

# Increasing fruit and vegetable consumption: a cost-effectiveness analysis of public policies

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**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 (less than +10 g/day/person on average) and health effects (<+600 DA, <+10 000 LYS) are modest. The costs/LYS are smaller for information campaign (€3 k), followed by VAT reduction (€99 k) and food stamp policy (€403 k). 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 (i) LYS are larger with VAT reduction than F&V stamps policies, (ii) information campaigns are the most cost-effective and (iii) market forces can limit the impacts of public health policies designed to favour F&V consumption increase.

**Keywords:** cost-effectiveness analysis, economic modelling, fruit and vegetables, health impact assessment, health policy

## 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 400 g of fruit and vegetables (F&V) per day.<sup>1,2</sup> 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.<sup>3–5</sup>

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 0.2–0.6 servings per day.<sup>6</sup> 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.<sup>7</sup> 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.<sup>8</sup>

In the economic literature, pricing policies aimed at favouring healthy diets have been considered in several

investigations, either through unhealthy food taxation<sup>9–11</sup> or healthy food consumption subsidizing.<sup>12</sup> Food assistance programmes that provide low-income households with the resources to purchase healthier diets have also been investigated in order to assess their impacts on consumption.<sup>13–16</sup> However, very few studies have proposed analyses integrating economic and health parameters.<sup>17</sup>

The goal of the present study was to quantify cost-effectiveness of policies aimed at increasing F&V consumption. We consider three policies: (i) reduction of the consumer price through a decrease in VAT on all F&V, (ii) consumption subsidies through F&V stamps and (iii) 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 Data). 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 (P). 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 an 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.<sup>18</sup>

### Policies

The first policy is a decrease in VAT (P1) 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% that 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 (P2). Such a policy can be considered as an increase in the income of targeted consumers.<sup>13</sup> For ease of comparison with P1, 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 that 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 (P3). 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. P3 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 (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 Data). The analysis of P1 and P2 are based on well-documented data and are designed for the French situation. P3 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<sup>2</sup> and for cardiovascular deaths (coronary and stroke).<sup>19,20</sup> 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 zero to the missing RR. Furthermore, when the RRs for fruit and vegetables were reported

**Table 1** Distribution of F&V intake (g/day) by levels of income

F&V consumption (in g/day)	Average	First quartile	Second quartile	Third quartile	Fourth quartile
First decile of income	227	86	168	257	397
Rest of the population	353	147	264	403	597

**Table 2** Elasticities data obtained from the literature

Considered elasticity	P 1 (VAT decrease) Mean (SD)	P 2 (Consumption subsidies) Mean (SD)	P 3 (Information campaign) Mean (SD)
Supply elasticity	1 (0.25)	1 (0.25)	1 (0.25)
Demand elasticity			
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		0.4 (0.3)	
Information impact			
'Pessimistic'			0.01 (0.002)
'Optimistic'			0.1 (0.02)

**Table 3** Estimated 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 additional serving of F&V: mean (CI 95%)	Number of deaths		Expected number of years of life lost per death	
		Whole population	First decile of income	Men	Women
<b>Cancer</b>					
Mouth, pharynx and larynx	0.92 (0.81–1.06)	5536	1013	18.5	20.4
Oesophagus	0.92 (0.85–1.00)	3837	696	16.1	15.8
Stomach	0.97 (0.93–1.01)	4763	820	13.7	13.7
Pancreas	0.97 (0.90–1.04)	8263	1369	14.5	13.9
Lung	0.94 (0.92–0.97)	28 347	5088	16.0	20.0
Colon and rectum	0.99 (0.94–1.04)	16 426	2733	12.4	12.6
Ovary	0.84 (0.62–1.13)	3342	463		17.1
<b>Cardiovascular disease</b>					
Coronary heart disease	0.97 (0.94–0.99)	38 806	7497	11.6	8.4
Stroke	0.96 (0.94–0.98)	32 652	6335	10.2	8.8

separately, we estimated the RR for F&V intake as follows:  $RR_{F\&V} = RR_{Fruit}^{0.5} \times RR_{Vegetable}^{0.5}$ .

The latest available mortality and cause specific mortality data (in France in 2006) was downloaded from Cepidc web site (<http://www.cepiddc.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–C14, C32), oesophagus (C15), stomach (C16), pancreas (C25), lung (C33, C34), colon and rectum (C18–C21), ovary (C56), coronary heart disease (I20–I25), stroke (I60–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.<sup>21</sup>

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:  $(1 - RR^{\Delta F\&V}) \times$  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 80 g/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,<sup>22</sup> 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.<sup>22</sup> 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 80 g 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 and LYS, odds ratio and costs per statistical DA and LYS 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 4.8 g/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 €100 k (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 [7.0 g/day (6.0–9.2)] and a small decrease in the consumption of SIC [–0.3 g/day (–0.5 to –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 0.4 g/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 k€27 (14–49). However, if consumers are more responsive to generic information (optimistic scenario) the impacts are 10 times higher and the cost per statistical LYS is k€3 (1–5). 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

**Table 4** Simulation results: consumption, health impacts and cost-effectiveness of policies

Policy comparison	P1	P2	P3	
	(3.4% VAT decrease)	(Food stamps)	(Information campaign) Pessimistic scenario	(Information campaign) Optimistic scenario
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Consumer price variation (%)	-1.8 (-2.3 to -1.1)	0.1 (0.1 to 0.2)	0.1 (0.1 to 0.2)	1.2 (0.7 to 2.0)
Individual consumption variation (g/day)				
All deciles (mean)	4.8 (3.1 to 7.1)	0.4 (0.2 to 0.6)	0.4 (0.2 to 0.6)	4.0 (2.2 to 6.4)
First decile of income	3.4 (1.2 to 7.5)	7.0 (6.0 to 9.2)	0.3 (-0.1 to 0.5)	2.6 (-0.8 to 5.3)
Other deciles	5.0 (3.1 to 7.6)	-0.3 (-0.5 to -0.2)	0.4 (0.2 to 0.7)	4.1 (2.0 to 6.9)
Number of DA				
All deciles	363 (200 to 582)	77 (48 to 116)	30 (15 to 51)	298 (149 to 507)
First decile of income	48 (15 to 111)	99 (62 to 146)	4 (-1 to 8)	37 (-12 to 81)
Other deciles	315 (164 to 526)	-21 (-37 to -10)	26 (11 to 47)	262 (114 to 472)
Cancer	216 (98 to 373)	42 (21 to 67)	18 (7 to 32)	178 (74 to 323)
Coronary and stroke	147 (68 to 250)	36 (18 to 58)	12 (5 to 22)	120 (52 to 216)
Number of LYS				
All deciles	5024 (2711 to 8132)	1032 (634 to 1554)	414 (203 to 710)	4126 (2022 to 7077)
First decile of income	643 (205 to 1497)	1330 (827 to 1972)	49 (-16 to 110)	492 (-156 to 1 092)
Other deciles	4381 (2226 to 7368)	-297 (-519 to -140)	364 (156 to 663)	3633 (1557 to 6611)
Cancer	3589 (1655 to 6141)	688 (355 to 1100)	296 (126 to 535)	2949 (1255 to 5333)
Coronary and stroke	1435 (653 to 2460)	344 (167 to 561)	118 (50 to 212)	1177 (499 to 2122)
Mean cost per DA (kEUR)	1379 (799 to 2322)	6316 (4 015 to 9663)	369 (197 to 670)	37 (20 to 67)
Mean cost per LYS (kEUR)	100 (57 to 171)	474 (299 to 733)	27 (14 to 49)	3 (1 to 5)
Health disparity index: odds ratio (First vs. others) variation	0.002 (-0.004 to 0.007)	-0.008 (-0.012 to -0.005)	0.000 (-0.000 to 0.001)	0.002 (-0.003 to 0.008)

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: (i) targeted and non-targeted policies to promote F&V intake have a modest impact on consumption and as a result on health gains, (ii) non-targeted interventions through price modifications appear to be more cost-effective than targeted actions through subsidizing the consumption of the most disadvantaged subpopulations and (iii) 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,<sup>2,18,19</sup> are moderate compared to earlier estimations based on case-control studies. Finally, although the burden of cancer and cardiovascular diseases represents more than two-third of total deaths in France, the favourable association with F&V consumption is documented for only about half of their etiologies (one-third 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 P1 and P3, are close to those obtained in a similar study.<sup>9</sup> Moreover, they are comparable with the value of statistical DA obtained in many other types of public interventions.<sup>23,24</sup> 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 disadvantaged subpopulations. 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 (~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 P1, 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 P3, 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 article rely on restrictive assumptions and the results are necessarily influenced by some of these limitations. Among the three policies, it is certainly P3 which has the most debatable parameters of the model. However, we compared the results obtained in P3 with a rough estimate of the impact of the French programme on F&V that started in 2001. According to Afssa<sup>25</sup> the increase in the mean F&V consumption was ~25 g/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 4 g/day per person per year for an annual amount of ~€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 per 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 that 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.<sup>26</sup> 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 ischaemic cardiovascular prevention,<sup>27</sup> 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.

## Supplementary data

Supplementary data are available at *EURPUB* online.

*Conflicts of interest:* None declared.

### Key points

- In France, 3.4% reduction in F&V VAT, €100/year/person F&V stamp policy and €10M information campaign would have a modest impact on consumption and as a result on health gains.
- The number of statistical DA and the cost per LYS are comparable with those obtained in other types of public interventions.
- Intervention through VAT reduction is more cost-effective than subsidizing the consumption of some disadvantaged subpopulations.
- 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.

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