Credence Attributes' Valuation and Price Dispersion: Quantile Regression vs. Stochastic Frontier – an Application to Health Claims in Yogurts

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014.

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Abstract

Food manufacturers use health claims to signal higher product quality and attract health oriented consumers. However, consumers' willingness to pay for health-related attributes may not be large enough to repay firms of the high costs associated with developing, certifying, and marketing such products. We investigate the impact of several health-related credence attributes on product's price, and what may help manufacturers to reach consumers with the highest willingness to pay for yogurt. To achieve our goals we use a large database of yogurt sales in Italy and two empirical approaches recently introduced in the hedonic price literature: Quantile Regression (QR) and Stochastic Frontier Analysis (SFA). Results show that the implicit prices of health claims differ across price levels (i.e. quantiles), and that manufacturers differ in their ability to target consumers with high willingness to pay.

JEL codes: Q11 Q13 I12

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1. Introduction

Food manufacturers use health claims to signal the presence of health-related beneficial product attributes to consumers;[1] as the presence of properties which may help or improve the functioning of one or more organs of the bodies, that is *functional* properties, is a credence attribute (Grunert 2005), information asymmetry between producers and consumers may lead to consumers' distrust of these products' beneficial properties (*e.g.*, Verbeke, 2005a, 2005b). Third party labeling and labeling regulations which reduce asymmetric information and enhance consumer welfare (e.g. Caswell and Padberg, 1992; Caswell and Mojduszka, 1996; Teisl and Roe, 1998) have emerged also in the context of health claims.[2]

Even with the regulations being in place, consumers' understanding of the messages provided to them may vary in function of (*inter alia*) geographic contexts, consumer type, the claims' wording, the claimed benefit, and the relationship between products and claims (see Lähteenmäki (2011) and Nocella and Kennedy (2012) for a discussion of the different types of health claims, consumers acceptance and understanding). Research exploring cognitive, motivational and attitudinal determinants of consumer acceptance of functional food products shows also heterogenous findings (West et al., 2002; Urala and Lähteenmäki, 2004; Ares et al., 2008; Hailu et al., 2009). Similarly, while some authors indicate that consumers have a high willingness to pay for

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[1] However, using third party certifications and claims on the packaging of the product can be one of the many tools manufactures can use to communicate the presence of credence attributes to consumers (see Kirmani and Rao (2000) for a review of marketing tools used to signal quality).

[2] For example the European Union has created Regulation (EC) No.1924/2006 aiming to reduce the risk of asymmetric information between manufacturers and consumers, and to guarantee that the claims are truthful and understandable. Reg. (EC) No.1924/2006 sets the criteria for products' health claims to be approved while classifying them in two different categories and are required to undergo a rigorous authorization procedure based on the review of a dossier by the European Food Safety Authority's (EFSA). Claims falling under article 13 are divided in two groups: 1) Article 13.1: "general function" claims related to growth, development, and functions of the body. 2) Article 13.5 are general function claims based on new and/or proprietary data. Claims falling under article 14, i.e. "risk reduction" claims state, suggest, or imply, that the consumption of a food category, a food, or one of its constituents, reduces a risk factor in the development of a human disease. While the approval of Article 13.1 claims is based upon existing knowledge or links between food and health, Article 13.5 and the Article 14 are assessed separately on case-by-case basis by EFSA

functional products (West et al. 2002; Larue et al. 2004; Markosyan et al. 2009), literature reviews (Menrad, 2003; Siro` et al., 2008) indicate that only a limited price premium is achievable.[3]

The heterogeneity in findings, in particular with respect to w.t.p. leaves open the possibility that given the uncertainty present in these markets, investments in functional products may not be profitable. Verbeke et al. (2009) who studied consumers' reactions toward combinations of three product concepts with nutrition claims, health claim and reduction of disease risk claim, concluded that investments necessary to obtain the requested approvals for reduction of disease risk claims, arguably more expensive to achieve, may be prohibitive if consumers do not show higher w.t.p. for products carrying such credence attributes.

However, the issue at hand is that, for credence attributes, consumers' assessment is conditional on their beliefs (*e.g.* inferred environmental and health qualities of organics and local products as in Costanigro *et al.* 2013) and that manufacturers may not be able to communicate effectively the properties of the products in question. Most extant analyses of consumers' valuation of credence attributes and/or hedonic models assessing the marginal price of these attributes have used data samples which may be too small (coming from survey data and choice experiments) and simple empirical tools too simple (OLS regression) to assess all the dispersion of prices which are the outcome of both products and consumers heterogeneity in this market. Two things are needed to resolve these issues.

First, having access to a large database of *actual* sales data, encompassing a large number of products (and therefore product attributes) as well as multiple markets, one could properly identify the market valuation of each attribute. In spite of the intuitive need for these kinds of data, the number of analyses that have investigated the market value of credence attributes using actual market data and large samples of observations are limited. For example Huang and Lin (2007) use homescan Data to assess the market value of Organic Tomatoes in the US. Szathvary and Trestini

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[3] Furthermore, food companies show concerns due to the across–the–board high risk of product's failure and that of low returns for their investments. In fact, data show that at least 75 per cent of newly launched functional food products are withdrawn from the market within the first two years from launch (Stein and Rodríguez-Cerezo, 2008).

(2014) estimate the value of health and nutritional claims using homescan data in the North-Eastern Italian fruit and beverage markets, finding that health claims outperform nutritional claims and that both positively affect retail prices. Bimbo *et al* (2014), using a large PoS scanner data on yogurt sales in Italy, expand upon Szathvary and Trestini (2014) including also reduction of disease risk claims and find considerable variation in the marginal price associated with different health claims, conditional on their strength (disease reduction risk > health claims > nutritional claims).

Second, traditional hedonic regression via OLS only allows to assess the *average* marginal price of different product attributes; and may leave out important dependencies between product features and price (see Carlucci *et al.* (2013); Bimbo *et al* (2014); Szathvary and Trestini (2014), for applications of hedonic price models in the context of products carrying health-claims). As Costanigro, McCluskey, and Mittelhammer (2007) point out, using OLS one would not to be able to assess whether the market is segmented and / or there are structural breaks in the attributes marginal prices across price levels. Furthermore, in presence of asymmetric information (as in Kuhmbakar and Parmeter,2010) or unobserved product quality (Corriazo et al. 2013) price dispersion may be such that the estimation of one, average, hedonic price function may only allow for a partial representation of the relationship between product attributes and price, and in the worst case, produce biased results.

In this paper we assess the contribution of different types of product attributes, and in particular health-related credence ones, to a product's price, taking explicitly into account the fact that product attributes may contribute differently to a product's price, conditionally on the price level. We achieve our goal thanks to a large database of yogurt sales in Italy and the use of two different empirical approaches: Quantile Regression (QR) and Stochastic Frontier Analysis (SFA). Both QR and SFA have been recently used to add flexibility to the estimation of hedonic price models. While in the case of QR some notable examples assess market segmentation and labelling in the wine market (*e.g.* Costanigro, Mc Cluskey and Mittelhammer, 2007; Costanigro, McCluskey, and Goemans, 2010), in the case of SFA, the analysis has verged on housing markets (Kumbhakar, S.C., Parmeter, C.F., 2010. Carriazo et al., 2013).

Recently, some research has emerged using QR in place of SFA models in the context of efficiency analysis (*e.g.* Bernini, Freo, and Gardini. 2004; Knox, Blankmeyer and Stutzman. 2007, Liu, Laporte, and Ferguson. 2008, Behr 2010). We show how these two approaches (QR and SFA) can complement each other in assessing the role of product attributes on firms' ability to price their products at different levels (that is, borrowing from Kamakura and Moon (2009) price operating more or less closely to the "price frontier"). Furthermore, the QR and SFA approaches allow for some complementarity: the former allows to assess the role of product attributes at the different quantiles of the price distribution, while the latter, through the parameterization of the variance one-sided half normal SFA error term, allows to study the factors determining price dispersion.

The data used in our analysis are from a scanner database encompassing 2 years of monthly observations of yogurt sales 17 Italian regions' hyper- and supermarkets, augmented with information on health-related attributes of these products, from manufactures' websites. We focus on the Italian yogurt market for three reasons: first, the yogurt category constitutes a good case study as it offers a high level of differentiation in terms of health attributes, while also being considered as intrinsically healthy and one of the most credible carriers of functional attributes (Sirò et al., 2008; Ozer and Kirmaci, 2010); second, yogurt and fermented dairy, made up the dairy-based functional dairy market in almost its entirety, which account for nearly 43% of that total functional products market (Ozer and Kirmaci, 2010); third, Italian yogurt manufacturers have invested largely in the development of functional products, reviving a market which was once considered mature (Bonanno 2013).

Preliminary findings discussed in this paper indicate that both QR and SFA present richer and more insightful results in understanding price creation in markets with credence attributes. We find that the marginal price of most credence attributes varies in function of the conditional price quantile considered and that food manufacturers can price at price levels closer to the "price froniter" as they increase their presence in the functional segment.

2. Conceptual Framework

We start from the hedonic price model formalized by Rosen (1974) to study markets for differentiated products. According to this framework, consumers choose products containing an optimal (utility maximizing) bundle of attributes, subject to a budget constraint; while producers choose a profit-maximizing combination of attributes within the constraints imposed by the available technology, which are embedded in the cost function. The first order conditions to each maximization problem provide the economic rationale for deriving two families of indifference curves having product attributes as their arguments: consumers' bid and producers' offer functions. The *bid function* $\theta = \theta(x_1,...,x_K; u, y)$ represent the amount a consumer is willing to pay for varying levels of the vector of characteristics $\mathbf{x}$, holding utility, *u*, and income, *y*, constant. Analogous to the consumer's bid function, the seller's *offer function* $\phi = \phi(x_1,...,x_k; \pi)$ indicates the price that a firm is willing to accept for selling the differentiated good **x** and maintain the (fixed) profit π. Under the assumptions of perfect competition and full information, the double envelope traced by the points of tangency between bid and offer curves delineates the hedonic price function $p(\mathbf{x}) = p(x_1, x_2, x_3,..., x_K)$, which establishes a unique price conditional on attribute levels. This is represented in the upper panel of figure 1, where we portray the hedonic price function, $p^{FULL}(\mathbf{x})$, and two matched sets of bid/offer curves.

Recently, (Kumbhakar and Parmeter 2010) modified the classical hedonic framework to relax the full information assumption, and discussed how multiple price equilibriums can exist when information is imperfect or asymmetric. In their model, the authors hypothesize that consumers with the highest WTP for a certain attribute level identify the upper boundaries of the attainable market prices, $p^{HIGH}(\mathbf{x})$, while producers with the lowest WTA trace the lower bounds, $p^{LOW}(\mathbf{x})$ (see figure

1, lower panel). Lacking full information, transactions can occur anywhere in-between the two lines, with the two polar cases of fully informed producers (3 and 4 in figure 1) matched to information deficient consumers (not shown) or fully informed buyers (5 and 6 in figure 1) matched with information-deficient sellers (not shown). Thus, equilibrium prices cover a hedonic price surface, rather than a line.

Making the case for the wide applicability of the imperfect information setting to most empirical applications is easy. (Kumbhakar and Parmeter 2010) note that in the housing market buyers can obtain information regarding house and neighborhood characteristics only through costly search. Similarly, sellers cannot be fully aware of buyer's preferences and WTP. In food markets, the asymmetric structure of information has been discussed by numerous studies involving credence or experience product attributes and the informative role of food labels (e.g. Caswell and Padberg 1992). An additional layer of uncertainty (for producers) arises from the heterogeneity in consumers' beliefs, who may associate different outcomes to the same attribute (see Costanigro et al. (2013) on the inferred environmental and health qualities of organics and local products). The extension to include functional products carrying health claims, for which consumers show a wide range of responses and acceptance and a varied level of understanding of the different health claims is immediate (see Siro et al, 2008; Nocella and Kennedy 2013).

The typical empirical approach to estimate hedonic price functions involves the specification of econometric models where observed prices are a function of product attributes, plus an error term accounting for random shocks and unexplained product heterogeneity. For product *j* in market *m* at time *t*, takes the form

$$P_{jmt} = f\left(\mathbf{x}_{jmt}, \boldsymbol{\beta}\right) + \varepsilon_{jmt} \quad (1)$$

where the functional form $f(.)$ needs to be empirically determined and $\boldsymbol{\beta}$ is a conforming vector of parameters to be estimated (Costanigro and Mccluskey 2011). The model in equation (1) essentially treats the error term as a nuisance parameter, devoid of any economic interpretation. This approach is obviously insufficient if variations above and below the (full information) hedonic price function result from random shocks *plus* systematic information asymmetries and/or heterogeneous beliefs.

Fortunately, the econometrics armamentarium offers several approaches to study central tendencies and price variations systematically and simultaneously. One way to represent the systematic nature of price variations is through an appropriately specified heteroskedastic process, which we may represent with the general form:

$$P_{jmt} = f\left(\mathbf{x}_{jmt}, \boldsymbol{\beta}\right) + \sigma\left(\mathbf{x}_{jmt}; \boldsymbol{\gamma}\right)\varepsilon_{jmt} \quad ; \tag{2}$$

where $\boldsymbol{\gamma}$ is an additional vector of parameters to be estimated. (Koenker and Bassett 1982) have demonstrated how these types of heteroskedastic models can be robustly estimated by means of quantile regression (Koenker and Bassett 1978). Defining $Q_\tau\left(\varepsilon_{jmt}\right)$ as the quantile function of the random shock, i.e. $Q_\tau\left(\varepsilon_{jmt}\right) = F^{-1}\left(\varepsilon_{jmt}\right)$ for $\tau \in [0,1]$ and the CDF $F\left(\varepsilon_{jmt}\right) = pr[\varepsilon \leq \varepsilon_{jmt}]$, the conditional quantile function can be represented as follows (subscripts omitted for brevity):

$$Q_\tau\left(\mathrm{P} \mid \mathbf{x}\right) = f\left(\mathbf{x}, \boldsymbol{\beta}\right) + \sigma\left(\mathbf{x}; \boldsymbol{\gamma}\right) Q_\tau\left(\varepsilon\right) \ . \tag{3}$$

Equation 3comprises many possible forms of multiplicative heteroskedasticity, and a correspondence between quantile regression parameters and those in equation 3 can be established under specific assumptions. (Buchinsky, 1998) considers the linear case, where $f\left(\mathbf{x}, \boldsymbol{\beta}\right) = \mathbf{x}'\boldsymbol{\beta}$ and $\sigma\left(\mathbf{x}; \boldsymbol{\gamma}\right) = 1 + \mathbf{z}'\boldsymbol{\gamma}$; implying that $Q_\tau\left(p \mid \mathbf{x}\right) = \mathbf{x}'\left(\boldsymbol{\beta} + \boldsymbol{\gamma} Q_\tau\left(\varepsilon\right)\right) + Q_\tau\left(\varepsilon\right)$.

Application of quantile regression in hedonic functions are limited, and include analysis of the existence of markets segments in the U.S. wine market (Costanigro, Mc Cluskey and Mittelhammer, 2007) and the evaluation of the impact of different nested attributes (name, geography, reputation) in the California wine market (Costanigro, McCluskey, and Goemans, 2010).

Kumbhakar and Parmeter (2010) took another approach to model price variation in hedonic function by adapting methods from the stochastic frontier analysis (SFA) literature to the problem at hand. Essentially, equilibrium market prices results from a mixture of distributions

$$P = f(\mathbf{x}, \boldsymbol{\beta}) + \varepsilon = f(\mathbf{x}, \boldsymbol{\beta}) + v + w - u \quad (4)$$

Where u and w are one-sided errors: the term w ($w \geq 0$) represents the cost incurred by consumers for not being fully informed and/or for not being able to assess the "true" value of a given product. The term u instead ($u \geq 0$), is the loss that a seller may incur for not being able to target the "right" consumers group with the highest w.t.p. for a product containing a given bundle of characteristics.

Equation (4) indicates that, in a market where uncertainty is present, the random term ε embodies two different measures of *price inefficiencies*, one from the consumers' standpoint, (v) and another from the producer's (u). Note that, since $E(\varepsilon)$ may be non-zero even when $E(v)$=0. As a result, if the error components are correlated with any of the goods' characteristics, estimates of the vector $\boldsymbol{\beta}$ in equation (4) will be biased. Thus, in presence of inefficiencies on both sides, or in one sides alone of the market (*e.g.* Kamakura and Moon (2009) and Carriazzo, et al. (2013)) a proper specification of the half-positive errors should be appropriately specified.

3. Empirical model Specification

In our case, Z is partitioned into five vectors: X^{HC}, X^{OC}, X^{P}, X^{R} and X^{B}. X^{HC} represents a vector of product characteristics capturing health claims (HC) indexed by h ($h=1,\ldots,H$). . X^{OC} includes other product characteristics, indexed by l ($l=1,\ldots,L$), while X^{P} and X^{R} include package and retail characteristics and are indexed by ($p=1,\ldots,P$) and ($r=1,\ldots,R$), respectively. X^{B} is a vector of indicator variables indexed by b ($b=1,\ldots,B$) capturing the role of brand image/loyalty on yogurt prices, as brand image and reputation strongly impact consumers' acceptance of functional products (Ares and Deliza, 2010; Annunziata and Vecchio, 2013).

Following previous literature, we estimate equation (1) using a single equation approach (Costanigro, McCluskey, and Mittelhammer 2007; Panzone, 2011; Carlucci et al., 2013). For the empirical specification of equation (1) we use a semi-logarithmic functional form:

$$\ln P_{jmt} = \alpha + \sum_{h=1}^{H} \alpha_h X_{hmt}^{HC} + \sum_{l=1}^{L} \beta_h X_{lmt}^{OC} + \sum_{p=1}^{P} \delta_p X_{pmt}^{P} + \sum_{r=1}^{R} \gamma_r X_{rmt}^{R} + \sum_{b=1}^{B} \gamma_b X_{bmt}^{B} + \sum_{m=1}^{17} \lambda_m d_m + \sum_{t=1}^{25} \theta_t d_t + \varepsilon_{jmt} \qquad (5)$$

here we also control for a vector of M market-level (region) and T time (month) indicators, d_m and d_t, respectively. The α_s, β_s, and γ_s are parameters to be estimated capturing, respectively, the implicit values associated with health-claims, other product characteristics, brands plus and ϵ_{jmt} is an error term whose properties will be discussed below.

4. Data and Estimation

The main database used in the estimation comes from SymphonyIRI Group and contains information on monthly points-of-sales yogurt sales in the whole Italian market (17 IRI regions[4]) encompassing a 25-month period between November 29, 2010, and December 31, 2012. The data contains information on volume sold and value of sales, price (€/L), percentage of store selling, number of references in the shelves.

The IRI data allows to separate functional yogurts (under the general umbrella term of "*sante'*" – health), from others, and also provides detailed information on vendors, brands, flavors, fat content, drinkability, whether a yogurt is sold as organic or natural, if it is targeted to kids or if it presents an additional compartment with cereals, chocolate etc. Scanner database was augmented with information retrieved from manufacturers' websites and cross validated using front-of-package and nutritional labels. The health claims reported on label were classified according to whether a

[4] Although the Italian regions are 20, SymphonyIRI groups data from Piedmont and Aosta Valley, Abruzzo and Molise, Basilicata and Calabria, resulting in 17 "IRI regions".

claim was targeted to: lowering or managing the cholesterol in the blood; support health bone; enhance the immunity system; and sustain bowel regularity.

The functional yogurts in our sample are 1 in 10 products. The most popular functional yogurts, that account the 37.3% of functional Italian yogurts market, are those which carry a claim as that "supporting the immune system" (*Immunity*). The second largest functional yogurt category encompasses those products which carry a statement "*reduces LDL-cholesterol*" or "*it contribute to the maintenance of normal blood cholesterol levels*" that were classified as "Cholesterol related health claim" (*Chol_Reduction*). These products account for 24.7% of Italian functional yogurt market. Lastly, yogurts sustain bowel regularity (*Regularity*) and contributing to maintain health bone (*Bone_ Health*) jointly account for 38% of the Italian functional yogurts market, 25.3% and 12.7% respectively. Additionally, we collected information on whether a product was sold as "organic" or "natural," since consumers seems to perceive products with those features as healthier than regular ones (Rozin et al., 2004). We also control for retail variables to capture the variance in retailer pricing strategy: these variables are the number of product references of each vendor (*NumberReferences*), the percentage of stores selling the product *(%_Stores_Selling*) and the average weighted distribution (*AWD*), or the percentage of outlets offering the product, in numeric terms, conditional on the manufacturer's products being available in a given store.

Combining the product characteristics present in both the original scanner data with those obtained by manufactures website, we identified 220 products[5] representing unique combinations of attributes, encompassing 59 brands sold by 13 vendors for a total of 54,386 observations. Summary statistics of products attributes are reported in Table 1.

One can estimate equation (1) using a single equation approach via Ordinary Least Squares (OLS), however, the estimated parameters would only represent the *average* effect of the product' attributes in explaining its price. However the relationship between product's price and its

[5] Private labels, whose attributes could not be verified are not included in the analysis along with products classified as having "other functionality". Other products excluded from analysis were yogurts made with milk different from cow milk and yogurts for kids. Also we eliminate those vendors that were absent in one or more Italian region.

attributes may be non-linear and it may change across price's levels. To obtain estimates of the relationship between product's characteristics and its price at different points of price distribution, we use quantile regression (Koenker and Bassett,1978). This method allows to obtain parameter estimates for each quantile of the dependent variable's distribution, without requiring specific assumptions on the distribution of the error terms.[6] The estimated parameters are the obtained minimizing the weighted sum of absolute deviations in the *n*-th quantile by weighting the residuals by a factor $\theta \in (0,1)$.

$$\text{(6)} \qquad \min_{\alpha \in \mathbb{R}^k} \left[\sum_{i \in \{\ln P_i \geq X'\alpha\}} \theta \left| \ln P_i - X'\alpha \right| + \sum_{i \in \{\ln P_i \geq X'\alpha\}} (1-\theta) \left| \ln P_i - X'\alpha \right| \right]$$

We evaluate the model parameters at the 5th, 25th, 50th, 75th, 95th percentiles of the dependent variable distribution, replacing the customary 10th and 90th quantile (*e.g.* Atella et al., 2008; Villar and Quintana-Domeque, 2009; Pieroni and Salmasi, 2014) with the 5th and 95th as in Behr (2010). Note also that other analysis, such as Bernini, Freo and Gardini (2004) who evaluate the use of quantile regression for the estimation of frontier production functions.

In order to estimate a model consistent with the specification of the modified hedonic price function in (4) one would need to apply the estimation of the two-tiered frontier model as in Kumbhakar and Parmeter (2009, 2010). In this version of the manuscript we approach the problem in a simplified fashion, estimating two different models with one-sided errors; that is following the notation in Kumbhakar and Lovell (2000) we estimate an equation of the type $P = f(\mathbf{x}, \boldsymbol{\beta}) + \varepsilon = f(\mathbf{x}, \boldsymbol{\beta}) + v + su$, where s={-1,+1}; s=-1 indicates the estimation of a production frontier (i.e. the prices that manufacturers would reach to capture the highest consumers' w.t.p.), while s=+1 implies the estimation of a cost frontier (i.e. lowest prices consumers would be paying if they matched the lowest manufacturer's willingness to accept).

[6] Furthermore, compared to OLS, this method appears less sensitive to outliers (Koenker and Hallock, 2001).

We specify the error terms as $v \sim N(0,\sigma_v^2)$ and $u \sim N^+(0,\sigma_u^2)$. Following the notation of Kumbhakar and Lovell (2000, p.140) one has

$$(7)\quad f(\varepsilon)=\frac{2}{\sigma}\phi\left(\frac{\varepsilon}{\sigma}\right)\Phi\left(\lambda\frac{\varepsilon}{\sigma}\right);$$

where $\sigma^2=\sigma_u^2+\sigma_v^2$; $\lambda=\frac{\sigma_u}{\sigma_v}$, $\phi(.)$ and $\Phi(.)$ are the standard normal *pdf* and *CDF*, respectively. Using the sum of the half normal and Normal distributed errors, the parameters of equation (5) can be obtained maximizing the following likelihood function;

$$(8)\quad L=\prod_j\prod_m\prod_t\frac{2}{\sigma}\phi\left(\frac{\varepsilon_{jmt}}{\sigma}\right)\Phi\left(\lambda\frac{\varepsilon_{jmt}}{\sigma}\right);$$

Wald tests on the estimated variance terms of the half-normal error, σ_u, will indicate whether the data support the use of a stochastic frontier model: if the null of σ_u =0 is not rejected, there is no systematic variation in the error term and the use of OLS will be appropriate. For the case in analysis, failing to reject the null of σ_u =0, implies the absence (from a statistical point of view) of a systematic positive (or negative) departure from a cost (production) frontier. In the case in analysis, the intuitive implication of σ_u not being statistically different than zero, is that, in the case of the cost frontier model would be that the data do not support the existence of price inefficiencies from the point of view of consumers.

In presence of the one sided error with variance statistically different than zero, one can test whether its variance is function of some explanatory variables. This would be equivalent to assume that there is a heteroschedastic disturbance which results in price inefficiencies. We assume the following parameterization:

$$(9)\quad \sigma_u=\exp(\gamma_0+\gamma_{NIT}NIT+\sum_{i=1}^{4}(\gamma_i NF_i+\gamma_{NITi}NF_i\,NIT))$$

where *NFi* is an indicator variable capturing whether a manufacturer produces a certain number of functional alternatives {*i*=1,…,4} and *NIT* represents the number of items sold for each product. The underlying hypothesis is that producing more functional alternatives, as well as having a higher level diffusion, or more items sold in a market (*i.e.* manufacturers can price closer to the consumers highest w.t.p.) that is, the variance of the half-normal error decreases).

5. Empirical Results and Discussion

Table 2 presents the estimated parameters of equation (5) obtained via OLS (first column) and at the different percentiles of the log-price distribution (second to sixth columns) obtained using quantile regression. The *F*-statistic values for a test of the coefficients' equivalence across quantiles are reported in the last two columns, and indicate that for only 6 of the 21 estimated parameters (excluding fixed-effects) we cannot reject the null hypothesis of them being statistically equal across quantiles at the 10% of significance level. The differences in estimated parameters across quantiles emerge also from Figure 2. The graphs in figure 2 illustrate the variation of the estimated effects on price of the different health claims (as well as other product characteristics) vary across quantiles and how these differ from OLS estimates (horizontal solid line). The shaded areas represent 95% confidence intervals for the quantile estimates while the dotted lines represent the 95% confidence interval for the OLS estimates. Shaded areas falling outside the OLS confidence intervals suggest a statistical difference between quantile regression coefficients and OLS; and our results supports using quantile regression instead of OLS to capture the heterogeneous effect of product's attribute across different price levels.

The first result of interest is that health attribute variables affect positively yogurts' prices but at decreasing magnitude across quantiles. *Bone Health* and *Cholesterol Reduction* claims outperform the other claims variables. The premium attached to *Bone Health* claim ranges from +82.7% at the 5th quantile to +79.4% at the 95th quantile, while that of *Cholesterol Reduction* contributes to yogurt's price in measure of +79.4% (5th quantile) to +46.3% (95th quantile). The magnitude of the impact of *Regularity* claims becomes circa half across quantiles from +22.8%, at the lowest estimated quantile, to +11.8% (95th quantile). The health claim which results in the lowest contribution to prices is “Supporting the immune system” (*Immunity*) whose estimated effect varies from +11.5% to +8.2 %, remaining statistically the same across quantiles.

If one considers the 95th percentile as the “price frontier” (Kamamura and Moon 2009) not all health claims seem to be a powerful tool to obtain higher prices once a manufacturer is able to extract the highest prices from consumers (that is the consumers with the highest w.t.p are targeted). In particular, for products located at the “price frontier” only bone health, whose impact on price doesn’t change much across quantiles, may allow to reach higher price level.

This finding is supported by prior literature which finds that consumers who may be able to afford higher prices for a product may not be willing to pay a higher price for a functional attribute. Medium and high income consumers as well as high-educated people may often prefer to improve their health status using pills or supplements and change their lifestyles rather than to consume functional foods (Hailu et al, 2009; Landstrom et al, 2009). The high market valuation found for Cholesterol Reduction and especially Bone Health are in line with other literature that shows strong consumers’ preferences towards both functional dairy which prevent or reduce the risk of cardiovascular diseases by lowering the cholesterol level in blood, as well as, those supporting bone health (Ares and Gambaro, 2007; Landström et al., 2007; Siegrist et al., 2008; Williams, 2008). [7] Focusing on the estimated impact of the other product characteristics on price, plain and fruit flavors have a negative and statistically significant impact across different log-price quantiles. However their magnitude becomes smaller at higher quantiles and in the case of fruit flavor coefficient it turns positive and statistically significant. The effect of those two attributes on yogurt’s price ranges from -1.9% (*Plain*) and -3.1% (*Fruit flavor*), at the 5th percentile, to -2.5% (*Plain*) and +0.06% (*Fruit flavor*), at the 95th percentile. This means that only products targeting the highest w.t.p. consumers may be able to benefit from a product differentiation strategy based on

[7] The willingness to use dairy products with cholesterol-lowering is generally requested by male consumers since they seem more expose to health diseases beside being more aware of the relationship between dairy products consumption, cholesterol level and heart disease (Van Kleef et al. 2005; Landström et al., 2007; Verbeke et al. 2009). In turn, dairy products which support bone health are typically demanded by female consumers to prevent/reduce the risk of osteoporosis which they are more exposed to (Siegrist et al., 2008; Williams, 2008; Ares and Gámbaro, 2007).

adding different types of fruits to their products. The *Low_Fat* attribute has a negative and statistically significant impact on yogurt prices in Italy across quantiles, tripling its effect across different quantiles. This results are partially in line with Carlucci et al. (2013) who found a negative but not significant relationship between the "low-fat" attribute and yogurt's price. *Fat_Free* attribute, in turn, affects yogurt's price of -0.04% for lowest priced product while its effect is more marked as one approaches the price frontier (-3.6% and -1.6%, respectively at 75th and 95th quantile of price distribution).

The Lactose Free attribute affects positively the yogurt' prices at prices below the median and negatively afterwards; at the 5th percentile, yogurts being enriched in fiber can benefit by a +28% margin (circa) while at the 95th percentile, one observe a negative marginal price of this attribute (-31.8%,), meaning that premium yogurts, are less likely to have this attribute, and those which do are prices below the others in the same price group. The Drinkable attribute shows a positive and significant impact on prices ranging from +12.5% to +15% across quantiles. These results are in line with Bonanno's (2012, 2013) findings which indicate that, in the Italian market, consumers seem to prefer drinkable yogurts rather than regular ones, in particular with regard to functional alternatives. Additionally, the higher price of drinkable yogurt could be justified by the higher level of convenience that drinkable products have compared to regular ones.

Presence of added fiber (*Fiber*) affects yogurt's price negatively and in a statistically significantly way across different price levels (from -10.7%, 5th percentile to -5.9%, 95th percentile). Thus, in the Italian market adding fiber to yogurts will generate a price reduction independently on where the product is positioned in terms of pricing levels. This result is largely supported by other studies which find consumers being skeptical regarding features which are "unnatural" or artificially added to a product (Bech-Larsen and Grunert, 2002; Krutulyte et al., 2010; Annunziata and Vecchio, 2013), and "fiber" may not appear as a natural pairing with dairy products.

The Natural and Organic attributes have a positive and statistically significant impact on yogurt's prices in the Italian market across price levels; the positive valuation of these attributes is likely to be the result of consumers higher willingness to pay for these features having a “halo effect” (Schuldt and Schwarz, 2010; Schuldt, 2013), which may also be due to the fact that products labeled “Organic” and “Natural” are often perceived as healthier than regular ones (Hughner et al. 2007; Lodorfos and Dennis 2008; Schuldt and Schwarz, 2010). However, although Natural attribute's implicit price is positive and constant across different quantiles (from +49% to +54.24%) that of Organic impacts yogurt prices at higher levels as one moves towards higher quantiles. Thus, manufacturers who operate at the price frontier amy benefit from including a “natural” label to their products as it may help them reach consumers with the heighest w.t.p. for yougurts.

The other parameter estimates are consistent with previous literature (Carlucci, 2013; Szathvary and Trestini, 2014; Bimbo et al. 2014) and show a higher price to yogurts sold in glass packaging (Glass Pack) and those sold as two compartment package (Two Compartments). The *Glass Pack* attribute impacts yogurt’s price positively and with a magnitude that increase across quantiles, from +29.6% to +53.2%. This result is line with previous research that finds non sensory characteristics, such as products packaging, to strongly affect consumer purchase decisions of yogurt (Ares et al., 2010) as consumers associate different levels of product quality to different types of packaging materials. For example a packaging in the shape of a bottle (instead of a vase) seems to be used by consumers to infer yogurt wholesomeness (Grunert, 2005). However, the existence of a price premium associated with glass packaging may also reflect the higher cost of the material, as suggested by Silayoi and Speece (2004). The *Two Compartments* variable affects positively yogurt’s prices in Italy, varying little across percentiles.

Last, the estimated coefficients associated with indicators capturing package size differences are negative and suggest that unitary price per liter declines with size. Package size effect on yogurt' price is more marked for high products priced closely to the price frontier. *Medium Pack* and *Large Pack* variables have a negative effect on yogurt price that ranges from -1.6% and 0% respectively, at 5th percentile of price distribution, to -20% and -50%, at 95th percentile.. Such effects are consistent with the results of Carlucci (2013) and Szathvary and Trestini (2014).

The results of the SFA approach are illustrated in Tables 3 and 4. In particular, table, 4 compares the results of OLS (first column) with those of the hedonic equation estimated using SF models with half-normal one-sided errors. The second column contains the results of a "Cost frontier" while the third to fifth columns those of a "production frontier." One first result is that the variance of the cost-frontier model is not statistically different than zero; differently the same parameter is statistically different than zero in the production model, meaning that our data allow us to capture some drivers of price dispersion using a one-sided error in the "production frontier" case (that is, assessing the deviation from manufacturers' ability to reach the highest consumers' w.t.p.). However, under the assumption that the results of our model are not impacted in any way by the estimation of a one-tiered deviation from the frontier, the SF approach is still able to lead to some interesting insight on the structure of price creation in the Italian yogurt market.

As expected, the estimated coefficients obtained using the production frontier SFA models are close to those of the higher percentiles obtained using quantile regression: thus, as reported elsewhere in the literature the two methods can be equally valid in depicting attributes' contribution of firms which are closer to be price efficient. The results in table 4 show that decomposing the term σ_u according to equation (9), we find that manufacturers producing increasingly more varieties of functional alternatives, experience less variation from the frontier, as hypothesized.

6. Discussion and conclusions

In this paper we present evidence of how, in presence of complex products carrying credence attributes, the existence of multiple market-clearing prices, results in the inadequacy of using traditional hedonic price methods to evaluate accurately the implicit price of the different attributes in the market. To this end, we present insights obtained from two alternative methodologies, Quantile Regression (QR) and Stochastic Frontier Analysis (SFA), to evaluate different aspects of credence attributes' contribution to price in presence of price dispersion.

The QR results support the existence of a considerable price premium for yogurts carrying a "bone health" and cholesterol reducing claims, at all the different quantiles. This result is in line with other research finding that European consumers seem to prefer dairy products with a positive benefit for bone health and to control blood cholesterol level (van Kleef et al., 2005; Hailu et al., 2009; Annuziata and Vecchio, 2013; Verbeke et al., 2009). The SFA results also indicate that manufacturer's price efficiency is different across firm and claimed functionality, as market leaders seem to be able to price at level closer to the frontier and that they experience less systematic departure from the highest hedonic price curve. In particular, the variance of the half-normal one-sided error decreases with an increase in the number of functional options sold by the same manufacturer. This result has two implications. In the first place, as leading manufacturers may be able to price at their maximum achievable level, they may be able to recover the costs of investing in health-claims, especially if economies of scope arise from the production of different functional products. In the second place, this results rests well with the findings of previous literature which reported that consumers' perception of functional claims may differ on the basis of brand image (Ares et al. 2007, 2010; Ares and Delizia, 2010; Annunziata and Vecchio, 2013).

The results of the SFA estimation show, in the case of the production frontier model, the parameter estimated are close to those obtained for the highest price percentiles obtained using quantile regression; corroborating findings that QR and SFA produce qualitatively similar result to explain the price behavior of price-efficient firms. Furthermore, the SFA results show that manufacturers producing more functional alternatives and with higher market diffusion, are more likely to show less-price dispersion as they price their products closer to the consumers' higher wtp for yogurt. However, our results are only partial: a two-tiered error estimator, a la Kumbakhar and Parmeter (2010) may be more appropriate in the context of our analysis and its use is suggested for future analysis.

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Table 1. Descriptive statistic (N=54386)

Variable	*Mean*	*Std.Dev.*	*Min*	*Max*
Price	4.255	1.361	0.890	15
Health Claims				
Chol_Reduction	0.034	0.181	0	1
Immunity	0.114	0.318	0	1
Regularity	0.144	0.351	0	1
Bone Health	0.011	0.107	0	1
Other Product characteristics				
Plain	0.294	0.455	0	1
Fruit Flavors	0.502	0.500	0	1
Others Flavors (excluded)	0.205	0.404	0	1
Regular (Excluded)	0.482	0.500	0	1
Low Fat	0.261	0.439	0	1
Fat Free	0.257	0.437	0	1
Lactose_Free	0.020	0.139	0	1
Drinkable	0.216	0.412	0	1
Fiber	0.060	0.238	0	1
Natural	0.015	0.120	0	1
Organic	0.074	0.261	0	1
Packaging and size				
Glass Pack	0.022	0.146	0	1
Two Compartments	0.096	0.294	0	1
Regular Pack (excluded)	0.751	0.432	0	1
Medium Pack	0.249	0.433	0	1
Large Pack	0.001	0.036	0	1
Packaging characteristics				
Num References	2.990	3.011	0	29
% Sales Prom	0.147	1.438	0	100
WADist: Weighted Average Distribution	31.331	28.502	0	100

Table 2. OLS and Quantile Regression Results

	OLS		5th Quantile		25th Quantile		50th Quantile		75th Quantile		95th Quantile		*Test* $F_{(1, 58213)}$	Prob>F
Chol. Reduction	0.575	***	0.794	***	0.678	***	0.573	***	0.546	***	0.463	***	72.72	0.000
	(0.007)		(0.002)		(0.001)		(0.005)		(0.001)		(0.015)			
Immunity	0.097	***	0.115	***	0.117	***	0.096	***	0.100	***	0.082	***	0.03	0.853
	(0.004)		(0.014)		(0.007)		(0.001)		(0.007)		(0.027)			
Regularity	0.095	***	0.228	***	0.171	***	0.117	***	0.101	***	0.118	***	7.55	0.006
	(0.006)		(0.028)		(0.006)		(0.002)		(0.015)		(0.012)			
Bone Health	0.997	***	0.827	***	0.822	***	0.768	***	0.757	***	0.794	***	0.34	0.559
	(0.037)		(0.013)		(0.006)		(0.011)		(0.009)		(0.020)			
Plain	-0.050	***	-0.019	***	-0.027	***	-0.031	***	-0.036	***	-0.025	***	11.35	0.000
	(0.002)		(0.004)		(0.003)		(0.001)		(0.001)		(0.000)			
Fruit Flavors	-0.031	***	-0.057	***	-0.033	***	-0.019	***	-0.012	***	0.006	***	675.90	0.000
	(0.002)		(0.005)		(0.004)		(0.001)		(0.001)		(0.001)			
Low Fat	-0.064	***	-0.030	***	-0.030	***	-0.044	***	-0.073	***	-0.094	***	7.59	0.006
	(0.005)		(0.002)		(0.002)		(0.001)		(0.002)		(0.025)			
Fat Free	-0.037	***	-0.004	***	-0.009	***	-0.018	***	-0.036	***	-0.016	***	65.94	0.000
	(0.002)		(0.001)		(0.001)		(0.000)		(0.002)		(0.005)			
Lactose Free	0.073	***	0.284	***	0.198	***	0.097	***	-0.051	***	-0.318	***	377.24	0.000
	(0.011)		(0.012)		(0.007)		(0.005)		(0.012)		(0.035)			
Drinkable	0.164	***	0.136	***	0.150	***	0.155	***	0.125	***	0.139	***	0.02	0.880
	(0.005)		(0.004)		(0.009)		(0.007)		(0.000)		(0.030)			
Fiber	-0.070	***	-0.089	***	-0.065	***	-0.059	***	-0.067	***	-0.107	***	0.88	0.349
	(0.006)		(0.005)		(0.011)		(0.003)		(0.000)		(0.004)			
Natural	0.761	***	0.426	***	0.508	***	0.544	***	0.541	***	0.551	***	0.56	0.456
	(0.037)		(0.018)		(0.001)		(0.004)		(0.017)		(0.003)			
Organic	0.696	***	0.521	***	0.542	***	0.492	***	0.495	***	0.532	***	49.25	0.000
	(0.037)		(0.015)		(0.002)		(0.002)		(0.010)		(0.009)			
Glass Pack	0.533	***	0.296	***	0.308	***	0.273	***	0.327	***	0.432	***	22.91	0.000
	(0.037)		(0.001)		(0.005)		(0.004)		(0.008)		(0.003)			
Two Compartments	0.367	***	0.340	***	0.387	***	0.372	***	0.354	***	0.345	***	3.40	0.065
	(0.006)		(0.029)		(0.002)		(0.007)		(0.006)		(0.012)			
Medium Pack	-0.119	***	-0.016	**	-0.061	***	-0.104	***	-0.159	***	-0.200	***	18.01	0.000
	(0.003)		(0.007)		(0.016)		(0.009)		(0.007)		(0.008)			
Large Pack	-0.273	***	-0.243		-0.162	***	-0.227	***	-0.385	***	-0.503	***	1.02	0.312
	(0.027)		(0.226)		(0.025)		(0.007)		(0.012)		(0.036)			
Num References	-0.004	***	0.005	***	0.000	**	-0.003	***	-0.005	***	-0.008	***	1674.39	0.000
	(0.000)		(0.001)		(0.000)		(0.000)		(0.000)		(0.000)			
%Sales Prom	-0.003	***	-0.013	***	-0.009	***	-0.006	***	-0.001	***	0.001		47.49	0.000
	(0.000)		(0.001)		(0.001)		(0.001)		(0.000)		(0.001)			
WADist	-0.001	***	0.000	***	-0.001	***	-0.001	***	-0.001	***	-0.001	***	19.71	0.000
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)			
Constant	0.809	***	0.859	***	1.007	***	1.128	***	1.214	***	1.239	***	128.18	0.000
	(0.037)		(0.003)		(0.003)		(0.001)		(0.006)		(0.008)			
R2(PseudoR2)	0.788		0.564		0.584		0.574		0.573		0.605			

Note:* ,** *and *** are 10, 5 and 1% significance levels* –Standard errors in parenthesis. Monthly dummies', region-level and brand-level fixed-effects coefficients omitted

Table 3. OLS and Stochastic Frontier models (Half Normal positive errors)

	OLS		Cost Frontier		Prod. Frontier Model (1)		Prod. Frontier Model (2)		Prod. Frontier Model (3)	
Chol. Reduction	0.575	***	0.575	***	0.542	***	0.555	***	0.520	***
	(0.007)		(0.007)		(0.007)		(0.007)		(0.006)	
Immunity	0.097	***	0.097	***	0.094	***	0.097	***	0.064	***
	(0.004)		(0.004)		(0.004)		(0.004)		(0.004)	
Regularity	0.095	***	0.095	***	0.072	***	0.090	***	0.075	***
	(0.006)		(0.006)		(0.006)		(0.006)		(0.006)	
Bone Health	0.997	***	0.792	***	0.791	***	0.718	***	0.729	***
	(0.037)		(0.011)		(0.010)		(0.010)		(0.010)	
Plain	-0.050	***	-0.050	***	-0.048	***	-0.037	***	-0.043	***
	(0.002)		(0.002)		(0.002)		(0.002)		(0.002)	
Fruit Flavors	-0.031	***	-0.031	***	-0.018	***	-0.012	***	-0.012	***
	(0.002)		(0.002)		(0.002)		(0.002)		(0.002)	
Low Fat	-0.064	***	-0.064	***	-0.081	***	-0.076	***	-0.087	***
	(0.005)		(0.005)		(0.005)		(0.004)		(0.004)	
Fat Free	-0.037	***	-0.037	***	-0.048	***	-0.038	***	-0.051	***
	(0.002)		(0.002)		(0.002)		(0.002)		(0.002)	
Lactose Free	0.073	***	0.073	***	-0.001		-0.021	*	-0.005	
	(0.011)		(0.011)		(0.011)		(0.011)		(0.011)	
Drinkable	0.164	***	0.164	***	0.152	***	0.149	***	0.153	***
	(0.005)		(0.005)		(0.005)		(0.004)		(0.004)	
Fiber	-0.070	***	-0.070	***	-0.069	***	-0.064	***	-0.076	***
	(0.006)		(0.006)		(0.006)		(0.005)		(0.005)	
Natural	0.761	***	0.556	***	0.573	***	0.532	***	0.545	***
	(0.037)		(0.011)		(0.010)		(0.011)		(0.011)	
Organic	0.696	***	0.490	***	0.486	***	0.469	***	0.466	***
	(0.037)		(0.009)		(0.009)		(0.010)		(0.010)	
Glass Pack	0.533	***	0.327	***	0.343	***	0.351	***	0.335	***
	(0.037)		(0.010)		(0.009)		(0.010)		(0.010)	
Two Compartments	0.367	***	0.367	***	0.359	***	0.345	***	0.350	***
	(0.006)		(0.006)		(0.005)		(0.005)		(0.005)	
Medium Pack	-0.119	***	-0.119	***	-0.140	***	-0.152	***	-0.123	***
	(0.003)		(0.003)		(0.003)		(0.003)		(0.003)	
Large Pack	-0.273	***	-0.273	***	-0.327	***	-0.338	***	-0.334	***
	(0.027)		(0.027)		(0.026)		(0.025)		(0.026)	
Num References	-0.004	***	-0.004	***	-0.006	***	-0.005	***	-0.009	***
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
%Sales Prom	-0.003	***	-0.003	***	-0.002	***	-0.002	***	-0.002	***
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
WADist	-0.001	***	-0.001	***	-0.001	***	-0.001	***	-0.001	***
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Constant	0.809	***	1.139	***	1.282	***	1.291	***	1.308	***
	(0.037)		(0.061)		(0.008)		(0.009)		(0.009)	
σ_v			0.152	***	0.096	***	0.090	***	0.093	***
			(0.000)		(0.001)		(0.001)		(0.001)	
σ_u			0.000		0.195	***				
			(0.076)		(0.002)					
σ^2			0.023	***	0.047	***				
			(0.000)		(0.001)					
λ			0.001		2.044	***				
			(0.076)		(0.002)					

Note: **, ** and *** are 10, 5 and 1% significance levels*. Standard errors in parenthesis. Monthly dummies. Brand-level and region-level fixed-effects'coefficients omitted for brevity

Table 4. Decomposition of Half-Normal Error Variance Component (σ_u) – "Production Frontier Models"

	Model (2)			Model (3)				
	Dummy N Functionalities		$\exp(\gamma_{NF})$	Dummy N Functionalities		Number of References		$\exp(\gamma_{NF} + \gamma_{NR}\overline{NumR})$
NFunc=1	-0.570	***	0.565	-0.343	***	-0.072	***	0.564
	(0.028)			(0.036)		(0.008)		
NFunc=2	-0.503	***	0.605	-0.367	***	-0.034	***	0.626
	(0.028)			(0.037)		(0.008)		
NFunc=3	-1.098	***	0.334	-5.393	***	1.821	***	0.084
	(0.058)			(0.627)		(0.205)		
NFunc=4	-1.674	***	0.188	-1.008	***	-0.239	***	0.144
	(0.054)			(0.062)		(0.025)		
Const	-2.694	***	0.068	-2.736	***	-0.004	***	0.064
	(0.020)			(0.026)		(0.006)		

Note: **, ** and *** are 10, 5 and 1% significance levels*. Standard errors in parenthesis

Figure 1. Graphical representation of equilibrium prices and hedonic price curves. Top panel: Traditional hedonic price model; Bottom panel: incomplete/asymmetric information model.

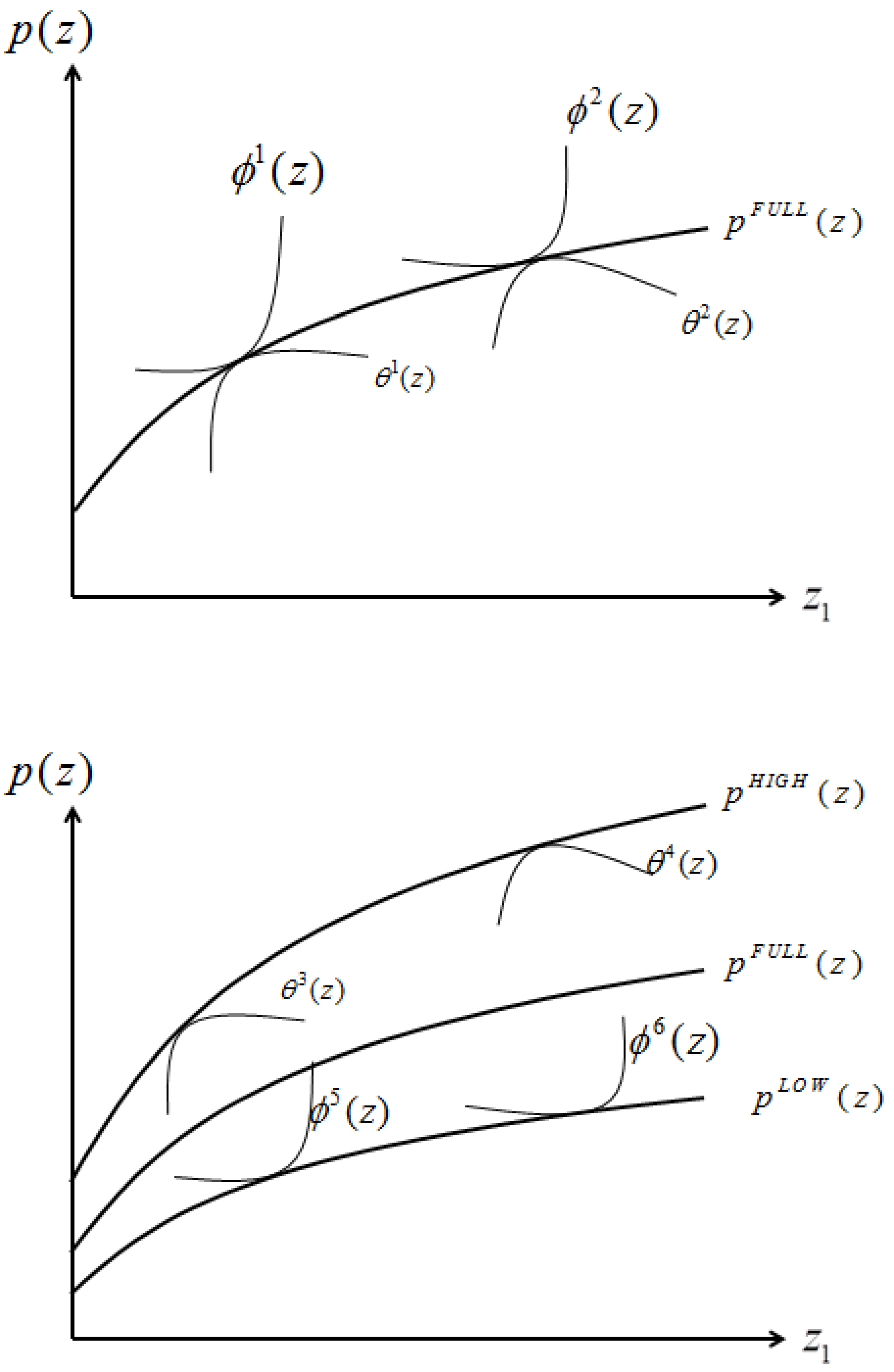

Figure 2. Plots of Selected Quantile Regression (shaded area) and OLS regression (clear area) coefficients with 95% confidence intervals