ARE FRUIT AND VEGETABLE STAMP POLICIES COST-EFFECTIVE?

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ABSTRACT

In many countries, consumption of fruits and vegetables (F&V) is below recommended levels. We quantify the economic and health effects of F&V stamp policy designed for low-income consumers. The analysis combined two models: an economic model which predicts how F&V consumption is affected by a change in policy and a health model which evaluates the impact of a change in F&V consumption in terms of death avoided (DA) and life-years saved (LYS). Finally we computed the costs per DA and LYS as the ratio between the taxpayer cost of the policy and the number of DA and LYS.

The main findings of the present study are: (1) F&V stamp policy has a positive and significant impact on the consumption of small F&V consumers of the targeted population, (2) at the aggregate level, this policy has a modest impact on consumption and as a result on health gains, (3) for a given budget allocated to the policy, the cost per DA or LYS decreases when the targeting is smaller, at least as long as consumption remains in plausible values, (4) the policy reduces the health inequalities between low and high income populations, (5) when well designed, F&V stamp policy is as cost-effective as price policy (about 42 k€/LYS).

KEY WORDS: Cost-effectiveness analysis, Fruits and Vegetables, Health Impact Assessment, Health Policy

JEL CODES: D61, I18, Q18.

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Introduction

Poor nutritional outcomes in disfavoured and low-income households are crucial issues for health policy makers in many industrialized countries (Lock et al., 2005). Population groups with high poverty rates and low education levels are indeed often reported to face higher obesity and overweight prevalence, associated with lower-quality diets, higher intakes of energy-dense foods and smaller consumption of fruits and vegetables (F&V) (Blisard et al., 2004; Disball et al., 2007; Fox and Cole, 2004; Frazao, 2007; Wilde at al., 1999). Even if other factors seem to play important roles (French et al., 2001; Cassady et al. 2007), economic factors are frequently considered as major determinants of food behaviours, low incomes binding the food diet choices and limiting the ability to have adequate food intakes according to dietary guidelines (Bihan et al., 2010; Drewnowski at al., 2004; Drewnowski and Specter, 2004; Drewnowski and Darmon, 2005; Lin and Guthrie, 2007; Olson, 1999).

In the United States, food assistance programs have been implemented for a long time to help disfavoured populations from an economic point of view (Landers, 2007). Besides education programs, Food Stamp Program (FSP) aims to increase food expenditures by delivering to the households monthly stamps only useable to buy foods. In present days, 25 millions of people are involved in this program and receive a mean amount of 200 dollars per household per year.

FSP is generally considered to be successful in that sense that it provided food assistance to many low-income people, leading to a decrease in child poverty and food insecurity (Le Blanc et al., 2007; Pan and Jensen, 2008; Wilde and Nord, 2005). However the impacts on diet quality and on other nutrient needs are not so clear and the goals related to the reduction of obesity and overweight prevalence are not always met (Chen et al., 2005; Jones and Frongillo, 2006; Gibson, 2003 and 2006; Meyerhoefer and Pylypchuk, 2008; Ver Ploeg et al., 2007: Wilde et al., 2000; Webb et al., 2008). In fact, it is worthwhile to note that the FSP allows participants to buy any foods they want and then to consume the same diet as previously, even if it is dominated by energy-dense foods and beverages (Fox et al., 2004; Fox and Cole, 2004; Frongillo, 2003). For this reason, some authors proposed to re-design the FSP to allow only the purchase of healthy foods, especially F&V (Guthrie et al., 2007). Such a measure has been experimented within the Special Supplemental Nutrition Program for Women, Infants, and Children and the Food Stamp (WIC), in which pregnant women in low-income households get a $10 voucher per week to purchase only fresh F&V. This experiment confirmed that providing F&V vouchers would increase purchase and consumption of a wide variety of nutrient dense fresh F&V among low income women and their families (Herman et al., 2008).

In Europe, food stamp programs have not been implemented yet, as food assistance programs rely mainly on charity associations which distribute food surpluses. However the increase in health inequalities and in obesity prevalence among low income populations led some policy makers to propose to implement F&V stamp programs[1]. Some local experiments have been made in France to assess the impacts of €10 monthly vouchers per person. First results seem to attest some positive effects on F&V consumption (Bihan, 2008).

However, redesigning the FSP in the US by limiting their use to F&V purchases, or generalizing the first European experiments to all the low income households raises the

[1] See for instance, the project discussed in the French Parliament in June 2010 (http://www.assemblee-nationale.fr/13/pdf/propositions/pion2671.pdf).

question of the cost-effectiveness of this policy. Cost-effectiveness of F&V stamp policy depends on several factors. First, it depends on the total budget used to fund this policy and the size of the targeted population, these two parameters determining the level of the individual subsidy each participant gets to buy F&V. Secondly, it depends on the initial consumption patterns of each participant. It is well-known that the behaviour of the household will depend on the value of the stamp compared to the initial expenditure (Alston et al. 2009). If the stamp is smaller than the budget initially devoted to F&V purchases, it acts as an income increase and has the same effect on consumption as a cash transfer. If the stamp is greater, the value above the current F&V expenditure is fully devoted to F&V purchases. According to the case, the impacts will be more or less important. Thirdly, the cost-effectiveness of the policy will depend on its aggregated effects on the participants and the non participants as well (Alston et al., 2009; Dallongeville et al., 2010). Indeed, if the participants' income increase leads to an increase in the F&V demand, it is likely that all the households will face higher prices which can limit the consumption increase among the participants to the program and favour a consumption decrease among the non participants. Finally, the cost-effectiveness of such a policy will depend on the health benefits linked to an increase of F&V consumption.

Previous works showed that F&V stamp policy seemed to be able to reduce health inequalities but its cost-effectiveness appeared to be smaller than non-targeted policies relying on F&V price reduction or generic information campaigns (Dallongeville et al., 2010). However, we argue here that targeting the F&V stamp policy is an important issue which can influence a lot its cost-effectiveness. The goal of the paper is to assess the effects of various dimensions mentioned above on the optimal size of the targeted population.

Following Cash et al. (2005) and Dallongeville et al. (2010), we propose an approach which matches economic and health issues. Firstly an economic model of the F&V market is used to provide the impacts of the food stamp policy on F&V consumption. Then a health model is used to assess the impact of the changes in F&V consumption levels on the number of deaths avoided (DA) and life-years saved (LYS) from non communicable diseases. This economic/health model is used to simulate a F&V stamp policy and determine the modifications of F&V consumption among participants and non participants to the F&V stamp program, according to the amount of the total budget and the size of the targeted population. According to the health consequences assessed by simulation, we finally compute the costs per DA and LYS induced by this policy and we compare them to other public health interventions. The simulations are made with French data.

We present the general economic model in section 1, and the health model in section 2. In section 3 we explain how these models are applied to simulate F&V stamp policies and assess their cost-effectiveness. The main results are presented in section 4. The limits of our results and their policy implications are discussed in section 5.

1. The 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 and other parameters. The supply function represents the total quantity of F&V delivered by the producers according to the price the producer gets and other parameters. Any change in policy variables, such as consumers' income, affects the equilibrium characterized by the quantities consumed as well as market prices. This kind of model, known as Equilibrium Displacement Model, was developed to analyze market impacts of various policies such as country of origin labeling (Lusk and Anderson, 2004), R&D expenses (Wolghenant, 1993), price floor mechanisms (Bouamra-Mechemache and Réquillart, 2000).

In the following, we distinguish two segments in the population: the targeted population which benefits from the food-stamp policy and the non-targeted one. Formally, the market equilibrium is defined by the following equations:

$$Q_{d1} = g_1(P_d, Y_1, Z_{d1}) \qquad (1)$$

$$Q_{d2} = g_2(P_d, Y_2, Z_{d2}) \qquad (2)$$

$$Q_d = Q_{d1} + Q_{d2} \qquad (3)$$

$$Q_s = f(P_s, Z_s) \qquad (4)$$

$$Q_s = Q_d \qquad (5)$$

$$P_d = (1 + \tau)P_s \qquad (6)$$

with $\mathrm{Q_d}$ the total quantity demanded, $\mathrm{Q_{d1}}$ and $\mathrm{Q_{d2}}$ the quantities demanded by population 1 (the targeted population) and population 2 (the non-targeted one) respectively, $\mathrm{P_d}$ the consumer price, Y_1 and Y_2 the income of population 1 and 2, Q_s the quantity supplied, P_s the producer price, Z_s, Z_{d1} and Z_{d2} shifters of supply and demand functions, and τ the tax coefficient. In this setting, prices and quantities are the endogenous variables while the other ones (income, supply and demand shifters as well as tax coefficient) are exogenous.

Equations (1) and (2) define the demand function for the two populations. These demands depend on consumer price, income and other elements that might shift the demand such as information. To simplify the presentation, we assume that the good consumed is homogenous; then both populations are facing the same consumer price. Equation (3) states that the total quantity demanded is the sum of the demand from population 1 and 2. Equation (4) states that the supply depends on producer price and other elements that might change the supply such as the level of technology or weather conditions. Equation (5) states that at equilibrium the quantity demanded is equal to the quantity supplied. Finally equation (6) defines the relation between the producer price and the consumer price.

Totally differentiating the set of equations (1) to (6) leads to the following system which relates the relative change of endogenous variables to the relative change of exogenous variables:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & -\varepsilon_p^{d1} \\ 0 & 1 & 0 & 0 & 0 & -\varepsilon_p^{d2} \\ -\alpha & \alpha-1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -\eta_p^s & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} EQ_{d1} \\ EQ_{d2} \\ EQ_d \\ EQ_s \\ EP_s \\ EP_d \end{bmatrix} = \begin{bmatrix} \varepsilon_Y^{d1} EY_1 + \varepsilon_z^{d1} EZ_{d1} \\ \varepsilon_Y^{d2} EY_2 + \varepsilon_z^{d2} EZ_{d2} \\ 0 \\ \eta_z^s EZ_s \\ 0 \\ \tau E\tau \ /(1+\tau) \end{bmatrix} \qquad (7)$$

denoting EX the ratio dX/X with X representing any variable; and with $\eta_p^s = \frac{\partial f}{\partial P_s}\frac{P_s}{Q_s}$ the own-price elasticity of supply, $\eta_z^s = \frac{\partial f}{\partial Z_s}\frac{Z_s}{Q_s}$ the elasticity of supply with respect to Z_s, $\varepsilon_p^{di} = \frac{\partial g_i}{\partial P_d}\frac{P_d}{Q_{di}}$

the own-price elasticity of demand of population *i*, $\varepsilon_Y^{di} = \frac{\partial g_i}{\partial Y_i}\frac{Y_i}{Q_{di}}$ the income elasticity of demand of population *i*, $\varepsilon_Z^{di} = \frac{\partial g_i}{\partial Z_{di}}\frac{Z_{di}}{Q_{di}}$ the elasticity of demand with respect to Z_{di}, and $\alpha = \frac{Q_{d1}}{Q_{d1}+Q_{d2}}$ the share of demand from population 1. In the standard case, we have $\eta_p^s > 0$; $\varepsilon_p^{d1} < 0$; $\varepsilon_p^{d2} < 0$; $\varepsilon_Y^{d1} > 0$; $\varepsilon_Y^{d2} > 0$.

Then to analyze the impact on endogenous variables of a change in exogenous variables, the system of equations (7) is solved given the value of the change in exogenous variables.

F&V stamps policy must be analyzed by considering that F&V stamps act through two channels: a direct one and an indirect one. The direct one only applies if the value of the F&V stamp (denoted *F*) given to one consumer is larger than his current expenditure in F&V (denoted *E*). In that case, the consumer is somewhat forced to buy a larger quantity of F&V. The increase in consumption is equal to $(E\text{-}F)/P_d$. The indirect channel corresponds to a change in income and applies to the part of the F&V stamp which is lower or equal to the current expenditure. To get the intuition, assume that $F \leq E$ and that the consumer does not change his habits. This consumer uses the F&V stamp to purchase part of his consumption of fruits and vegetables. By doing so, he saves money which can be used for any other use. In that case, the F&V stamp is equivalent to a change in income (see Alston et al. (2009) for a discussion).

Let us consider first the case with $F \leq E$. In that case, a food stamp targeted to a given product is interpreted as a change in income (Y_1). To infer the impact of this policy, we solved the system (7) with $EY_1 > 0$ while the other exogenous variables are kept constant ($E\tau = 0$, $EY_2 = 0$, $EZ_s = 0$, $EZ_{d1} = 0$ and $EZ_{d2} = 0$). We get:

$$EQ_{d1} = \left(1 + \frac{\alpha\varepsilon_p^{d1}}{A_2}\right)\varepsilon_Y^{d1} EY_1 \qquad (8)$$

$$EQ_{d2} = (\frac{\alpha\varepsilon_p^{d2}}{A_2})\varepsilon_Y^{d1}EY_1 \quad (9)$$

$$EQ_d = EQ_S = (\frac{\alpha\eta_p^s}{A_2})\varepsilon_Y^{d1}EY_1 \quad (10)$$

$$EP_d = EP_S = \frac{\alpha}{A_2}\varepsilon_Y^{d1}EY_1 \quad (11)$$

with $A_2 = \eta_p^s - \alpha\varepsilon_p^{d1} - (1-\alpha)\varepsilon_p^{d2}$. In the standard case, we have $A_2 > 0$. Equation (8) provides the relative change of consumption in population 1. It is the sum of the relative increase in consumption at constant price ($\varepsilon_Y^{d1}EY_1$) and the relative decrease in consumption ($\frac{\alpha\varepsilon_p^{d1}}{A_2}$) due to the price increase (Equation (11)). The final relative increase of consumption by population 1 is positive as the price effect is lower than the direct effect. The quantity consumed by population 2 always decreases ($EQ_{d2} < 0$).

Let us consider now the case with F>E. The amount *F-E* will be used by the consumer to increase his F&V consumption while the amount *E* corresponds to an increase in his income. The model is adapted by introducing a new exogenous variable that shifts the demand of population 1. The first element of the RHS of (7) is now $\varepsilon_Y^{d1}EY_1 + \varepsilon_z^{d1}EZ_{d1} + ED_1$ with $ED_1 = (F-E)/(p_d * Q_{d1})$ the relative change of consumption due to the '*F-E*' part of food stamp. The system (7) is now solved with $E\tau = 0$, $EZ_s = 0$, $EY_1 > 0$; $EZ_{d1} = 0$, $EZ_{d2} = 0$ and $ED_1 > 0$, and we get:

$$EQ_{d1} = (1 + \frac{\alpha\varepsilon_p^{d1}}{A_2})(\varepsilon_Y^{d1}EY_1 + ED_1) \quad (12)$$

$$EQ_{d2} = (\frac{\alpha\varepsilon_p^{d2}}{A_2})(\varepsilon_Y^{d1}EY_1 + ED_1) \quad (13)$$

$$EQ_d = EQ_S = (\frac{\alpha\eta_p^s}{A_2})(\varepsilon_Y^{d1}EY_1 + ED_1) \quad (14)$$

$$EP_d = EP_S = \frac{\alpha}{A_2}(\varepsilon_Y^{d1}EY_1 + ED_1) \quad (15)$$

As compared to the previous case, we get similar results except that the shift is larger. While in the first case, the impacts on the endogenous variables were proportionate to $\varepsilon_Y^{d1} EY_1$, in the second case they are proportionate to $\varepsilon_Y^{d1} EY_1 + ED_1$ which is larger.[2]

2. The health model

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. Table 1 gives the relative risks (RRs) of specific causes of death associated with an increase by one serving of F&V, *i.e.* the decrease in the probability of each disease induced by an additional consumption of 80g/d. These data were taken from recently published meta-analyses for cancer deaths and for cardiovascular deaths (coronary and stroke) (Dauchet et al., 2005; Dauchet et al., 2006). 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 evaluate the latter, we used recent mortality and cause specific mortality data for France in 2006 (additional details in Dallongeville et al., 2010). 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 (Murray, 1994).

[2] By writing this, we neglect the changes of the consumer price in the value of ED_1. In the empirical version, we run the model twice in order to deal with this non linear effect.

To account for the effect of social disparities on disease rates we used the relative inequality index (RII) associated with occupational status in France (Saurel-Cubizolles et al., 2009), thus estimating cancer and cardiovascular death rates in the lowest deciles 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. Numbers in brackets represent 95% confidence intervals.

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

Table 1 clearly shows that, in proportion of the population, the number of deaths related to cancer and cardiovascular diseases among poor people (here the first decile of income) are much higher than in the population considered as a whole.

3. Empirical simulations

The empirical version of the economic model is richer than the theoretical one (which was simplified to make it easier to read) as it deals with the distribution of consumption in each population. This is particularly important as the impact of the F&V stamps depends on the value of the stamp (F) as compared to the initial expenditure (E) of each consumer. In the empirical version of the model, we first define two populations differing by their level of income. Using data from the INCA 2 survey (http://www.afssa.fr/index.htm), which provides (among others) the F&V consumption as well as income, we distinguished low income consumers (LIC) who belong to the first three deciles of income from standard income consumers (SIC).[3] Those two segments of consumers differ by the distribution of F&V consumption with LIC consuming less than SIC (see Table 2).

The targeted population (that is population 1 in the theoretical model) is a part of LIC. This means that in the empirical model, population 2 is the combination of non-targeted LIC and SIC (who are always non-targeted). As explained above, in the empirical model, we also take into account the distribution of consumption in each population. To do so, we used the empirical distribution of F&V consumption in each population (see table 2).

[3] To define LIC, we choose to aggregate consumers from the first three deciles of income because there were no significant differences in the distribution of their respective F&V consumption.

Daily Consumption	Proportion of consumers (%)	
	Low Income Consumers (LIC)	Standard Income Consumers (SIC)
< 100 g/day	21	13
< 200 g/day	48	34
< 300 g/day	67	54
< 400 g/day	80	70
< 500 g/day	88	80
< 600 g/day	95	89
	Consumption (g/day)	
Mean	258	326
Median	210	281

Table 2: Distribution of F&L consumption in the two sub-populations

The extent of the consumers' or producers' responses to any policy varies according to the economic parameters of the model. Table 3 provides price and income elasticities of demand as well as price elasticity of supply. These parameters were defined on the basis of French studies and other studies when data were not available in France (for more detail, refer to Dallongeville et al., 2010). Among the LIC, demand parameters of targeted and non targeted population (F&V stamps scenario) are identical. The results of F&V stamps scenario are reported for targeted population and non targeted population. The latter is the aggregate of non targeted LIC and SIC.

	Mean	SD
Supply price elasticity	1	0.25
Demand price elasticity (LIC)	-0.85	0.4
Demand price elasticity (SIC)	-0.85	0.3
Income elasticity (targeted population)	0.4	0.3

Table 3: Elasticities of supply and demand

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 scenario for the following variables: F&V consumption for each category of consumers, number of statistical DA, number of statistical LYS, cost per statistical DA, cost per statistical LYS. We then calculate the median and the 2.5 and 97.5 centiles for each variable.

Finally we determine whether the policies reduce or not the health disparities within the population. We compute an odds-ratio defined as:

$$\frac{[\%\text{ death among LIC population} \,/\, (1 - \%\text{ death among LIC population})]}{[\%\text{ death among SIC population} \,/\, (1 - \%\text{ death among SIC population})]}$$

4. Results

Impact of the rate of targeting

For a given amount of financing, the impact of F&V stamp policy decreases with the rate of targeting.[4] Thus, for a 300 M€ budget, the median increase in consumption for the whole population is 0.4 g/day when targeting is 10%, 0.9 g/day when it is 5%, 1.9 g/day when it is 2.5% and 3.2g/day when it is 1.25% (Table 4). Targeted population increases significantly her consumption while non-targeted population (whatever they are LIC or SIC) decreases her consumption due to a price effect. For example, when targeting 2.5% of the population the median consumption increase for targeted consumers is 135.6 g/day while the median consumption variation for non-targeted LIC and SIC consumers is decreased by 1.2 and 1.7 g/day, respectively. In this example, the increase in demand from targeted consumers generates a slight increase in the consumer price (0.6%).

Figure 1 provides the initial and final distribution of F&V consumption of LIC distinguishing between targeted consumers and non targeted consumers.[5] Among the targeted population, the increase in consumption is mainly from those who have a 'small' initial level of consumption, (i.e. for consumers for which the value of the food stamp was higher than their initial consumption of F&V). All those consumers, after the policy implementation, consume (almost) the same quantity which is the value of the stamp divided by the price of F&V.[6] Consumers with an initial level of expenditure larger than the value of the F&V stamp slightly increase their consumption. Non targeted consumers consume less as they face a price

[4] Note that a higher rate of targeting means that the targeted population is larger.

[5] Results for non-targeted SIC are similar to the one presented for non-targeted LIC. That is basically a slight decrease in consumption.

[6] It is slightly increasing with the initial consumption, as the initial expenditure acts as an increase in income which is partly used for purchasing F&V.

increase. The larger the initial consumption is, the larger the magnitude of this effect. The changes in consumption are larger when the targeting rate decreases, as the amount of the F&V stamp increases when the rate decreases (for a given total budget).

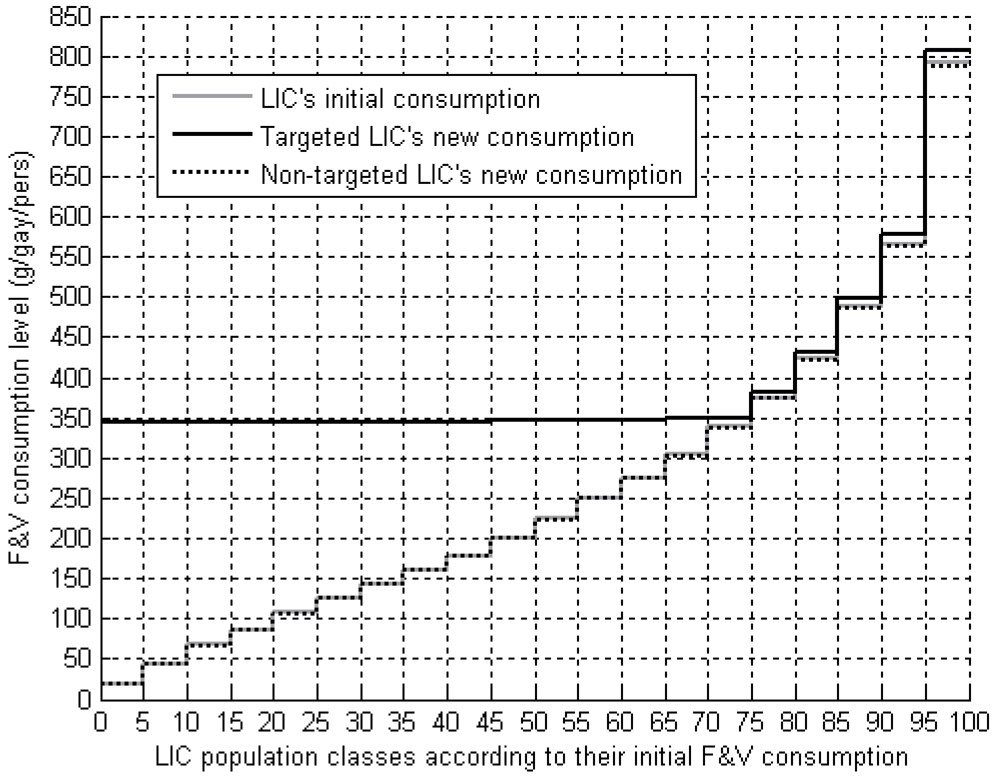

Figure 1. F&V consumption of LIC according the initial classes of consumption when F&V stamps are targeted on the 2.5ile of the population (Total budget=300 M€*)*

Policy comparison	Targeted LIC = 10%			Targeted LIC = 5%			Targeted LIC = 2.5%			Targeted LIC = 1.25%		
	Median	2.5%ile	97.5%ile	Median	2.5%ile	97.5%ile	Median	2.5%ile	97.5%ile	Median	2.5%ile	97.5%ile
Consumer price variation (%)	0,13	0,09	0,20	0,30	0,21	0,44	0,62	0,43	0,90	1,07	0,73	1,58
Individual consumption variation (g/day)												
Targeted LIC	6,9	6,3	8,9	32,4	30,9	37,6	135,6	131,5	150,1	465,9	441,1	557,0
Non-targeted LIC	- 0,3	- 0,6	- 0,1	- 0,6	- 1,4	- 0,2	- 1,2	- 2,8	- 0,5	- 2,1	- 4,8	- 0,9
Non-targeted SIC	- 0,4	- 0,6	- 0,2	- 0,8	- 1,3	- 0,4	- 1,7	- 2,6	- 0,9	- 2,8	- 4,6	- 1,6
Whole population	0,4	0,3	0,6	0,9	0,6	1,2	1,9	1,2	2,5	3,2	2,1	4,4
Number of death avoided (DA)												
Targeted LIC	100	65	144	242	159	332	494	326	664	755	487	1017
Non-targeted LIC	- 6	- 14	- 2	- 17	- 41	- 6	- 39	- 94	- 15	- 72	- 173	- 27
Non-targeted SIC	- 14	- 27	- 7	- 33	- 59	- 16	- 68	- 121	- 33	- 116	- 211	- 56
Whole population	79	50	115	189	122	265	379	246	524	553	345	770
Cancer	43	22	67	100	53	153	196	102	293	264	113	399
Cardio-Vascular	36	18	58	88	45	137	183	94	281	290	153	438
Number of of life-years saved (LYS)												
Targeted LIC	1346	858	1946	3242	2095	4470	6584	4284	8849	9910	6277	13237
Non-targeted LIC	- 77	- 189	- 29	- 230	- 557	- 86	- 535	- 1291	- 201	- 975	- 2369	- 364
Non-targeted SIC	- 202	- 375	- 95	- 459	- 837	- 218	- 948	- 1719	- 451	- 1630	- 2992	- 771
Whole population	1050	663	1549	2506	1604	3534	4991	3213	6883	7103	4338	9832
Cancer	700	370	1103	1651	883	2504	3217	1711	4757	4311	1949	6370
Cardio-Vascular	350	174	565	853	428	1333	1774	899	2724	2816	1457	4246
Mean cost per life saved (M€)	3,81	2,6	5,96	1,59	1,13	2,46	0,79	0,57	1,22	0,54	0,39	0,87
Mean cost per life-year saved (k€)	286	194	453	120	85	187	60	44	93	42	31	69
Health disparity index: odds-ratio (LIC vs. SIC) variation	- 0,003	- 0,005	- 0,002	- 0,008	- 0,011	- 0,005	- 0,016	- 0,022	- 0,010	- 0,024	- 0,034	- 0,015

Table 4. Policy comparison: simulation Results (Total budget=300 M€) for LIC and SIC (Low and Standard Income Consumers)

In line with the change in consumption, the number of DA and LYS increases when the rate of targeting decreases (Table 4). When targeting 10% of the population, the median numbers of DA and LYS are respectively 79 [50-115] and 1050 [663-1549], while targeting 1.25% of the population leads to median numbers of DA and LYS which are respectively 553 [345-770] and 7103 [4338-9832].[7] As a consequence the health disparities between SIC and LIC populations decrease when the size of the targeted population decreases: the benefits obtained by the targeted LIC population are greater than the price related effects on the non targeted LIC population (see the odds-ratio variation in Table 4).

Similarly, the cost per statistical LYS decreases when the rate of targeting decreases. It is 286k€ when targeting 10% of the population, 120 k€ when targeting 5%, 60 k€ when targeting 2.5% and 42 k€ when targeting 1.25%.

Thus, targeting a lower fringe of the population decreases the cost per LYS (or DA) of the policy. However, there is a limit. When targeting on fewer people (lower than 1% of the population in our example), the cost per LYS strongly increases (Figure 2a). This is because the number of LYS in the targeted population is now small due to the size of the population. The negative impact in the non targeted population might be larger than the positive impact in the targeted population. With a 300 M€ budget devoted to the policy, the optimal targeting is between 1% and 1.25% of the population that is 500 000 to 600 000 adults in France.

[7] 2.5 and 97.5 centiles are given in brackets.

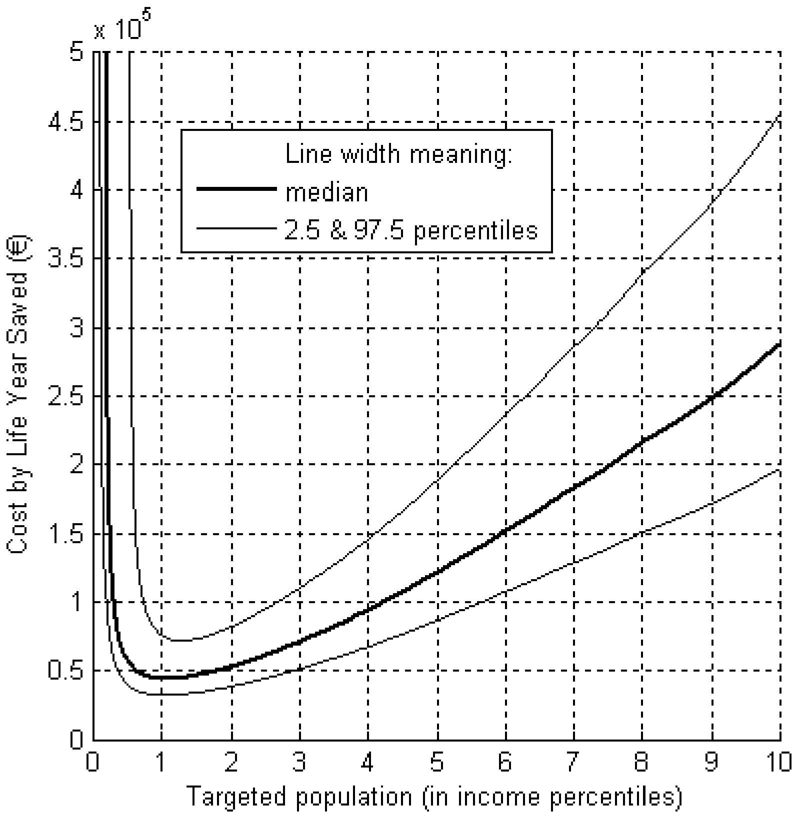

Figure 2a. Cost by LYS according to the size of targeted population
(Total budget=300 M€*)*

When targeting is large (Figure 2b), the cost per LYS is high but varies at a lower rate with targeting. In this zone, the value of the F&V stamp is lower than the lowest value (among consumers) of the initial F&V expenditure. In other words, the F&V stamp acts only indirectly through a change in income and not directly through a direct increase in consumption.

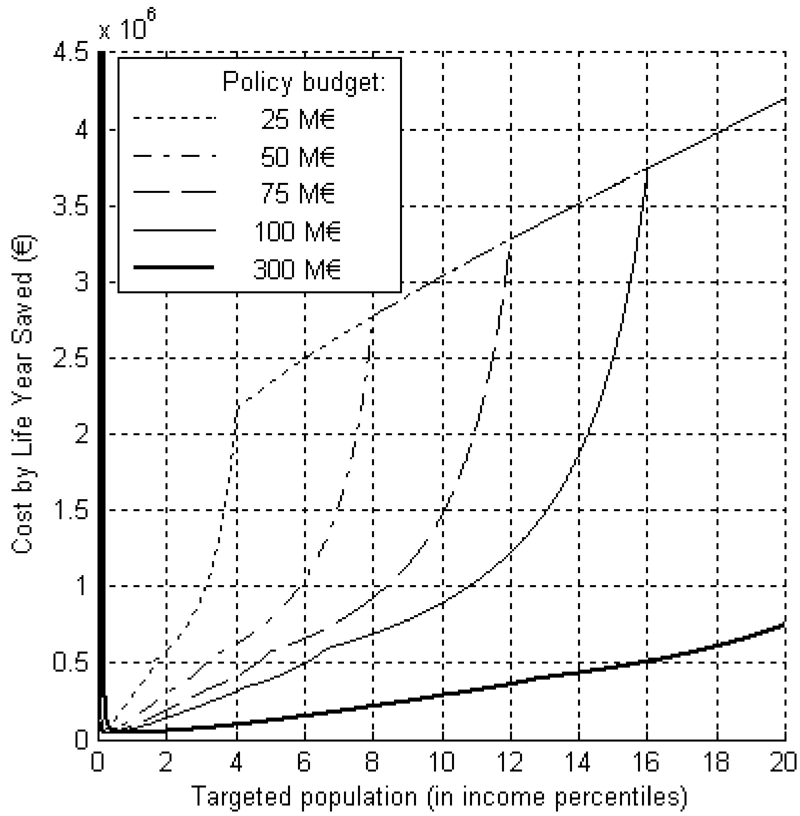

Figure 2b. Cost by LYS according to the size of targeted population
(Total budget=25, 50, 75, 100, 300 M€*)*

Optimal targeting

Figure 3a provides iso-LYS curves when both the targeting and the total amount of funding vary. As mentioned previously, for a given funding, the number of LYS increases when the size of the targeted population decreases (e.g., for 250 M€, 1000 LYS are obtained when targeting the poorest 8%, 3000 LYS for 3%, and 5000 LYS for 1.5%). Iso-LYS curves are increasing with the size of the targeted population. This means that the most cost effective policy for a given number of LYS is reached at the left end of each curve (e.g. 225M€ for the 1% poorest to obtain 5000 LYS). It also shows that higher resources devoted to the policy allow increasing the rate of targeting and the number of LYS.

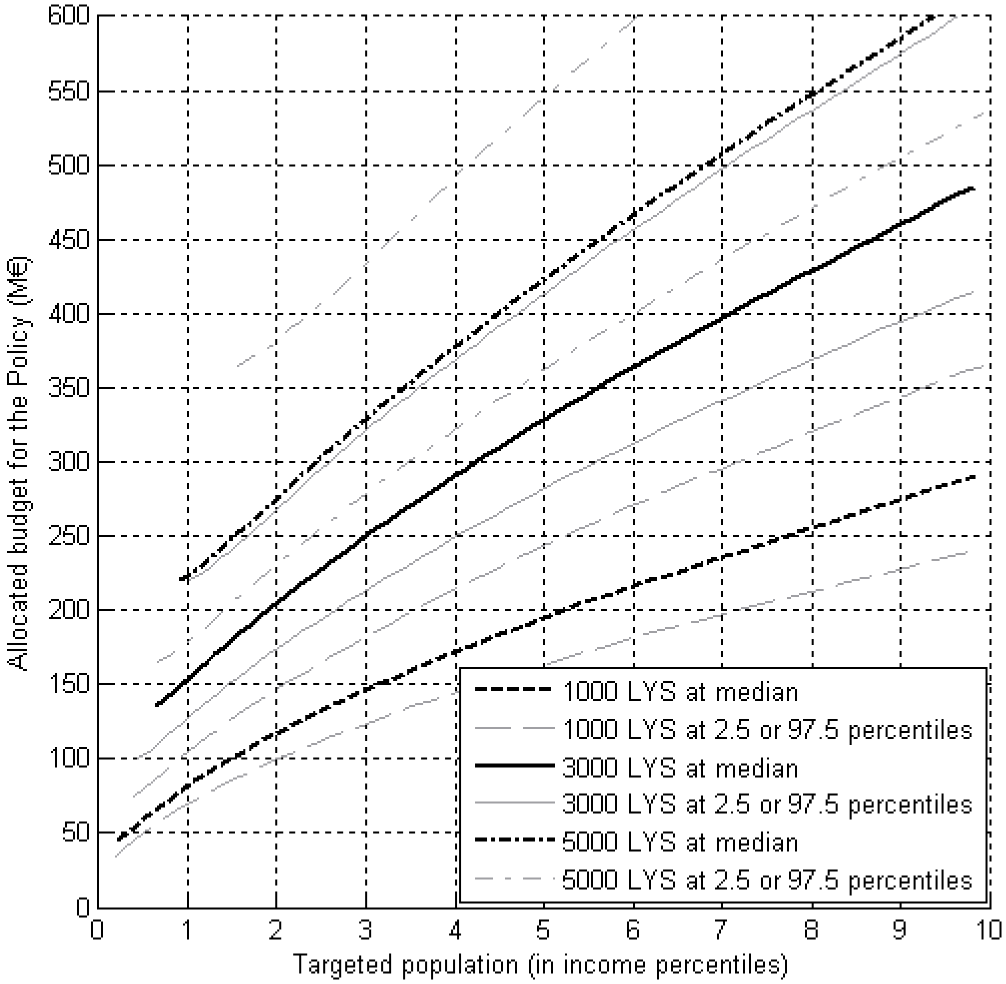

Figure 3a. Iso-LYS curves according to the size of the targeted population and the total budget allocated the F&V stamps

Similarly, Figure 3b presents iso-cost by LYS curves. It shows that, for instance, the effectiveness level of 75 k€/LYS can be reached by targeting 1% of the population with 90 M€ and 4% of the population with 380 M€. Contrarily to Figure 3a, in Figure 3b, all left ends are at (0,0): nobody targeted (and thus no budget allocated). Hence, all costs by LYS are possible either for a given target or for a given budget.

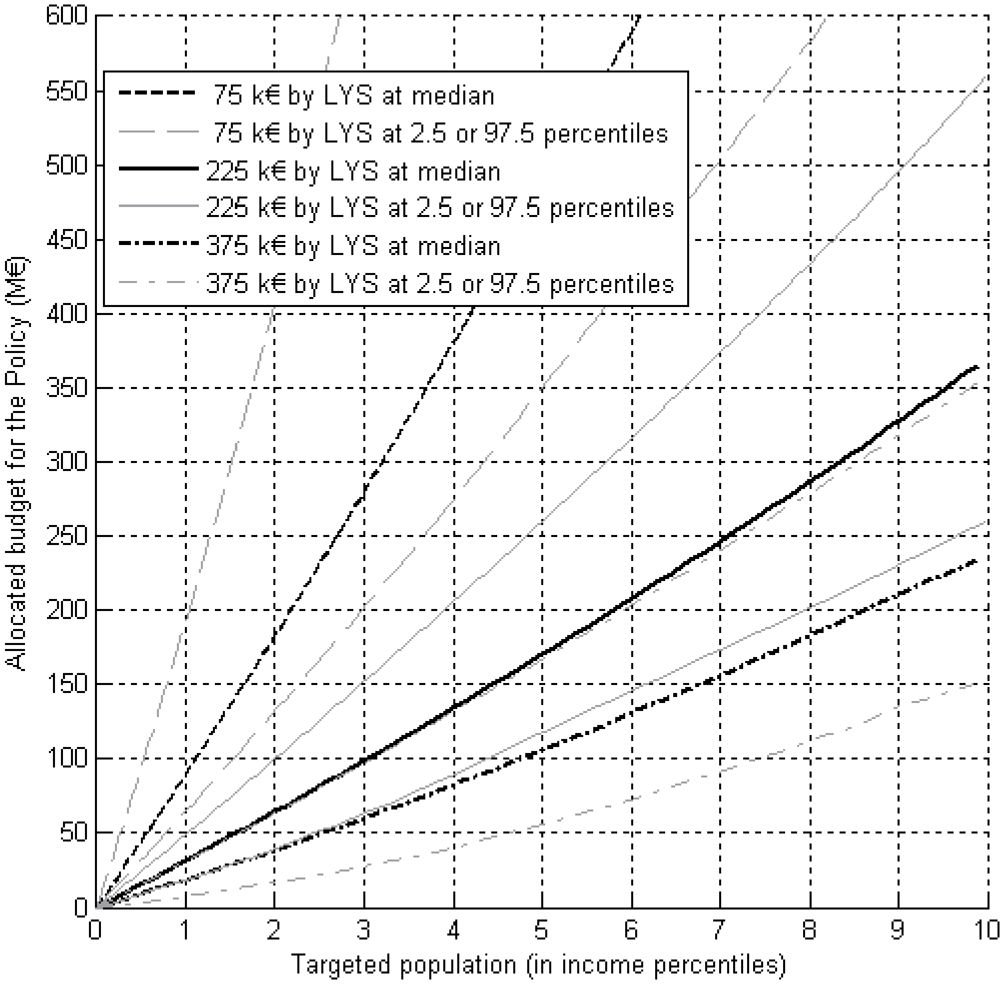

Figure 3b. Iso-cost by LYS curves according to the size of the targeted population and the total budget allocated the F&V stamps

5. Discussion

The analysis presented in this paper, based on collaboration between economists and epidemiologists combined two models: an economic model which predicts how F&V consumption is affected by a change in policy and a health model which evaluates the impact of a change in F&V consumption in terms of DA and LYS. Finally we computed the costs per

DA and LYS as the ratio between the taxpayer cost of the policy and the number of DA and LYS.

The interest of this approach is to propose *ex ante* analysis of the cost-effectiveness of policies whereas the large majority of works analyzing cost-effectiveness of health policies are based on *ex post* evaluation of policies or on ex post evaluation of experiments. Such an approach has been used previously for analyzing the possible effects of consumption subsidies for healthier foods (Cash et al., 2005) and for assessing the impacts of alcohol pricing policies and modelling the effect of consumption changes on mortality and disease prevalence (Purshouse et al., 2010).

The main findings of the present study are: (1) F&V stamp policy has a positive and significant impact on the consumption of small F&V consumers of the targeted population, (2) at the aggregate level, this policy has a modest impact on consumption and as a result on health gains, (3) for a given budget allocated to the policy, the cost per DA or LYS decreases when the targeting is smaller, at least as long as consumption remains in plausible values, (4) the policy reduces the health inequalities between low and high income populations, (5) when well designed, F&V stamp policy is as cost-effective as price policy (about 42 k€/LYS).

Despite the large shifts in F&V intake in the targeted population, the life gains appear to be quite modest. Indeed the expected benefits of F&V consumption, estimated from most recent meta-analyses, are moderate compared to earlier estimations based on case-control studies. Moreover 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.

The cost effectiveness of the policy increases when targeting a smaller share of the population because the F&V stamp acts through two channels. The direct action is more effective but requires providing to the targeted consumers a stamp whose value is larger than the initial expenditure in F&V of the consumer. This happens only when a ‘small’ number of consumers are selected. The indirect way is less effective as the F&V stamp is equivalent to an increase in income and can therefore be used for any purpose.

If the consumption of a part of the targeted population significantly increases, there are small but negative impacts on the consumption of non targeted population due to market mechanisms induced by the policy. In a recent paper Alston et al. (2008) put forward the fact that the induced changes in prices related to stamps limited to healthy food consumption could result in decreases in consumption of these healthy foods by targeted households and increases in consumption of “unhealthy” foods by other consumers. They considered that the net effect could be more overall consumption of healthy food and less consumption of the unhealthy foods, but that this overall net impact could reflect a complex of mixed effects that differ between rich and poor, participants and non-participants in the FSP. In our analysis, we identify such a non intentional effect but we show that it depends a lot on the size of the targeted population. On the basis of French data we show that is likely weak if the population is well targeted and it does not call into question the interest of such a policy.

Clearly, our results must be considered in relation with some limitations that open up the scope for further research. On the health model side, we limited our analysis to the assessment of DA and LYS. It is likely that considering only these criteria led us to underestimate the health benefits related to F&V consumption. It would be useful to widen the analysis by taking into account the possible effects of the policies on the health care costs and the morbidity levels. By doing so, it would possible to evaluate the variations of Quality Adjusted of Life Year Saved (QALYS) induced by the studied policies.

On the economic model side, we focused on a product category rather than considering a system of demand for food. Thus we ignored the substitutions that might occur with other foods which might have health impacts. On the other way, considering the F&V sector as a single product category prevented us from taking into account the heterogeneity of price sensitivity according to the type of products within this sector.

Elsewhere we considered that whatever their income consumers buy the same good at the same mean price and we ignored the possibility of quality differences. In fact, it is not necessarily the case and it is likely that the mean price of purchased F&V depends on the consumers' category. Moreover we assumed that an income increase led to an increase in the quantity of F&V bought by the households rather than to an increase in their quality (possibly with no increase in the quantity). Technically it is possible to deal with these issues. However, it would be necessary to get more information about the quality choice by consumers when their incomes change.

Another limit is related to the modeling of stamps. We have assumed that consumers do not resell the stamps and do 'eat' the additional quantities of F&V they buy, that they consider stamps as an increase in income (as long as the value of the stamp is not too high) and that the stamps do not convey any information. These are three strong assumptions.

Indeed, due to the first assumption, we over-estimate the impact of stamps. Thus reselling stamps (or selling the products one buys with the stamps) is equivalent to an increase of the size of the targeted population. We have seen that a larger targeting leads to a lower cost-effectiveness. The reasons for which consumers might want to sell the stamps or the products are numerous. Among others, it is well known that modifying his/her diet is difficult and that it is not only the budget constraint that fully explains a low consumption in F&V. Contrary to the second assumption, it is possible that some consumers consider that they have to buy some F&V with the stamps in addition to what they already buy. Social norms for instance could explain such practices and lead to larger effects than those assessed in our analysis. Finally, the third assumption led us to under-estimate the impact of food stamps by ignoring the fact that the stamp can convey some information and contribute to nutritional education that might change the consumers' demand.

Despite these limitations, the approach proposed in this paper contributes to open an interesting field of research and gives some results that are important to consider before implementing a public health policy dealing with food and health related issues.

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