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**THE FOOD PRICES / BODY MASS INDEX RELATIONSHIP:
THEORY AND EVIDENCE FROM A SAMPLE OF FRENCH ADULTS.**

Christine Boizot-Szantaï and Fabrice Etilé*

INRA – CORELA, 65 Boulevard de Brandebourg, 94205 Ivry-sur-Seine cedex, France.

Tel: (33)-1-49-59-69-86. E-mail: etile@ivry.inra.fr.



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Abstract

What would be the effect of a "fat tax" on obesity? This paper shows that the sign of the price-weight correlation is unclear, as variations of food price have a direct effect on weight through changes in energy intakes, and an indirect (income) effect that affects energy expenditure. Food expenditures data are used to examine the link between the prices of 16 food groups and the distribution of the Body Mass Index among French adults. We find positive correlations for ready-meals and snacks, and negative correlations for sea products and fruits. It is thus unlikely that the epidemic of obesity will react in the short-term to nutritional taxes.

Keywords: obesity, fat tax, price policies, quantile regressions.

J.E.L. classification: D1, H3, I1.

The Food Prices / BMI Relationship: Theory and Evidence from a Sample of French Adult.

Christine Boizot and Fabrice Etilé

Introduction

Trends in obesity have become in the last decade a major health concern for many developed and developing countries. Obesity is associated with a number of co morbidities, including heart disease and diabete, which represent an increasing burden. Although the prevalence of obesity is by far lower in France than in the UK or the USi, it has been found that the medical cost of obesity was at least 1 billions euros in 1991, and in developed countries it accounts for 2% to 6% of total health care costs (Detournay et al., 2000, WHO, 2005). The social cost of obesity is not limited to medical expenditures, as losses of productivity and foregone earnings due to premature deaths should increase the bill of what has been called, perhaps inappropriately, an epidemic. In the end, this cost may range as high as the social cost of smoking, which was estimated at 4 billions euros in 1997 (Kopp and Fenoglio, 2000). Expenditures in medical cares for obese individuals are paid by the whole community (at least in France via the Social Security), which suggests an obvious arena for policy intervention. Following the standard economic analysis, a "fat tax", or more generally taxes on some nutrients or food products, may help to internalize these externalities. However, the success of a fat tax depends crucially on the extent to which the weight distribution responds to price changes. This is the key concern of the current paper.

This paper will look on the relationship between food-at-home prices and a widespread measure of anthropometric status, the Body Mass Index (BMI: weight in kg divided by height squared in meter).

In this effort, we use the panel SECODIP, which provides us with exhaustive household data on food-at-home expenditures and, in 2002, measures of the BMI of all household members. As children have less control on their eating than adults, this research focus on the sub-sample of adults. Using the longitudinal nature of our data set, we estimate the effect of prices in 2001 on the BMI in 2002. Unfortunately, the BMI in 2001 is not available, which prevent us from estimating a dynamic model of BMI production with fixed effects. Hence, our specification is to be interpreted in terms of an equilibrium and stationary relationship between price and BMI, conditionally to age, for the specific population we consider. Most of the correlations between prices and means and quantiles of the BMI are insignificant. Hence, the scope for a food tax appears limited (in France) although this work should be completed by studies on the long-term trends in the price-BMI relationship, especially for children and adolescents.

Section 2 surveys the policy instruments that have been suggested for curbing the epidemic of obesity and, focussing on price policies, emphasises several theoretical aspects of the price-weight relationship. Section 3 presents the data and Section 4 considers econometric issues. Section 5 provides the results and Section 6 concludes by a general discussion on the pro and the cons of a fat tax.

Theoretical background and empirical specification

Policy instruments for the epidemic of obesity

Several policy instruments may be used for changing trends in obesity. This paper considers only interventions on the demand-side.ⁱⁱ At a macro-economic level, nutritional taxes, campaigns of public education, public subsidies to physical activity, advertising restrictions, or increase in the health care insurance rate of overweight individuals (or a tax on excess body "weight") have been suggested (Philipson, 2001, Schmidhuber, 2004). We focus here on tax and information policies.

Campaigns of public education may be ineffective, since a majority of people understand that they must control their weight at least for medical reasons, if not for aesthetic ones. The problem is that losing weight by applying simple recipes – eating less and exercising more – is not always effective. The quality of the diet is a key question, and many individuals do not know how to eat better given their budget constraint. Here, targeted programs of nutritional education may be helpful but are likely to be expensive (see for a French example, Basdevant *et al.*, 1999). These programs are often coupled with subsidies for physical exercise that decrease the price of energy expenditure relatively to the price of energy intakes.

There are a number of economic studies on the information-consumption relationship. When one uses time-varying aggregate information indices, such as counts of MEDLINE articles on the cholesterol-heart disease connection, significant information effects are usually found (see, for France, Nichèle, 2003). However, these aggregate indices tell us anything about how individuals, especially those at risk for obesity, react to information. At a micro-level, evidence in favour of a causal effect of individual knowledge on food choices are mixed and depends on the measure of knowledge that is used and the food choice that is under consideration (Blaylock *et al.*, 1999). Moreover, as noted by Park and Davis (2001), information effects are quite difficult to identify since, from a theoretical point of view, information is endogenous, and food demand and information search are affected by the same economic factors: information or knowledge are often instrumented on weak and *ad hoc* instruments. The evidence about information effects should thus be used cautiously. Last, note that advertising restrictions may be reconciled with normative neo-classical principles, if one admits that food-producing firms manipulate signals used by humans in the distant past in their search for food in hostile environments (Smith, 2004).

A tax on “excess body weight” may sound exotic at first sight, since it seems politically unfeasible, and perhaps ethically dangerous. However, for the U.S., it has been shown that there is a wage penalty for individuals in excess weight, especially women (Averett and Korenman, 1996, Cawley, 2005 and Conley and Glauber, 2005). This apparent labour market discrimination may be accounted for by the existence of employer-sponsored health insurance schemes, which adjust insurance premiums for individual risks (Bhattacharya and Bundorf, 2005). This solution seems difficult to implement in countries where Social Security largely covers health risks, and can not discriminate individuals on the basis of a health condition that could always be caused by unobservable or unknown genotypic predispositions.

Leicester and Windjmaier (2004) examine the potential for a “fat tax”. They argue that its implementation may give rise to a number of practical problems. Besides technical difficulties for measuring the content of all food products or legal challenges with WTO rules, the main drawbacks of a “fat tax” for the consumer are that: (i) ideally, one would like to tax over-consumption of fat (or sodium etc.) in order not to penalize those individuals who follow the recommended dietary guidelines; (ii) as any flat tax and given the income-related distribution of fat consumption – the more affluent consume less fat – , nutritional taxes would certainly have important redistributive effects.

The price-weight relationship has recently attracted the attention of economists, and has been examined in papers by Cutler *et al.* (2003) and Lakdawalla and Philipson (2002). Cutler and colleagues use various aggregate data to show that “the revolution in the mass preparation of food” explains the decline in prices of both food-at-home and food-away and the subsequent rise in obesity in the US. Lakdawalla and Philipson (2002) estimate on US regional data the impact of weight on the supply and demand curves for food, using regional variations in food tax. They find that, holding the BMI and the socio-demographic composition of the population constant, the supply price decreased by more than 6% between 1981 and 1994. Estimates of the demand curve imply in turn that this fall resulted in a 0.95 unit increase in BMI, hence 55% of the secular growth in BMI over the period considered. In these papers, the authors focus on the aggregate price of all food items, whereas a “fat tax” would apply to specific nutrients or food items. As a fat tax on nutrients is arguably difficult to implement, this paper will consider rather the correlation between the prices of various food groups and the BMI. Indeed, it seems more practical and cheaper to tax specific food products, such as snacks or ready-meals whose contribution to the epidemic of obesity is important. From a political point of view, such a tax could be likened to a tax on tobacco, alcohol or other harmful products. Before

turning our attention to empirical modelling, the rest of this section proposes some theoretical considerations about the price-weight relationship.

The dynamics of prices and weight

The weight control problem of the consumer has been carefully modelled by Cawley (1999) and Lakdawalla and Philipson (2002). The model we present hereafter is a modified version of the latter, and shows that Lakdawalla and Philipson's theoretical prediction about the price-weight relationship may not hold: food prices and weight are not necessarily negatively related.

Consider an agent who derives her utility u_t over period t from the consumption of food, C_t , and a numeraire good Z_t . Its well-being is conditioned to her weight or her BMI W_t :

$$u_t = U(C_t, Z_t; W_t) \quad (1)$$

where $U(\cdot)$ is a time-invariant utility function. Weight is produced by dietary intakes, but also physical activity. We suppose that the former are a deterministic function of food consumption, perfectly known by the consumer, and that the latter is one of the goods aggregated in Z_t . The weight production function writes:

$$W_{t+1} = (1 - \delta)W_t + w(C_t, Z_t) \quad (2)$$

where δ is a depreciation factor for the basal metabolism and other exogenous energetic constraints.ⁱⁱⁱ The investment function $w(\cdot)$ is non-increasing in Z_t and non-decreasing in C_t ($w_Z \leq 0$, $w_C \geq 0$). For given levels of income and prices, I and p ,^{iv} the consumption decisions of the consumer are governed by the following maximisation program:

$$\begin{aligned} V(W_t) &= \text{Max}_{Z_t, C_t} U[C_t, Z_t; W_t] + \beta V(W_{t+1}) \\ \left| \begin{aligned} W_{t+1} &= (1 - \delta)W_t + w(C_t, Z_t) \\ I &= Z_t + pC_t \end{aligned} \right. \\ W_0 &\text{ fixed} \end{aligned} \quad (3)$$

where β is a discount factor, and $V(\cdot)$ the indirect lifecycle utility of the consumer. Suppose that $U(\cdot)$ rises and is concave in C and Z , and that C and Z are complements in the production of utility. The first-order condition for this problem is:

$$\begin{aligned} U_C(C_t, I - pC_t; W_t) &= pU_Z(C_t, I - pC_t; W_t) \\ &+ \beta [pw_Z(C_t, I - pC_t) - w_C(C_t, I - pC_t)] V'(W_{t+1}) \end{aligned} \quad (4)$$

Equation (4) shows that the implicit price of food consumption is the sum of its market price and its effect on future well-being through marginal changes in weight. The latter is certainly positive when future well-being decreases in weight, and $w(\cdot)$ is increasing in food consumption. These conditions may hold if, for instance, BMI is over the morbidity threshold of 25 (according to the international standard for being overweight), the consumer eats fat- or sugar-rich food. The less her lifestyle^v and job are sedentary (which implies that w_Z moves down from 0), the better off is the consumer when she increases her expenditure in Z , because it lowers weight and improves future well-being. For an underweight consumer, $V'(\cdot)$ is positive: eating "junk-food" may improve her well-being and the full price of food consumption is lower than its market price.

There is an unique optimal consumption policy when: (i) $U(C, I-pC; W)$ is strictly concave, which means in particular that $U_C - pU_Z$ decreases in C ; (ii) $w(C, I-pC)$ is strictly convex in C , which implies that $w_C - pw_Z$ increases in C .^{vi} If these conditions hold, then V is unique, continuous, and strictly concave (Stokey and Lucas, 1989, theorem 4.8.). However V may be increasing or decreasing in W . Differentiation of equation (4) shows that, income being held constant, if V is decreasing in W and $w_{CZ} > 0$,^{vii} then the (short term) price-elasticity of food is negative:

$$\frac{dC}{dp} = \frac{U_Z - pCU_{ZZ} + \beta[(w_Z - pCw_{ZZ} + Cw_{CZ})V' - Cw_Z(pw_Z - w_C)V'']}{(U_{CC} - 2pU_{CZ} + p^2U_{ZZ}) + \beta[(w_{CC} - 2pw_{CZ} + p^2w_{ZZ})V' + (pw_Z - w_C)^2V'']} \quad (5)$$

Short term price-related changes in weight are given by the differentiation of the production function:

$$\frac{dW_{t+1}}{dp} = (w_C - pw_Z) \frac{dC_t}{dp} - C_t w_Z = \Delta_p^{CT}(W) \quad (6)$$

Given our assumptions on the derivatives of $w(\cdot)$, the sign of this price effect is ambiguous: a decrease in food price will increase food consumption which has a direct positive effect on weight. However, more resources can be devoted to Z , which may offset the effect of food consumption if energy expenditure associated to Z is high enough. The latter depends on the magnitude of w_Z .

Hence, the sign of the weight-price relationship is definitely more an empirical question than a theoretical one, and the usual claim that prices and weight are negatively related may not be true: the effect of food price on weight depends crucially on how energy expenditure varies with non-food consumptions, and empirical trends in food prices and in energy expenditures explain jointly trends in obesity.

This model has considered aggregated food consumption, using the implicit assumption that food quality is exogenous: w_C is fixed. We suppose now that the conditions for the existence of a unique stable steady-state are met^{viii} and we consider a static model of weight control to introduce quality effects and specify a reduced-form of the weight production equation.

Econometric modelling

Food prices, quality, quantity and weight: a simple empirical framework

The empirical modelling is based upon the following static maximisation problem:

$$\begin{aligned} \text{Max}_{Z, C, Q} U[C, Q, Z; W] \\ \left| \begin{aligned} W &= w(C, Z, Q) \\ I &= Z + pv(Q)C \end{aligned} \right. \end{aligned} \quad (7)$$

where Q is a quality index, and $v(Q)$ is an increasing function which captures the price variability between different quality of diets. Note that this framework readily extends to the case of several food groups, but structural derivation and estimation of demand systems, which usually requires that separability be assumed, is not straightforward: food expenditures and other expenditures are connected through the weight production equation. This simple model just tells us that an increase in p may induce a decrease in consumption C , but also lower quality Q as well as energy expenditure (through a decrease in Y): if quality has a negative effect on weight, and quantity a positive effect, the final impact of a price increase is ambiguous.

Since our main objective is to evaluate the price-BMI relationship, we adopt a reduced-form approach for modelling. The maximisation problem (7) yields optimal solutions for consumption and quality choices, whose empirical counterpart is specified as follows (assuming, *inter alia*, a linear weight-production function $w(\cdot)$):

$$\begin{cases} \ln(W) = a_0 + a_1 \ln(c) + a_2 \ln(q) + a_3 \ln(y) + a_4 X + \varepsilon_1 \\ \ln(c) = b_0 + b_1 \ln(p) + b_2 \ln(I) + b_3 X + \varepsilon_2 \\ \ln(q) = c_0 + c_1 \ln(p) + c_2 \ln(I) + c_3 X + \varepsilon_3 \\ \ln(y) = d_0 + d_1 \ln(p) + d_2 \ln(I) + d_3 X + \varepsilon_4 \end{cases} \quad (8)$$

where X is a set of socio-demographic variables that control for difference in tastes and the ε s are correlated residuals. Since y is unobserved in our data, we would like to estimate specification (A) that is deduced from (8):

$$(A) : \ln(W) = \alpha_0 + \alpha_1 \ln(p) + \alpha_2 \ln(I) + \alpha_3 X + \varepsilon_5 \quad (9)$$

The sign of the price effect α_i is not clear, as it depends on fundamental parameters a_1, a_2, a_3, b_1, c_1 , and d_1 . Furthermore, our data set provide us with unit values $p v(Q)$. Therefore, we can either construct price data by averaging unit values over some socio-demographic cells, or estimate specification (B):

$$(B) : \ln(W) = \beta_0 + \beta_1 \ln(pv(Q)) + \beta_2 \ln(I) + \beta_3 X + \varepsilon_6 \quad (10)$$

If specification (A) is the true model, the comparison of α_i and β_i gives:

$$\beta_1 - \alpha_1 = \text{cov}(\ln(v(Q)), \varepsilon_5 | I, X)$$

Since this covariance does not equal zero (quality is endogenous), we have to instrument unit values in order to recover price effects from specification (B) (see, for a similar approach, Pitt, 1983). Last, note that breaking food consumption into several food groups renders even more impossible any prediction about price effects, since a price increase in one food group may in addition induce substitutions between food groups.

Econometric modelling

This paper follows the approach proposed by Kan and Tsai (2004). First, we estimate the correlation between the logarithm of the unit values and the conditional mean of the logarithm of the BMI. In this step, instrumental GMM are used with tests of overidentification for the validity of our set of instruments in the latter, and a Hausman test of the endogeneity of the unit values. Second, we will estimate the correlation between prices and various quantiles of the distribution of the logarithm of the BMI. Besides the robustness of quantile regressions, the interest of this technique is that only the weight of individuals in the tails of the distribution is an actual public health problem. Hence, we would rather like to know the effect of prices on the behaviour of those in higher quantiles than how the average individual would react to a "fat tax", since the latter is clearly in the good range (18-25) for her BMI (see Figure 1). Given that we have to instrument 13 variables (we have 13 unit values), instrumental quantile estimators proposed by Chesher (2003) or Honore and Lu (2004) can not be implemented. We rather use a more ad hoc 2-Stage Least Absolute Deviation method proposed by Amemiya (1982): as for the 2SLS method, we regress in a first step the unit values on the instruments and, in the second step, we use the predicted unit values instead of the actual ones in the quantile regressions. Standard errors are computed by bootstrapping over these two steps (Buschinsky, 1998).

Data

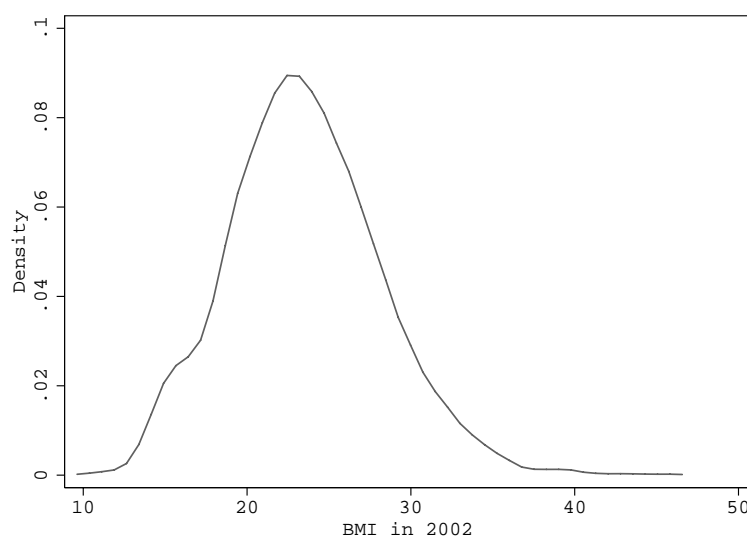
Our main interest in this paper is to explain the BMI as a function of the prices of a number of food groups, p , income, I , and socio-demographic variables, X . In this effort we use three years of food-at-home expenditures and quantities from the French household panel Secodip (2000-2002). We estimate specification (B) over the sub-sample of French adults observed over 2000-2002, for whom weight is observed in 2002 only (N=3668). We assume that, conditionally to age and control variables for pregnancy, these individuals are at their stationary weight level.^{ix} The next section will thus try to estimate the equilibrium relationship between the distribution of the BMI and the prices of a number of food groups.

The Body Mass Index

In 2002, the BMI of all household members were self-reported. We are not able to correct for declaration bias, as data with self-reported and "objective" weights are not available for France.^x

Figures 1 below shows a non-parametric estimate of the BMI distribution : it is not gaussian. This is one of the reasons that justify the application of robust estimation methods: this paper use quantile regressions to deal with this problem (Koenker and Bassett, 1978).

Figure 1. Distribution of the BMI.



Food groups

Food expenditures are broken into 16 subgroups: water, other non-alcoholic beverages, alcoholic beverages, sea products, cooked pork meats, non-cooked meats and eggs, vegetables (canned, frozen or fresh), fruits (canned, frozen or fresh), dairy, ready meals and sauces, milky deserts, sugars and sweets, animal fats and vegetable oils, cheeses, snacks, starchy foods (breads, cereals, rice and pasta). Following Cutler et al. (2003), we should expect a priori a negative correlation between price and weight for ready meals and snacks, as secular trends in the prices of processed food are likely to explain secular trends in obesity, at least in the US.

Prices

We suppose that prices in 2001 determined the weight reported in 2002. We construct prices by averaging the logarithm of unit values in 2001 over 48 cells. These cells are defined by crossing 3 indicators for the residential area (country, middle town, cities), 8 indicators for the region (North, North-East, Great Paris, West, East, Center, South-West, South-East), and 2 indicators for the socio-economic status (high equivalenced income vs. low equivalenced income).^{xi} It turns out that, for all food groups, there is much more variability in unit values than in prices. For instance, the unit values of sugar and sweets have a mean of 3.40 and a standard deviation of 0.28, while their cell-specific prices have about the same mean, but a standard deviation of 0.11. Hence, estimating specification **(B)** may allow us to use more information. However, the Secodip panel is made of two sub-panels, and expenditures in "fresh" starchy foods, fresh fruits and fresh vegetables are not measured on the sub-panel we use. The corresponding unit values are thus replaced in specification **(B)**, by cell-specific prices where cells are defined as above.

In specification **(B)**, the unit values of the remaining 13 good groups are likely to be endogenous as emphasized in the previous section. Moreover, differences in unit values may reflect heterogeneity in food supply (Boizot, 2000). We solve the latter problem by including in the control variables X informations about the presence of supermarkets, hypermarkets and hard-discounters in individual-specific regions defined by the district of residence and the adjacent districts (there are 95 administrative districts). More precisely, we construct two indicators: one for the surface (in square meters) per 100 inhabitants allotted to large-scale distribution stores in the individual-specific region, and another for the share of this surface that is provided by hard-discounters. We solve the former problem by instrumenting unit values.^{xiii} To this end, we assume that for each k of the 13 food groups $\ln(v(Q_k))$ follows a random walk, because food habits are persistent. Then, $\ln(p_{k,2001}(v(Q_{k,2001})))$

$\ln(p_{k,2000}(v(Q_{k,2000})))$, as well as the cell-specific average prices constructed as above, are valid instruments for $\ln(p_{k,2001}(v(Q_{k,2001})))$.

Socio-demographic controls

A number of sociodemographic variables are available. Household income is measured by an 18-intervals indicator. We use the center of each interval to build a continuous proxie of income (the highest category, over 45000 Euros a year, being dropped). We also control for gender, the household structure, the number of consumption units, and education (seven levels of qualification) since education renders health production through food choices more efficient (Grossman, 2001). We include a polynomial trend in age, as well as a dummy which indicates recent pregnancy, to ensure that stationarity holds. Self-production of vegetables and fruits is also controlled. Last, a dummy indicate if the individual is responsible for the food expenditures, as the meal planner may be more able to control her/his weight. Some descriptive statistics are presented in Table 1 below.

Table 1. Descriptive statistics (N=3668).

Variable	Mean (Variance)
Male	48.4%
Responsible for food expenditures	39.0%
No qualification	5.7%
Primary Education (CEP)	16.8%
First cycle, secondary education (BEPC)	10.4%
Vocational education (CAP)	32.3%
Baccalaureat (Bac)	16.3%
2 years after the Baccalaureat (Bac+2)	8.1%
3 years and more after the baccalaureat (Bac+3)	10.4%
Household yearly income	15340 (6876)
Age	48.5 (12.5)
Has had a baby in the last year	5.0%
Produces fruits	16.6%
Produces vegetables	8.6%

Results

The short-term ineffectiveness of price policies in preventing obesity.

The results are presented in Table 2. The coefficients of the prices and unit values are to be interpreted in terms of elasticity. The first column reports the estimates of specification **(B)** where unit values are not instrumented, while the second columns show the results for specification **(B)** where unit values have been instrumented. The overidentification test does not reject our set of instruments (P-value=0.3003). A Hausman test reject exogeneity of the unit values at the 1% level (P-value=0.0014). Indeed, the results turn out to be quite different. When we do not instrument unit values, we find negative correlations for non-alcoholic beverages (mostly sodas) and fats, which is good news. However, we find positive correlations for sugar and sweets, ready-meals, milky deserts and fruits. When unit values are instrumented, the only correlation that remains significant is for ready-meals, and it is a positive effect. There is one negative effect for fish products. Hence, the scope for a "fat" tax appears limited, at least if one expects short-term effects. Finding positive as well as negative price effects is not surprising, as was shown in the previous section.

The next columns of Table 2 present the results of the estimates of specification **(B)** for several quantiles. For these quantile estimates, unit values are replaced by their predicted values.^{xiii} The price effects fall in three categories. First, taxing sugars, sweets, non-cooked meats and eggs may increase the BMI of those in the lowest quantiles of the distribution which, from a public health perspective, may be worthwhile. Second, there are negative correlations between the prices of sea products, water, and fruits for over the median. Last, obese individuals (those over the 90th percentile) react positively to price increases in ready-meals and snacks, at least in the short-term, which should be reconciled with the argument that a long-term fall in the price of these goods has caused the epidemic of obesity. Indeed, sedentarity may be the major risk factor, not the relative food prices.

Being responsible for food expenditures shifts upward the distribution. This may reflect a "snacking effect" due to a more intense exposition to food. Note also that self-producing fruits has a negative effect, while the development of the large-scale distribution seems to be positively correlated with obesity. Another factor that may explain the rise in obesity may therefore be the increasing availability of manufactured food: the full price of food is to be blamed, not its retail price (see Chou *et al.*, 2002, for a similar argument).

Socio-demographic effects

We find a positive gender effect, and a concave age effect, which have simple biological reasons. Perhaps somewhat surprisingly, having a new-born has a negative effect for males under the median.

Whereas income has no effect, there is a clear negative educational gradient that is perhaps more important in the higher quantiles. This may reflect either differences in the capability of using information (the efficiency argument proposed by Grossman, 2001), or differences in the opportunity costs of weight control. Indeed, the more educated have more incentives to control their weight. Controlling one's weight is *per se* a signal of self-control in the French higher social classes (Bourdieu, 1979, chap. 3), and the more educated have also more to loose if they become overweight, because their life expectancy is basically higher, as well as their life-cycle earnings.

Table 2. Results.

<i>Specification</i>	<i>B</i>	<i>B-instrumented</i>									
Moment	Mean	Mean	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
<i>IMC value at the moment</i>	23.53	23.53	17.78	19.61	21.03	22.21	23.30	24.46	25.71	27.32	29.41
Log Price Water	-0.001 (0.006)	-0.025 (0.016)	-0.015 (0.027)	-0.010 (0.016)	-0.006 (0.018)	-0.013 (0.015)	-0.031* (0.018)	-0.024 (0.019)	-0.038 (0.025)	-0.039 (0.028)	-0.036 (0.033)
Log Price Alcohol	-0.008 (0.008)	-0.015 (0.019)	-0.043 (0.032)	-0.024 (0.024)	0.010 (0.020)	0.011 (0.027)	-0.001 (0.030)	-0.026 (0.027)	-0.016 (0.029)	-0.024 (0.029)	-0.043 (0.030)
Log Price Non-alcoholic beverages	-0.017* (0.010)	0.020 (0.026)	0.049 (0.052)	0.040 (0.039)	0.015 (0.039)	0.025 (0.035)	0.034 (0.037)	0.031 (0.040)	0.032 (0.032)	0.039 (0.034)	0.009 (0.039)
Log Price Fats (& Oils)	-0.044*** (0.014)	0.010 (0.035)	0.037 (0.053)	-0.021 (0.041)	-0.060* (0.034)	-0.050 (0.037)	-0.034 (0.040)	0.029 (0.028)	0.019 (0.041)	-0.004 (0.050)	0.049 (0.040)
Log Price Sugars and sweets	0.022* (0.013)	0.021 (0.034)	0.086 (0.063)	0.071** (0.034)	0.023 (0.031)	0.009 (0.031)	0.043 (0.042)	0.012 (0.039)	-0.006 (0.042)	-0.030 (0.052)	0.001 (0.055)
Log Price Non cooked meats & eggs	0.008 (0.013)	0.040 (0.040)	0.083 (0.078)	0.077* (0.046)	0.100 (0.065)	0.098* (0.057)	0.036 (0.053)	0.036 (0.062)	-0.018 (0.050)	-0.016 (0.050)	-0.057 (0.066)
Log Price Milky Deserts	0.021* (0.012)	-0.002 (0.029)	-0.063 (0.053)	0.018 (0.035)	0.020 (0.031)	-0.016 (0.035)	-0.024 (0.041)	0.028 (0.043)	0.033 (0.046)	0.017 (0.046)	0.031 (0.046)
Log Price Sea Products	-0.019 (0.013)	-0.060** (0.028)	-0.035 (0.044)	-0.051 (0.038)	-0.031 (0.035)	-0.019 (0.037)	-0.026 (0.043)	-0.078** (0.038)	-0.066** (0.032)	-0.101** (0.041)	-0.099** (0.042)
Log Price Cooked pork meats	-0.020 (0.017)	0.043 (0.042)	0.038 (0.093)	0.028 (0.061)	0.014 (0.067)	0.030 (0.056)	0.041 (0.064)	0.069 (0.064)	0.071 (0.066)	0.049 (0.069)	0.099 (0.077)
Log Price Dairy	0.004 (0.008)	-0.009 (0.030)	0.018 (0.065)	0.043 (0.040)	0.007 (0.041)	-0.012 (0.052)	-0.012 (0.039)	-0.021 (0.039)	-0.001 (0.036)	0.041 (0.047)	0.002 (0.038)
Log Price Ready Meals & sauces	0.023** (0.011)	0.043* (0.026)	0.013 (0.041)	0.058** (0.029)	0.047* (0.028)	0.042 (0.027)	0.039 (0.026)	0.045 (0.031)	0.038 (0.032)	0.033 (0.032)	0.075** (0.036)
Log Price Cheeses	0.009 (0.021)	0.023 (0.062)	0.058 (0.086)	-0.044 (0.081)	0.007 (0.069)	0.025 (0.094)	0.049 (0.088)	-0.015 (0.082)	0.003 (0.094)	-0.023 (0.068)	-0.092 (0.079)
Log Price Snacks	0.006 (0.013)	0.010 (0.031)	-0.078 (0.072)	-0.047 (0.044)	-0.023 (0.052)	0.035 (0.047)	0.004 (0.040)	-0.005 (0.046)	0.017 (0.051)	0.049 (0.046)	0.079*** (0.031)
Cell-specific log Price Starchy Foods	0.016 (0.101)	-0.088 (0.106)	-0.227 (0.233)	-0.184 (0.156)	-0.117 (0.165)	-0.105 (0.144)	-0.008 (0.151)	0.047 (0.176)	-0.015 (0.175)	0.053 (0.153)	0.147 (0.193)
Cell-specific Log Price Vegetables	0.045 (0.100)	0.048 (0.103)	0.227 (0.201)	0.114 (0.137)	0.041 (0.139)	0.016 (0.143)	-0.002 (0.120)	0.087 (0.110)	0.018 (0.173)	-0.010 (0.188)	-0.104 (0.174)
Cell-specific Log Price Fruits	-0.124** (0.060)	-0.063 (0.066)	-0.181 (0.111)	-0.125 (0.082)	-0.096 (0.086)	-0.092 (0.078)	-0.119* (0.067)	-0.164* (0.090)	-0.032 (0.054)	-0.026 (0.072)	-0.066 (0.091)

Male	0.174*** (0.009)	0.175*** (0.009)	0.119*** (0.014)	0.162*** (0.014)	0.175*** (0.013)	0.188*** (0.010)	0.192*** (0.011)	0.196*** (0.011)	0.203*** (0.012)	0.189*** (0.012)	0.197*** (0.014)
Responsible for food expenditure	0.183*** (0.009)	0.185*** (0.009)	0.168*** (0.013)	0.181*** (0.010)	0.172*** (0.007)	0.171*** (0.007)	0.170*** (0.008)	0.173*** (0.009)	0.183*** (0.013)	0.189*** (0.011)	0.218*** (0.018)
No qualification (Ref: Bac+3)	0.077*** (0.016)	0.088*** (0.019)	0.078** (0.033)	0.086*** (0.031)	0.067*** (0.022)	0.082*** (0.025)	0.089*** (0.026)	0.093*** (0.025)	0.104*** (0.024)	0.094*** (0.035)	0.129*** (0.030)
CEP (Ref: Bac+3)	0.057*** (0.013)	0.058*** (0.014)	0.061** (0.025)	0.055*** (0.020)	0.057*** (0.019)	0.070*** (0.020)	0.069*** (0.021)	0.063*** (0.021)	0.067*** (0.019)	0.068*** (0.019)	0.051** (0.023)
BEPC (Ref: Bac+3)	0.041*** (0.013)	0.047*** (0.015)	0.034* (0.019)	0.019 (0.025)	0.037* (0.021)	0.051*** (0.019)	0.047** (0.019)	0.054** (0.019)	0.050*** (0.017)	0.055*** (0.021)	0.074*** (0.025)
CAP (Ref: Bac+3)	0.031*** (0.011)	0.031*** (0.012)	0.022 (0.016)	0.020 (0.018)	0.019 (0.015)	0.034** (0.013)	0.036** (0.017)	0.034** (0.019)	0.041*** (0.015)	0.041*** (0.016)	0.054*** (0.020)
BAC (Ref: Bac+3)	0.021** (0.012)	0.018 (0.013)	0.000 (0.020)	0.005 (0.014)	0.021 (0.018)	0.028* (0.015)	0.033** (0.015)	0.030* (0.017)	0.024 (0.017)	0.022 (0.017)	0.035** (0.018)
BAC+2 (Ref: Bac+3)	-0.004 (0.013)	-0.006 (0.014)	-0.012 (0.020)	-0.009 (0.016)	-0.017 (0.019)	-0.006 (0.019)	0.004 (0.020)	-0.002 (0.019)	-0.005 (0.023)	0.003 (0.025)	0.002 (0.022)
Log Income	0.013 (0.010)	-0.007 (0.013)	0.032 (0.027)	0.014 (0.021)	0.007 (0.015)	-0.005 (0.016)	-0.007 (0.019)	-0.016 (0.017)	-0.028 (0.017)	-0.025 (0.021)	-0.019 (0.023)
Age/10	0.137*** (0.019)	0.133*** (0.022)	0.210*** (0.034)	0.188*** (0.032)	0.155*** (0.027)	0.142*** (0.024)	0.142*** (0.027)	0.098*** (0.030)	0.064** (0.028)	0.065 (0.040)	0.054 (0.041)
(Age/10) ²	-0.009*** (0.002)	-0.009*** (0.002)	-0.015*** (0.003)	-0.013*** (0.003)	-0.011*** (0.003)	-0.011*** (0.002)	-0.010*** (0.003)	-0.007** (0.003)	-0.004* (0.002)	-0.004 (0.004)	-0.003 (0.004)
Male & Has a baby aged under 1	-0.060*** (0.019)	-0.060** (0.027)	-0.117*** (0.019)	-0.149*** (0.037)	-0.089* (0.054)	-0.095*** (0.036)	-0.060 (0.043)	-0.032 (0.036)	-0.010 (0.026)	0.018 (0.033)	0.002 (0.025)
Female & Has a baby aged under 1	0.000 (0.019)	0.002 (0.020)	0.017 (0.035)	0.003 (0.033)	0.036 (0.034)	0.017 (0.026)	-0.009 (0.024)	0.016 (0.023)	-0.008 (0.023)	-0.008 (0.029)	-0.033 (0.029)
Self-production of fruits	-0.013* (0.008)	-0.014* (0.008)	-0.004 (0.015)	-0.013* (0.007)	-0.018* (0.010)	-0.019** (0.009)	-0.019* (0.010)	-0.008 (0.009)	-0.001 (0.008)	-0.011 (0.013)	-0.024* (0.014)
Surface large-scale distribution	0.004 (0.006)	0.013** (0.006)	0.007 (0.013)	0.011 (0.010)	0.002 (0.008)	0.007 (0.009)	0.009 (0.008)	0.009 (0.008)	0.015* (0.008)	0.023** (0.011)	0.022** (0.010)
Other control variables : Logarithm of household consumption units (generally insignificant), Self-production of vegetables (insignificant), Share of hard-discounters in the large-scale distribution surface(insignificant)											
Constant	2.546*** (0.129)	2.348*** (0.178)	1.606*** (0.265)	2.134*** (0.234)	2.308*** (0.171)	2.287*** (0.173)	2.304*** (0.197)	2.478*** (0.243)	2.769*** (0.242)	2.997*** (0.240)	2.934*** (0.284)

Note : * = significant at the 10%-level; ** = at the 5%-level, ***, at the 1%-level; In columns 3 to 11, prices are predicted from instrumental SUREG regressions.

Conclusion

This paper has used three years of food-at-home expenditures data to examine the price-BMI relationship, which according to recent papers by Lakdawalla and Philipson (2002) and Cutler *et al.* (2003) should be negative. We first note that there are few significant correlations between the prices of various food groups and the BMI in our sample of French adult women, and there are interesting positive effects for the goods that have been suggested for tax policies, as well as negative correlations for some food groups whose consumption is not, *a priori*, a risk factor for obesity.

We have two main conclusions. First, our simple theoretical analysis suggests that the price effect on weight is not necessarily negative. It depends heavily on how choices of non-food goods affect energy expenditure and on the substitution between different varieties of a same food product and between different food products.

Perhaps the more striking contribution of this paper is that "fat tax" or any nutritional tax will not curb the epidemic of obesity in the short-term. However, we can not infer from our estimates predictions about the effect of prices on the probability that children today become overweight tomorrow. But we firmly believe that the costs of tax policies in terms of well-being (their redistributive effects) and their short-term inefficiencies strongly outweigh their potential long-term benefits, as the latter would have to be discounted over at least 30 years (to see their effects on the children of today to be realized). Actions on energy expenditures (physical exercise, sedentarity at the workplace) as well on specific nutritional knowledge (how, where and when purchasing good products) may be much more attractive.

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ⁱ The prevalence of obesity is much lower in France than it is in the UK or the US. In 2000, 9% of the population was obese in France, against 21% in the UK and more than 31% in the US (OECD, 2004).

ⁱⁱ Interventions on the supply side include *inter alia* legal norms on the nutritional content of food, or enforcement of liability rules (Leicester and Windmeijer, 2004, Coestier *et al.*, 2005).

ⁱⁱⁱ Contrary to Lakdawalla and Philipson (2002), we consider that occupational choices are given, so that job strenuousness is exogenous.

^{iv} We suppose that weight does not affect income. This is maybe a strong assumption, especially for women (*cf.* Averett et Korenman, 1996, Cawley, 2004).

^v By "lifestyle", we mean a given set of possible choices predetermined by individual tastes and habits. Lifestyles can be identified empirically by examining health-related choices of exercising, sleeping, eating everyday a breakfast, watching television, using public transportation or individual car for commuting, etc. (Kenkel, 1991, Contoyannis and Jones, 2004). In any data set, one will find a lot of individuals who do not exercise, always use their car instead of walking etc. Double-hurdle models are often used for these decisions, which reflect the fact that, beyond economic factors such as price or income, many individuals do not even

consider the possibility of, say, exercising: their choice set is restricted. We are aware that such explanations are not appealing to economists (see Stigler and Becker, 1977). However, the marketing research has shown that individual choice sets are, every economic conditions being equal, heterogeneous (Filser, 1994).

^{vi} Of course, U and w are continuous.

^{vii} For instance, the more you eat, the less you loose weight by playing sport.

^{viii} Which is not trivial; see Stokey and Lucas (1989), theorem 6.9. Indeed, the empirical modelling is largely constrained by the data: we observe weight in one period only, and can only estimate static weight functions. Suppose that $w(\cdot)$ is strictly increasing in C (*i.e.* $w_C > 0$ and/or $w_Z < 0$), then equation (2) implies that C_{t-1} is a function of W_t and W_{t-1} . Still using equation (2) but for period t , a plausible reduced form specification for weight is obtained: $W_{t+1} = \gamma_0 + \gamma_1 P_t + \gamma_2 P_{t-1} + \gamma_3 I_t + \gamma_4 I_{t-1} + \gamma_5 W_t + \gamma_6 W_{t-1}$. This equation shows that current weight depends on past weights. Omission of the latter will induce an omission bias.

^{ix} We have hip measurements in 8 intervals in 2001 and 2002. Only 3.7% of the women in our sample changed hip category between these two dates. Given the measurement errors in self-reported weight, the stationarity assumption does not look too strong.

^x See Chou *et al.* (2001), Lakdawalla and Philipson (2002) and Cawley (2004) for a correction procedure on US data.

^{xi} These two economic indicators are constructed by the data owner, SECODIP, using the households' income and its demographic structure. Documentation is available upon request.

^{xii} We would have clearly preferred a structural approach as in Laisney *et al.* (2003). However, as noted above, separability does not hold. This is left for future research.

^{xiii} Predictions are constructed using a SUREG regression of the unit-values on the instrument. Individual time-variations of unit-values and cell-specific prices strongly instrument unit-values, with t statistics around (respectively) 20 and 5.