Measuring willingness to pay for drinking water quality

using

the econometrics of equivalence scales

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Introduction

A safe, reliable and inexpensive drinking water supply is one of the easiest aspects of life in developed countries to take for granted. Yet, water supplies can and do provide water of variable quality. During the late eighties and more accurately during the early nineties, questions about supplied water quality arose in France. Firstly originated by miscellaneous publications of supplied water test results giving serious cause for concern with respect to public health, these questions recently became matter of urgent political decisions. In 1996, a consumers' organization of Guingamp (Bretagne) brought lawsuits against one of the major water companies for having supplied water over 50 mg of nitrates per liter, the legal concentration threshold. The organization won the case and the producer had to reimburse customers for extra cost as they had to purchase bottled water.

Thank to the generalization of water treatment against bacteriological and fungi contamination, the quality of supplied water may only be questionable in some parts of France for chemical reasons. French households begin only to purchase private treatment means such as filters[1] and seem to circumvent the problems of supplied water quality they face by purchasing bottled water and, perhaps in some cases, other soft drinks. Thus, the French consumers seem to mainly attribute a value to the supplied water quality when tap water is used as a beverage.

The dramatic increase in bottled water consumption during the eighties (+65% for the *per capita* consumption from 1981 to 1991) thus suggests a decrease in water quality in France, at least in consumers' minds (Figure 1). This decrease in the true or presumed quality of supplied water must be proved and its cost for the French consumers assessed to provide

[1] However, in regions with highly chalky grounds, some households have got softeners.

insights to policy makers[2]. More specifically, economic assessments of the costs incurred by households presumably supplied with low quality water are necessary and still to perform. These are the objectives of this study.

We propose and implement a method to infer the value of supplied water quality when tap water is used as beverage. This inference method is indirect and is based on the observation of the French households' soft drink demand.

The lack of data we have to face and the nature of the question we have to deal with preclude direct use of the standard methods of environmental goods valuation: the averting expenditure approach originated by Courant and Porter (1981) and the "public good as quality characteristic of a privately consumed good" originated by Mäler (1974). In fact, the tap water quantities that are drunk by the households are not measured and the available data concerning the French tap water quality are very poor for the period considered in this study.

Also, in the first part of this paper, we develop a theoretical framework that is adapted to our objectives and data. As any indirect method of public good measurement, it relies on some maintained assumptions related to the relationships between the good to be valued and the observed market good demands. We present these assumptions and argue their plausibility. A crucial point for the use of indirect valuation methods is the existence of a particular situation where the quantity or the quality public good to be valued does not affect consumers' behavior. In theory, the valuation question is generally solved by analytical or

[2] If this hypothesis was true, it would have important policy implications. Quality improvement policies would be needed in the case of a true decrease in supplied water quality whereas information policies would be warranted in the case of a decrease in supplied water quality only in consumers' minds. See, e. g., Smith *et alii* (1995) and Chern *et alii* (1995) for studies of the effects of information on consumers' mitigating behavior.

numerical (see Vartia, 1983) integration of an estimated system of Marshallian demand functions[3] to obtain the expenditure functions that allow welfare comparisons. However, the result of the integration contains unknown terms (only Marshallian demand functions are estimated not Hicksian demand functions) in addition to the constant of integration (see, e.g., Mäler, 1974). The situation where the quality of the public good to valued does not affect consumers' welfare is used to solve this problem of identification and to determine the constant of integration. We show that our model provide strong arguments in favor of the existence of a price regime where such a situation occurs.

In the second part, we present the econometric model and the procedure used to implement our approach. Given that our model rests on many unobservable variables, we can't specify a structural econometric model that embodies all the features of the theoretical model (see, e.g., Larson, 1991 and 1992). In order to overcome this problem, we use the analogy that exists between the estimation of public good values and that of equivalence scales (Blundell and Lewbel, 1991; Pollack, 1991). Estimation of equivalence scales, e.g. in order to estimate child cost, has received considerable attention in the applied economics literature (see, e.g., Blundell *et alii*, 1993; Blundell and Lewbel, 1991). It generally relies on the estimation of a demand system model is that is explicitly derived from a parametric cost function. However, Marshallian demand functions can only be used to recover the cost of attaining each indifference curve in the market goods' space. The valuation of the public good quality requires the recovery the cost of attaining each indifference curve in the space of both the public good and the market goods. Hence, Marshallian demand functions *a priori* only contains information on conditional preference orderings (*i.e.*, where the quality of the public good is given) whereas identification of equivalence scales requires information relative to the

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[3] If it satisfies the Slutsky conditions for integrability.

unconditional preference ordering (i.e., the one that describes the consummers' preferences in the space of both the marketed goods and the public good). As noted by Blundell and Lewbel (1991), this identification problem is generally solved by imposing severe restrictions on households' preferences in the studies dealing with equivalence scales. In fact, in our case, the existence of a price regime where the quantity or the quality of the public good to be valued does not affect consumer's welfare allows to compare the conditional preference orderings that are revealed by the estimated Marshallian demand functions. We propose two simple methods that allow estimation of this price regime by use of estimated Marshallian demands and, consequently, that allow recovery of the whole set of expenditure function parameters. Due to data constraints and for simplicity, we use a version of Deaton and Muellbauer's (1980a, 1980b) Almost Ideal Demand System (AIDS) model. This model is extensively used and seems to perform relatively well for computing equivalence scales[4] (See, e.g., Blundell *et alii*, 1993; Blundell and Lewbel, 1991).

In a third part, we present our data set and the approach that we use to handle the inconvenient originated by the lack of data about tap water quality. Once again, our study needs to rely on maintained assumptions that we explicitly present and argue.

Results are presented and commented in the fourth part.

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[4] It can be noted that the Quadratic AIDS model introduced by Banks, Blundell and Lewbel (1996) seems to be now preferred. Being quadratic in expenditures (and as such a generalization of the AIDS model), it possesses many of the attractive features of the AIDS model while allowing for more general Engel curve behavior (See, e.g., Blundell and Robin, 1997).

1. Theoretical framework

As described above and from the consumers' viewpoint, the eventual deterioration of supplied water quality in France may have mainly influenced the properties of tap water when it is used as a beverage. We thus focus our study on the estimation of the use value of supplied water quality[5] and only consider a single use of this quality, its use as a complement of drunk tap water. As a result, we neglect the value of the effects of this quality when supplied water is used in the bathroom, in the swimming pool, to wash the dishes, ..., i.e. the other uses that may originate ingestion of small quantities of supplied water by the consumer. It can be argued that this value should be very closed to zero since it not recommended to wash fruit and vegetables to be eaten without preparation with bottled water. We also exclude the value associated to the effect of supplied water quality on the households' equipment maintenance. To a very large extent these problems are originated by hard water, i.e. by a permanent characteristic of the water supplied in chalky areas, a sort of problem traditionally out of the scope of public intervention.

As almost every environmental good, tap water quality is a non-market good and consequently a good whose economic value is implicit. Thus, apart from costly and "*in vitro*" contingent valuation methods, only indirect methods remain available to value supplied water quality (Freeman, 1993).

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[5] It can be argued here that supplied water quality has only use value, by definition. The only known indirect method for estimating nonuse values of quality changes rely on the integration of some function of the marginal effects of the considered quality on the Marshallian demand of some chosen market goods (Neill, 1988; Larson, 1992; Flores, 1996). The lack of data related to supplied water quality in France precludes estimation of this marginal effects.

Within this context, one of the most popular inference strategy treats the public good to be valued as a characteristic of a market good whose demand is observable (Bockstael and McConnell, 1993). Supplied water quality can obviously be interpreted as a characteristic of tap water. In this case, the most appealing strategy is to consider that the public good and the market good are linked *via* a specific relationship labeled by Mäler (1974) as weak complementarity (Bockstael and McConnell, 1993) or its generalization: the weak Hicks neutrality of Larson (1992)[6]. However, within this context, we face a serious lack of data. The consumed quantities of tap water that are drunk by households, i.e. what can be considered as the only market good that has a direct relationship with supplied water quality, are generally unknown. As the part which is used as a beverage in the households' total consumption of supplied water is very small, it is not possible to infer the value of the quality of drinking tap water by studying the global demand of supplied water. In our case, however, another strategy to value environmental goods may be used. Along the line of Courant and Porter (1981), it seems natural to interpret households' bottled water expenditures as averting expenditures. Where quality is (perceived as) low, the concerned households are facing a trade-off: either consuming the supplied low quality water, risking illness and/or sustaining some degree of disutility due to bad taste thereby, or incurring costs in order to improve the supplied water quality or to purchase drinking water from other sources. Where the trade-off is well defined and its determinants well identified, it is possible to use a model derived within an household production framework to assess the benefits of a change in the considered public good (Harrington and Portney, 1987; Shibata and Winrich, 1983; Harford, 1984). In the case of supplied water quality, Harrington *et alii* (1989), Abdalla *et alii* (1992) and Laughland *et alii*

[6] In fact, Larson (1992) first defined his weak Hicks neutrality concept as a generalization of Neill's (1988) enlightening but rather unrealistic Hicks neutrality concept. See also Flores (1996).

(1993) used a cost of illness approach to value the cost associated with a groundwater contamination incident in Pennsylvania[7]. Two main problems are associated with the application of the standard averting expenditure approach (Cropper and Oates, 1992). The first one is that it requires an explicit specification of the trade-off faced by the considered households. In order to directly use this approach, we would have to specify the effects of the supplied water quality on households' utility. Apart from the taste effects, we would have to specify the effects of the drunk tap water quality on consumers' health. More exactly, since these effects are not well defined, we would have to specify these effects as they are expected by the households. Even if progress have been done in this area (see, e. g., Chern *et alii*, 1995), use of this approach remains difficult. The second problem associated with the averting expenditure approach is concerned with the existing link between the public good to be valued and the good that is used to avert its effects. In order to specify a tractable model we would have to assume that bottled water is only used to avoid consumption of tap water (Freeman, 1993; Smith, 1991). Several facts lead us to cast serious doubt on such an assumption. Firstly, consumption of mineral water may be warranted by doctors for medical reasons (specifically for old people and young children). Secondly, bottled water producers advertise their product by presenting it as a diet product[8]. Finally, and perhaps more importantly, bottled water is consumed all over France, even in areas supplied by sources that also supply mineral bottled water producers.

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[7] Other applications of this approach may be found in Murdoch and Thayer (1990); Joyce, Grossman and Goldman (1989); Gerking and Stanley (1986) and Watson and Jaksh (1982) among others.

[8] During the eighties, mineral water represented more than 80% (in volume) of the market of flat bottled water in France.

Because we can't directly use any of the standard indirect valuation methods presented, we develop a specific framework. As any other valuation method using an indirect approach, our method relies on some hypothesized relationships between the observed demands for market goods and the unobservable demands for environmental goods. These relationships are generally assumed *a priori*. In our case, the demand for the only market good that has a direct relationship with the public good to be valued is not observed. Thus, we must be very careful in defining the assumed relationship upon which our entire analysis will rely.

If one can easily have strong intuition about the effects of the public good on Marshallian or ordinary demands[9], *a priori* imposing some patterns on Hicksian demands, as it is usually done, seems more difficult since those demands are mainly defined as an analysis tool. Contrary to other studies, our approach involves two steps.

The objective of the first one is to precisely define and compare the characteristics of tap water, of bottled water and of the other soft drinks as well as the characteristics of tap water quality using ordinal concepts, i.e. mainly using marginal rates of substitution. These concepts have the advantage of being more intuitive and, thus easier to check *a priori*, than patterns of Hicksian demands[10]. Comparative statics defined on marginal rates of substitution only involves two or three goods whereas comparative statics defined on Hicksian demands involves the whole set of goods.

In the second step, the implications of these characteristics on the patterns of the Hicksian demands are derived. We argue that this approach is necessary in our case since the lack of data related to tap water consumption we face renders our assumptions even more

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[9] If one does not omit the income effects.

[10] Nevertheless, it remains that the characteristics of the considered goods will only help to define other maintained assumptions.

difficult to check than those imposed in the other previous studies related to this topic. It can be noted that Bockstael and McConnell (1993) provide some arguments in favor of this approach without pursuing it very far.

The model

We assume the following separable structure for utility function *F(.)* of the representative consumer:

(1) $F(x_1, x_2, z, q, \mathbf{G}) \equiv F(U(x_1, x_2, z, q), \mathbf{G})$

U(.) is the partial utility function of soft drinks of the representative consumer. x_1 represents the consumed quantity of bottled water, x_2 that of an aggregate of the other standard soft drinks and z that of drinking tap water. q is a quality indicator of supplied water and $q \in [q_{min}, q_{max}]$. q only represents the properties of supplied water where it is used as a beverage. $\mathbf{G}$ is a vector of quantities of the other market goods.

Only considering the quantity of supplied water that is drunk by the household requires a latent separability assumption (Blundell and Robin, 1995). The part of purchased supplied water used as drinking water can be considered as a single (latent) good and that its demand can be analyzed independently with respect to the other parts of the total purchased supplied water. The definition of the partial utility *U(.)* requires the assumption that bottled water, the other soft drinks, tap water and the effects of tap water quality are weakly separable from the other goods in consumers' preferences. Even if, the weak separability assumption of groups of good sharing some characteristics is now standard in applied demand economics, the separability assumption of the tap water quality effects deserves some comments.

When considering the flavor of tap water, the separability assumption seems natural. However, purchase of medical care may affect the marginal rates of substitutions of the market soft drinks for tap water. A consumer could drink tap water and not purchase bottled water because he expects that in case of illness he will be able to purchase medical care and appropriate medicine[11]. It is difficult to *a priori* assess the effects of maintaining this separability assumption. On the one hand, the French state provides a compulsory health insurance coverage to the population. This situation may generates "moral hazard like" patterns, in the sense that this insurance coverage can reduce incentives to avert the adverse effects of tap water consumption. In this case, maintaining the separability assumption would imply an underestimation of the value of the degradation of the supplied water quality due to the quasi-gratuity of medical care[12]. On the other hand, these effects may also be limited since the uncertainty related to the health effects of the contamination of the supplied water remains considerable. Neither the potential effects on health of consumption of many water pollutants, and consequently, nor the appropriate medicine to treat them are well known yet. Moreover, monetary payments do not avoid the disutility caused by illness or potential irreversible effects such as sterility. Hence, a consumer exhibiting some degree of risk aversion or prudence may choose to not drink tap water as soon as he becomes aware of this considerable uncertainty.

Focusing on the value of supplied water quality as a complement of drunk tap water, we only consider the cost minimization problem associated with the partial utility *U(.)*, i.e., the soft drink utility:

(2a) $$\underset{x_1,x_2,z}{Min}\; p_1x_1 + p_2x_2 \quad s.t. \quad U(x_1,x_2,z,q) \geq \overline{U}$$

which is the dual of the standard partial maximization problem:

(2b) $$\underset{x_1,x_2,z}{Max}\; U(x_1,x_2,z,q) \quad s.t. \quad y \geq p_1x_1 + p_2x_2$$

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[11] He may also expect that consumption of appropriate food builds sufficient resistance with respect to the eventual adverse effects of tap water consumption. However, this case *a priori* seems unlikely.

[12] Any other method of inference of consumers' willingness to pay would face the same problem.

where p_i is the unit price (index) of good i, $\overline{U}$ is an arbitrary level of $U(.)$ and y the expenditure level allocated by the consumer for soft drink purchases. Given that the price of its closest (and currently consumed) substitutes are *50* times (spring water) to *100* times more expensive than it is, it can safely be assumed that the price of supplied water can't explain its level of consumption as a beverage, i.e. that tap water expenditures are negligible in the programs (2a) and (2b). Hence, we assume here that the price of tap water is null. In addition to assume that $U(.)$ and its derivatives are continuous and differentiable, we adopt the following restrictions:

(3a) $U(.)$ is strictly increasing and strictly quasi-concave in (x_1, x_2) at any level of (q, z). This ensures the existence of a single solution for (2).

(3b) $U(.)$ admits a unique maximum in z and is strictly concave in z at any level of (x_1, x_2, q) where $U_z(.)$, the partial derivative of $U(.)$ in z, is null.

(3c) $U(.)$ is strictly increasing in q at any level of (x_1, x_2, z) where $z \neq 0$ and is constant in q at any level of (x_1, x_2, z) where $z = 0$.

Assumption (3b) implies that when q is not maximum (i.e. tap water is safe and has good flavor), the consumer faces an implicit trade-off between the desirable effects of tap water consumption (thirst-quenching) and its undesirable effects (bad taste and potential health state deterioration). This assumption is consistent with the models developed within the standard averting expenditure framework. Where q is maximum, assuming that $U(.)$ admits a maximum in z relies on a satiation effect. The assumption that q has no effect on utility when tap water is not consumed is crucial for the definition of conditions that allow identification of expenditure function parameters. But it is consistent with our focus on estimation of use values.

These assumptions ensure that the solutions of (2a), respectively (2b), i.e. the Hicksian demands associated to the partial utility level $\overline{U}$, respectively Marshallian demands associated to the expenditure level y, exist and are unique[13]. These are written as: $h_i\ (p_1, p_2, q, \overline{U})$ and $h_z\ (p_1, p_2, q, \overline{U})$, respectively: $m_i\ (p_1, p_2, q, y)$ and $m_z\ (p_1, p_2, q, y)$. They are derived from the following Lagrangian functions maximization programs:

(4a) $$\underset{x_1,x_2,z}{Max} - (p_1x_1 + p_2x_2) + \mu\left(U(x_1,x_2,z,q) - \overline{U}\right)$$

respectively:

(4b) $$\underset{x_1,x_2,z}{Max}\, U(x_1,x_2,z,q) + \lambda\left(y - p_1x_1 - p_2x_2\right).$$

Use of the Hicksian demands enables to write the cost function associated to (2a) that are at the core of any welfare comparison as:

(5) $$C(p_1,p_2,q,\overline{U}) \equiv p_1h_1(p_1,p_2,q,\overline{U}) + p_2h_2(p_1,p_2,q,\overline{U})$$

while use the Marshallian demands enables to write the partial indirect utility function associated to (2b) as:

(6) $$V(p_1,p_2,q,y) \equiv U(m_1(p_1,p_2,q,y), m_2(p_1,p_2,q,y), m_z(p_1,p_2,q,y))$$

As noted by Hanemann and Morey (1992), the cost function defined is associated to a partial utility function and does not allow to compute standard compensating or equivalent variations in income. Nevertheless, this cost function provides a basis to define partial compensating variations in soft drink expenditure from state q_0 to state q_1 ($CV(.)$):

(6a) $$\overline{U}_0 \equiv V(p_1,p_2,q_0,y) = V(p_1,p_2,q_1,y - CV(p_1,p_2,q_0,q_1,\overline{U}_0))$$

or equivalent variations in soft drink expenditure from state q_0 to state q_1 ($EV(.)$):

(6b) $$\overline{U}_1 \equiv V(p_1,p_2,q_0,y + EV(p_1,p_2,q_0,q_1,\overline{U}_1)) = V(p_1,p_2,q_1,y).$$

Definition of the relationships between q, x_1, x_2 and z

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[13] The uniqueness is not necessary but is assumed for simplicity.

Tap water, bottled water and the other soft soft drinks share the characteristics of non-alcoholic beverages (justifying, at least to some extend, our separability assumptions). But, we can assume that a rational consumer considers that bottled water is a closer substitute of tap water than the other soft drinks are. Formally, such an assertion can be written in terms of marginal rates of substitution as:

(7) Whenever $U_z \geq 0$, $\left.\frac{d^2 x_2}{-dx_1 dz}\right|_{u=cst} < 0$.

This assumption can be related to the central hypothesis in economics, that of diminishing marginal rate of substitution. By the strict quasi-concavity assumption in (3a), we have:

$$\left.\frac{d^2 x_2}{-dx_1 dx_1}\right|_{u=cst} < 0$$

In other words, a given good is its closest substitute and consumers have a basic inclination to diversification. Thus assumption (7) can be interpreted as follows: a consumer having a basic inclination to diversification would need smaller amounts of (other) soft drinks to compensate for a decrease in bottled water consumption as tap water (when it is desired) consumption increases because bottled water is a closer substitute of tap water than it is of the other soft drinks. We can derive the implications in terms of Hicksian demand pattern by solving the following constrained cost minimization program:

(8) $\underset{x_1, x_2}{Min}(p_1 x_1 + p_2 x_2) - \gamma\left(U(x_1, x_2, z, \mathbf{q}) - \overline{U}\right)$

Using standard comparative statics (for interior solutions) and noting γ^* the optimal value of the Lagrange multiplier γ and $h_i^c(.)$ the constrained Hicksian demands, one obtains:

(9) Whenever: $U_z(h_1^c, h_2^c, z) \geq 0$, $\frac{dh_1^c}{dz} = \frac{1}{\Delta^c}\left(\frac{p_2}{\gamma^*}\right)^3 \left.\frac{d^2 x_2}{-dx_1 dz}\right|_{u=cst} < 0$

where Δ^c is the (positive) determinant of the bordered Hessian matrix of *U(.)* in (x_1 , x_2). That is, in Neill's (1988) terminology, where tap water is desired by the consumer, tap water and bottled water are Hicksian substitutes. Note that, given (3a), (7) is a necessary and sufficient condition for (9).

We now need to establish the presumed relationships between *q* and the demands of the market goods. Quality is defined as a characteristic of good that increases desirability of this good for the consumer. Hence if quality is considered as a good, it can be defined as the "best" complement of the good to which it is associated. Formally, this can be written in terms of marginal rates of substitution as:

(10) Whenever $U_z(h_1^c, h_2^c, z) \geq 0$ and $z \neq 0$, $\left.\dfrac{d^2 x_i}{-dzdq}\right|_{u=cst} > 0$, $i = 1,2$.

That is, an increase in tap water quality makes a decrease in (desired) tap water consumption more harmful for the consumer. This simply comes from the fact that an increase in *q* leads to an increase in the desirability of *z*. Let us now define how the relationship between *z* and x_1 is affected by *q*. In order to do this, we roughly need i-to rank the desirability of tap water of various quality with respect to desirability of bottled water and ii-to rank the presumed quality of bottled water within the set of potential qualities of tap water. We begin here with the second question. Provided that bottled water is unambiguously safe because of compulsory controls, is supposed to have diet and medical properties and is chosen by the consumer according to his taste, one can say that whatever is the value of *q*, consumption of a given quantity of bottled water provides higher utility to the consumer than consumption same quantity of tap water does. Formally, this can be written as:

(11) $\forall q, \quad U(x_1, x_2, z, q) < U(x_1 + z, x_2, 0, q)$

Provided that bottled water has to be purchased, is voluminous and is heavy to carry, this assumption seems rather strong. However, almost every household now has got a car and goes regularly to supermarkets to buy food. Under these circumstances, the marginal transport cost associated to the bottled water purchase can be considered as limited. Note that writing equation (11), we consider that tap water is not an essential good in soft drink utility. This assumption is natural since bottled water is a good that has all the advantages of tap water and (almost) none of its inconvenient. Now, what are the effects of *q* on the relative desirability of tap water and bottled water? Equation (11) states that bottled water is drinking water of the highest quality. Thus, intuition suggests that the higher the quality of tap water is the closer to those of bottled water are the characteristics of tap water. In other words, tap water becomes a closer substitute of bottled water as *q* increases. Formally, this can be written in terms of marginal rates of substitution as:

(12a) Whenever $U_z(h_1^c, h_2^c, z) \geq 0$ and $z \neq 0$, $\left.\frac{d^2 x_2}{-dx_1 dq}\right|_{u=cst} < 0$.

It can be noted that (3c) implies that:

(12b) Whenever $U_z(h_1^c, h_2^c, z) \geq 0$ and $z = 0$, $\left.\frac{d^2 x_2}{-dx_1 dq}\right|_{u=cst} = 0$,

i.e., that tap water quality only affects utility if tap water is consumed. Indeed, the interpretation of (12a) is very close to that of (7). Equation (12a) indicates that the desirability of bottled water is lowered by an increase in *q*. As *q* increases, tap water becomes a closer substitute of bottled water. Thus, when tap water is consumed, an increase in its quality leads to a decrease in the desirability of bottled water if the considered consumer exhibits an inclination to diversification.

Now, having formalized our prior assumptions on the characteristics of the different soft drinks in terms of relative desirability (i.e. only ordinal concepts), it is possible to derive some of the patterns of the soft drinks Hicksian demands. Using standard comparative statics (for interior solutions) and noting m^* the optimal value of the Lagrange multiplier of the program (4a), one obtains after some tedious but straightforward computations:

(13a) $$\frac{dh_1}{dp_1} = \left(-\frac{1}{\Delta}\right)\left(\frac{p_2}{m^*}\right)^3 \frac{U_{zz}}{p_2} < 0\,,$$

(13b) $$\frac{dh_z}{dp_1} = \frac{1}{\Delta}\frac{p_2}{(m^*)^2}\left.\frac{d^2x_2}{-dx_1dz}\right|_{u=cst} > 0\,,$$

(13c) $$\frac{dh_1}{dq} = \left(-\frac{1}{\Delta}\right)\left(\frac{p_2}{m^*}\right)^3\left[\frac{p_2}{m^*}\left.\frac{d^2x_2}{-dx_1dz}\right|_{u=cst}\left.\frac{d^2x_2}{-dzdq}\right|_{u=cst} - U_{zz}\left.\frac{d^2x_2}{-dx_1dq}\right|_{u=cst}\right] < 0$$

and:

(13d) $$\frac{dh_z}{dq} = \left(-\frac{1}{\Delta}\right)\left(\frac{p_2}{m^*}\right)^4\left[\left.\frac{d^2x_2}{-dx_1dz}\right|_{u=cst}\left.\frac{d^2x_2}{-dx_1dq}\right|_{u=cst} - \left.\frac{d^2x_2}{-dzdq}\right|_{u=cst}\left.\frac{d^2x_2}{-dx_1{}^2}\right|_{u=cst}\right] > 0\,.$$

All functions are taken at (h_1, h_2, h_z), Δ is the (negative) determinant of the bordered Hessian matrix of *U(.)* in (x_1 , x_2 , z). Equation (13c) indicates that bottled and supplied water quality are Hicksian substitutes while equation (13d) indicates that tap water and supplied water quality are Hicksian complements in the soft drink partial utility. Equation (13b) indicates that tap water and bottled water are Hicksian substitutes. These patterns suggest use of concepts similar to Mäler's (1974) weak complementarity and Feenberg and Mills' (1980) weak substitutability in order to define conditions for the expenditure function recovery in terms of price regime situations.

Conditions for recovery the expenditure functions

According to Mäler's definition, tap water and the quality of supplied water are weakly complementary if:

a-they are Hicksian complements $\frac{dh_z}{dq} > 0$, *b*-there exists a price system (p_1^c, p_2^c) such that whenever $p_1 \le p_1^c$ and $p_2 \le p_2^c$ we have: $h_z(p_1, p_2, q, \overline{U}) = 0$, i.e. the Hicksian demand of tap water is choked off

and:

c- whenever $p_1 \le p_1^c$ and $p_2 \le p_2^c$ we have: $\dfrac{\partial C(p_1, p_2, q, \overline{U})}{\partial q} = 0$.

According to Feenberg and Mills' definition, bottled water and the quality of supplied water are weak substitutes if:

d- they are Hicksian substitutes $\dfrac{dh_1}{dq} < 0$

and:

e-there exists a price system (p_1^{cc}, p_2^{cc}) such that whenever $p_1 \le p_1^{cc}$ and $p_2 \le p_2^{cc}$ we have: $\dfrac{\partial C(p_1, p_2, q, \overline{U})}{\partial q} = 0$.

By application of the Envelope Theorem to the cost minimization program (4a) and using assumption (3c), one easily obtains that:

$$\text{(14)} \qquad \frac{\partial C(p_1, p_2, q, \overline{U})}{\partial q} = 0 \qquad \Leftrightarrow \qquad h_z(p_1, p_2, q, \overline{U}) = 0$$

Using the result (13d) that tap water quality strictly increases tap water consumption, in order to check that conditions *a*-*e* are met in our case, one just needs to check that there exists a price system that chokes off the demand for tap water where $q = q_{max}$. As a result, the price systems (p_1^{cc}, p_2^{cc}) and (p_1^c, p_2^c) are analogously defined. Assumption (11):

$$\overline{U} = U(h_1, h_2, h_z, q) < U(h_1 + h_z, h_2, 0, q)$$

indicates that it is always possible to get at least the utility level $\overline{U}$ by totally substituting consumption of bottled water for consumption of tap water. Equation (13b) indicates that lowering the price of bottled water leads to a decrease in the demand of tap water and to an increase in the demand of bottled water. Thus, simply lowering the bottled water price may be a solution to get a "choke" price system. However, the previous assumptions do not ensure the existence of a "choke" price system.

We simply assume that this "choke" price system exists. Moreover, in order to avoid some difficulties (Smith, 1991), we assume that it is strictly positive. To be fully developed, arguments in favor of this assumption could rely on satiation effects. Such a development is out of the scope of this paper. Moreover, it would considerably complicate the entire analysis. We just provide some intuition about it and present the main assumptions upon which it relies. Intuition suggests that consumption of beverages can reach satiation, at least for physiological reasons. The satiation level for water may depend on the household composition, on the age of its members, etc. It may also depend on the level of consumption of the other beverages. But it does not depend on tap water quality, it is only defined over total consumed water quantity. As the price of bottled water continuously decreases, consumption of bottled water increases to finally reach the satiation level of water consumption. Given that bottled water is not only drunk for thirst-quenching, but also for diet or medical purpose, consumers' marginal willingness to pay for bottled water can be considered as always non-negative, even at the satiation level. However, where bottled water is consumed up to the water satiation level, consumers' marginal willingness to pay for tap water is likely to be negative since i-at the water satiation level the consumer's marginal utility of thirst-quenching is zero while ii-the marginal utility of the adverse effects of tap water can be considered as always negative. Under these assumptions, the price that sets bottled water consumption at the consumer's satiation level of water is i-strictly positive and ii-implies a corner solution in tap water consumption. Under these assumptions, lowering the price of bottled water up to the point where bottled water consumption reaches the consumer's satiation level allows to define a strictly positive "choke" price system. Furthermore, according to this analysis, one can say that the price of bottled water that chokes off tap water consumption increases as: i- $\overline{U}$ and p_2 increase and as: ii- q decreases.

Assuming that a strictly positive choke price system exists enables to solve the problem of the identification of the expenditure function. However, to be useful in applied work, this choke price system must be determined. Consider an initial situation defined by $(p_1, p_2, q, \overline{U})$. According to our previous analysis, a "choke" price system (p_1^c, p_2) can be defined by the condition:

(15) $\quad \forall p_1 \leq p_1^c, \quad h_z(p_1, p_2, q_{max}, \overline{U}) = 0$

Condition (15) simply states that for any bottled water price inferior to p_1^c, the Hicksian demand for tap water is choked off. Being defined on the Hicksian demand of an unobservable good, condition (15) can't be used as such to empirically determine p_1^c. However, equation (9):

$$\text{Whenever } U_z(h_1^c, h_2^c, z) \geq 0, \ \frac{dh_1^c}{dz} = \frac{1}{\Delta^c}\left(\frac{p_2}{g^*}\right)^3 \left.\frac{d^2 x_2}{-dx_1 dz}\right|_{u=cst} < 0$$

indicates that increasing consumption of tap water decreases bottled water consumption. Thus, condition (15) can be restated in terms of Hicksian demands as:

(16) $\quad \forall p_1 \leq p_1^c, \quad \dfrac{dh_1(p_1, p_2, \overline{U}, q)}{dq} = 0$.

To be useful in applied work, condition (16) must now be restated in terms of Marshallian demands. Using duality relations, one obtains:

$$\text{(17)} \quad \frac{dh_1(p_1, p_2, q, \overline{U})}{dq} = \frac{dm_1(p_1, p_2, q, C(p_1, p_2, q, \overline{U}))}{dq_k} + \frac{dm_1(p_1, p_2, q, C(p_1, p_2, q, \overline{U}))}{dy}\frac{dC(p_1, p_2, q, \overline{U})}{dq}$$

This, allows us to restate condition (15) as:

(18) $$\forall p_1 \le p_1^c, \quad \frac{dm_1(p_1, p_2, y, q)}{dq} = 0 \quad \text{and} \quad \frac{dm_2(p_1, p_2, y, q)}{dq} = 0$$

where: $y = C(p_1, p_2, \overline{U}, q)$.

Condition (18) can be used in applied work since it simply indicates that consumers supplied with various supplied water quality but having the same amount of soft drink expenditures and the same preferences will purchase equal amounts of bottled water and of other soft drinks only if the price system they face chokes off their tap water consumption. As such, condition (18) can used in applied work. It only defines conditions on Marshallian demand patterns. It defines conditions easily checked where standard demand systems are estimated.

2. The empirical model and the empirical recovery of the cost function parameters

Due to lack of data related to tap water quality and consumption, we are not able to estimate a structural model of demand of soft drinks. As a result, we can't impose the weak complementarity and substitutability properties presented in the previous section as it is warranted by Larson (1991) and Smith (1991). This motivates our use of an empirical approach inspired by the studies related to equivalence scales estimation (See e.g., Blundell and Lewbel, 1991).

We first show that estimation of compensating variations in income is analogous to estimation of equivalence scales. Both rely on similar logic. Both involve expenditure functions, reference utility levels and reference state levels and, more importantly, aim at comparing situations or welfare by use of monetary measures. We then describe how the empirical procedures usually used for equivalence scales estimation can be adapted for the estimation of public good values. More specifically, we show how the standard theoretical concepts developed for public valuation can be used within the empirical framework developed for equivalence scale measurement.

Partial compensating variations in income and true cost of drinking indices

Here, we restrict the analysis to the estimation and the interpretation of equivalence scales or equivalently to the estimation of true cost of soft drink (sub)indices. According to (Deaton and Muellbauer, 1980a), the quantity:

(19) $$\frac{C(p_1,p_2,q_1,\overline{U}_0)}{C(p_1,p_2,q_0,\overline{U}_0)} \quad \text{where} \quad \overline{U}_0 \equiv U(m_1,m_2,m_z,q_{\mathbf{0}}) = V(p_1,p_2,q_{\mathbf{0}},y)$$

has the form of a true cost of living (sub)index. It can be interpreted as price index of soft drink utility level $\overline{U}_0$ where q_0 is taken as the reference state. For short and by reference to the so-called true cost of living index, we label this ratio as the "true cost of drinking index"

(TCDI) in state q_1, q_0 being the invariant reference state. In order to provide an interpretation for this price subindex, we first derive the effects of changes of q on *V(.)* and *C(.)*. Using the Envelope Theorem, one obtains that:

$$\text{(20a)} \quad \frac{\partial C(p_1,p_2,q,\overline{U})}{\partial q} = \mu \frac{\partial U(h_1,h_2,h_z,q)}{\partial q} = \mu U_q(h_1,h_2,h_z,q) \geq 0$$

and:

$$\text{(20b)} \quad \frac{\partial V(p_1,p_2,q,y)}{\partial q} = \frac{\partial U(m_1,m_2,m_z,q)}{\partial q} = U_k(m_1,m_2,m_z,q) \geq 0\,.$$

By (20a)[14], the cost of achieving the partial utility level $\overline{U}$ increases as the quality of tap water decreases. Also, it is easily shown that a deterioration (improvement) in q_1 tends to increase (decrease) TCDI in state q_1. It is more (less) costly for a consumer supplied with low (high) quality water to achieve a given partial utility $\overline{U}_0$ that it is for a consumer supplied with high (low) quality water. The TCDI in state q_0 is equal to 1. As such, the TCDI is a good indicator of the effects of q on consumers' welfare with respect to soft drink consumption.

The TCDIs have the same information content as the corresponding variations in soft drink expenditure. The former are expressed in terms of cost ratio whereas the later are expressed in terms of difference in expenditures.

However, the fact that these concepts are defined with respect to a partial utility function must be acknowledged and commented. In particular and as noted by Deaton and Muellbauer (1980a), the TCDI is only a true cost of living subindex. It is not a true cost of living index, i.e. the index used to define standard equivalence scales. Similarly, Hanemann

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[14] Note that, by assumption (3c), these derivatives are null if and only if h_z, respectively, m_z is null. In fact, assumption (3c) implies that q has only use value associated with the consumption of tap water for the consumer.

and Morey (1992) note that partial compensating variations in income are likely to differ substantially from the standard compensating variations in income, the later being defined with respect to the global utility function. This negative result leads Hanemann and Morey (1992) to cast doubt on the usefulness of partial expenditure function estimations, at least with respect to policy design.

However, Hanemann and Morey (1992) also show that the partial compensating variation $CV(p_1, p_2, q_0, q_1, \overline{U}_0)$[15] is a lower bound on the desired or conventional compensating variation in income. Thus if $q_0 > q_1$, $CV(p_1, p_2, q_0, q_1, \overline{U}_0)$ is an upper bound of how much the consumer would have to be paid to accept the deterioration of the tap water quality from q_0 to q_1. A simple interpretation of Hanemann and Morey's (1992) result using the Le Châtelier Principle and the TCDIs tends to show that measurement of TCDI or partial compensating variation in income may nevertheless be quite useful. In fact they are useful because i-they are easily interpretable and ii-partial utility of soft drink seems to be an operational concept.

Consider a consumer initially in state q_0 and finally in state q_1 where $q_0 > q_1$. Deterioration from q_0 to q_1 tends to increase the TCDI faced by the considered consumer. Due to this implicit price increase, this consumer would have chosen a lower level of soft drink utility than $\overline{U}_0$ if he was free to do so. That is, in the first stage of the two stage budgeting procedure implied by our separability assumption, the consumer would have reduce his demand for soft drink utility, this partial utility being more expensive in the final state. As a result, by decreasing his level of soft drink utility, he would have partially overcome this soft drink price index increase. This adjustment lies at the root of Hanemann and Morey's (1992)

15 See equation (6a).

result. It is not allowed where only partial compensating variations in income are computed while it is allowed where standard compensating variations in income are computed. In the empirical part of this study, we estimate price indices of soft drink utility, i.e. TCDIs. The previous discussion show that they allow situation comparisons in partial utility of soft drinks and that they are easily interpretable. Moreover, in 1989 the French Government changed the fiscal status of the soft drinks. These are now considered as necessity goods and are subject to a 5,5% value added tax whereas they were considered as luxury goods before 1989 and were subject to a 18,6% value added tax. This status change reflects the fact the utility of soft drinks is considered as a priority by the French Government and provides another argument in favor of the interpretation of the TCDIs as useful (partial) relative welfare measures.

The empirical specification

To fix ideas, we assume that consumers' have preferences for which the cost function has the so-called PIGLOG form:

(21) $lnC(p_1, p_2, u_q; q) = A(p_1, p_2,; q) + u_q B (p_1, p_2,; q), \quad U \in [0,1]$

This form can be interpreted as a first order approximation in u_q of any cost function logarithm. According to Muellbauer's (1976) interpretation the functions *A(.)* and *B(.)* represent the costs of subsistence and bliss, respectively, at the normalization point. As functions of *q*, those costs depend on tap water quality. Thus, the forms of these functions implicitly embody the Hicksian demand function for tap water. Given that we have no strong prior about the true forms of *A(.)* and *B(.)*, we adopt Deaton and Muellbauer's (1908b) choice of "almost ideal" flexible functional forms. That is, we assume that:

(22a)
$$A(p_1, p_2; q) \equiv \alpha_0(q) + \sum_k \alpha_k(q) ln p_k + \frac{1}{2}\sum_k \sum_l \gamma_{kl}(q) ln p_k ln p_l$$
$$\equiv \alpha_0(q) + a(p_1, p_2; q)$$

and:

(22b)
$$B(p_1, p_2; q) \equiv \prod_k p_k^{\beta_k(q)} \equiv b(p_1, p_2; q).$$

The prefix *ln* indicates a transformation by natural logarithm. For (21) to have the properties of cost function (excepted concavity in prices), the following parametric restrictions must be imposed:

(23)
$$\sum_k \alpha_k(q) = 1,\ \sum_k \gamma_{kl}(q) = 0, \gamma_{kl}(q) = \gamma_{lk}(q) \text{ and, } \sum_k \beta_k(q) = 0$$

Noting r the price ratio p_1 / p_2, we can rewrite (21), (22a) and (22b) as:

(24)
$$ln C(r, p_2, u_q; q) \equiv \alpha_0(q) + \alpha_1(q) ln r + ln p_2 + \frac{1}{2}\gamma_{11}(q)(ln r)^2 + u_q r^{\beta_1(q)}.$$

(25a)
$$A(r, p_2; q) = \alpha_0(q) + \alpha_1(q) ln r + ln p_2 + \frac{1}{2}\gamma_{11}(q)(ln r)^2$$

and:

(25b)
$$B(r, p_2; q) = r^{\beta_1(q)},$$

respectively. Application of Shephard's lemma and use of the equality of the Marshallian and Hicksian demands at the optimal consumption level allows derivation of the Marshallian demand functions associated to (24). Because only two goods are considered, we only present the demand function of bottled water, the demand for the other soft drinks being easily recovered by use of the adding-up condition. Expressed in terms of budget share, the Marshallian demand of bottled water derived from (24) has the following form:

$$
\begin{aligned}
w_1(r,p_2,y;q) &\equiv \frac{p_1 m_1(r,p_2,y;q)}{y} \\
&\equiv \alpha_1(q) - \beta_1(q)\alpha_0(q) + \gamma_{11}(q)\ln r \\
&\quad + \beta_1(q)\left[\ln\left(\frac{y}{p_2}\right) - \alpha_1(q)\ln r - \frac{1}{2}\gamma_{11}(q)(\ln r)^2\right]
\end{aligned} \tag{26}
$$

The TCDI identification problem stems from the fact that the parameters $\beta_1(q)$, $\alpha_1(q)$, $\alpha_0(q)$ and $\gamma_{11}(q)$ represent the consumers' preferences conditional on q according to Blundell and Lewbel's (1991) terminology. That is, they only allow to recover the cost of attaining each indifference curve u_q in the marketed soft drinks' space for a given q. Formally speaking, where $q_1 \neq q_0$, u_{q1} and u_{q0} do not represent the same preference ordering. As such, they cannot be directly compared.

The identification of the TCDI with the "choke price"

Blundell and Lewbel (1991) note that without further restriction or extra information, observation of ordinary demand provide no information about equivalence scales in a single price regime[16]. However, these authors also show that if the true value of equivalence scale is known in one positive price regime, then Marshallian demands can be used to recover the true values of all equivalence scales in all other price regimes. This shows that the existence of the "choke" price regime is a crucial point in our case. Further, it shows that a common practice for environmental good valuation, i.e. the definition of a price regime implying "cost independence" situation, may also solve, at least partially, the problem of equivalence scale identification. This provides a bridge to use approaches developed for estimation of equivalence scales for estimation of public good values.

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[16] See also Lechene (1993) for a comprehensive survey related to this topic.

Assume that the choke price ratio r^c corresponding to the unconditional utility level U and soft drink price p_2 is known. We know that with this price system consumers attain the unconditional utility level at the same cost whatever the level of q is. Also, in this price regime the true TCDI is 1. Formally this can be written as:

(27) $$C(r^c, p_2, q, u_q) = cst \equiv C^c(U, p_2) \qquad \forall q$$

This equality provides a link between the conditional preference orderings and the unconditional preference ordering at any other bottled water price level and, as a result, allows to compute the TCDI's at (r, p_2, U, q_1, q_0) for any r and any (q_1, q_0). According to the preceeding equation, for a given tap water quality q, the unconditional utility level U corresponds to the conditional utility level u_q where:

(28) $$u_q(U) = \frac{\ln C^c(U, p_2) - A(r^c, p_2; q)}{B(r^c, p_2; q)} = \frac{\ln C(r^c, p_2; u_q(U), q) - A(r^c, p_2; q)}{B(r^c, p_2; q)}$$

the TCDI at (r, p_2, U, q_1, q_0) is given by:

(29) $$\frac{C(r, p_2, u_{q1}(U); q_1)}{C(r, p_2, u_{q0}(U); q_0)} = \frac{A(r, p_2; q_1)\exp\left[B(r, p_2; q_1)u_{q1}(U)\right]}{A(r, p_2; q_0)\exp\left[B(r, p_2; q_0)u_{q0}(U)\right]}.$$

Where U is chosen as the utility level of an household supplied with water of quality q_0 and whose actual soft drink expense is y, we have:

(30a) $$C(r, p_2, u_{q0}(U); q_0) = y,$$

(30b) $$u_{q0}(U) = \frac{\ln y - A(r, p_2; q_0)}{B(r, p_2; q_0)},$$

(30c) $$u_{q1}(U) = \frac{\ln C(r^c, p_2, u_{q0}(U); q_0) - A(r^c, p_2; q_1)}{B(r^c, p_2; q_1)},$$

and:

(30d) $$\frac{C(r, p_2, u_{q1}(U); q_1)}{C(r, p_2, u_{q0}(U); q_0)} = \frac{A(r, p_2; q_1)\exp\left[B(r, p_2; q_1)u_{q1}(U)\right]}{y}.$$

Identification of the « choke price » system

It still remains to determine the "choke" price ratio r^c. A "choke" price system can thus be defined as the price ratio r^c satisfying condition (18) with (q_0, q_1, p_2, U) taken as given. This "choke" price ratio is simply recovered by solving the following equation:

(31) $$w_1(r^c, p_2, C(r^c, p_2, u_{q0}(U); q_0); q_0) = w_1(r^c, p_2, C(r^c, p_2, u_{q0}(U); q_0); q_1)\ .$$

Choosing the reference utility level U as above, we have:

(32a) $$C(r^c, p_2; u_{q0}(U), q_0) = A(r^c, p_2; q_0)\exp\left[B(r^c, p_2; q_0)u_{q0}(U)\right]$$

and:

(32b) $$u_{q0}(U) = \frac{\ln y - A(r, p_2; q_0)}{B(r, p_2; q_0)}\ .$$

Given, our functional form choice, equation (31) is equivalent to:

(33a) $$\begin{aligned} &\alpha_1(q_0) + \gamma_{11}(q_0)\ln r^c \\ &\quad + \beta_1(q_0)\left[\ln\left(\frac{C(r^c, p_2, u_{q0}(U); q_0)}{p_2}\right) - \left(\alpha_0(q_0) + \alpha_1(q_0)\ln r^c + \frac{1}{2}\gamma_{11}(q_0)(\ln r^c)^2\right)\right] \\ &= \\ &\alpha_1(q_1) + \gamma_{11}(q_1)\ln r^c \\ &\quad + \beta_1(q_1)\left[\ln\left(\frac{C(r^c, p_2, u_{q0}(U); q_0)}{p_2}\right) - \left(\alpha_0(q_1) + \alpha_1(q_1)\ln r^c + \frac{1}{2}\gamma_{11}(q_1)(\ln r^c)^2\right)\right] \end{aligned}$$

where :

(33b) $$\begin{aligned} \ln C(r^c, p_2, u_{q0}(U); q_0) = \alpha_0(q_0) + \alpha_1(q_0)\ln r^c + \frac{1}{2}\gamma_{11}(q_0)(\ln r^c)^2 \\ + u_{q0}(U)\exp(\beta_1(q_0)\ln r^c) \end{aligned}$$

and:

(33c) $$u_{q0}(U) = \frac{\ln y - \left[\alpha_0(q_0) + \alpha_1(q_0)\ln r + \frac{1}{2}\gamma_{11}(q_0)(\ln r)^2\right]}{\exp(\beta_1(q_0)\ln r)}\ .$$

Finally, we have:

$$
\begin{aligned}
& \beta_1(q_1)\frac{1}{2}\left[\gamma_{11}(q_1)-\gamma_{11}(q_0)\right](\ln r^c)^2 \\
& +\left[\left[\gamma_{11}(q_0)-\gamma_{11}(q_1)\right]+\beta_1(q_1)\left[\alpha_1(q_1)-\alpha_1(q_0)\right]\right]\ln r^c \\
(34) \qquad & +\left[\beta_1(q_0)-\beta_1(q_1)\right]\frac{\ln y-\left[\alpha_0(q_0)+\alpha_1(q_0)\ln r+\frac{1}{2}\gamma_{11}(q_0)(\ln r)^2\right]}{exp(\beta_1(q_0)\ln r)}exp(\beta_1(q_0)\ln r^c) \\
& +\left[\alpha_1(q_0)-\alpha_1(q_1)\right]+\beta_1(q_1)\left[\alpha_0(q_1)-\alpha_0(q_0)\right]-\left[\beta_1(q_0)-\beta_1(q_1)\right]\ln p_2 \\
& = 0
\end{aligned}
$$

This equation has the following form in lnr^c:

$$
(35) \qquad a(q_1,q_0)(\ln r^c)^2+b(q_1,q_0)\ln r^c+c(q_1,q_0,\ln r,\ln y)exp(\beta_1(q_0)\ln r^c)+d(q_1,q_0,\ln p_2)=0
$$

and has no simple analytical solution. Several comments are in order with respect to this procedure of recovery of the choke price system. The first one is that this equation may admit more than one solution. If the problem is correctly specified one should find at least one solution such that $r > r^c$. Such a case provides a simple way to find r^c. Starting with $lnr^c = lnr$, lowering lnr^c leads to a solution to (34). The second one is that (34) may have no solution at all. However, if one observes that the share difference (31) tends to be very close to zero as r^c decreases, one may nevertheless judge that the model is correctly specified. Determining r^c by directly solving (34) fails to recognize that estimated demand equations are only approximations of the true ones. According to this point, a reliable way to determine r^c should rely on some statistical procedure. We propose such a (simple) procedure in Appendix 1. Our last comment is that if r^c is very different from r, it must be used with caution since it may be determined by using the estimated demand out of the domain where they can be considered as good approximations to the true ones.

3. Implementation of the approach in the French case

The data

We use data provided by INSEE (*Institut National de la Statistique et des Etudes Economiques*): the Food Consumption Surveys (*Enquêtes Consommation Alimentaire*). We have currently access to 7 surveys, one every second year from 1979 to 1991. Each survey provides a random sample of the population each year where it is performed. About 9000 households are surveyed each time, excepted in 1989 when only 3000 households were surveyed. Apart from standard demographic and economic characteristics (households' composition, localization, income, *etc*), it provides specific data on food consumption at a rather detailed level. However, the information content of these surveys is very difficult to exploit at the individual household level. Each household is surveyed during only one week, and is asked to report its food purchases in terms of quantity and expenditures. For goods such as bottled water that is generally packaged in France as sets of six bottle of 1 or 1,5 liter this survey method originates serious problems. At the individual household level, relevant econometric models of demand need to take into account infrequency of purchase, corner solutions and censoring[17] features. Even if considerable progress has been performed in this research area, estimation of such models still remains difficult in practice (Gouriéroux, 1989).

A way to avoid these problems is to work with data aggregated over households. However, given the infrequency of purchase and censoring problems that are present in our data, we are not able to use the exact aggregation procedure that is allowed by the Deaton and Muellbauer's (1980b) demand system model. We use a simple aggregation procedure. Thanks to the large number of surveyed households, we define 8 cohorts of six-year age bands and aggregated the households of these cohorts as "representative aggregated households" in each

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[17] Where the purchased quantity is null, prices are not reported.

survey. For example, households whose head was born during the 1944-1950 period were aggregated in each survey thus forming a representative household whose head was approximately 28 years old in 1979, 30 years old in 1981, etc. Such a procedure is used for the construction of pseudo-panels (Deaton, 1985). However, we do not construct a pseudo-panel, i.e. a set of pseudo- or mean individuals for each defined cohort in each survey, we construct a set of representative households for each defined cohort. The main advantage of the aggregation procedure is that it overcomes the infrequency of purchase and censoring problems. The main advantages of the by cohort aggregation procedure are threefold. Firstly, it generates more "aggregated observations" than does a simple global aggregation procedure. Secondly, it allows aggregation of households that are approximately at the same point of their respective life-cycle. Ultimately, this allows comparisons of "similar" households across time. This is important where welfare comparisons are to be made (Pollack, 1991). Thirdly, it allows the specification of dynamic models, a feature not allowed by use of series of independent cross-sections (Deaton, 1985). We eliminate the aggregated "representative households" that represent less than 100 individuals.

Formally, starting with N_{ct} individual household demands of the form:

$$(36)\quad w_{1ci,t} = \alpha_1 - \beta_1\alpha_0 + \gamma_{11}\,ln\,r_t + \beta_1\left[ln\left(\frac{y_{ci,t}}{p_{2,t}}\right) - \alpha_1\,ln\,r_t - \frac{1}{2}\gamma_{11}(ln\,r)_t^2\right] + e_{ci,t}$$

$$ci = 1,\ldots,N_{ct}$$

for cohort c in survey t, we end with the demand of a single representative household of the form:

$$(37)\quad w_{1C,t} = \alpha_1 - \beta_1\alpha_0 + \gamma_{11}\,ln\,r_t + \beta_1\left[ln\left(\frac{y_{C,t}}{p_{2,t}}\right) - \alpha_1\,ln\,r_t - \frac{1}{2}\gamma_{11}(ln\,r)^2{}_t\right] + e_{C,t}$$

with:

(38) $$w_{1C,t} \equiv \frac{\sum_{ci=1}^{Nct} p_{1ci,t} x_{1ci,t}}{\sum_{ci=1}^{Nct} y_{ci,t}} \quad \text{and} \quad y_{C,t} \equiv \sum_{ci=1}^{Nct} \frac{y_{ci,t}}{N_{c,t}}$$

Thus, the bottled water budget share of the "representative hosuehold" ($w_{1C,t}$) is the share bottled water total expenditure of the cohort in the soft drink total expenditure of the cohort. The soft drink expenditures of the "representative household" are simply the mean of the soft drink expenditures of the cohort represented by the considered "representative household ". The price variables are provided by INSEE as standard indices at the country level.

The tap quality "indicators"

Having no relevant measure of tap water quality over the studied period, we defined three areas in France by grouping the 95 *départements* (French administrative areas) according to our prior on the quality of their supplied water and its evolution. Hence, we defined three sub-surveys, one for each area. The aggregation procedure was used for each sub-survey, giving us three sets of 60 "representative households". We used geological and topological arguments as well as observations of the bottled water consumption means per *département.* These three areas are represented in Figure 2. As such, our quality indicators are simply dummy variables.

We first defined what we called the Mountain Area (MA). Since supplied water in this area directly comes from preserved sources, tap water quality can be presumed as very good and constant over the 1979-1991 period. Households in this area represent about 25% of the surveyed population. Their bottled water consumption is very low at the beginning of the period (around 1 liter *per* household *per* week) and, despite a slight increase during the period, remains low in 1991 (around two liters *per* household *per* week) (See Figure 3a). This region is used as the reference area for drinking water quality since one may reasonably assume that tap water quality is (and is perceived as) invariantly good in this area during the 1979-1991 period. An eventual structural change in soft drink demand in this area, i.e. a change not originated by price or income changes, may not be due to tap water quality. It may rather be originated by bottled water and/or soda advertising. Thus, if it exists, this structural change may certainly also have affected the demands of the other regions along the same ways.

We next defined the Industrial and Agricultural Plain Area (IAPA). This area is characterized by a high population density. It concentrates a large part of the French industries. It also includes the Large Paris Basin, the most fertile region of France where intensive agriculture is common practice since the early sixties. It is the area where the supplied water quality can be considered as the lowest, at least at the beginning of the period. It might have slightly decrease in consumers' minds. In this area, industrial and agricultural pollution problems are certainly combined with hard water problems, at least in the Large Paris Basin which is characterized by chalky grounds. Households in this area represent about 50% of the surveyed population. Their bottled water consumption is the highest at the beginning of the period (from around 2,5 liters *per* young household *per* week to around 3,5 liters *per* old household *per* week) and, due to a significant increase during the period remains one of the highest in 1991 (from around 3,5 liters *per* young household *per* week to around 5 liters *per* old household *per* week) (See Figure 3b).

Finally, we defined the "Big West" Area (BWA). This area is characterized by a medium population density and a medium industrial activity. It is very heterogeneous from a geological point of view. Households in this area represent about 25% of the surveyed population. Their bottled water consumption lies in between that of the other areas at the beginning of the period (around 2 liters *per* household *per* week). Due to a dramatic increase during the period, it is one of the highest in 1991 (from around 3 liters *per* young household *per* week to around 4,5 liters *per* old household *per* week) (See Figure 3c). Anticipating the econometric analysis, it seems that a structural change has affected bottled water consumption in this region. If it is originated by tap water quality, tap water quality may be considered as medium-good at the beginning of the period, while it seems to be one of the lowest at the end of the period. In order to simplify our application, this area is not considered in what follows.

The econometric model and estimation procedure

All figures showing bottled water consumption indicate a positive correlation according to the age of the household (see Figure 3a-3c). Similarly, the figures representing the consumption of other soft drinks (juices, sodas, sparkling water) tend to indicate a negative correlation according the age of the household (see Figure 4a-4c). After several specification researches, this effect is introduced in equation (37) by transformation of the parameter a_1 into a linear function of the mean of the cohort household heads' age (age_{Ct}):

(39)
$$\begin{aligned} w_{1C,t} = {} & (a_{10} + a_{11} age_{C,t}) - b_1 a_0 + g_{11} \ln r_t \\ & + b_1 \left[\ln\left(\frac{y_{C,t}}{p_{2,t}}\right) - (a_{10} \ln r_t + a_{11}(age_{C,t} \ln r_t) - \frac{1}{2} g_{11} (\ln r)^2{}_t \right] + e_{C,t} \end{aligned}$$

Quadratic terms in *age* where not found significant.

Structural changes are specified as dummy variables affecting the b_1 parameter. In the specification (34), this parameter becomes:

(40) $b_1 = b_{10} + b_{11} T(s)$ where $T(s) = 0$ if $t < s$ and $T(s) = 1$ otherwise .

In this case, a test of structural change is simply a standard test of the statistical significance of the b_{11} parameter estimate.

The demand equation of bottled water (34)-(35) is estimated for each sub-survey aggregated data set. We used two stage nonlinear least squares estimators in order to take into account the eventual endogeneity of the soft drink expenditure variable (*y*). Total income was used as instrumental variable in addition to price and age (and their combinations) variables that are exogenous. At least price variable are assumed as such. The econometric model is thus just identified. The parameter s of (40) is estimated by grid search. Finally, the error terms $e_{C,t}$ are assumed to be independent and identically distributed.

It is also well-known that where the price variation is limited, as it is the case here, the practical identification of a_0 from a_1 is problematical. This lack of identification may be solved by imposing constraints on either a_0 or a_1 (Blundell, Pashardes and Weber, 1993, Deaton and Muellbauer, 1980b). Here, we found that bottled water is an inferior good. Furthermore, bottled water is equal to about 85% of the total soft drink quantities purchased by the oldest households. Provided that a_1 represents the share of bottled water in soft drink expenditures for the poorest households, we adopt $a_1 = 1$ for the oldest household as the identifying constraint. Given an appropriate normalization of the variable *age*, this constraint is simply introduced in the estimation procedure by imposing $a_{10} = 1$.

4. Results

The demand function estimation

As no structural change was found for the MA and the IAPA, the bottled water demand is simply estimated without equation (40).

Table 1. Estimates (and parameter estimator standard deviation estimates) of the parameters of the bottled water demand for the two considered areas

Parameters	Mountain Area	Industrial and Agricultural Plain Area
a_0	1.29	4.95
	(2.14)	(0.52)
a_{10}	1	1
	(-)	(-)
a_{11}	$2.72\ 10^{-3}$	$6.37\ 10^{-3}$
	$(9.46\ 10^{-4})$	$(9.80\ 10^{-4})$
g_{11}	-0.38	-0.59
	(0.35)	(0.34)
b_1	-0.12	-0.24
	(0.05)	(0.07)
R^2	0.50	0.55

Two main points are in order. Firstly, only two of the MA parameter estimates are statistically significant at the 5% or 10% level while three of the IAPA parameter estimates are significant at the 1% level, the last one being significant at the 1% level. Secondly, Figure 1 and Figure 5 show that the real price of soft drinks decreased by 10% in 1989 when compared to 1988. This corresponds to the decrease from 18,6% to 5,5% of the value added tax of these goods in 1989. Hence, the price effects may partially embody the eventual structural change specificied as in (40). As expected, the subsistence (natural logarithm) cost for soft drink a_0 is much higher in the IAPA than it is in the MA.

In the MA, the estimated own price elasticities of the Hicksian[18] demand of bottled water range from -1.4 at the beginning of the period to -1.7 in 1991. In the IAPA, the estimated own price elasticities of the Hicksian demand of bottled water range from -1.5 at the beginning of the period to -2 in 1991. They slightly depend on households' age, being larger in absolute value for the younger households. In the IAPA, the estimated elasticity of the bottled water demand with respect to total soft drink expenditure is equal to 0.5 in 1979 and decreases to be equal to 0.3 in 1991. In the MA, the estimated elasticity of the bottled water demand with respect to total soft drink expenditure decreases from 0.7 to be equal to 0.6. This evolution may be explained by the dramatic decrease in the consumption of low quality alcoholic beverages observed in France during the period. These beverages seem to be close substitutes of the other soft drinks at the beginning of the period. Campaigns against alcohol abuse may have led to the exclusion of beers and wines out of the thirst-quenching beverage traditional group by the French consumers. Becoming the only "safe" goods remaining for thirst-quenching, soft drinks may have become more necessary for the French consumers. This also provides a justification in favor of the value added tax cut decided by the French Government in 1989. The difference between the expenditure elasticities in the MA and in the IAPA would indicate that bottled water appears more necessary in areas supplied with low tap water quality. This is consistent with the hypothesis of a substitution between bottled water and tap water due to quality. The subsistence cost a_0 is higher in the IAPA than in the MA. This is also consistent with our hypothesis. However, it can be noted that the (unconditional) subsistence utility levels may be different in both areas.

[18] Compensated on the soft drink utility.

Globally, these results seem intuitive. However, they also show that our specifications of the structural change must be improved or, at least, carefully checked.

The fact that no structural change was found in the MA would indicate that no global factor has affected the pattern of the demand for bottled water within the soft drink group. Global factors such as real price effects or the decrease in alcoholic demand, have similarly affected the demand for all soft drinks. However, it can be noted that this changes may affect differently the young and the old households. Similarly the fact that no structural change was found in the IAPA also suggests that the perception of the tap water quality has not changed in this area. Thus, a non negligible part of the increase in the demand of bottled water in this area can be attributed to factors as well as to the decrease in beer and wine consumption.

The estimated "true cost of drinking index"

In order to compare welfare across regions, we take as reference the situation in the IAPA. The "choke" price ratios are computed according to the simplest method, i.e. by directly solving the equality of the Hicksian demand of bottled water in the IAPA with that of the same household in the MA, the reference utility level being the one actually achieved by the household living in the IAPA. The estimated "choke" price ratios show that if the bottled water price is cut in a range of 83%-92% of its initial level, an household living in the MA would achieve the the actual utility level of a similar household living in the IAPA with the same Hicksian demands for soft drinks. In this context, both households incure the same cost.

In this application, we just compute the cost ratio:

$$(41) \qquad \frac{C(r,p_2,U_{IAPA};q_{MA})}{C(r,p_2,U_{IAPA};q_{IAPA})} = \frac{C(r,p_2,U_{IAPA};q_{MA})}{y_{IAPA}}$$

for each of the representative household of the IAPA to compare the situation of households in the MA with that of representative household in the IAPA. This ratio is the true price subindex of soft drink in MA with the soft drink utility level reached in the IAPA as reference. For short, we label this ratio, the true cost of drinking index (TCDI) in the MA.

Figure 6 shows the TCDI as a function of age for the eight cohorts. For households in the MA region it lies between 0.55 and 0.61 at the end. It is always inferior to 1, suggesting that achieving a given soft drink utility level is cheaper in the MA than it is in the IAPA. This result is consistent with our formalization of the effects of tap water quality in the soft drink utility level. Results also indicate that older households generally have lower TCDIs, at least at the beginning of the period. An explanation could be that they have more health considerations when choosing soft drinks. Moreover, younger households (especially those with children) may prefer soft drinks such as sodas and juices and may less rely on water to satisfy their soft drink utility than the older households do. Thus a low tap water quality may affect more importantly old households than young households. Secondly, Figure 6 also indicates that the TCDI tends to slightly increase at the end of the period for the older households while it tends to slightly decrease for the younger ones. This may be originated by the price decrease in soft drink prices that allows household to purchase more soft drinks, and especially bottled water and, as a result, to less rely on tap water consumption. The actual ratio: current soft drink expenditures in the MA over current soft drink expenditures in the IAPA is close but generally (excepted in 1981) superior to the TCDI. This suggests that the households in the MA have slightly higher soft drink utility that the households in the IAPA. As explained in the previous section, households in the IAPA face a relatively high true soft drink price index and, as a result, allocate their income in favor of other consumptions than those of soft drinks. For them, soft drink utility is a relatively expensive "good". Thank to this flexibility in the income allocation process, the willingness to pay of households in the IAPA for tap quality equivalent to that of the MA would be lower than:

(42) $$C(r, p_2, U_{MA}; q_{IAPA}) - C(r, p_2, U_{MA}; q_{MA})$$

as suggested by Hanemann and Morey's (1992) result. However, our results suggest that the households' demand for soft drink utility is rather inelastic, implying that the estimated differences $C(r, p_2, U_{MA}; q_{IAPA}) - C(r, p_2, U_{MA}; q_{MA})$ would provide a good approximation of the corresponding willingness to pay.

Conclusion

The fact that the drunk tap water quantities are genrally unknown preclude direct use of the standard "public good as quality characteristic of a privately consumed good" approach to value tap water quality. Moreover, given that bottled water is not only drunk to eliminate tap water consumption, the standard "averting expenditure approach" cannot be used. This led us to develop a theoretical framework that is adapted to our objectives and data. As any indirect method of public good measurement, it relies on some maintained assumptions related to the relationships between the good to be valued and the observed market good demands. We present these assumptions (using the "weak complementarity" and "weak substitutability" concepts) and argue their plausibility. A crucial point for the use of indirect valuation methods is the existence of a particular situation where the public good to be valued does not affect consumers' behavior. Generally, expenditure functions that allow welfare comparisons can't be fully recovered from observed data. The situation where the public good to be valued does not affect consumer's welfare is used to solve this problem of identification. We show that our model provide arguments in favor of the existence of a price regime where such a situation occurs.

Given that our model rests on many unobservable variables, we can't specify a structural econometric model that embodies all the features of the theoretical model as it is usually done in environmental good valuation studies. In order to overcome this problem, we use the analogy that exists between the estimation of public good values and that of equivalence scales.

Estimation of equivalence scales generally relies on the specification of a demand system model is that is explicitly derived from a flexible parametric cost function. In the studies dealing with equivalence scales, the expenditure function identification problem is generally solved by imposing severe restrictions on households' preferences. The existence of a price regime where the quantity or the quality of the public good to be valued does not affect consumer's welfare is shown to solve this identification problem without further restrictions on households' preferences.

Our results appear relatively intuitive. They would indicate that consumers living in the French mountain areas where tap quality is good can reach the utility level of identical consumers living in the French industrial and agricultural plains while spending much less on soft drinks. In this context, the expenditures of the former range from 55% to 65% of the expenditures of the later. Provided that this ratio appears to be close to its analog in actual expenditures, we conclude that the French consumers' demand of soft drink partial utility is rather inelastic. This would imply that our partial measure of welfare can be considered as a rather good approximation to the true one.

However, it must be noted that our results must be interpreted with caution. Due to data constraints we had to estimate rather simple demand functional forms as well as to use aggregated data.

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Appendix 1: A simple "statistical" method to recover the choke price

A crucial step of our approach is the estimation of a "choke" price ratio r^c that ultimately allows the comparison of the conditional preference orderings denoted by the utility levels u_q. As explained above, for y, p_2, q_1 and q_0, determining the "choke" price system defined as the price ratio r^c by using condition (18) is equivalent to solve the following equation:

$$
\begin{aligned}
& \mathrm{b}_1(q_1)\frac{1}{2}\left[\mathrm{g}_{11}(q_1)-\mathrm{g}_{11}(q_0)\right](ln\, r^c)^2 \\
& +\left[\left[\mathrm{g}_{11}(q_0)-\mathrm{g}_{11}(q_1)\right]+\mathrm{b}_1(q_1)\left[\mathrm{a}_1(q_1)-\mathrm{a}_1(q_0)\right]\right] ln\, r^c \\
& +\left[\mathrm{b}_1(q_0)-\mathrm{b}_1(q_1)\right]\frac{ln\, y-\left[\mathrm{a}_0(q_0)+\mathrm{a}_1(q_0)\, ln\, r+\frac{1}{2}\mathrm{g}_{11}(q_0)(ln\, r)^2\right]}{exp(\mathrm{b}_1(q_0)\, ln\, r)} exp(\mathrm{b}_1(q_0)\, ln\, r^c) \\
& +\left[\mathrm{a}_1(q_0)-\mathrm{a}_1(q_1)\right]+\mathrm{b}_1(q_1)\left[\mathrm{a}_0(q_1)-\mathrm{a}_0(q_0)\right]-\left[\mathrm{b}_1(q_0)-\mathrm{b}_1(q_1)\right] ln p_2 \\
& = 0
\end{aligned}
$$

This procedure of recovery of the choke price ratio simply consists in solving this equation in lnr^c. Driscoll (1994) shows that, for any strictly positive price system and soft drink expenditure, the AI expenditure function can be interpreted as a Taylor's approximation to the true one, i.e. that the AIDS can be interpreted as a Taylor's approximation to the true demand system. The main drawback of the previous approach, is that it fails to recognize that estimated demand equations are only approximations of the true ones. According to this point, a reliable approach to determine r^c should rely on some statistical procedure. We propose such a (simple) procedure in this appendix.

In what follows, $\boldsymbol{\theta}_q$ denotes the parameter vector $\left[\mathrm{a}_0(q),\mathrm{a}_1(q),\mathrm{b}_1(q),\mathrm{g}_{11}(q)\right]'$, $\mathbf{X}_q$ denotes the variable vector $\left[w_1(q), ln\, r, (ln\, r)^2, ln\left(\frac{y(q)}{p_2}\right)\right]'$, $\mathbf{Z}_q$ denotes the instrumental variable vector $\left[1, ln\, r, (ln\, r)^2, ln\, I(q)\right]'$, where $lnI(q)$ is the natural logarithm of the (correctly aggregated) households' income, and $\mathbf{C}(s)$ denotes the variable vector

$\left[\ln s, \ln r, \ln p_2, \ln y(q_0)\right]'$, where s is a given value for the price ratio to be computed r^c. The two stages nonlinear least square estimator of $\boldsymbol{\theta}_q$ based on the model:

$$w_{1C,t} = \alpha_1 - \beta_1\alpha_0 + \gamma_{11} \ln r_{C,t} + \beta_1 \left[\ln\left(\frac{y}{p_2}\right)_{C,t} - \alpha_1 \ln r_{C,t} - \frac{1}{2}\gamma_{11}(\ln r)^2{}_{C,t} \right] + e_{C,t}$$

where $\mathbf{Z}$ is used as the instrument vector can be defined as the optimal[19] Generalized Method of Moments estimator of $\boldsymbol{\theta}_q$ based on the orthogonality conditions:

$$E\left[\mathbf{H}(\mathbf{Z},\mathbf{X};\boldsymbol{\theta}_q)\right] \equiv E\left[\mathbf{Z}e(\mathbf{X};\boldsymbol{\theta}_q)\right] = \mathbf{0}\,.$$

This estimator is denoted by $\tilde{\boldsymbol{\theta}}_{q,N}$, N being the total number of representative households in each area. Under the assumption that the observations are i.i.d. and other standard assumptions (see Hansen, 1982), this estimator is strongly consistent and its asymptotic distribution is given by:

$$\sqrt{N}\,(\tilde{\boldsymbol{\theta}}_{q,N} - \boldsymbol{\theta}_q) \xrightarrow[N_q \to +\infty]{} \mathbf{N}\left(\mathbf{0}, \boldsymbol{\Sigma}_q\right)$$

where:

$$\boldsymbol{\Sigma}_q \equiv \left(\mathbf{J}_q{}' \boldsymbol{\Omega}_q^{-1} \mathbf{J}_q\right)^{-1},$$

$$\mathbf{J}_q \equiv E\left[\frac{\partial\, \mathbf{H}(\mathbf{Z},\mathbf{X};\boldsymbol{\theta}_q)}{\partial\, \boldsymbol{\theta}'}\right] = -E\left[\mathbf{Z}\frac{\partial\, w_1(\mathbf{X};\boldsymbol{\theta}_q)}{\partial\, \boldsymbol{\theta}'}\right]$$

and:

$$\boldsymbol{\Omega}_q \equiv E\left[\mathbf{H}(\mathbf{X},\mathbf{Z};\boldsymbol{\theta}_q)\mathbf{H}(\mathbf{X},\mathbf{Z};\boldsymbol{\theta}_q)'\right].$$

Provided that the subsamples of representative households in different areas (e.g., for q_0 and q_1 where $q_0 \neq q_1$) are independent, we have:

---

[19] See Newey (1993) or Gouriéroux and Monfort (1989).

$$\sqrt{N}\begin{bmatrix} \hat{\boldsymbol{\theta}}_{q0,N} - \boldsymbol{\theta}_{q0} \\ \hat{\boldsymbol{\theta}}_{q1,N} - \boldsymbol{\theta}_{q1} \end{bmatrix} \equiv \sqrt{N}\left[\hat{\boldsymbol{\theta}}_N - \boldsymbol{\theta}\right] \xrightarrow[N\to+\infty]{} \mathbf{N}\left(\mathbf{0}, \begin{bmatrix} \boldsymbol{\Sigma}_{q0} & 0 \\ 0 & \boldsymbol{\Sigma}_{q1} \end{bmatrix}\right) \equiv \mathbf{N}(\mathbf{0}, \boldsymbol{\Sigma})$$

Noting the equation to be solved as:

$$\psi(\boldsymbol{\theta}, \mathbf{C}(s)) = 0$$

and using Slutsky's Theorem, one easily obtains that:

$$\sqrt{N}\left(\psi(\hat{\boldsymbol{\theta}}_N, \mathbf{C}(s)) - \psi(\boldsymbol{\theta}, \mathbf{C}(s))\right) \xrightarrow[N\to+\infty]{} \mathbf{N}(0, \mathbf{W}'\boldsymbol{\Sigma}\mathbf{W})$$

where:

$$\mathbf{W} \equiv E\left[\frac{\partial \psi(\boldsymbol{\theta}, \mathbf{C}(s))}{\partial \boldsymbol{\theta}}\right].$$

Given the properties of $\hat{\boldsymbol{\theta}}_N$, the matrices $\boldsymbol{\Sigma}$ and $\mathbf{W}$ can be consistently estimated by their sample counterparts $\hat{\boldsymbol{\Sigma}}_N$ and $\hat{\mathbf{W}}_N$ taken at $\hat{\boldsymbol{\theta}}_N$.

A simple Wald type test of:

$$\mathrm{H}_0 : \psi(\boldsymbol{\theta}, \mathbf{C}(s)) = 0 \quad \textit{versus} \quad \mathrm{H}_a : \psi(\boldsymbol{\theta}, \mathbf{C}(s)) \neq 0$$

can be constructed with the test statistic:

$$\hat{T}_N^W(\mathbf{C}(s)) \equiv \frac{\left[\psi(\hat{\boldsymbol{\theta}}_N, \mathbf{C}(s))\right]^2}{\hat{\mathbf{W}}_N' \hat{\boldsymbol{\Sigma}}_N \hat{\mathbf{W}}_N}$$

and its associated critical region at the α % confidence level:

$$\left\{\hat{T}_N^W(\mathbf{C}(s)) > \chi^2_{1-\alpha}(1)\right\}.$$

Under the hypotheses that:

$$\left|\psi(\boldsymbol{\theta}, \mathbf{C}(r))\right| \neq 0$$

and that $\left|\psi(\boldsymbol{\theta}, \mathbf{C}(s))\right|$ decreases as *s* decreases starting from *r*, one can recover the choke price ratio r^c as:

$$r^c \equiv \underset{S}{Max}\left\{s \,/\, \hat{T}_N^W(\mathbf{C}(s)) \leq \chi^2_{1-\alpha}(1)\right\},$$

i.e., the highest value of s for which the test of H_0 is accepted at the α confidence level.

It should be noted that if r^c is very different from r, this estimated choke price ratio must be used with caution since it may be determined by using the estimated demand out of the domain where they can be considered as good approximations to the true one, i.e. out of the neighborhood of the point of approximation.

Figure 1. Bottled water consumption and price in France (French Francs 1980 per capita and deflated price indices in base 100 in 1980)

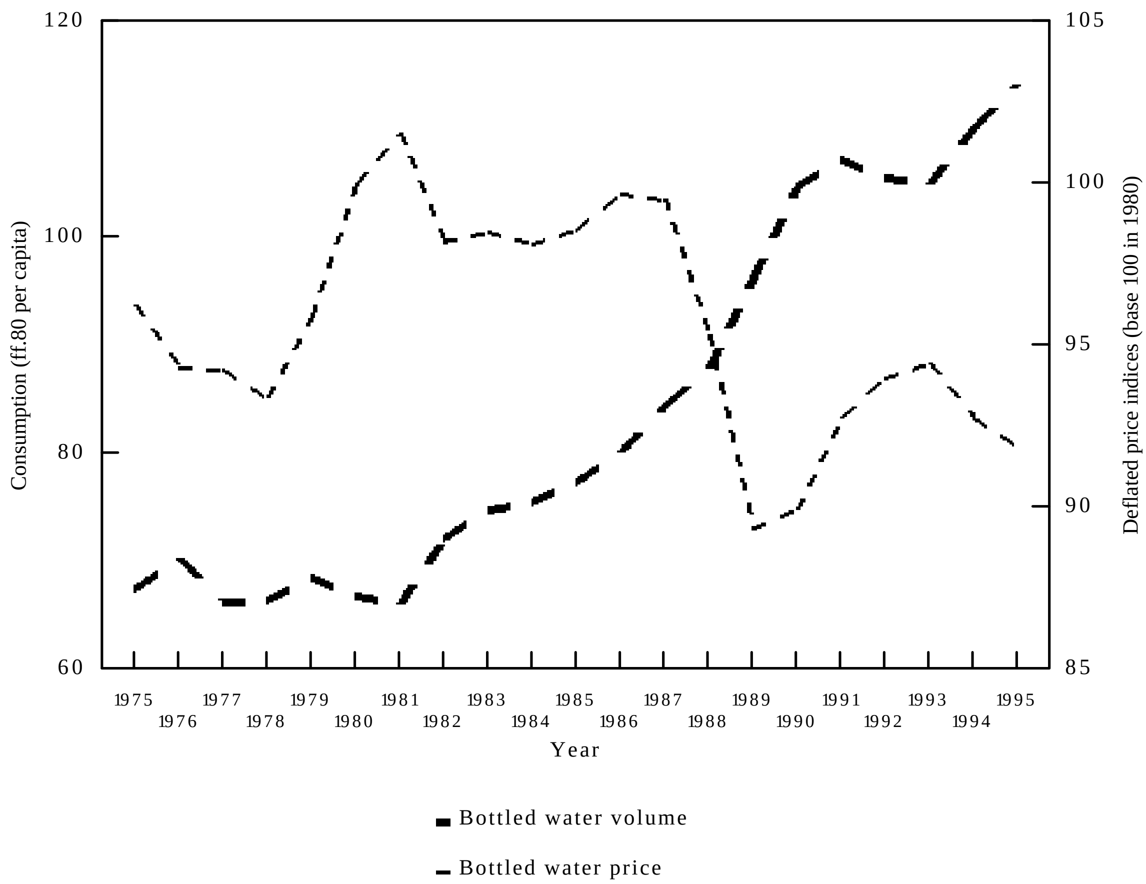

Figure 2. Areas of France defined according to presumed similarities and/or differences in tap water quality

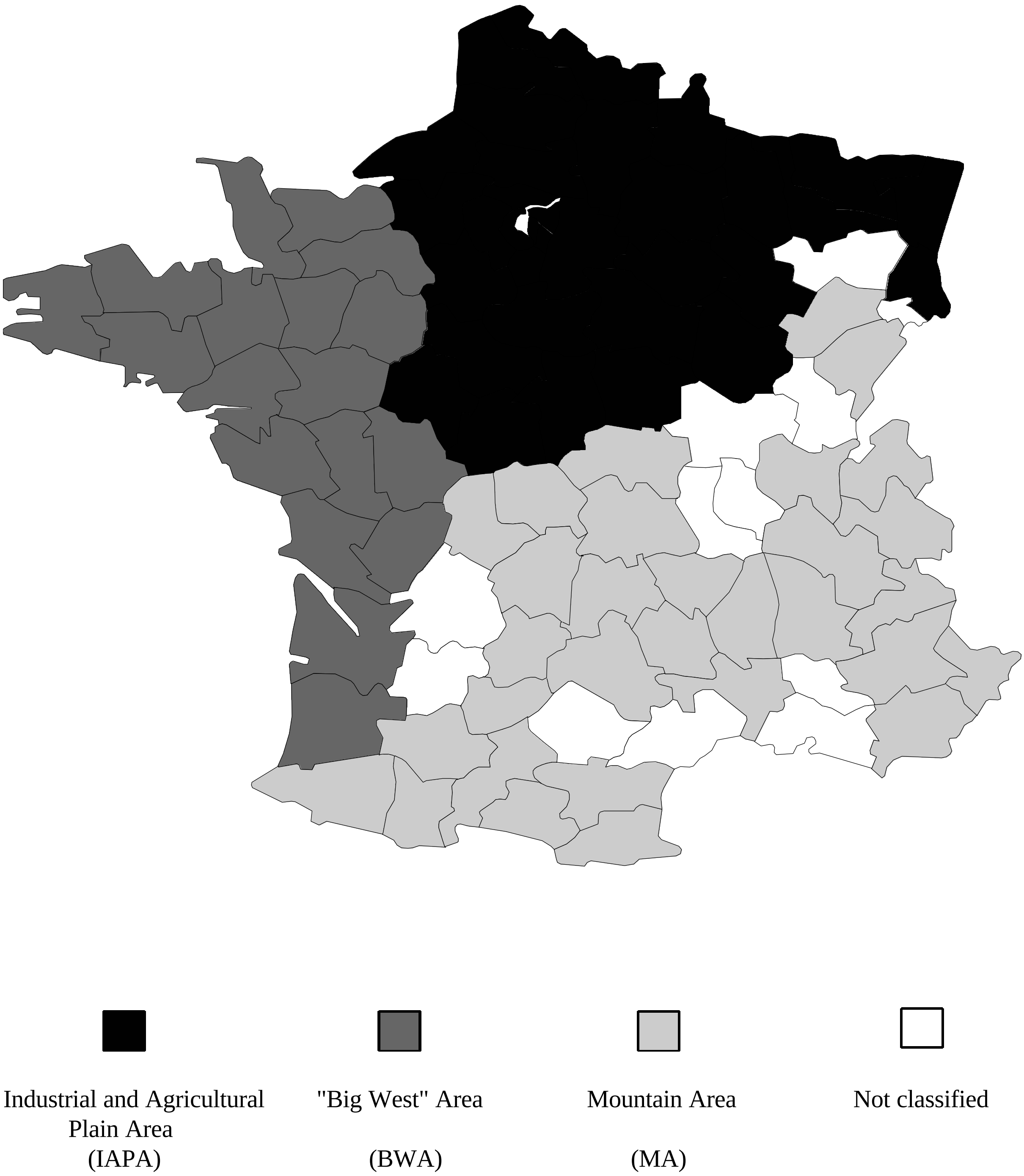

Figure 3a. Bottled water purchase mean in the Mountain Area (cl per household per week)

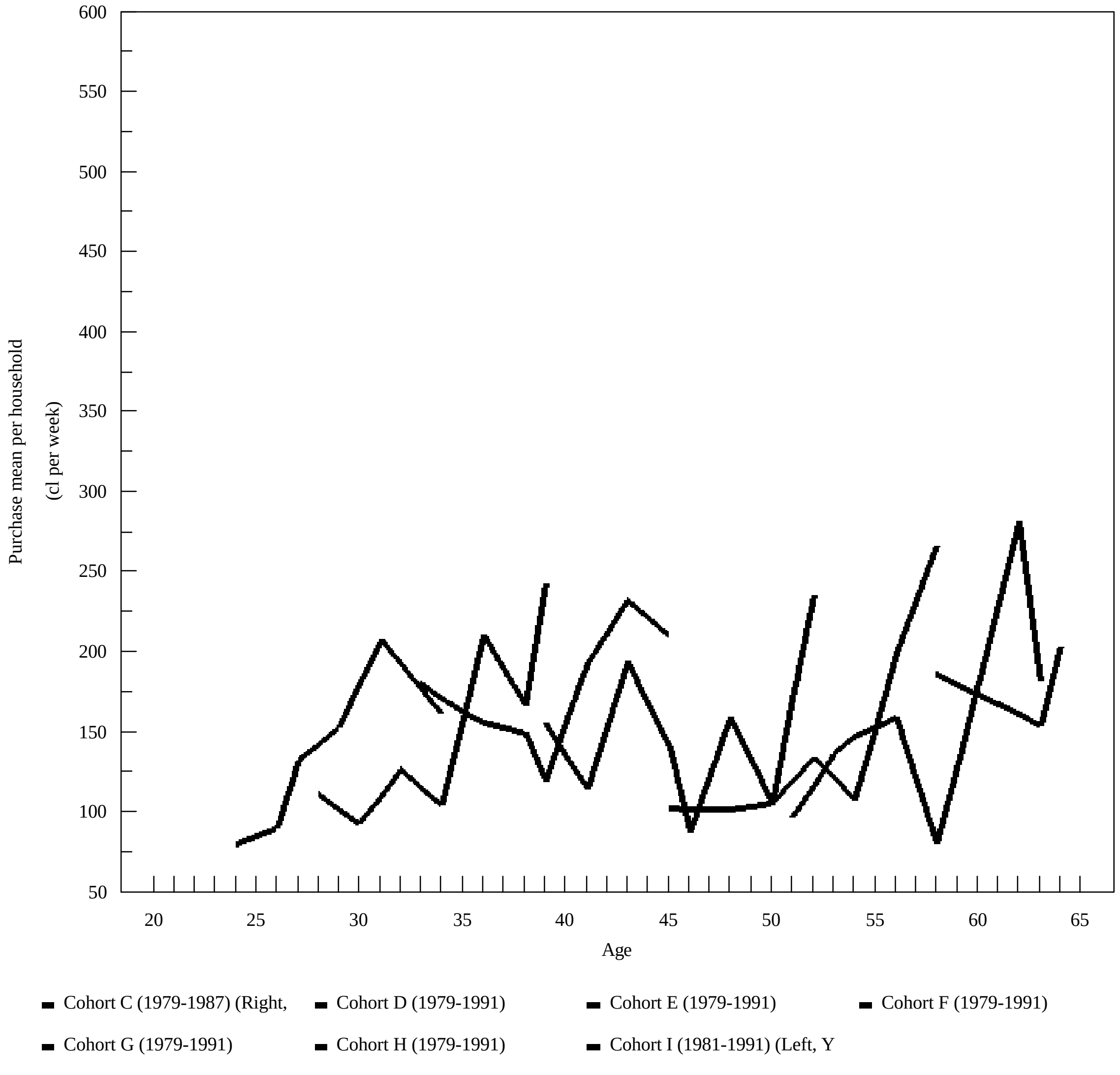

Figure 3b. Bottled water purchase mean in the Industrial and Agricultural Plain Area (cl per household per week)

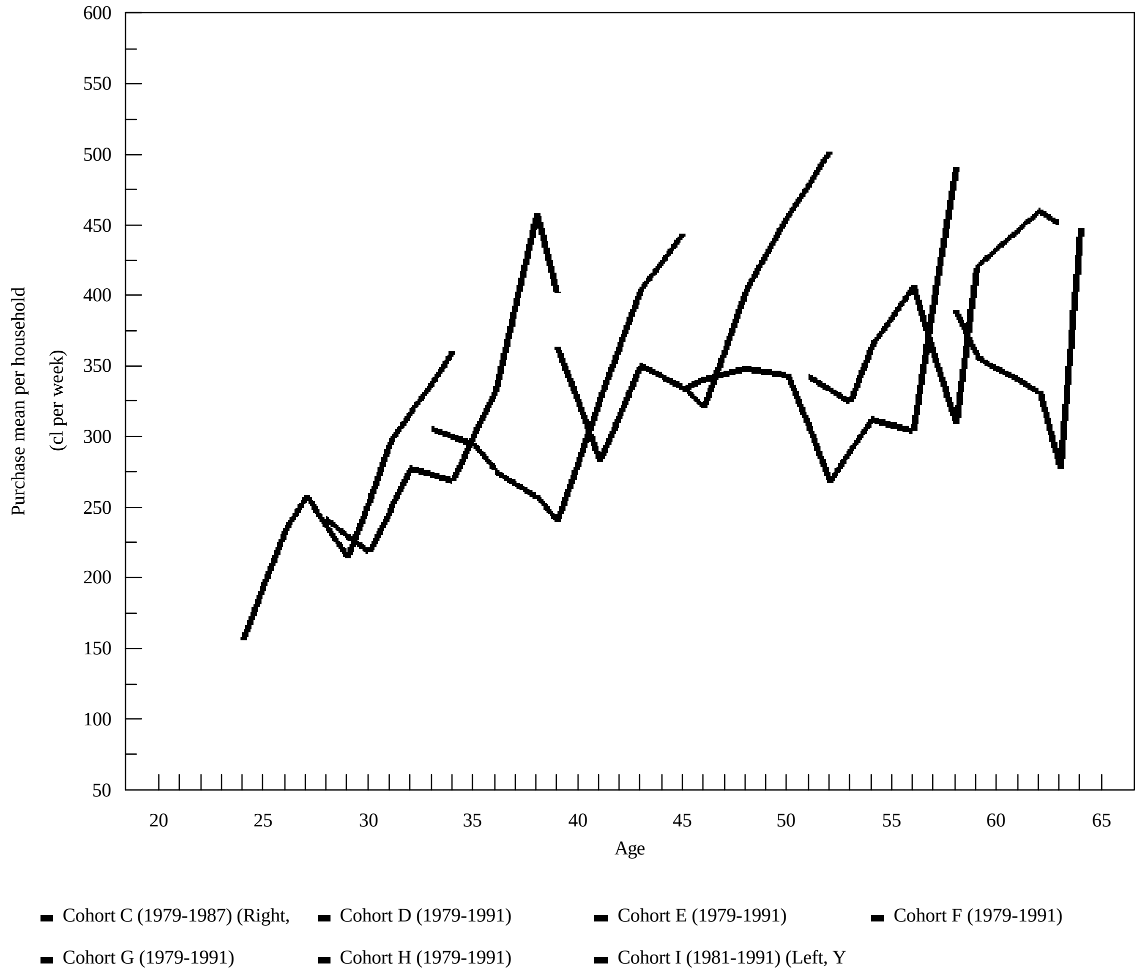

Figure 3c. Bottled water purchase mean in the "Big West" Area (cl per household per week)

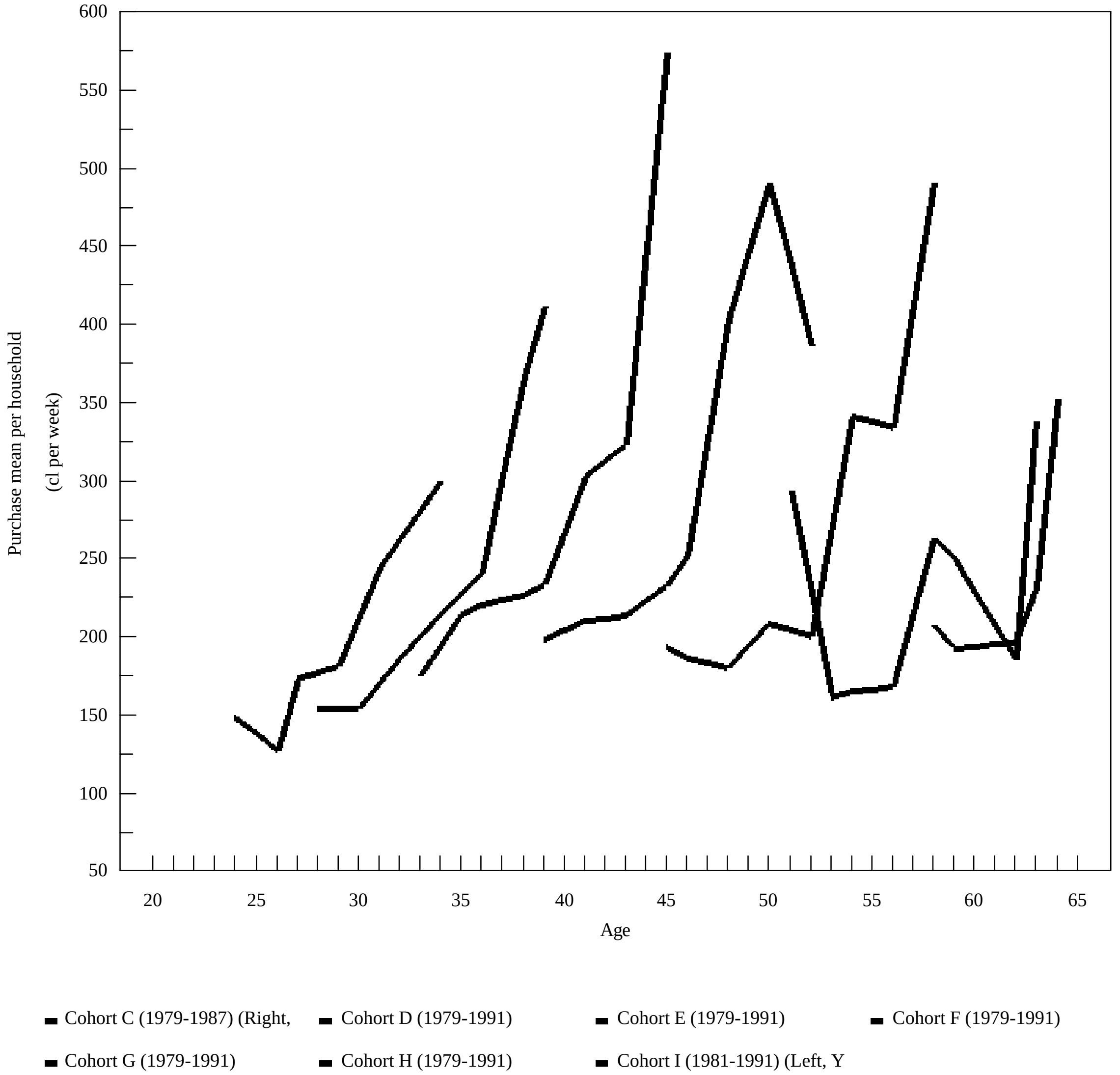

Figure 4a. Soft drink (excepted bottled water) purchase mean in the Mountain Area (cl per household per week)

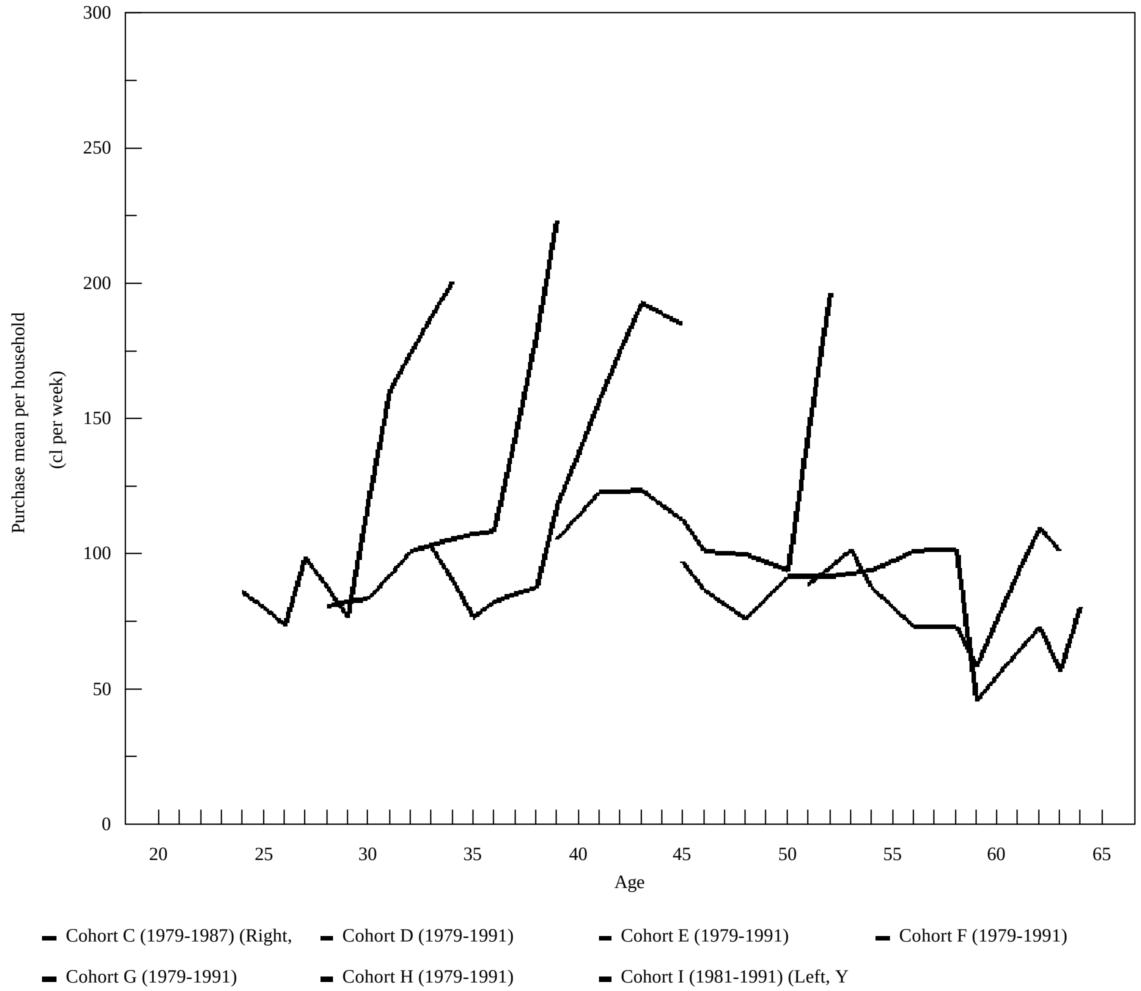

Figure 4b. Soft drink (excepted bottled water) purchase mean in the Industrial and Agricultural Plain Area (cl per household per week)

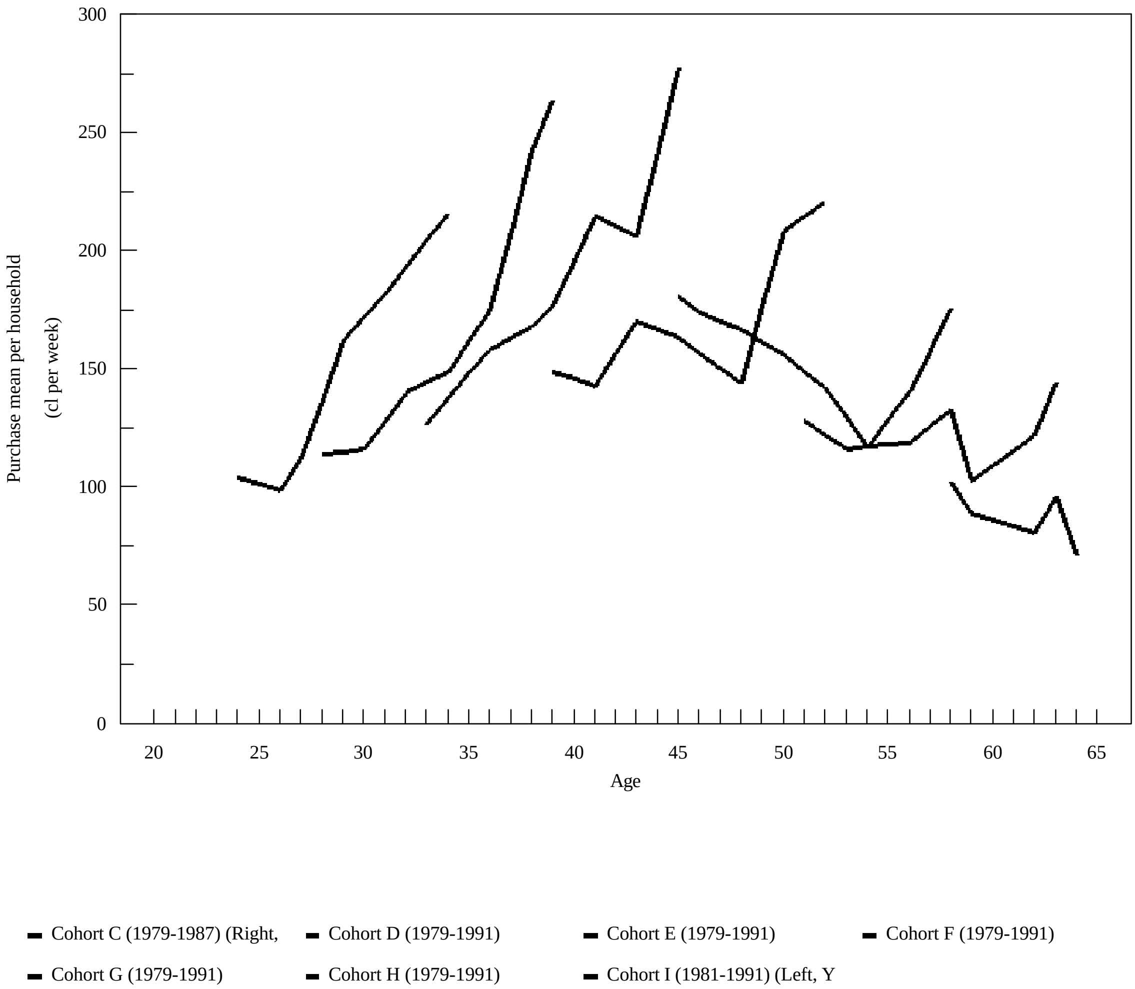

Figure 4c. Soft drink (excepted bottled water) purchase mean in the "Big West" Area (cl per household per week)

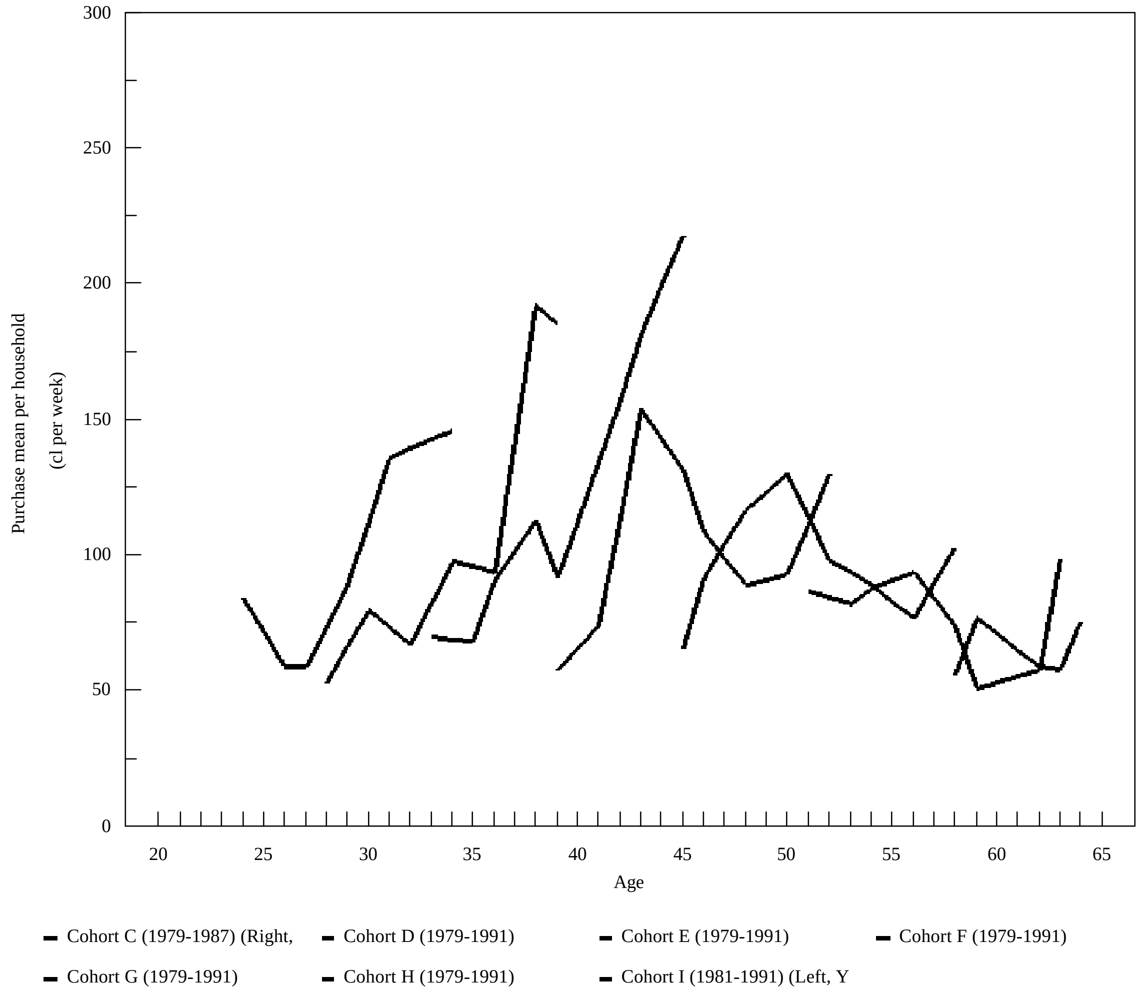

Figure 5. Soft drink consumption and price in France (French Francs 1980 per capita and deflated price indices in base 100 in 1980)

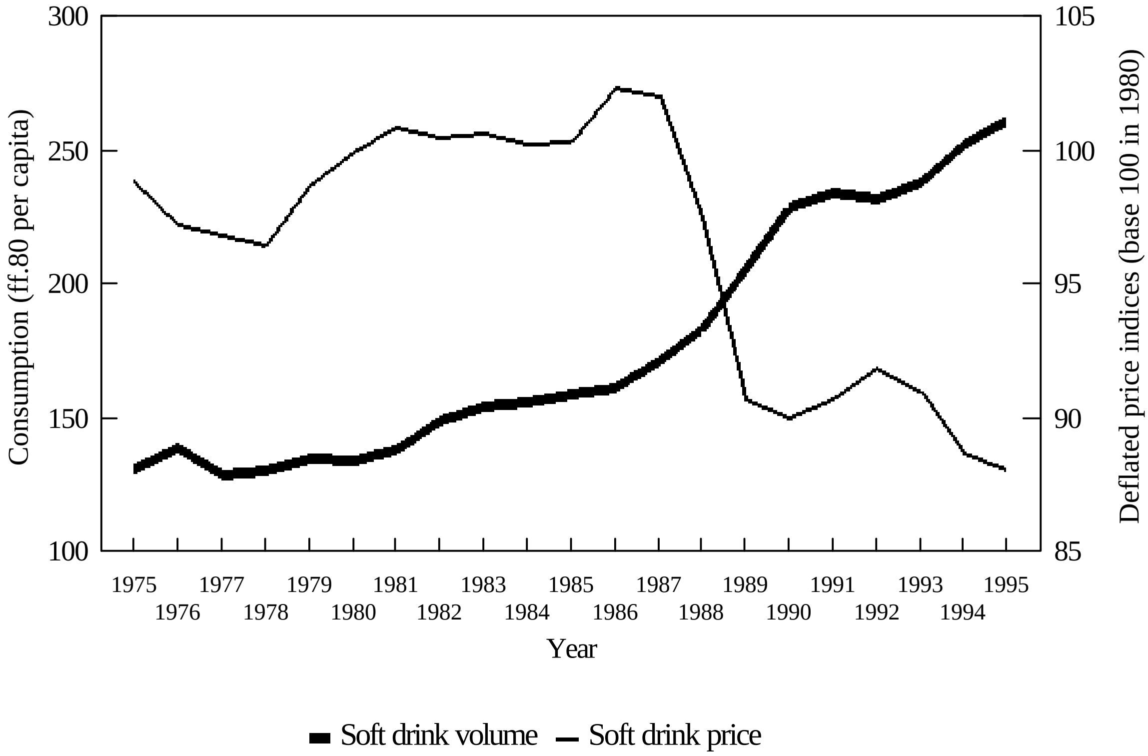

Figure 6. True cost of drinking in the MA, the reference state being the IAPA situation