKET

In this section we try to measure empirically the welfare bias when product differentiation is overlooked. We apply our theoretical analysis to the US beef market, where product differentiation matters for consumers.

2.1 Estimation of beef demand elasticities

The literature about beef demand elasticities shows different results depending on countries and periods.

For the USA, Schroeder et al. (2000) have displayed a review of selected studies estimating beef 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 beef demand own-price elasticity is equal to -0.608. They conclude that demand for beef is inelastic and, as consumer incomes rise, beef demand will remain inelastic especially for high-quality cuts which have few substitutes . More particularly, Lusk et al. (2001) have calculated demand price elasticities for US beef demand. Two types of beef are modeled, "Choice beef" which could be considered as high-quality beef (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. This paper shows a substitution between beef qualities in the US demand and the high-quality demand is more inelastic than the low-quality demand.

Another study (Van Eeno et al. 2000) summarizes the estimations from (Tvedt et al. 1991) about own-price elasticities of beef 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. These estimations show a great dispersion due to the difference of beef demand elasticities from one country to another. For the US, these elasticities are -0.774 for hqhq, -1.816 for lqlq, 0.728 for hqlq and 1.292 for lqhq. These results contrast with the precedent in the order of magnitude but they lead to some similar conclusions. The two qualities are substitutes and high-quality is more inelastic than low-quality beef demand. Then the demand for low-quality beef is more responsive to the price of high-quality meat than the contrary (Tvedt et al. 1991).

The literature on European beef market also shows great differences between own-price elasticities from a European country to another. For Great Britain, Tiffin & Tiffin (1999) find an own-price elasticity of demand for beef equal to -1.642, while Fousekis & Revell (2002) estimate a beef price elasticity equal to -0.49. The periods they use for the estimation are different and surely the BSE crises have affected the beef demand elasticity in Great Britain. In Spain, Laajimi & Albisu (1997) find an own-price elasticity close to unity (-0.97), while Gracia & Albisu (1998) obtain a more inelastic beef demand (-0.66). In Norway, Rickertsen (1996) estimates an uncompensated demand price elasticity for beef demand of -0.87. In Europe as in the US, the beef demand is inelastic. Unfortunately, the literature about beef elasticities in Europe doesn't consider quality differentiation. We therefore, decide to calibrate the demand functions defined previously using the elasticities estimated by Lusk et al. (2001).

2.2   Parameters Calibration of the Demand Functions

We have calibrated the parameters of the demand functions using the differentiated elasticities and average values of prices and quantities provided by Lusk et al. (2001). The "homogeneous" elasticity is drawn from Eales et al. (1998). Tables 3 and 4 display these values.

The calibrated parameters are presented in the next demand equa-

Table 3: *Price Elasticities at Point of Means*

ε_{11}	-0.432
ε_{22}	-0.633
ε_{12}	0.196
ε_{21}	0.269
ε	-0.28

Source:(Lusk et al. 2001) and (Eales et al. 1998)

Table 4: *Definition and Average values of the variables used in the parameters calibration.*

Variables	Definitions	Units	Average Values
q_1^d	Demand of high-quality beef	1000t	19.21
q_2^d	Demand of low-quality beef	1000t	14.81
Q^d	Demand of "aggregated" beef	1000t	34.02
p_1	Price of high-quality beef	\$/kg	2.17
p_2	Price of low-quality beef	\$/kg	2.06
P	Price of the aggregated beef	\$/kg	2.12

Source:(Lusk et al. 2001)

tions:

A) Product differentiation specification:

$$q_1 = 22341230 - 3824295p_1 + 2508490p_2 \qquad (5)$$

$$q_2 = 21281970 - 4550840p_2 + 1337677p_1 \qquad (6)$$

B) "Homogeneous" product specification:

$$Q = 43545600 - 4488733P \qquad (7)$$

The calibrated parameters show a substitution relationship between the two qualities as the sign of the cross-price elasticity predicts. β and φ parameters are greater than δ and ψ, so the concavity of the utility function is guaranteed. The φ value is greater than β and α is next to ω according to Spence parameters hypotheses.

We observe that the value of b parameter of the "homogeneous" beef demand lies between φ and $\frac{\beta}{2} + \varphi$ values. Then, according to the relationship between parameters b, β and φ, we may infer that welfare under the "homogeneous" product specification will be greater than the welfare under the product differentiation specification.

Then, we can show the coherence between our theoretical result and this application to the US beef market.

We use the equations (5), (6) and (7) to calculate the welfare's values under both specification and compare them. Then we introduce a 10% tax

on the price of beef.

We have calculated the welfare (consumer surplus) and the welfare change under both specifications and measured the welfare ratios [2] to compare them and to explain the relationship between them.

Table 5: *Welfare Results in the case of the US beef market.*

	Product differentiation specification	Homogenous product specification	Wh/Wd	$\Delta Wh/\Delta Wd$
Welfare	72345758	128990303	1.783	1.013

Under constant returns to scale, when the b demand parameter for the homogenous product demand is greater than φ and smaller than $\frac{\beta}{2} + \varphi$, the welfare ratio will be greater than 1 (see Table 2). In this particular case the welfare under a "homogeneous" product specification is greater than the welfare calculated for a product differentiation specification. The aggregation of two qualities/varieties when product differentiation matters induces a bias in welfare measurement (Anderson 1985).

3 EXTENSIONS

In defining analytical framework, we have made many restrictive assumptions for simplicity. In order to test the robustness of our results we consider the following extensions.

1. In the model we assume linear demand functions. Other functional forms like Cobb-Douglas or Constant Elasticity of Substitution (CES) are often used to introduce the non-linearity in economic functions. For that reason, we have tested our results under a Cobb-Douglas demand system, always keeping the rest of the hypotheses about demand parameters and market structure. For the theoretical case we obtained the same ambiguity for the welfare ratio (Table 6). The only difference between the linear and the Cobb-Douglas cases is the inflexion point: for the linear case $\frac{Wh}{Wd} \approx 1$ for $b \approx 2$ and for the Cobb-Douglas case $\frac{Wh}{Wd} \approx 1$ for $b \approx 1.146$.

2. Perfect competition is a strong hypothesis in our model. For that reason, we have tested the results under imperfect competition. We consider monopoly power in the "homogeneous" product specification and Bertrand duopoly for the specification of product differentiation. We keep linear demand functions and their hypotheses about the parameters. In this particular case the ambiguity about the welfare ratio values is found too (Table 7).

3. The application case in this paper considers the US beef market. However, welfare analysis is a decisional approach in the case of trade agreement. For that reason and continuing in the beef sector, it would be interesting to test the same application to the possible free trade agreement between the European Union (EU) and

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[2]Wh/Wd, where Wh is the welfare under the "homogeneous" product specification and Wd is the welfare under the product differentiation specification.

Table 6: *Welfare under both specifications with Cobb-Douglas demand functions.*

Product differentiation specification						
$\alpha = \omega$	β	φ	$\delta = \psi$	Wd	t	ΔWd
10	1	1.5	0.5	28.45	0.1	2.48

Homogenous product specification					
a	b	Wh	ΔWh	Wh/Wd	$\Delta Wh/\Delta Wd$
20	$\beta > b = 0.5$	187.662	3.04	6.60	1.22
	$\beta = 1$	40.2981	1.73	1.42	0.70
	$b \approx 1.15$	28.48	1.31	**1.00098**	0.53
	$\frac{\beta+\varphi}{2} = 1.25$	22.6034	0.99	0.794542	0.39

Table 7: *Welfare under Monopoly and Duopoly market structure.*

Product differentiation specification						
$\alpha = \omega$	β	φ	$\delta = \psi$	Wd	t	ΔWd
10	1	1.5	0.5	21.8021	0.1	5.73

Homogenous product specification					
a	b	Wh	ΔWh	Wh/Wd	$\Delta Wh/\Delta Wd$
20	$\beta > b = 0.5$	72.25	16.45	3.31	2.87
	$\beta = 1$	$\frac{289}{8}$	8.25	1.66	1.43
	$\frac{\beta+\varphi}{2} = 1.25$	28.9	6.58	1.33	1.15
	$\varphi = 1.5$	24.08	5.48	1.1	0.96
	$b \approx 1.66$	21.8	4.11	**0.999968**	0.72

the MERCOSUR, because the quality differentiation is important in their bilateral trade. The issue is particularly sensitive in the beef sector, since beef production is an important component of farm income in a very large number of family farms in Europe. There is a considerable interrogation on the effects of potential liberalization and the possibility that beef from Argentina and Brazil (where the production is increasing rapidly) could wipe out EU production is put forward by farmers associations. Another interesting aspect in beef trade between the EU and Mercosur is that beef faces differentiated tariffs at the entry of the EU according to the quality of beef. The tariff of the low-quality beef is higher than the tariff of the high-quality beef.

Anderson treats the bias in welfare measurement due to data aggregation. For that reason, he introduces many varieties of cheese to analyze US cheese import from different countries. The disaggregation by exporting countries is considered too in this paper in order to minimize biases (Anderson 1985).

CONCLUSION

Welfare measurement is the basic analysis in applied economics, even more in public economics. For that reason it is important to emphasize the risks of over or under-estimation in welfare measurement depending on the modelling assumptions and data.

The literature states that the welfare is larger if goods are characterized by product differentiation under monopolistic competition than if goods are homogeneous, because of "love for variety".

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

Considering these hypotheses, we compare welfare effects under an "homogeneous" product specification and under a product differentiation specification. We show that the relationship between the welfare's values in these two cases is not straightforward. The fragility and the ambiguity of the results depends on demand parameters and the relationship between them.

Regarding the ambiguity in the results, it is very difficult to draw general conclusions. However, we may infer that under constant returns to scale, if b (demand parameter of the "homogeneous" product) lies between β and $\frac{\beta}{2} + \varphi$ (demand parameters of quality differentiated product), the welfare ratio is greater than 1 and if b is greater than $\frac{\beta}{2} + \varphi$ (for example $b = \beta + \varphi$), the welfare ratio is smaller than 1.

The previous relationship between demand parameters has been found under others hypotheses like, non-linear demand functions (Cobb-Douglas) and under imperfect competition assumption (monopoly and duopoly).

Our hypotheses are confirmed in the case of US beef market. The aggregation assumption generates a bias in the welfare measurement.

On the basis of these findings we consider that it is essential to differentiate between varieties/qualities in agricultural goods in order to compute welfare effects correctly and to avoid calculation biases. An agricultural product generally shows cross-prices effects which aren't negligible, so if we consider agricultural product as "homogeneous" products, we may omit the interaction effects between varieties/qualities of the same product. Consequently, We can over or under-estimate welfare effects, which may carry out erroneous political decisions.

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