TSE working paper series

09-135

Research Group: *Food, Farms, and Firms*

December, 2009

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Increasing Fruit and Vegetable Consumption:

A Cost-Effectiveness Analysis of Public Policies

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Short Running Head: Health Impacts of Fruit and Vegetable Policies

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Abstract

BACKGROUND: In many countries, consumption of fruits and vegetables (F&V) is below recommended levels. We quantify the economic and health effects of alternative policy (P) scenarios aiming to increase F&V consumption: (**P1**) 3.4% reduction in VAT, (**P2**) €100/year/person F&V stamp policy designed for low-income consumers (LIC) and (**P3**) €10 M information campaign.

METHODS: An economic model of the F&V market provides F&V consumption variations to a health impact model, leading to the number of deaths avoided (DA) and life-years saved (LYS). We compare the cost per statistical DA and LYS, taking into account the public costs of alternative policies. This analysis is applied to France in 2006.

RESULTS: Relative risks of death for one additional F&V portion are disease-dependent (range: 0.84-0.99). The highest variations in F&V consumption levels (<+10g/day/person on average) and health effects (<+600DA, <+10,000LYS) are modest. The costs/LYS are smaller for information campaign (3kEuros), followed by VAT reduction (99kEuros) and food stamp policy (403kEuros). However, the information campaign leads to less LYS than VAT reduction. The food stamp policy reduces health inequalities between LIC and others, whereas the other ones can increase them.

CONCLUSION: Our results suggest that (1) LYS are larger with VAT reduction than F&V stamps policies, (2) information campaigns are the most cost effective, (3) market forces can limit the impacts of public health policies designed to favour F&V consumption increase.

Keywords: Cost-effectiveness analysis, Fruit and Vegetables, Health Impact Assessment, Economic modeling, Health Policy.

Conflicts of interest: None

Introduction

In order to combat the burden of non-communicable diseases, public health actions are implemented in many countries to reach the recommended intake of 400g of fruit and vegetables (F&V) per day.[1,2] A first type of action aims at modifying the consumers' behaviors through information campaigns. A second type of action is based on economic instruments. The rationale of the latter approach is that a healthy diet is costly and that low-income consumers cannot always afford high F&V consumption levels.[3,4,5]

In the nutrition and health literature, several studies have dealt with the effect of targeted information campaigns. A review showed that such campaigns can lead to an individual consumption increase of 0.2 to 0.6 servings per day[6]. The most significant modifications are obtained with intensive interventions performed in a medical environment or for subjects with a history of chronic disease. Fewer studies deal with general information campaigns[7]. In both cases the economic effects have not been considered despite the possibility that the positive impact on consumers' demand could be offset by the price increase, thereby resulting in a weak variation of the actual F&V consumption.[8]

In the economic literature, pricing policies aimed at favoring healthy diets have been considered in several investigations, either through unhealthy food taxation[9,10,11] or healthy food consumption subsidizing.[12] Food assistance programs which provide low-income households with the resources to purchase healthier diets have also been investigated in order to assess their impacts on consumption.[13,14,15,16] However, very few studies have proposed analyses integrating economic and health parameters[17].

The goal of the present study was to quantify cost-effectiveness of policies aimed at increasing F&V consumption. We consider three policies: (1) reduction of the consumer price through a decrease in VAT on all F&V, (2) consumption subsidies through F&V stamps, (3) generic information campaigns. The analysis is applied to France in 2006 where the “National Nutrition and Health Program” has been carried out by health authorities since 2001.

Methods

Our analysis is based on an economic model of the F&V market which is used to assess the effect of different policies on F&V consumption and on costs to the taxpayer (detailed methods are presented in **supplementary material** on the web site of the journal). On the basis of the available literature, we then assess the health effects linked to the variation in F&V consumption levels induced by each policy. Finally, we compare the costs of a statistical death avoided (DA) and life-year saved (LYS) taking into account the public costs induced by the implementation of these policies.

Economic model

The current consumption of F&V can be seen as the result of the market equilibrium between, on the consumers’ side, a demand function, and, on the producers’ side, a supply function. The demand function represents the total quantity bought by households depending on the F&V price. This demand increases when the price decreases. It increases also if the consumers’ income increases or if the consumers’ information related to the health benefits of F&V increases. The supply function represents the total quantity of F&V delivered by the producers according to the price the producer gets.

On this basis, it is possible to design a F&V market model in order to obtain the prices and the quantities consumed by households. Thus, a policy is seen as a way to move the demand or the supply functions so as to modify the levels of consumption.

The initial situation corresponds to the mean consumption observed in France. As the consumption level depends on income, we distinguished low income consumers (LIC) who belong to the first decile of income from standard income consumers (SIC). The F&V intakes (**Table 1**) were obtained from the national population survey INCA[18].

Policies

The first policy is a decrease in VAT (**policy 1**) whose direct effect is a reduction in the difference between consumer and producer prices. We considered a reduction in VAT from 5.5% - the current level - to 2.1% which corresponds to the minimum value allowed by the European tax policy. The cost to the taxpayer of this policy is €465 M and corresponds to the loss of tax revenues due to the VAT reduction. The reduction of the consumer price induces an increase in the consumption of all consumers. The increase depends on the price demand elasticity as well as the initial level of consumption**.**

The second policy consists in subsidizing consumption through F&V stamps given to LIC (**policy 2**). Such a policy can be considered as an increase in the income of targeted consumers.[13] For ease of comparison with policy 1, we assumed that €465 M were used to subsidize F&V consumption of LIC. This represents a €100/year/person F&V stamp. The result is an increase in demand of LIC which depends on income elasticity. This increase in F&V demand pushes up prices and thus reduces the consumption of the population that does not receive F&V stamps.

The third policy is based on an information campaign promoting F&V consumption (**policy 3**). Such a campaign is supposed to increase the 'information- stock' of each consumer. The greater the 'information- stock' for a consumer and the greater is his demand for the product. This increase depends on the budget used to inform each individual consumer. We considered a €10 M information campaign budget which corresponds to the annual amount spent by public authorities and producers' associations to promote F&V consumption in France. Policy

3 affects the information-stock of consumers depending on their ability to "understand the messages" (referred to as information-responsiveness - *i.e.* the shift in demand linked to an additional unit of budget used to inform an individual consumer). It has a secondary impact through the change in demand and thus in price, which can limit the increase in consumption.

Economic data

The economic model was used to assess how much the initial equilibrium is modified by the three policy scenarios. Each scenario affects market prices and F&V intakes in a different way. The extent of the consumers' or producers' responses varies according to economic parameters such as the price demand elasticity, the income elasticity and the information-responsiveness of consumers, and the price elasticity of supply (see **Table 2**). These parameters were defined on the basis of French studies and other studies when data were not available in France (see the **supplementary material**). The analysis of policies 1 and 2 are based on well-documented data and are designed for the French situation. Policy 3 relies on more uncertain values. The main source of data was found in the literature dealing with the effects of generic advertising campaigns implemented by governments or producer associations in the US. Even if the social context is different, we considered that these data were relevant for identifying lower and upper bounds of possible effects of F&V campaigns. On this basis, we designed two scenarios, a pessimistic one and an optimistic one.

Modeling of cancer and cardiovascular benefits of F&V consumption

Owing to the well-documented association between F&V consumption and cancer or cardiovascular diseases, we focused the analysis only on these major causes of death. The relative risks (RRs) of specific causes of death associated with an increase by one serving of

F&V (**Table 3**) were taken from recently published meta-analyses for cancer deaths[2] and for cardiovascular deaths (coronary and stroke).[19,20] When the data for specific cancers were not available in the WCRF report we assumed that the link with the other cancers was not sufficiently proven. We assumed that the RRs for death were similar to the RRs of occurrence of the disease provided in the meta-analyses. Similarly, when the RR for cancer was available for fruit but not for vegetable intake (or vice versa), we attributed a value of 1 to the missing RR. Furthermore, when the RRs for fruit and vegetables were reported separately, we estimated the RR for F&V intake as follows: $RR_{F\&V} = RR_{Fruit}^{0.5} * RR_{Vegetable}^{0.5}$.

The latest available mortality and cause specific mortality data (in France in 2006) was downloaded from Cepidc web site (http://www.cepidc.vesinet.inserm.fr/) and the National Institute for Statistics and Economic Studies (INSEE: http://www.insee.fr) (**Table 3**). Causes of death were selected according to ICD10 classification as follows: mouth, pharynx and larynx cancer (C00 to C14, C32), esophagus (C15), stomach (C16), pancreas (C25), lung (C33, C34), colon and rectum (C18 to C21), ovary (C56), coronary heart disease (I20 to I25), stroke (I60 to I69). We estimated the life expectancy at each age using French mortality data on total deaths. Then an expected number of years of life lost for each cause of death was calculated according to distributions of causes of death by age[21].

To assess the number of deaths by cancer and cardiovascular disease avoided by changes in F&V intake, we hypothesized a log linear dose effect relationship using the following formula: $(1-RR^{\Delta F\&V}) *$ number of deaths, where RR is the relative risk for an additional serving per day and $\Delta F\&V$ is the change in F&V intake (in servings of 80g per day). The number of LYS was estimated by multiplying the number of DA by the mean expected number of years of life lost for each disease. To account for the effect of social disparities on disease rates we used the relative inequality index (RII) associated with occupational status in France,[22] thus estimating cancer and cardiovascular death rates in the lowest decile of income distribution of the French population. Owing to the lack of specific RII values for each cancer type and for stroke or coronary heart diseases, we used the following values: 4.53 [3.94-5.21] and 2.09 [1.71-2.56] for cancers and 4.50 [3.65-5.54] and 5.84 [3.94-8.65] for cardiovascular diseases, in men and women respectively[22]. Numbers in brackets represents 95% confidence intervals.

Monte-Carlo Simulations

The parameters of the model (6 economic and 13 health parameters) were supposed to follow independent lognormal distributions. Monte-Carlo simulations were performed by drawing 10 million times a 19-uplet of parameters. For each uplet, we computed the changes induced by each policy for the following variables: F&V consumption for each category of consumers, number of statistical DA, number of statistical LYS, cost per statistical DA (by dividing the policy implementation cost by the number of DA), cost per statistical LYS, health disparity index. The latter is defined as the variation in the odds ratio for each policy. The odds ratio is related to mortality in LIC and SIC and is 2.08 [2.05-2.10] in the initial situation.

Results

Estimations of Health impacts

Table 3 presents the RRs of cancer and cardiovascular disease deaths for an 80g increase in F&V intake, the number of deaths and expected years of life lost by cancer subtypes and cardiovascular disease causes in 2006 in France. The total number of deaths is approximately 140,000 representing 30% of total deaths and 50% of total cancer and cardiovascular deaths in 2006 in France.

Impact of policies on F&V intake and mortality

Changes in market prices, consumption levels, numbers of statistical DA, odds ratio and costs per statistical DA are given in **Table 4**.

At equilibrium, VAT reduction induces a 1.8% [1.1-2.3] decrease in the consumer price. We obtain a 4.8g/day [3.1-7.1] increase of the mean level of F&V consumption. However, LIC benefits less from the price reduction than the others. VAT reduction allows 363 DA [200-582] and 5024 LYS [2711-8134]. The cost per statistical LYS is €100k [57-172]. On average, the health disparity index is marginally increased.

F&V stamps to LIC leads to a very small increase in mean consumption (0.4 g/day [0.2-0.6]). This results from an increase in the mean consumption of LIC (7.0g/day [6.0 - 9.2]) and a small decrease in the consumption of SIC (-0.3 g/day [-0.5 - -0.2]). The latter is due to the slight increase in the consumer price (0.1%), a consequence of the increase in demand from LIC. With F&V stamps policy, the total number of DA is 77 [48-116] and the number of LYS is 1032 [634-1554]. The cost per statistical LYS is €474 k [299-733]. This policy reduces the disparity between LIC and SIC.

If consumers are weakly responsive to generic information campaigns (pessimistic scenario), a €10 M campaign induces a 0.1% [0.1-0.2] increase in price and a mean increase of 0.4g/day [0.2-0.6] in F&V consumption. This policy allows 30 DA [15-51] and 414 LYS [203-710]. The cost per statistical LYS is €27 [14-49] k. However, if consumers are more responsive to generic information (optimistic scenario) the impacts are 10 times higher and the cost per statistical LYS is €3 [1-5] k. On average the health disparity is increased. This is particularly the case when consumption from LIC decreases. This situation occurs when LIC are less responsive to information than SIC. The increase in demand from SIC generates an increase in the market price, thereby inducing a decrease in the consumption of LIC.

Discussion

The main findings of the present study, based on the most recent updates of economic modeling and assessment of F&V intake health benefits are the following : (1) targeted and non-targeted policies to promote F&V intake have a modest impact on consumption and as a result on health gains, (2) non-targeted interventions through price modifications appear to be more cost-effective than targeted actions through subsidizing the consumption of the most disfavored sub-populations, (3) owing to their lower cost, information campaigns are more cost-effective, despite lower DA than VAT reduction.

The reason for the modest life gain is related to the small shifts in F&V intake resulting from market equilibriums induced by the different policies. Furthermore, the expected benefits of F&V consumption, estimated from most recent meta-analyses[2,18,19], are moderate compared to earlier estimations based on case-control studies. Finally, although the burden of cancer and cardiovascular diseases represents more than 2/3 of total deaths in France, the favorable association with F&V consumption is documented for only about half of their etiologies (1/3 of total deaths). This means that the overall impact of increasing F&V intake on total mortality is calculated on this third of total deaths.

If the health gain seems to be modest, the costs per statistical DA, at least for policies 1 and 3, are close to those obtained in a similar study[9]. Moreover, they are comparable to the value of statistical DA obtained in many other types of public interventions.[23,24] However, health outcomes have not been adjusted for differential timing thus implicitly assuming a zero discounting factor. The results suggest that price reduction (VAT) is more cost-effective than subsidizing the consumption of disfavored sub-populations. The price reduction does not reduce social inequalities. However, the price reduction is beneficial to all consumers. Comparison of non-targeted policies suggests that an information-based policy is more cost-effective than a price reduction policy, as the cost per DA is to a great extent lower through information campaigns than through VAT reduction. This is the consequence of a much lower cost of the information campaign (approximately 50 times less) than the VAT cut, despite a very low assumed value for the information responsiveness of consumers. Using more 'optimistic' values reinforces the conclusion that information-based policy is more cost-effective than price policy, even if it saves less people.

For each policy, the impact on consumption and thus on total number of DA obviously depends on the allocated budget. In case of policy 1, it is likely that the increase in F&V consumption would be linearly related to the budget. In other words, doubling the budget allocated to the policy would generate roughly an increase in consumption which is twice the one generated in our analysis. On the contrary, in case of policy 3, it is very unlikely that doubling the budget allocated to generic-information would double the impact on consumption. This is because the information-responsiveness of consumers is certainly non-linear due to 'saturation' problems.

The methods we used in this paper rely on restrictive assumptions and the results are necessarily influenced by some of these limitations. Among the three policies, it is certainly policy 3 which has the most debatable parameters of the model. However we compared the results obtained in policy 3 with a rough estimate of the impact of the French program on F&V which started in 2001. According to Afssa[25] the increase in the mean F&V consumption was around 25g/day/person from 1999 to 2006. If we assume that this increase is only due to the information campaigns implemented from 2001 to 2006, it means that these campaigns induced a maximum increase of 4g/day/person per year for an annual amount of approximately €10 M. This rough estimate is in line with results from the 'optimistic' scenario which might suggest that French consumers were rather receptive to that information campaign.

The estimates for DA/year depend on the validity cause of death in national statistics and of the assumed benefits (estimated relation between F&V intake and mortality gain). In this study we did account for ill-defined and unspecific cause of deaths which may affect DAs. We used the latest available meta-analyses obtained from observational studies due to the lack of randomized intervention studies. These estimates are affected by methodological constraints such as accuracy of food intake assessment, quality of event ascertainment, measurement of confounders or publication bias.[26] Furthermore, most cohort studies were conducted in middle aged subjects, which may affect the strength of the associations. Altogether this constraint may affect the estimation of the association between F&V intake and events and produce uncertainty. However, a recent intervention trial promoting F&V intake found no evident benefit on cancer or ischemic cardiovascular prevention,[27] suggesting that the effects of F&V on cancer and cardiovascular prevention are at best modest, which is consistent with our hypotheses. In contrast, besides DA and LYS there are additional possible cardiovascular and cancer benefits from increasing F&V intake, e.g. decreased morbidity, hospitalization and improved Quality Adjusted Life Year. Given the paucity of data on incident rates of cardiovascular disease and cancer in France it was not possible to assess these effects and their economic counterpart. Therefore, the present estimation may appear rather conservative.

In conclusion, despite certain limitations, our simulations give some useful insights for policy makers to select the most appropriate and cost-effective policies to reduce the burden of cancer and cardiovascular disease through nutritional intervention.

Key points:

- In France, 3.4% reduction in F&V VAT, €100/year/person F&V stamp policy and €10 M information campaign would have a modest impact on consumption and as a result on health gains.
- The number of statistical death avoided and the cost per life years saved are comparable to those obtained in other types of public interventions.
- Intervention through VAT reduction is more cost-effective than subsidizing the consumption of some disadvantaged sub-populations.
- Information-based policy is more cost-effective than the VAT reduction policy.
- Market forces can limit the impacts of public health policies designed to favour F&V consumption increase.

[1] WHO (World Health Organization). Diet nutrition and the Prevention of Chronic Diseases. Technical Report Series Geneva, Switzerland; 2003: 916-117.

[2] WCRF (World research cancer fund) and AICR (American Institute for Cancer Research). Food, nutrition physical activity and the prevention of cancer: a global perspective, Washington DC; 2007: 517p.

[3] Drewnowski A, Darmon N, Briend A. Replacing Fats and Sweets with Vegetables and Fruits – A question of Cost. *AJPH*. 2004; 94(9); 1555-1559.

[4] Darmon N, Drewnowski A. Does Social Class Predict Diet Quality? *American Journal of Clinical Nutrition.* 2008; 87(5); 1107-1117.

[5] Ard JD, Fitzpatrick S, Desmond RA, Sutton BS, Pisu M, Allison DB, Franklin F, Baskin ML. The Impact of Cost on the Availability of Fruits and Vegetables in the Homes of Schoolchildren in Birmingham, Alabama. *AJPH*. 2007; 97(2); 367-372.

[6] Pomerleau J, Lock K, Knai C, McKee M. Interventions Designed to Increase Adult Fruit and vegetable Intake Can Be Effective: A Systematic Review of the Literature. *J. Nutr.* 2005; 135; 2486-2495.

[7] Pollard CM, Miller MR, Daly AM, Crouchley KE, O'Donoghue KJ, Lang AJ, Binns CW. Increasing fruit and vegetable consumption: success of the Western Australian Go for 2&5 campaign *Public Health Nutrition.* 2007; 11(3); 314-320.

[8] Mazzocchi M, Traill WB , Shogren JF. *Fat Economics: Nutrition, Health, and Economic*. Oxford University Press, USA, 208p.

[9] Caraher M, Cowburn G. Taxing Food: Implications for Public Health Nutrition. *Public Health Nutrition.* 2005; 8(8); 1242-1249.

[10] Chouinard H, Davis DE, LaFrance J, Perloff J. Fat Taxes: Big Money for Small Change. *Forum for Health Economics & Policy*. 2007; 10(2); 1071-1071.

[11] Mytton O, Gray A, Rayner M, Rutter H. Could targeted Food Taxes Improve Health? *J. Epidemiol Community Health.* 2007; 61; 689-694.

[12] Cash SB, Sunding DL, Zilberman D. Fat Taxes and Thin Subsidies: Prices, diet, and health outcomes. *Food Economics*. 2005; 2(3-4); 167-174.

[13] Chen Z, Yen ST, Eastwood DB. Effects of Food Stamp Participation on Body Weight and Obesity. *Amer. J. Agr. Econ.* 2005; 87(5); 1167-1173.

[14] Meyerhoefer CD, Pylypchuk Y. Does Participation in the Food Stamp Program Increase the Prevalence of Obesity and Health Care Spending? *Amer. J. Agr. Econ.* 2008; 90(2); 287-305.

[15] Ver Ploeg M, Ralston K. Food Stamps and Obesity What Do We Know? 2008. *Economic Information Bulletin* (34), ERS-USDA, 37p.

[16] Alston JM, Conner CM, Sumner DA, Townsend M, Vosti SA. Likely Effects on Obesity from Proposed Changes to the US Food Stamp Program. *Food Policy*. 2009; 34(2); 176-184.

[17] Veerman J.L., Barendregt J.J., Mackenbach J.P. The European Common Agricultural Policy on fruits and vegetables: exploring potential health gain from reform. *EJPH*, Vol. 16, 1, 31-35.

[18] Afssa (2008), Summary of the Individual and National Study on Food Consumption (INCA 2) 2006-2007, http://www.afssa.fr/Documents/PASER-Sy-INCA2.pdf

[19] Dauchet L, Amouyel P, Dallongeville J. Fruit and vegetable consumption and risk of stroke: a meta-analysis of cohort studies. *Neurology*. 2005 ; 65(8):1193-1197.

[20] Dauchet L, Amouyel P, Hercberg S, Dallongeville J. Fruit and Vegetable Consumption and Risk of Coronary Heart Desease: A Meta-Analysis of Cohort Studies. *J. Nutr.* 2006; 136; 2588-2593.

[21] Murray CJ. Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bull World Health Organ*. 1994;72(3):429-45.

[22] Saurel-Cubizolles MJ, Chastang JF, Menvielle G, Leclerc A, Luce D. Social inequalities in mortality by cause among men and women in France. *Journal of Epidemiology and Community Health.* 2009; 63: 197-202.

[23] Viscusi WK, Aldy J. The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World. *The Journal of Risk and Uncertainty*. 2003; 27(1); 5-76.

[24] Kochi I, Hubell B, Kramer R. An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for Environmental Policy Analysis. *Environmental & Resource Economics*. 2006; 34; 385-406.

[25] Afssa (2008), Summary of the Individual and National Study on Food Consumption (INCA1 and INCA 2) http://www.afssa.fr/index.htm

[26] Dauchet L, Amouyel P, Dallongeville J, Fruits, vegetables and coronary heart disease. *Nat Rev Cardiol.* 2009 Sep; 6(9): 599-608.

[27] Howard BV, Van Horn L, Hsia J, Manson JE, *et al*. Low-fat dietary pattern and risk of cardiovascular disease: the Women's Health Initiative Randomized Controlled Dietary Modification Trial. *JAMA.* 2006; 295(6): 655-66.

Table 1. Distribution of F&V intake (g/d) by levels of income

F&V Consumption (in g/day)	Average	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
1st Decile of income	227	86	168	257	397
Rest of the population	353	147	264	403	597

Table 2. Elasticities used for the simulations

Considered elasticity		Policy 1 (VAT decrease)		Policy 2 (Consumption subsidies)		Policy 3 (Information campaign)	
		Mean	SD	Mean	SD	Mean	SD
Supply elasticity (a)		1	0.25	1	0.25	1	0.25
Demand elasticity (b)	First decile	-0.85	0.4	-0.85	0.4	-0.85	0.4
	Other deciles	-0.85	0.3	-0.85	0.3	-0.85	0.3
First decile income elasticity (c)				0.4	0.3		
Information impact (d)	'Pessimistic'					0.01	0.002
	'Optimistic'					0.1	0.02

Table 3. Estimated relative risk (RR) of death for one additional portion of F&V, number of death and period expected year of life lost by each cause of death

Disease	RR for one aditional serving of fruits and vegetables: Mean [CI 95%]	Number of deaths		Expected number of years of life lost per death	
		Whole population	First decile of income	Men	Women
Cancer					
Mouth, pharynx and larynx	0.92 [0.81 - 1.06]	5,536	1,013	18.5	20.4
Esophagus	0.92 [0.85 - 1.00]	3,837	696	16.1	15.8
Stomach	0.97 [0.93 - 1.01]	4,763	820	13.7	13.7
Pancreas	0.97 [0.90 - 1.04]	8,263	1,369	14.5	13.9
Lung	0.94 [0.92 - 0.97]	28,347	5,088	16.0	20.0
Colon and rectum	0.99 [0.94 - 1.04]	16,426	2,733	12.4	12.6
Ovary	0.84 [0.62 - 1.13]	3,342	463		17.1
Cardiovascular disease					
Coronary heart disease	0.97 [0.94 - 0.99]	38,806	7,497	11.6	8.4
Stroke	0.96 [0.94 - 0.98]	32,652	6,335	10.2	8.8

Table 4 : Impact of alternative policies on market prices, consumption levels, numbers of statistical DA, odds ratio and costs per statistical DA

Policy comparison	Policy 1 (3.4% VAT Decrease) Mean [CI (95%)]	Policy 2 (Food Stamps) Mean [CI (95%)]	Policy 3 (Information Campaign) Pessimistic scenario Mean [CI (95%)]	Policy 3 (Information Campaign) Optimistic scenario Mean [CI (95%)]
Consumer price variation (%)	-1.8 [-2.3 – -1.1]	0.1 [0.1 – 0.2]	0.1 [0.1 – 0.2]	1.2 [0.7 – 2.0]
Individual consumption variation (g/day)				
All deciles (mean)	4.8 [3.1 – 7.1]	0.4 [0.2 – 0.6]	0.4 [0.2 – 0.6]	4.0 [2.2 – 6.4]
First decile of income	3.4 [1.2 – 7.5]	7.0 [6.0 – 9.2]	0.3 [-0.1 – 0.5]	2.6 [-0.8 – 5.3]
Other deciles	5.0 [3.1 – 7.6]	-0.3 [-0.5 – -0.2]	0.4 [0.2 – 0.7]	4.1 [2.0 – 6.9]
Number of death avoided (DA)				
All deciles	363 [200 – 582]	77 [48 – 116]	30 [15 – 51]	298 [149 – 507]
First decile of income	48 [15 – 111]	99 [62 – 146]	4 [-1 – 8]	37 [-12 – 81]
Other deciles	315 [164 – 526]	-21 [-37 – -10]	26 [11 – 47]	262 [114 – 472]
Cancer	216 [98 – 373]	42 [21 – 67]	18 [7 – 32]	178 [74 – 323]
Coronary and stroke	147 [68 – 250]	36 [18 – 58]	12 [5 – 22]	120 [52 – 216]
Number of life-years saved (LYS)				
All deciles	5,024 [2,711 – 8,132]	1,032 [634 – 1,554]	414 [203 – 710]	4,126 [2,022 – 7,077]
First decile of income	643 [205 – 1,497]	1,330 [827 – 1,972]	49 [-16 – 110]	492 [-156 – 1,092]
Other deciles	4,381 [2,226 – 7,368]	-297 [-519 – -140]	364 [156 – 663]	3,633 [1,557 – 6,611]
Cancer	3,589 [1,655 – 6,141]	688 [355 – 1,100]	296 [126 – 535]	2,949 [1,255 – 5,333]
Coronary and stroke	1,435 [653 – 2,460]	344 [167 – 561]	118 [50 – 212]	1,177 [499 – 2,122]
Mean cost per death avoided (kEUR)	1,379 [799 – 2,322]	6,316 [4,015 – 9,663]	369 [197 – 670]	37 [20 – 67]
Mean cost per life-year saved (kEUR)	100 [57 – 171]	474 [299 – 733]	27 [14 – 49]	3 [1 – 5]
Health disparity index: odds-ratio [1st vs. others] variation	0.002 [-0.004 – 0.007]	-0.008 [-0.012 – -0.005]	0.000 [-0.000 – 0.001]	0.002 [-0.003 – 0.008]

Additional document: presentation of economic method and data[1]

General Model

In order to evaluate the impact on health of alternative policies, using the model developed by Cash et al.[i], we consider a health risk production function that is the risk of a disease (R_i^j) for consumer *i* and disease *j*. This risk is a function of consumption (X_i) and other factors (Z_i). The level (X_i) of consumption of a consumer depends on market price (*p*), his income (Y_i) and his 'stock' of information (I_i). Note that the market price is common to all consumers while the other two parameters are consumer specific. Formally, we write $R_i^j = g^j(X_i(p, Y_i, I_i), Z_i)$.

The change in the individual risk of a policy which affects any of these variables is given by:

$$dR_i^j = \frac{\partial g^j}{\partial x_i}\frac{\partial x_i}{\partial p}dp + \frac{\partial g^j}{\partial x_i}\frac{\partial x_i}{\partial Y_i}dY_i + \frac{\partial g^j}{\partial x_i}\frac{\partial x_i}{\partial I_i}dI_i + \frac{\partial g^j}{\partial Z_i}dZ_i \qquad (1)$$

Because we assume that the policies investigated in this paper do not change the other factors (Z_i), the last term of (1) vanished. Then, the change in incidence of a disease is the sum of three terms: the first is related to the change in market price (d*p*), the second is related to the change in consumer income (dY_i) and the third is related to the change in the stock of information (dI_i). For each of the three terms the change in incidence of a disease is the combination of a health response ($\partial g^j / \partial X_i$), a consumption response ($\partial X_i / \partial V$, where V represents the variables *p*, Y_i or I_i) and a policy response. Consumption of F&V by a consumer decreases when the price increases, and increases when his income increases or when his information 'stock' is increased:

$$\frac{\partial x_i}{\partial p} \leq 0; \frac{\partial x_i}{\partial Y_i} \geq 0; \frac{\partial x_i}{\partial I_i} \geq 0.$$

At the aggregate level, the equilibrium on the market – defined by prices and quantities produced and consumed – depends on supply and demand functions. Before implementing a policy, supply and demand functions provide the initial price and quantity equilibrium. As is usually the case in such a context, the initial equilibrium will be modified by the policy scenarios[ii].

Policies

The first policy is a decrease in VAT (**policy 1**) whose direct effect is a reduction in the difference between consumer and producer prices. With respect to (1), this policy affects *p* while *Y*, *I* and *Z* remain unchanged. This modification induces an increase in the consumption of all consumers due to the reduction of the consumer price. The change in consumption depends on the initial level of consumption of each consumer, on the level of the VAT decrease, and on the supply and demand elasticities.

The second policy consists in subsidizing F&V consumption through F&V stamps given to the poorest consumers (**policy 2**). Such a policy can be considered as an increase in the income of the targeted consumers. Consider two sub-populations: sub-population 1 (the targeted one) composed of the lowest income households, and sub-population 2 composed of the other households. With respect to (1), policy 2 affects the income of sub-population 1 (*Y1)* while *Y2* (income of sub-population 2), I and Z remain unchanged. A direct effect of the policy is an increase in the demand for F&V by the targeted population. This increase in consumption of sub-population 1 induces an increase in the market price. Then, consumption in sub-population 2 will decrease as its demand function remains unchanged while she is

[1] A presentation of the economic model is available on request from the authors.

facing higher price of F&V. This is an indirect effect of policy 2. At the aggregate level, the increase in consumption depends on the level of the subsidies, on the elasticity of supply, and on the price and income elasticities of demand.

The third policy is based on a general information campaign promoting F&V consumption (**policy 3**). We consider that the "stock of information" of a consumer corresponds to his product characteristics-knowledge related to its positive effect on health. The greater the stock of information is, the greater the demand for this product. An information campaign is supposed to increase the stock of information of each consumer, but this increase depends on the budget used to inform each individual consumer. Moreover, the consumer response will depend on his information-responsiveness. With respect to (1), policy 3 affects the information-stock I of the populations, while Y and Z remain unchanged. It has an indirect impact through the change in p which lowers the increase in consumption. At the aggregate level, the increase in consumption depends on the budget dedicated to the campaign, on the "information-responsiveness" and on the supply and demand price elasticities.

Economic Data

Key parameters of the analysis are the (1) price elasticity of demand, (2) income elasticity of low income population, (3) price elasticity of supply (4) consumer response to generic advertising.

(1) Price elasticity of demand

Price elasticity of demand is defined as the measure of responsiveness in the quantity demanded for a product as a result of change in its price. It is expressed as the ratio between the percentage change in quantity demanded and the percentage change in price. A price elasticity of demand equals to -0.5 means that the demand for a product decreases by 0.5% in response to a 1% increase in its price. Several studies at the international level show that the price elasticity of F&V demand depends on the types of products (processed/non processed, F or V), the population categories and the countries[iii]. Given the consumption specificities of each country, the simulations were computed with price elasticities estimated in the French case. On the basis of the literature dealing with French consumption (see Table A below), it appears that the price elasticity of demand of the whole population for different categories of F&V ranges between -0.24 and -1.15. Price elasticity of demand from low income population ranges between a low price elasticity of -0.06 to a high elasticity of -1.27. Based on the average and standard deviations computed from the results available in the literature, we consider that the price elasticity of F&V demand is -0.85 for the two populations, and that the standard deviation is 0.4 for the first decile of income population and 0.3 for the other part of the population.

		Price elasticity	*Price elasticity*	*Income Elasticity*
		Whole population	*Poor households*	*Poor Households*
Nichele[iv] (2003)	Fruits	-0,7		
	Vegetables	-0,92		
Andrieu and[v] Caillavet (2006)	Fruits			0,89
	Vegetables			0,3
Andrieu *et al*.[vi] (2006)	Fresh Fruits	-1,06	-0,89	0,22
	Fresh Vegetables	-1,06	-0,82	0,22
	Processed Fruits	-0,79	-1,15	0,37
	Processed Vegetables	-1,02	-1,03	0,27
Allais *et al*.[vii] (2008)	Fresh Fruits	-0,24*	-0,06	
	Fresh Vegetables	-0,34*	-0,2	
	Processed Fruits	-0,58*	-0,61	
	Processed Vegetables	-0,94*	-0,95	
Caillavet *et al*.[viii] (2009)	Fresh Fruits	-1,15	-1,23	
	Fresh Vegetables	-0,68	-0,83	
	Processed Fruits	-1,13	-1,14	
	Processed Vegetables	-1,04	-1,27	

Table A. Price and income elasticities in France
(* elasticities for non poor people rather than for the whole population)

(2) Income elasticity of low income population

In order to assess the effect of the F&V stamp policy, it is necessary to determine how F&V stamps can modify the households' consumption. From an economic point of view, the most rigorous approach leads to consider that F&V stamps are equivalent to an increase of income. Indeed, even if the F&V stamps are specifically designed for F&V consumption, consumers can always save the equivalent amount of money they used previously for F&V and use it for purchasing any other goods. Thus, the impact of the F&V stamps will depend on the income elasticity of F&V demand of the consumers.

Income elasticity of demand is defined as the measure of responsiveness in the quantity demanded for a product as a result of a change in the income of consumers. An income elasticity of demand equals to 0.5 means that the demand for a product increases by 0.5% in response to a 1% increase in the income of consumers.

Based on the data published in the literature dealing with French population, we consider that the mean income elasticity of F&V demand is 0.4 for the low-income population, with a standard deviation of 0.3 (see Table A).

(3) Price elasticity of supply

Price elasticity of supply is defined as the measure of responsiveness in the level of production as a result of a change in the market price. A price elasticity of supply equals to 0.5 means that the production of a given product increases by 0.5% in response to a 1% increase in the market prices. A robust result in economic literature is that in the short-run, supply elasticity is rather small while it is significantly higher in the medium-run and long-run. This is because in the medium or long run producers have much more possibilities to respond to price changes by adapting their production capacity (change in acreage, investments in glasshouses…), while in the short-run it is much more difficult to react to price changes. In this analysis, we will consider medium-run elasticity as we are interested in the impact of policies when the agents have some 'time' to react to the changes.

Some studies give estimates of the price elasticity of F&V supply but they do not refer specifically to France. However, contrary to the F&V demand which is likely to be country-specific, the producers' flexibility of supply is more similar from one country to another. For this reason, we considered that it was admissible to use values obtained in non French studies. For instance, a study from DEFRA[ix] for the UK reports short run elasticity of 0.21 and medium run elasticity of 0.68. Alston *et a*l.[x] in a study on food stamps in the US, use a supply elasticity of 1.0 arguing that it reflects medium run response. Jetter *et al*.[xi] analyze the impact of '5 a day' campaign and consider the following values for the supply price elasticity of vegetables, fruits and perennial crops: 0.5, 1.0 and 0.75 (respectively) for low values and 1.0, 1.5 and 1.25 (respectively) for high values. In this study, we thus choose a value of 1 for the price elasticity of supply with a standard deviation of 0.25.

(4) Consumer response to generic advertising

Consumer response to generic advertising is defined as a measure of responsiveness in the quantity demanded of a product as a result of a change in the stock of information. Rather than using an elasticity measure, which is a ratio of percentage changes, we use here the percentage change in the demand for one additional € of information per consumer. Thus, we can consider that each consumer holds a certain level of information (a 'stock' of information) related to the benefits of F&V consumption, which influences his consumption. A generic campaign such as '5 a day' aims to increase this 'stock' of information, assuming that the greater the increase in the 'stock' of information, the greater the increase in the F&V consumption. The increase in the 'stock' of information held by each consumer will depend on the level of the funds spent to promote F&V consumption through various media. The responsiveness of each consumer to an increase in his stock of information will depend on his own 'response to advertising' which expresses how much his F&V consumption will go up if the advertising budget is increased by a given amount.

Because we do not have econometric studies on the French case, we defined two levels of consumer responsiveness: a lower bound and an upper bound for this parameter. To set these bounds, we exploited two sources of information:

The first one is the literature on ‘generic advertising’ campaigns implemented by producers or governments to promote the consumption of various food products. This literature was recently reviewed by Crespi[xii] who reports the effects of such campaigns on producers’ returns or/and demand modification in the US. This leads to consider that the percentage change in the demand for one additional € of information per consumer ranges between 0.01 and 0.1.

The second source of information is related to the variation of F&V consumption observed in France. According to Afssa[xiii] (INCA surveys) and the data on the variation of the apparent consumption, the increase of the mean F&V consumption was around 25g/day/person during the last decade. If we assume that this increase is only due to the information campaigns implemented between 2001 and 2006, it leads to assume that these campaigns induced a maximum increase of around 4g/day/person/year for an annual amount of around 10 millions of euros (we take into account public and private generic campaigns). Such an increase corresponds to a percentage change in the demand for one additional € of information per consumer of about 0.1%.

Finally, the simulations were made with a ‘pessimistic’ mean lower bound of 0.01 and a standard deviation of 0.002, and an ‘optimistic’ mean upper bound of 0.1 and a standard deviation of 0.02.

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[i] Cash SB, Sunding DL, Zilberman D. Fat Taxes and Thin Subsidies: Prices, diet, and health outcomes. *Food Economics*. 2005; 2(3-4); 167-174.

[ii] Alston JM, Conner CM, Sumner DA, Townsend M, Vosti SA. 2009. Likely Effects on Obesity from Proposed Changes to the US Food Stamp Program. *Food Policy*. 2009; 34(2); 176-184.

iii Durham C., Eales J. A Demand Elasticities for Fresh Fruit at the Retail Level. Demand elasticities for fresh fruit at the retail level. Oregon State University, Corvallis, OR, and Purdue University, West Lafayette, IN, 2006:1–19.
Oregon State University Food Innovation , 2006, 21p.

[iv]Nichèle V., 2003. Health Information and Food demand in France, in Health, Nutrition and Food demand, Ed. W.S Chen and Rickertsen, CABI Publishing, pp 131-151.

[v] Andrieu, E., and Caillavet, F. (2006). Inégalités nutritionnelles au sein des ménages : la pauvreté joue-t-elle un rôle ? *Cahiers de Nutrition et de Diététique* 41(2), 75-85.

[vi] Andrieu, E., Caillavet, F., Lhuissier, A., Momic, M., and Regnier-Chauvel, F. (2006). L'alimentation comme dimension spécifique de la pauvreté. Approches croisées de la consommation alimentaire des populations défavorisées. In "Les travaux de l'Observatoire national de la pauvreté et de l'exclusion sociale 2005-2006" (s. Observatoire national de la pauvreté et de l'exclusion, Ed.), pp. 247-278.

[vii] Allais O., Bertail P., Nichèle V. 2009 . The Effects of a Fat Tax on French Households‘ Purchases, *American Journal of Agricultural Economics* (in press).

[viii] Caillavet F., Lecongne C., Nichèle V., 2009. Is Subsidy Policy of Fruits and Vegetables beneficial to the most Underprivileged Population ? Working Paper, INRA-ALISS, 25 p.

[ix] Defra, UK - Department for Environment, Food and Rural Affairs, http://www.defra.gov.uk/

[x] Alston JM, *et al.* (2009) , *op. cit.*

[xi] Jetter K.M., Chalfant J.A., Sumner D.A., 2004. *An Analysis of the Costs and Benefits to Consumers and Growers from the Consumption of Recommended Amounts and Types of Fruits and Vegetables for Cancer Prevention*, Final report prepared for the California Department of Health Services Cancer Prevention and Nutrition Section, University of California, Agricultural Issues Center, April 2004.

[xii] Crespi JM., The Generic Advertising Controversy: How Did We Get Here and Where Are We Going? *Review of Agricultural Economics*. 2003; 25(2); 294-315.

[xiii] Afssa (2008), Summary of the Individual and National Study on Food Consumption (INCA 2) 2006-2007
http://www.afssa.fr/Documents/PASER-Sy-INCA2.pdf