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Welfare Measurement and Quality Product Differentiation in Agriculture: An Example from the EU 15 Beef Sector

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Welfare Measurement and Quality Product Differentiation in Agriculture: An Example From the EU15 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 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 EU15 beef market. We show that the welfare when the product differentiation is taken into account by the econometric estimation is lower than the welfare when the product differentiation is overlooked.

Keywords: product differentiation, beef demand, European Union, welfare.

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 or and variety matter for producers and consumers.

Many empirical models consider that agricultural products are 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 "homogenous" 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 question: 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 given by Spence [4] is considered for specifying the product differentiation model. 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 estimation under both specification exhibits an ambiguous result. Depending on the parameter values, the welfare with the product differentiation specification is lower or larger than the welfare under the homogenous product specification.

Second, a calibration of the previous models is realized by considering econometric estimations of the two different specifications. The beef market in the European Union (EU15) has been chosen since quality and prices differences are large and matter for consumers. We show that the welfare under the homogeneous product specification is much larger 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 contradicts 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.

In this article, section 1 presents the different model specifications. The section 2 presents an empirical case from the European Union (EU15) beef market. In section 3 we discuss other questions and applications around this subject and finally, we conclude about the relevance of using an

adequate model of product differentiation for agricultural products in welfare measurement terms.

1 TWO SIMPLE MODEL SPECIFICATIONS

1.1 Product differentiation specification

For simplicity, we introduce a model with two imperfect substitutes that only differ according the quality. The demand for each quality depend 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 (see [4], and [6]). The positive parameters α and ω are the intercepts, β and φ are positive and, the positive δ and ψ capture the substitution between varieties.The bigger δ and ψ values, the greater the substitutability level between qualities. However, the parameter's values of the own-price effect must be bigger than the parameter's values of the cross-price effect in order to assure the utility function's concavity (see [6]). Specific values for demand parameters leads to well-known frameworks of product differentiation specification given by Spence [4].

For simplicity, we assume that firms exhibit constant returns to scale in their production functions in a context of perfect competition. With prices equal to the respective marginal costs, the welfare is equal to the consumers' surplus (see Appendix for the mathematical details). We represent the welfare under the product differentiation specification in figure 1.1(a) and 1.1(b). 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.

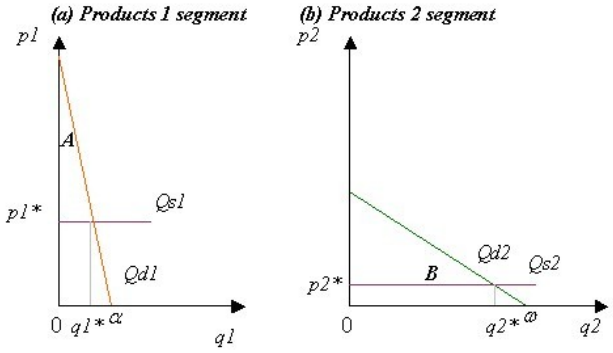

Figure 1: *Equilibrium and welfare under the product differentiation specification.*

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 1.1). Considering

figures 1.1(a) and 1.1(b), the overall welfare is given by areas A+B for the model of product differentiation.

1.2 A homogeneous product specification

Many models implicitly consider the absence of product differentiation, where quality differences are overlooked via some aggregation devices when aggregated data are considered. The aggregated price may be approximated by the overall value of the products sold 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 allow to calculate the surplus for welfare measurement (Cf. Appendix). For the analysis of welfare effects, we consider equations 3 and 4 to graph the supply and the demand curves. In the figure 1.2, the consumer surplus is represented by the area G considering the homogeneous product specification.

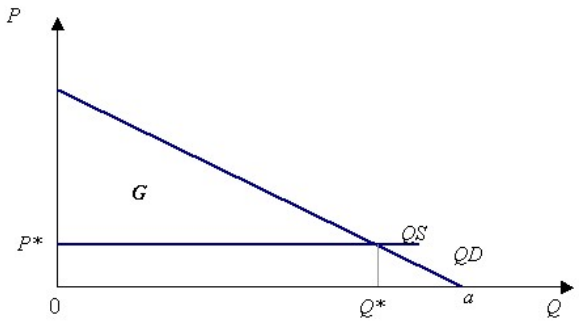

Figure 2: *Equilibrium and welfare under the homogeneous product specification.*

1.3 Welfare Comparison between both specifications

Several assumptions are made for allowing the comparison between both specifications. The aim is to get relevant connections between parameters of equations 1,2 and **??**. As quantities are aggregated for the homogeneous market, the first link between the two models are the values of the intercepts ($a = \alpha + \omega$), for a price equal to zero. It means that the quantity a(on the X-axis of Figure 1.2), under the homogeneous product specification, is equal to the sum of quantities α and ω (on the X-axis of Figure 1.1), 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, some calculations were made by considering some restrictions for the equations 1 and 2 given by Spence [4]. The interaction effect between imperfect substitutes

is the same in both demand functions 1 and 2. Table 1 presents the conditions for the demand parameters under the product differentiation specification.

Table 1: *The models of product differentiation*

Spence Product Differentiation Model [4]
$\alpha = \omega > 0$
$\varphi > \beta > 0$
$0 < \delta = \psi < \beta$

Eventually, we need to define possible values of the parameter b of the equation 4. The value of b is hard to predict without any details coming from econometric works. Different configurations for this parameter b are possible regarding the restrictions presented in the table 1. The table 2 presents the equilibrium quantities and welfare values (consumer 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	$\delta = \psi$	p_1^*	p_2^*	q_1^*	q_2^*	WD	
10	1	1.5	0.5	4	2	7	9	51.5	
Homogenous product specification									Wh/Wd
a	b			P^*		Q^*		WH	
20	$\beta = 1$			3		17.25		146.633	2.85
	$\frac{\beta+\varphi}{2} = 1.25$			3		16.4		107.66	2.09
	$\varphi = 1.5$			3		15.69		82.03	1.59
	$\frac{\beta}{2} + \varphi = 2$			3		14.25		50.77	0.99
	$\beta + \varphi = 2.5$			3		12.81		32.83	0.64

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

As we can see 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 is between β and φ values ($\beta \leq b \leq \varphi$) then the ratio of welfare will be bigger than 1 ($Wh/Wd > 1$). The ratio of welfare will be smaller than 1 ($Wh/Wd < 1$) if the parameters b is bigger than $\frac{\beta}{2} + \varphi$. An finally, the ratio of welfare will be approximately equal to 1 ($Wh/Wd \approx 1$) only for b values next to $\frac{\beta}{2} + \varphi$. These different values for b show the consequences of different aggregation hypotheses on welfare.

These results suggest complex variations in welfare measurement (under or over-estimation of welfare). A Differentiated product specification may lead to a welfare measurement smaller than in the homogeneous product specification in accordance with the assumptions of constant returns to scale as we have shown. 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, it is ambiguous and fragile.

2 APPLICATION TO THE EU-15 BEEF MARKET

2.1 Estimation of beef demand elasticities

We decide to illustrate our theoretical result by an application to the EU-15 beef market. The beef market is interesting because quality matters for beef consumers, and the EU has introduced a system of carcass classification based on 5 fatness (1, 2, 3, 4, 5) and 6 fleshiness (S,E,U,R,O,P) grades[1].The best grades (showing the best price differentials) being E2 to U4.

A document on carcass classification from the University of Bristol showed that *"classification is limited to price and it generally provides the basis for the transaction between the farmer and the slaughterhouse"*. A price grid example where figures in cells are the deviation in price (here pounds/kg) from the base price (each slaughterhouse publishing its own grid) is given:

Table 3: *Carcass classification: Price deviations from a base price.*

	1	2	3	4L	4H	5L	5H
E	-4	+8	+8	+8	+4	-5	-20
U+	-3	+6	+6	+6	+2	-8	-20
U-	-2	+4	+4	+4	0	-10	-20
R	-2	0	0	0	-4	-15	-25
O+	-10	-5	-5	-5	-10	-20	-30
O-	-20	-12	-12	-12	-15	-25	-35
P+	-20	-20	-20	-20	-20	-30	-35
P-	-30	-30	-30	-30	-30	-35	-40

Source:Bristol University
http://www.kt.iger.bbsrc.ac.uk/FACT%20sheet%20PDF%20files/kt38.pdf

We gathered data on total slaughters (for bullocks, bulls, heifers and calves), on prices (for calves R3, cows O3, bullocks R3) and heifers R3 and on the repartition between types of animals and grades of carcass in the EU-15. The bullocks R3 being the best quality (higher price) and cows O3 the poorest quality, heifers R3 being an intermediate quality. Calves are excluded of the study being considered as an other product. They are monthly data from January 2002 to September 2004 taken from the EUROSTAT database and from OFIVAL.

We have ran three regressions of beef demand using Generalized Least Squares; (quality 1 denote high-quality beef and quality 2 denotes low-quality beef) and for an homogeneous product beef in

[1]EU Directives 1208/81 and 2930/81

the European Union (EU15) market at the equilibrium point.

The variables used in the regressions are shown in table 4.

Table 4: *Definition and Average values of the variables used in the econometric regression.*

Variables	Definitions	Units	Average Values
q_1^d	Demand of high-quality beef (bullock R3	kg	20210036
q_2^d	Demand of low-quality beef (cows O3)	kg	45139459
Q^d	Demand of beef (aggregation of the other two qualities)	kg	65349495
p_1	Real price of high-quality beef	euro/kg	2.36
p_2	Real price of low-quality beef	euro.kg	1.66
P	Real price of the aggregated beef	euro/kg	1.88
p_{pork}	Real price of pork meat	euro/kg	1.19
p_{int}	Real price of an intermediate quality of beef (Heifer R3)	euro/kg	2.43
Y	Deflated GDP per capita in the EU15	euro	1834.96
d_1	Dummy time series where data=1 for January or 0 elsewhere		
d_4	Dummy time series where data=1 for April or 0 elsewhere		
d_6	Dummy time series where data=-1 for June or 0 elsewhere		
d_{10}	Dummy time series where data=1 for October or 0 elsewhere		
d_{12}	Dummy time series where data=-1 for December or 0 elsewhere		

Source:Eurostat/Ofival

Prices are deflated by the Price Index for Meat and the GDP per capita by the General Price Index for Consumer for Food.

Next equations (5 and 6) show the regression estimations with t-statistics noted in the parentheses below the coefficients. We present the R^2 and the statistic DW values of the estimations too.

$$\begin{aligned} q_1^d = & -68207149_{(-2.234405)} - 19449631_{(-5.640745)}p_1 - 3206941_{(-0.954092)}p_2 + 24303237_{(3.804825)}p_{pork} + \\ & + 18963537_{(2.291270)}p_{int} + 35449.55_{(3.795614)}Y + 2393943_{(2.601560)}d_4 + 4365904_{(4.721539)}d_6 + \\ & + 4481357_{(3.513332)}d_{12}; \qquad R^2 = 0.782193; \qquad DW = 2.297660 \end{aligned} \tag{5}$$

$$\begin{aligned} q_2^d = & -114000000_{(-2.192080)} - 21492757_{(-3.986661)}p_2 - 14383500_{(-2.196589)}p_1 + 39156417_{(3.635324)}p_{pork} + \\ & + 42606139_{(3.231667)}p_{int} + 42493.94_{(2.456350)}Y + 9452956_{(5.521062)}d_1 + 2833361_{(1.927400)}d_6 + \\ & + 5919017_{(2.842247)}d_{10}; \qquad R^2 = 0.802526; \qquad DW = 2.207627 \end{aligned} \tag{6}$$

An interesting result of these regressions is that parameters show a complementary relationship between high and low-quality beef. These are not attended results for us but analyzing European consumer behavior, we may justify these estimations.

Normally, a consumer of high-quality beef will prefer to substitute this meat by other high-quality meat (for example by high-quality pork, lamb or fish) vis-à-vis a rise in high-quality beef price. It is the reason why the pork meat appears in the regression 5 as a substitute. Similar analysis may be done for low-quality beef. Concerning the apparently complementarity between beef qualities, we observe that if the price of one of beef qualities rises, it is perceive for the consumer as a price augmentation in beef, that is mean for both qualities. That is mean that if high-quality price rises the negative impact will touch high and low-quality beef. But, if we observe cross-price effects we may see that this effect on the low-quality beef demand is greater than the impact of an augmentation in low-quality beef price on the demand of high-quality beef.

Then, using the same econometric methodology and based on the equation 4, we estimate the homogeneous demand function for beef in the EU15, and the coefficient results are shown in the next equation.

$$\begin{aligned} Q_d = & -110000000_{(-1.490170)} - 28614828_{(-2.869704)}P + 47983557_{(3.299120)}p_{pork} + \\ & + 53719415_{(2.828375)}p_{int} + 22161.32_{(22161.32)}Y + 7586018_{(3.243473)}d_1 + 7887974_{(3.684626)}d_6 + \\ & + 14482656_{(5.177034)}d_{10}; \qquad R^2 = 0.756921; \qquad DW = 2.275625 \end{aligned} \tag{7}$$

We observe that the b parameter of the homogeneous beef demand is next to φ parameter of the low-quality demand but smaller $\frac{\beta}{2} + \varphi$. This is an attended result for us.

Then, according to this relationship between parameters b, β and φ in this application case, we may infer that welfare under the homogeneous product specification will be larger than the welfare under the product differentiation specification.

In the next section we will show the coherence between the our theoretical result (subsection 1.3) and this application case to EU15 beef market.

For that, the next step is to use this estimated coefficients to calibrate our specifications in order to calculate the welfare's values and compared them.

2.2 Parameters calibration and welfare measurement

In order to apply our theoretical specifications and to show the ambiguity on welfare's relationship, we introduce an application case to the EU15 beef sector.

We first calibrate both specifications (product differentiation and homogenous products). Then, we calculate welfare's values (consumer surplus because we assume constant returns to scale and none fiscal policy).

The calibration is done for September 2004 using the EUROSTAT database about EU15's beef market.

Once the specifications have been calibrated, we calculate welfare values for compare them and explain the relationship between them and the demand parameters.

Table 5: *Welfare Results in the case of the EU15's beef market.*

	Product differentiation specification	Homogenous product specification	Wh/Wd
Welfare	55386477.45	72899079.096	1.31

Under constant returns to scale, when the b demand parameter for the homogenous product demand is smaller than $\frac{\beta}{2} + \varphi$, the welfare ratio will be greater than 1.

3 EXTENSIONS

A lot of uncertainties surrounds the effects of a possible agreement between the European Union (EU) and the MERCOSUR. 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. The possibility that beef from Argentina, and in a lesser extent Brazil (where the production is increasing rapidly) could wipe out EU production is put forward by farmers associations.

An 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 bigger than the tariff of the high-quality beef. This empirical case and the comparison of different kind of modelling (SDS Model, Armington Hypotheses, Linear Model) may be some good extensions for the analysis of quality differentiation in international trade.

So far, the various models that have been used to simulate the effects of trade liberalization in the beef sector rely on very crude assumptions. Products are often considered as homogenous or imperfectly substitutable and a single elasticity represents the potential substitution in a CES function. The application of the previous forms of product differentiation could shed light on the potential effect of trade liberalization between Argentina and the EU in the beef sector. Another useful specification is that products are horizontally differentiated. The most common representation is the SDS (or DSK) representation, inspired by the combined efforts of Spence [5], Dixit and Stiglitz [1] and Krugman ([3] and [2]). The SDS differentiation which is also widely used is not very appropriate for agricultural products. The monopolistic competition assumption is not particularly relevant for the agricultural sector. This specification introduces a welfare gain simply when the number of products increases. The "love of variety" effect clearly has a positive impact on welfare in countries where supply is limited to a small number of varieties (i.e. some evidence was provided in the case of developing countries), but the effect should not be overestimated in the food sector of developed countries. More generally, one may wonder whether a new agricultural product should be considered as a new segment of the same market instead of a new-variety creation.

As we know, there exist many ways to compute welfare, equivalent and compensate variation and the most common way, which we will use in this article, is the calculation of consumer and producer surpluses. For the calculation of consumer (and producer) surplus, the assumption about demand, supply and the market structure matter for welfare measurement. For that reasons, we have to be meticulous in the choice of the model specifications in order to get the more precise welfare

measurement.

CONCLUSION

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

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 of variety".

In our paper, we justify the necessity of introducing quality product differentiation in agricultural good 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).

Under 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 supply hypotheses and on demand parameters (demand parameters) and the relationship between them.

Regarding the ambiguity in the results, it is very difficult to get general conclusions. However, we may infer that under constant returns to scale, if the b demand parameter of the homogeneous product is between β and $\frac{\beta}{2} + \varphi$ values of de 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 application case to EU15 beef market, is an illustration that confirms our hypotheses of fragility and ambiguity about welfare measurement vis-à-vis different other specifications.

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 to make a mistake when political decisions are concerned.

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THEORETICAL APPENDIX

PART A1: Product differentiation specification: Expressions of equilibrium price, quantity and surplus.

We assume constant returns to scale,so the prices are equal to constant marginal costs: $p_i = c_i$.

$p_1* = c_1$

$p_2* = c_2$

$q_1* = \alpha - \beta c_1 + \delta c_2$

$q_2* = \omega - \varphi c_2 + \psi c_1$

In this case the welfare is equal to the consumer surplus, as we can see in the next equation.

$$W = CS = \int_{p_1^*}^{\frac{\alpha+\delta p_2^*}{\beta}} (\alpha - \beta p_1 + \delta p_2^*) dp_1 + \int_{p_2^*}^{\frac{\omega+\psi p_1^*}{\varphi}} (\omega - \varphi p_2 + \psi p_1^*) dp_2 =$$
$$\frac{1}{2}\left(\beta c_1^2 + \frac{(\omega+\psi c_1)^2}{\varphi} - 2(\omega + \psi c_1)c_2 + \varphi c_2^2 - 2c_1(\alpha + \delta c_2) + \frac{(\alpha+\delta c_2)^2}{\beta}\right)$$

PART A2: Homogeneous product specification: Expressions of equilibrium price, quantity and surplus.

We consider the Homogeneous product specification under perfect competition.

In the first situation, we consider constant returns to scale en in production functions, so the P=C.

$$P^* = C = \frac{\sum_i q_i c_i}{\sum_i q_i}$$

$Q^* = a - bC$

$$W = CS = \int_{P^*}^{a/b} (a - bP) dP = \frac{(a-bC)^2}{2b}$$