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EVALUATION WITH INADEQUATE DATA:  
THE IMPACT OF THE FRENCH VENDING MACHINE BAN

ABSTRACT

We estimate the effects of the 2005 ban on vending machines in French schools using the 1998 and 2006 INCA nutrition surveys. These surveys contain no information on the presence of vending machines in schools attended by respondents, but the adoption of a Difference-in-Difference design, and a Regression Discontinuity Design enable us to obtain indirect estimates of the policy impact. Results are consistent and suggest that the measure has had a small but significant impact on teenager nutrition, especially in terms of reduced fat intakes.

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Evaluation with inadequate data: The impact of the French vending machine ban

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## I. INTRODUCTION

Concerns for growing childhood obesity rates in Europe have led Western health authorities to increasingly direct their attention to the school environment as a useful path to reach and influence pupils nutritional practices. Policies for food provision in schools have been enforced in most European countries, with a growing focus on regulating the presence of vending machines (VM), which are very common in secondary schools in Europe. Actions vary from replacing unhealthy snacks with fresh and healthy foods to complete bans of VM from schools (Capacci et al. 2012). The latter option was chosen in France, where as a part of a wide package on public health regulation (Dubuisson et al., 2009), the 2004 Public Health Law has banned all kinds of vending machines in secondary schools from 1<sup>st</sup> September 2005.

To our knowledge there has been no rigorous evaluation of the effect of this measure on nutritional practices, mostly because of the absence of adequate purposely collected data. The present work aims at evaluating the outcomes of the ban by exploiting a combination of policy evaluation techniques. The rationale is that a multiple methods approach may compensate for information gaps, and lead to more robust evaluation.

This paper employs two cross-sectional nationally representative data-sets, with nutrition data collected before and after the implementation of the ban, respectively. Through the joint application of a Difference-in-Difference approach and a Regression Discontinuity Design, we produce an estimate of the effects of the ban on children and adolescent dietary quality.

The nutritional environment in schools has been covered in French nutrition policies since the early 2000s, when the first National Nutrition and Health Plan (NNHP) has been enforced<sup>1</sup>. The first NNHP covered the period 2001-2005 and its nutritional objectives were based on nine public health priorities targeted at the population at large (e.g. increasing fruit and vegetables consumption, reducing the average contribution of total fat intakes, etc.) and nine priorities targeted at specific

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<sup>1</sup> Programme national nutrition santé (2001-2005) Paris: Ministère de l'Emploi et de la solidarité – Ministère délégué à la Santé, Janvier 2001. Available in English at <http://www.sante.gouv.fr/htm/pointsur/nutrition/index.htm>

population sub-groups, children and adolescents being one of them. A variety of actions, especially nutritional education measures, have been funded under the NNHP framework. A set of national food guidelines has been defined for the general public and for sub-groups, each one been accompanied by subsequent mass-media campaigns, whose targets were the general population (2002), adolescents and older people (2006) and pregnant women (2007). Guidance on school meals has been provided in order to meet the nutritional guidelines, initially as a circular letter on 25 June 2001, a non-binding recommendation intended for applications by public officers. After revision in 2007, this guidance scheme became compulsory by law enforcement in 2010<sup>2</sup>. In March 2004 a further circular letter was produced by the Ministry of Education to discourage morning snacks at school, considered a cause of unbalanced dietary intakes<sup>3</sup>. Instead, schools were invited to provide a healthy snack (like fruit juice, low-fat milk and dairy products, bread, non-sweetened cereals). In August 2004 a Public Health Law<sup>4</sup> was approved in France providing many compulsory actions in healthy eating promotion. The two main actions were the ban of vending machines from secondary schools premises and the introduction of a food advertising regulation imposing health information to accompany promotional messages for certain (unhealthy) food and drinks. The former has been enforced at the start of the 2005 school year (September), while the latter has been applied since October 2007, after the definition of specific health messages. Since the first NNHP two further Programs have been approved and enforced, for the periods 2006-2010 and 2011-2015.

No data have been purposely collected to evaluate the ban impact on young people eating habits. We exploit data from two French national nutritional surveys (*“Etude Individuelle Nationale des Consommations Alimentaires”*, INCA1 and INCA2). They are nationally representative cross-sectional dietary surveys, carried out respectively in 1998-99 and 2006-07 by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES). No intermediate survey exists. Given the timing of the ban enforcement the two surveys potentially provide a picture of the eating behaviour of young people before and after the 2005 ban.

Evaluation based on the simple comparison of averages from these two data-sets suffers from serious limitations. First, it is not straightforward to disentangle the effects of the ban from the other policy initiatives introduced in 2004, as there is no specific reference to the presence and the use of vending machine in schools. Second, changes in diets might be generated by other trending factors, including changes in the sample compositions or economic drivers. Third, not all schools

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<sup>2</sup> Loi n° 2010-874 du 27 juillet 2010 de modernisation de l'agriculture et de la pêche. In: Journal Officiel de la République Française; 2010. p. 13925.

<sup>3</sup> Collation matinale à l'école. Note de service n° 2004-095 du 25 mars 2004. DESCO, Ministère de l'Éducation nationale. [http://www.sante.gouv.fr/pointsur/nutrition/pol\\_nutri422.htm](http://www.sante.gouv.fr/pointsur/nutrition/pol_nutri422.htm) (accessed July 2010)

<sup>4</sup> Loi n° 2004-806 du 9 août 2004 relative à la politique de santé publique. In: Journal Officiel de la République Française. p. 14277

had vending machines before the ban. Data from a one-off independent survey, the National School Canteen Survey carried out between November 2005 and April 2006 (Dubuisson et al., 2009) suggest that 89.4% of public *lycées* (student age between 14 and 17) had vending machine on their premises before the ban, while only 39.3% of public *collèges* (student age between 11 and 13) had them.

We try to address these limitations by exploiting other interesting characteristics of the data-sets. The two INCA surveys provide nutrient intakes for each day of the 7-day windows, as well as the exact meal consumption dates, which allows to distinguish school days intakes from those on week-ends and holidays. This is especially convenient for France, since prior to 2008 there was no school on Wednesdays, which enables a comparison between dietary intakes on school days and outside school not simply based on the distinction between working-days and week-ends<sup>5</sup>. There is more potentially useful information in the INCA data-sets, as food intakes can be attributed to specific eating occasions over the day, including the morning snack. Finally, by exploiting the fact that vending machines have never been available in primary schools (student age between 6 and 10), this sub-sample can act as a control group after the appropriate conditioning. This enables the application of indirect policy evaluation methods for non-experimental data, like Difference-in-Difference (DiD) methods and Regression Discontinuity Designs (RDD). Since none of the methods is ideal, we rely on a comparison of the results from different approaches to check for their robustness.

The paper is structured as follow. Section II briefly introduces the evaluation methods, Section III illustrates the data-set characteristics and the variables used for the evaluation. Results are provided in Section IV, while some concluding remarks are drawn in Section V.

## II. METHODS

We use three different evaluation strategies to estimate the effects of the vending machine ban, and compare the results to check for robustness. Each evaluation strategy depends on a different interpretation of the selection process, i.e. the mechanism leading to the assignment of individuals to the treatment group (the policy). According to the potential outcome framework (Rubin, 1974) there is a set of two potential outcomes for each individual  $(y_0, y_1)$ , corresponding to outcomes recorded after receiving the treatment and after not receiving the treatment, respectively. The causal effect of the treatment on each individual  $i$  is defined as the difference of the two

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<sup>5</sup> We are grateful to Jean-Luc Volatier for suggesting this route to evaluation

potential outcomes  $y_{1i} - y_{0i}$ . The average treatment effect (ATT) on treated subjects can be computed as

$$ATT = E(y_1 - y_0 | D = 1) = E(y_1 | D = 1) - E(y_0 | D = 1)$$

where  $D$  is the binary treatment variable ( $D=1$  if treated,  $D=0$  if not), and the second term  $E(y_0 | D=1)$  is not observable. Yet, if treated subjects are not systematically different from not-treated subjects in terms of  $y_0$  (i.e.  $D$  and  $y_0$  are uncorrelated, which means that the assignment to the intervention is randomized), this term can be substituted with  $E(y_0 | D=0)$  and

$$ATT = E(y_1 - y_0 | D = 1) = E(y_1 | D = 1) - E(y_0 | D = 0)$$

where all terms are observable. This is the case for the experimental design. Treated and control group can be simply compared to measure the treatment effect. When  $D$  and  $y_0$  are not uncorrelated, treated subjects are systematically different from not-treated subjects and

$$ATT = E(y_1 - y_0 | D = 1) = E(y_1 | D = 1) - E(y_0 | D = 0) + \textit{selection bias}$$

The selection bias is caused by variables influencing the outcome which are also correlated with the treatment variable  $D$ . Knowledge of the selection process allows to purge the average effect of the intervention from the selection bias, which can be achieved through alternative evaluation strategies.

#### *Natural experiment and t-test*

Availability of the date variable for each food recorded in the diary enables us to consider separately food consumed on school days and off-school days, as if they were consumed under two different scenarios a treated and a not-treated one. Thus, the same subjects potentially provide data for both groups within the same INCA survey, while subjects change between INCA1 and INCA2. A first straightforward evaluation could be based on the comparison of the average outcome variable between school-days and non-school days. Yet, even if treated and not treated subjects are actually the same individuals, this does not necessarily mean that

$$E(y_0 | D = 1) = E(y_0 | D = 0)$$

i.e. their observed outcome under no intervention is equal to their potential outcome under no intervention, having been treated. Some observable and unobservable individual characteristics affecting food behaviour (height, gender, habits, etc..) are of course neutralized if individuals of the treated and not treated groups are the same. Yet, school and non-school scenarios affect the outcome variables differently, and make the two groups not strictly comparable even if composed by the same subjects. Thus we are able to control for individual effects by analysing the differential outcome variable, while the policy impact could be ascribed to the difference between the average value of this differential outcome before and after the policy.

Consider the regression equation

$$Y_{S,t} - Y_{NS,t} = \alpha + \beta POLICY_t + \varepsilon_t$$

where  $Y_{S,t}$  and  $Y_{NS,t}$  are the outcome variables on school days, and non-school days for the  $i$ -th subject and  $POLICY_t$  is the policy dummy which is 1 if the subject is exposed to the policy (on school-days), i.e. he/she belongs to the INCA2 survey. The coefficient  $\beta$  represent the average difference of the differential outcome between INCA1 and INCA2 and a  $t$ -test on the null hypothesis  $H_0: \beta = 0$  corresponds to a mean comparison test between the INCA1 (pre-policy) and INCA2 (post-policy) average differential outcome.

### *Difference-in-difference*

When the set of variables affecting the outcome and correlated with the treatment variable  $D$  are observable, under specific conditions, the availability of observations of the outcome levels for the treatment and control group in two different periods (before and after the intervention) opens the way to disentangle the treatment effect from the bias caused by unobservable confounding factors. This is feasible if, conditional on observed characteristics and in absence of the intervention, any difference between the control and treatment group outcome levels is stable over time (common trend assumption). Under this assumption, any observed variations in the above difference after the intervention identify the treatment effect. This is the difference in difference approach.

Formally, this translates in the following equation:

$$y_i = \alpha_0 + \alpha_1 GROUP_i + \alpha_2 POLICY_t + \alpha_3 GROUP_i POLICY_t + \beta x_i + \varepsilon_i$$

where  $y_i$  is the individual outcome variable,  $GROUP$  is the treatment dummy (which equals to 1 if the  $i$ -th individual  $i$  belongs to the treatment group, e.g. the individual is aged between 11 and

17), *POLICY* is the pre-post treatment dummy (1 if individual  $i$  belongs to the sample observed after the intervention, i.e. INCA2), and  $\mathbf{x}$  is a vector of characteristics predetermined with regard to the intervention which contribute explain heterogeneity in the outcome variables. Under the DiD approach, the  $a_3$  coefficient is a measure of the impact of the intervention.

### *Regression discontinuity approach*

Alternatively, the same policy setting can also be interpreted as if the selection process were driven exclusively by the age variable (i.e. the school level), which is observable for each individual. Subjects exceeding a known cut-off point (e.g. 11 years old) are automatically targeted by the ban after the policy is introduced. Thus, a discontinuity exists in the function linking treatment status and the assignment variable (age) around the cut-off point ( $c$ ). Moreover, individuals cannot manipulate the assignment variable. As a consequence of this inability, baseline characteristics have the same distribution just above and just below the threshold, and near the known cut-off the assignment to treatment is randomized.

The setting is thus suitable for Regression Discontinuity Design (RDD) analysis: comparing subjects around the threshold correspond to comparing randomized treated and control subjects. A pre-condition for the validity of the RDD approach is that all the factors affecting the outcome variables must be evolving smoothly (i.e. are continuous) with respect to the assignment continuous variable, which means that no other relevant change should occur at the discontinuity point. If this is the case, if the outcome variable  $y$  turns out to be a discontinuous function of the assignment variable (e.g. age) at the cut-off point (e.g.  $c=11$ ), and a shift in  $y$  at  $c$  can be reasonably ascribed to the intervention.

Regressing the outcome variable on the assignment variable separately on the two side of the threshold would yield the impact estimate (Lee & Lemieux, 2010). Once the cut-off value is subtracted from the discontinuity variable, the pooled regression is:

$$y_i = g_0 + g_1(AGE_i - c) + g_2 GROUP_i + g_3(AGE_i - c) * GROUP_i + \varepsilon_i$$

Where *GROUP* is the usual treatment dummy. According to the RDD, the coefficient  $g_2$  represents the treatment effect at the cut-off point (11 years old), and the policy can be considered effective if  $g_2$  is significantly different from zero, with the desired sign.

Note that this method could be potentially applied to post-policy data only. However, the pre-policy data-set can be exploited as a (precious) robustness check as in e.g. Beatty et al. (2011), which simply requires to pool the pre-policy and post-policy data, and define the treatment dummy *GROUP* as being equal to 1 if the individual exceed the cut-off point *and* belongs to the post-policy



data-set, while it is 0 for all other subjects, including those above the cut-off point from the pre-policy data-set. Furthermore, one can still control for other potential confounding variables. While these should not be relevant if they do not change abruptly around the discontinuity point, samples have typically a limited number of observations that are just below and above  $c$ . Thus, the estimate of  $g_2$  can rely on interpolation on a wider set of subject further away from the discontinuity point, but this raises the need to control for confounding variables. Using the same notation of the DiD equation, we define with  $\mathbf{x}_i$  the vector of characteristics that influence the outcome variables but are unrelated to the selection process. The equation becomes:

$$y_i = g_0 + g_1(AGE_i - c) + g_2 GROUP_i + g_3(AGE_i - c) * GROUP_i + \beta \mathbf{x}_i + \epsilon_i$$

bearing in mind the change in the definition of the treatment dummy  $GROUP$ .

### III. DATA

The INCA1 survey was conducted between August 1998 and June 1999 by the Research Centre for the Study and the Observation of Way of Life (CREDOC) and the French Food Safety Agency (AFSSA). The sample is nationally representative of French households and it includes two independent sub-samples, composed of 1985 adolescents and adults (aged 15 years and over) and of 1016 children (aged 3–14 years). The mixed sampling design was based on a combination of stratification (region of residence, agglomeration size) and quota sampling (age, sex, household size, head of household socio-professional status). The INCA2 survey was carried out between December 2005 and May 2007 by AFSSA. The sample structure includes again two independent random samples of children aged 3-17 and adults aged 18-79, which were obtained using a multistage cluster sampling technique.

A 7-days diary was used in both surveys to record food intakes. The data-sets contain information on consumed quantities, type of food (disaggregated in more than 1300 categories) and the eating occasion at which each food or drink was consumed (i.e. meals and snacks, broken down by time of the day). Individual nutritional intakes were then estimated using the French CIQUAL (*Centre d'Information sur la Qualité des Aliments*) food composition tables. For children younger than 10 the food diary was filled in by parents. Both surveys also include information on the exact date of each meal. This allowed to compute a dummy variable ( $SCHOOL$ ) for meals consumed during school days and meals consumed during non-school days. Wednesday and Sundays were recorded as non-school days, while data on Saturdays were excluded, since secondary schools had

the options of having lectures on Saturdays before 2008. All other weekdays were considered as school days, provided their date was not on a holiday period<sup>6</sup>, in which case the observation was dropped from the sample.

Given the heterogeneity in nutritional needs of children and adolescents, three variables were considered as confounding factors for the policy outcomes. These variables are the gender of the individual (*GENDER*), her/his age (*AGE*) and her/his height (*HEIGHT*). These variables are assumed to account for different nutritional needs across children and adolescents. Although the basal metabolic rate also depends on weight, we opted for height as an anthropometric measure, because its endogenous nature relative to nutritional behaviour is less serious compared to weight.

We consider a variety of nutritional outcomes as potential policy outcomes. These included calorie intake, intakes from specific nutrients (fats, saturated fats, sodium and free sugars) and the proportion of energy intakes from fats, saturated fats and free sugars. Furthermore, we considered the proportion of energy intakes from fats, saturated fats and free sugars and the sodium intake which exceeds the WHO recommended values<sup>7</sup>, coding the variable as missing values whenever the individual was meeting the recommendations. Descriptive statistics for the two samples are provided in Table 1.

**Table 1. Sample descriptive statistics**

| Variable                                  | INCA1   |          | INCA2   |          |
|---|---------|----------|---------|----------|
|   | Mean    | St. Dev. | Mean    | St. Dev. |
| Calorie intake (Kcal)                     | 1944.37 | 683.88   | 1863.09 | 589.77   |
| Fat intake (g)                            | 80.65   | 30.35    | 77.77   | 28.77    |
| Saturated fats intake (g)                 | 35.67   | 14.27    | 33.38   | 13.57    |
| Free sugar intake (g)                     | 103.31  | 49.79    | 99.31   | 42.06    |
| Sodium intake (mg)                        | 2550.62 | 1149.35  | 2271.55 | 919.66   |
| Soda (ml)                                 | 329.54  | 178.84   | 314.74  | 211.96   |
| Fats (% energy from)                      | 37.47   | 6.24     | 37.38   | 6.07     |
| Saturated fats (% energy from)            | 16.52   | 3.41     | 15.98   | 3.33     |
| Free sugar (% energy from)                | 21.12   | 6.96     | 21.29   | 6.03     |
| Excess fat (% of total energy)            | 8.77    | 5.24     | 8.62    | 5.06     |
| Excess saturated fats (% of total energy) | 6.67    | 3.26     | 6.21    | 3.10     |
| Excess free sugar (% of total energy)     | 11.82   | 6.41     | 11.65   | 5.69     |
| Excess sodium (mg)                        | 1055.74 | 1048.17  | 850.38  | 774.22   |
| Gender (% males)                          | 49.38   |          | 48.09   |          |
| Age (years)                               | 10.67   | 3.19     | 12.35   | 3.39     |
| Height (cm)                               | 143.39  | 18.83    | 151.55  | 18.84    |
|   |         | %        |         | %        |
| N   | 802     | 100.0    | 1572    | 100.0    |
| N (aged 14-17)                            | 176     | 21.9     | 704     | 44.8     |
| N (aged 11-13)                            | 224     | 27.9     | 372     | 23.7     |

<sup>6</sup> We accounted for all school holidays over the year, and for regional differences, referring to the holiday calendars of the INCA survey years. Since the INCA1 data-set had a regional classification which differs from the one by the Ministry of Education, we adopted a conservative approach and these observations were dropped.

<sup>7</sup> These are 30% for fats, 10% for free sugars, 10% for saturated fats, and 2g for sodium.

There are some differences in the sample means which support that the inclusion of covariates in the DiD and RDD models. The INCA2 sample is much larger, due to a larger sub-sample for the target group, as the sample of those aged 11-17 are 1076 compared to 400 within INCA1. This explains why the average age of the INCA1 sample is younger (less than 11 years compared to 12 in INCA2), and the average height is also lower, while the gender distribution is stable.

#### IV. RESULTS

As a first exploration, we report the averages for the selected nutritional outcomes in various sub-groups of the population, distinguishing by INCA survey wave and between school days and off-school days. Results from Table 2 are suggestive. In both surveys, absolute daily intakes are systematically higher on off-school days, the gap becomes generally larger in the INCA2 survey, so that a simple difference of the differences is negative. This, combined with lower intakes of unhealthy nutrients in INCA2, provide a first indicative evidence that the situation has improved. However, this change might be explained by a variety of factors not necessarily related to the policy intervention, especially if one considers that similar results hold for those aged below 11, which were not exposed to vending machines even before the ban. This might indicate that other policies than the ban acting on both primary and secondary schools have worked towards an improved diets. Further analysis is needed.

The descriptive statistics also confirm unhealthy eating habits for the average French school-aged children, as the proportions of energy from fats, saturated fats, free sugar, and sodium exceed the recommendations, also in INCA2.

Table 3 isolates the morning-break eating occasion, which provides some further insight. For all ages pertaining to schools potentially with vending machines before the ban (i.e. age between 11 and 17), the negative signs of the last column confirm a clear improvement, which is larger for those above 14, i.e. the age group associated with upper secondary schools with the largest prevalence of vending machines (around 90%). Instead, for primary schools where children have not been concerned by the ban, there is no sign of improvement. This, together with the assumption that vending machines are most accessed during the morning break compared to school lunches in canteens, reinforces the hypothesis that the ban might have had some impact.

We now turn to the application of the methods described in Section II, also taking into account potential changes in the sample composition between INCA1 and INCA2. Table 4 reports the estimates using the three approaches described in Section II, also indicating the p-value of the

corresponding *t*-test on the relevant coefficient, and the sample sizes for the treated and non-treated groups, which vary by approach and by outcome variable.

**Table 2. Average daily intakes in schooldays and at home**

|   | INCA1 (1998) |         |            | INCA2 (2006) |         |            | <i>DiD</i> |
|---|--------------|---------|------------|--------------|---------|------------|------------|
|   | Off-school   | School  | Difference | Off-school   | School  | Difference |            |
| Age 14-17                                 |              |         |            |              |         |            |            |
| Calorie intake (Kcal)                     | 2110.69      | 2041.50 | -69.20     | 2001.97      | 1904.46 | -97.51     | -28.32     |
| Fat intake (g)                            | 86.33        | 84.00   | -2.33      | 84.67        | 76.53   | -8.14      | -5.81      |
| Saturated fats intake (g)                 | 37.57        | 36.85   | -0.72      | 35.98        | 32.37   | -3.61      | -2.89      |
| Free sugar intake (g)                     | 104.38       | 100.82  | -3.56      | 101.96       | 98.27   | -3.69      | -0.13      |
| Sodium intake (mg)                        | 2992.19      | 2669.91 | -322.28    | 2425.91      | 2423.10 | -2.81      | 319.47     |
| Fats (% energy from)                      | 36.79        | 37.70   | 0.91       | 37.94        | 36.18   | -1.76      | -2.67      |
| Saturated fats (% energy from)            | 15.75        | 16.48   | 0.73       | 15.99        | 15.21   | -0.78      | -1.50      |
| Free sugar (% energy from)                | 19.35        | 19.38   | 0.02       | 20.22        | 20.52   | 0.29       | 0.27       |
| Excess fat (% of total energy)            | 7.58         | 7.92    | 0.34       | 8.33         | 6.63    | -1.70      | -2.04      |
| Excess saturated fats (% of total energy) | 5.85         | 6.49    | 0.64       | 6.07         | 5.27    | -0.79      | -1.43      |
| Excess free sugar (% of total energy)     | 9.66         | 9.55    | -0.11      | 10.33        | 10.57   | 0.24       | 0.36       |
| Excess sodium (mg)                        | 1163.37      | 824.24  | -339.13    | 627.32       | 591.17  | -36.15     | 302.98     |
| Age 11-17                                 |              |         |            |              |         |            |            |
| Calorie intake (Kcal)                     | 2054.36      | 2005.71 | -48.65     | 1961.44      | 1865.16 | -96.28     | -47.63     |
| Fat intake (g)                            | 85.67        | 82.76   | -2.92      | 83.54        | 75.05   | -8.49      | -5.57      |
| Saturated fats intake (g)                 | 36.91        | 36.29   | -0.62      | 35.76        | 31.94   | -3.82      | -3.20      |
| Free sugar intake (g)                     | 105.58       | 102.36  | -3.22      | 100.41       | 97.39   | -3.02      | 0.20       |
| Sodium intake (mg)                        | 2758.13      | 2592.95 | -165.17    | 2364.57      | 2355.21 | -9.36      | 155.81     |
| Fats (% energy from)                      | 37.66        | 37.51   | -0.14      | 38.11        | 36.13   | -1.98      | -1.83      |
| Saturated fats (% energy from)            | 16.11        | 16.43   | 0.32       | 16.20        | 15.31   | -0.89      | -1.21      |
| Free sugar (% energy from)                | 20.09        | 20.14   | 0.05       | 20.29        | 20.73   | 0.44       | 0.40       |
| Excess fat (% of total energy)            | 8.15         | 7.69    | -0.46      | 8.46         | 6.51    | -1.95      | -1.49      |
| Excess saturated fats (% of total energy) | 6.17         | 6.43    | 0.27       | 6.25         | 5.35    | -0.90      | -1.17      |
| Excess free sugar (% of total energy)     | 10.32        | 10.25   | -0.06      | 10.38        | 10.77   | 0.39       | 0.46       |
| Excess sodium (mg)                        | 939.89       | 755.19  | -184.70    | 581.71       | 537.40  | -44.32     | 140.38     |
| Age 6-10                                  |              |         |            |              |         |            |            |
| Calorie intake (Kcal)                     | 1864.04      | 1854.22 | -9.82      | 1798.74      | 1709.59 | -89.15     | -79.33     |
| Fat intake (g)                            | 77.79        | 76.41   | -1.38      | 78.54        | 70.41   | -8.13      | -6.75      |
| Saturated fats intake (g)                 | 35.25        | 34.26   | -1.00      | 34.31        | 30.41   | -3.90      | -2.90      |
| Free sugar intake (g)                     | 101.77       | 103.56  | 1.79       | 102.27       | 98.12   | -4.15      | -5.94      |
| Sodium intake (mg)                        | 2391.59      | 2461.04 | 69.45      | 2080.52      | 2079.32 | -1.20      | -70.66     |
| Fats (% energy from)                      | 37.48        | 37.24   | -0.24      | 39.01        | 36.88   | -2.14      | -1.89      |
| Saturated fats (% energy from)            | 16.91        | 16.63   | -0.29      | 17.07        | 15.89   | -1.18      | -0.89      |
| Free sugar (% energy from)                | 21.96        | 22.28   | 0.32       | 22.74        | 23.21   | 0.47       | 0.15       |
| Excess fat (% of total energy)            | 7.87         | 7.49    | -0.39      | 9.30         | 7.11    | -2.19      | -1.80      |
| Excess saturated fats (% of total energy) | 6.95         | 6.63    | -0.33      | 7.09         | 5.92    | -1.17      | -0.84      |
| Excess free sugar (% of total energy)     | 12.01        | 12.31   | 0.30       | 12.77        | 13.22   | 0.45       | 0.15       |
| Excess sodium (mg)                        | 576.54       | 588.88  | 12.34      | 343.87       | 307.58  | -36.30     | -48.64     |

The natural experiment tests whether individual gaps between school daily intakes and off-school daily intakes has changed between 1999 and 2006. In terms of absolute intakes, and considering the 14-17 age group, all impacts have the expected negative sign, which means that the quality of diet on school days exceeds the quality of diet on off-school days by a larger extent after

the policy. While these values are not significant at the 95% confidence level, large improvements are detected in terms of energy intakes for fats (including saturated fats). A result which is confirmed when the sample is extended to consider lower secondary schools (*colleges*). Interestingly, estimates for absolute intakes of fats become significant, although the magnitude of the impact is not too different. The reason is straightforward, as the sample size becomes larger to include the younger ages, albeit the extended sample has a lower exposition to the vending ban because of the largest proportion of schools with no vending machines before the ban.

**Table 3. Average intakes during the morning-break**

|                                | INCA1 (1998) |        |            | INCA2 (2006) |        |            | <i>DiD</i> |
|--------------------------------|--------------|--------|------------|--------------|--------|------------|------------|
|                                | Home         | School | Difference | Home         | School | Difference |            |
| Age 14-17                      |              |        |            |              |        |            |            |
| Calorie intake (Kcal)          | 259.44       | 369.81 | 110.37     | 148.27       | 143.77 | -4.49      | -114.86    |
| Fat intake (g)                 | 9.03         | 13.51  | 4.48       | 5.31         | 5.82   | 0.51       | -3.97      |
| Saturated fats intake (g)      | 3.77         | 6.23   | 2.46       | 2.55         | 2.66   | 0.11       | -2.35      |
| Free sugar intake (g)          | 27.35        | 38.00  | 10.66      | 12.81        | 11.73  | -1.08      | -11.74     |
| Sodium intake (mg)             | 235.65       | 407.29 | 171.64     | 108.76       | 106.00 | -2.77      | -174.40    |
| Fats (% energy from)           | 27.08        | 32.12  | 5.04       | 26.12        | 28.62  | 2.50       | -2.54      |
| Saturated fats (% energy from) | 11.69        | 15.62  | 3.94       | 12.10        | 12.53  | 0.43       | -3.51      |
| Free sugar (% energy from)     | 49.10        | 45.29  | -3.81      | 40.66        | 38.92  | -1.74      | 2.08       |
| Age 11-17                      |              |        |            |              |        |            |            |
| Calorie intake (Kcal)          | 249.82       | 280.03 | 30.21      | 137.68       | 132.88 | -4.80      | -35.00     |
| Fat intake (g)                 | 8.64         | 9.83   | 1.20       | 4.95         | 5.32   | 0.37       | -0.82      |
| Saturated fats intake (g)      | 3.69         | 4.57   | 0.88       | 2.43         | 2.47   | 0.05       | -0.83      |
| Free sugar intake (g)          | 26.66        | 29.09  | 2.42       | 11.95        | 10.74  | -1.21      | -3.63      |
| Sodium intake (mg)             | 267.21       | 289.89 | 22.68      | 105.20       | 101.49 | -3.71      | -26.39     |
| Fats (% energy from)           | 27.45        | 28.98  | 1.54       | 25.56        | 29.11  | 3.55       | 2.01       |
| Saturated fats (% energy from) | 12.23        | 13.92  | 1.69       | 12.22        | 13.08  | 0.86       | -0.84      |
| Free sugar (% energy from)     | 50.09        | 47.17  | -2.92      | 42.32        | 38.79  | -3.53      | -0.61      |
| Age 6-10                       |              |        |            |              |        |            |            |
| Calorie intake (Kcal)          | 189.76       | 196.15 | 6.39       | 105.40       | 122.66 | 17.26      | 10.87      |
| Fat intake (g)                 | 5.76         | 6.40   | 0.64       | 3.42         | 4.61   | 1.19       | 0.55       |
| Saturated fats intake (g)      | 2.88         | 3.17   | 0.29       | 1.76         | 2.29   | 0.53       | 0.24       |
| Free sugar intake (g)          | 20.36        | 21.72  | 1.35       | 10.91        | 11.89  | 0.98       | -0.37      |
| Sodium intake (mg)             | 179.08       | 153.49 | -25.58     | 70.47        | 77.34  | 6.87       | 32.46      |
| Fats (% energy from)           | 22.92        | 25.83  | 2.91       | 24.02        | 29.48  | 5.46       | 2.55       |
| Saturated fats (% energy from) | 11.47        | 13.20  | 1.73       | 12.26        | 14.98  | 2.73       | 1.00       |
| Free sugar (% energy from)     | 51.27        | 47.55  | -3.71      | 46.79        | 44.60  | -2.19      | 1.52       |

The natural experiment does not consider changes in the sample composition, while the DiD and RDD approaches include age, gender and height as covariates. While the DiD approach returns the same signs, the estimated impacts are lower and not-significant despite the larger sample sizes. The application of the RDD also returns the expected signs, and magnitudes that are closer to the natural experiment. The efficiency gain due to the largest number of available observations leads to the identification of significant impacts on the absolute intakes levels for calories, fats, and

saturated fats on the 11-17 sample, as well as a significant effect on sodium intake (albeit small, 0.3 grams) and an impact on free sugars which is significant at the 94% confidence level. These improvements in terms of absolute intakes do not seem to be reflected by the diet composition. There is still a negative sign, but the magnitudes are too small to be significant, as the impact on energy from fats improves by less than 0.3%. When the sample is restricted to those who consume unhealthy nutrients in excess to the WHO recommendations, the results are not significant with the exception of sodium.

The most appealing result is, however, that the different approaches, also based on different benchmarks (being at school for the natural experiment, secondary versus primary schools for the DiD and the RDD) return very similar impact estimates. Considering the overall diet, calorie intakes are reduced between 20 and 120 Kcal per day, fat intakes between 1.6 and 5.8 grams, saturated fats between 0.5 and 3.20. Instead sodium oscillates between negative values from the indirect approach and positive (significant) values in the natural experiment.

**Table 4. Estimated impact of the 2004-5 policy intervention on daily intakes**

|   | Natural experiment |             |     |     | Difference-in-Difference |         |      |      | Regression Discontinuity Design |             |      |      |
|---|--------------------|-------------|-----|-----|--------------------------|---------|------|------|---------------------------------|-------------|------|------|
|   | Impact             | p-value     | n0  | n1  | Impact                   | p-value | n0   | n1   | Impact                          | p-value     | n0   | n1   |
| Target group 14-17 y.o.                   |                    |             |     |     |                          |         |      |      |                                 |             |      |      |
| Calorie intake (Kcal)                     | -28.32             | 0.65        | 105 | 335 | -19.94                   | 0.76    | 1040 | 670  | -74.71                          | 0.10        | 1622 | 670  |
| Fat intake (g)                            | -5.81              | 0.08        | 105 | 335 | -1.66                    | 0.59    | 1040 | 670  | -3.68                           | 0.09        | 1622 | 670  |
| Saturated fats intake (g)                 | -2.89              | 0.07        | 105 | 335 | -0.46                    | 0.76    | 1040 | 670  | <b>-2.23</b>                    | <b>0.03</b> | 1622 | 670  |
| Free sugar intake (g)                     | -0.13              | 0.98        | 105 | 335 | 0.57                     | 0.91    | 1040 | 670  | -0.22                           | 0.95        | 1622 | 670  |
| Sodium intake (mg)                        | <b>319.47</b>      | <b>0.01</b> | 105 | 335 | -51.19                   | 0.62    | 1040 | 670  | <b>-215.77</b>                  | <b>0.00</b> | 1622 | 670  |
| Fats (% energy from)                      | <b>-2.67</b>       | <b>0.00</b> | 105 | 335 | -0.57                    | 0.39    | 1040 | 670  | -0.46                           | 0.33        | 1622 | 670  |
| Saturated fats (% energy from)            | <b>-1.50</b>       | <b>0.00</b> | 105 | 335 | -0.09                    | 0.81    | 1040 | 670  | -0.42                           | 0.09        | 1622 | 670  |
| Free sugar (% energy from)                | 0.27               | 0.70        | 105 | 335 | 0.30                     | 0.67    | 1040 | 670  | <b>1.19</b>                     | <b>0.01</b> | 1622 | 670  |
| Excess fat (% of total energy)            | <b>-2.02</b>       | <b>0.01</b> | 92  | 292 | -0.79                    | 0.18    | 937  | 593  | -0.54                           | 0.20        | 1455 | 593  |
| Excess saturated fats (% of total energy) | <b>-1.50</b>       | <b>0.00</b> | 103 | 321 | -0.17                    | 0.62    | 1021 | 643  | -0.40                           | 0.10        | 1590 | 643  |
| Excess free sugar (% of total energy)     | 0.41               | 0.57        | 100 | 327 | -0.13                    | 0.85    | 1007 | 646  | 0.69                            | 0.13        | 1568 | 646  |
| Excess sodium (mg)                        | <b>362.16</b>      | <b>0.00</b> | 69  | 213 | -205.76                  | 0.08    | 611  | 424  | <b>-276.69</b>                  | <b>0.00</b> | 966  | 424  |
| Target group 11-17 y.o.                   |                    |             |     |     |                          |         |      |      |                                 |             |      |      |
| Calorie intake (Kcal)                     | -47.63             | 0.28        | 224 | 514 | -41.65                   | 0.43    | 1264 | 1028 | <b>-123.26</b>                  | <b>0.00</b> | 1264 | 1028 |
| Fat intake (g)                            | <b>-5.57</b>       | <b>0.02</b> | 224 | 514 | -3.24                    | 0.21    | 1264 | 1028 | <b>-4.70</b>                    | <b>0.01</b> | 1264 | 1028 |
| Saturated fats intake (g)                 | <b>-3.20</b>       | <b>0.00</b> | 224 | 514 | -0.67                    | 0.58    | 1264 | 1028 | <b>-2.47</b>                    | <b>0.01</b> | 1264 | 1028 |
| Free sugar intake (g)                     | 0.20               | 0.95        | 224 | 514 | -2.84                    | 0.48    | 1264 | 1028 | -5.67                           | 0.06        | 1264 | 1028 |
| Sodium intake (mg)                        | 155.81             | 0.05        | 224 | 514 | 2.41                     | 0.98    | 1264 | 1028 | <b>-282.37</b>                  | <b>0.00</b> | 1264 | 1028 |
| Fats (% energy from)                      | <b>-1.83</b>       | <b>0.00</b> | 224 | 514 | -0.93                    | 0.09    | 1264 | 1028 | -0.37                           | 0.36        | 1264 | 1028 |
| Saturated fats (% energy from)            | <b>-1.21</b>       | <b>0.00</b> | 224 | 514 | -0.11                    | 0.70    | 1264 | 1028 | -0.34                           | 0.12        | 1264 | 1028 |
| Free sugar (% energy from)                | 0.40               | 0.40        | 224 | 514 | -0.17                    | 0.77    | 1264 | 1028 | 0.14                            | 0.75        | 1264 | 1028 |
| Excess fat (% of total energy)            | <b>-1.52</b>       | <b>0.00</b> | 198 | 448 | -0.95                    | 0.05    | 1136 | 912  | -0.52                           | 0.15        | 1136 | 912  |
| Excess saturated fats (% of total energy) | <b>-1.16</b>       | <b>0.00</b> | 222 | 494 | -0.10                    | 0.73    | 1242 | 991  | -0.35                           | 0.09        | 1242 | 991  |
| Excess free sugar (% of total energy)     | 0.48               | 0.32        | 214 | 504 | -0.40                    | 0.45    | 1219 | 995  | -0.31                           | 0.44        | 1219 | 995  |
| Excess sodium (mg)                        | 157.98             | 0.07        | 150 | 315 | -91.10                   | 0.36    | 765  | 625  | <b>-243.79</b>                  | <b>0.00</b> | 765  | 625  |

Note: Bold values indicate significance at the 95% confidence level

Table 5 reports the same analyses, this time limiting the exploration to the mid-morning eating occasion. Results are striking, despite the obvious reduction in sample sizes, many estimated impact become significant, especially for the most exposed group (ages between 14 and 17). All estimated impacts but two have the expected sign, and they oscillate within small ranges.

If we ascribe the change in behaviours to the vending machine ban (provision of healthy foods in schools is also likely to have had an effect), there is evidence of a significant reduction in calories ranging between 90 and 115, together with reductions in fat intakes (about 4 grams per morning break), saturated fats (1-2 grams), sodium (0.1-0.2 grams) and especially free sugar (10-12 grams). The decrease in energy from fats oscillates between 2.5 and 3% (and is significant under the RDD framework), and the decrease in overall energy from fats ranges between 4 and 5.5%, and is significant at the 90% confidence level. When the sample is extended to include those individuals aged between 11 and 13, these tests lose power and magnitudes decrease. It would seem that the noise from including children who possibly were not exposed to the intervention (as two-thirds of *colleges* had no vending machine) makes the analysis less powerful, bringing some extra (suggestive) evidence towards the attribution of the outcomes to the vending machine ban.

**Table 5. Estimated impact of the vending machine ban (morning-break intakes)**

|                                | Natural experiment |             |    |     | Difference-in-Difference |             |     |     | Regression Discontinuity Design |             |     |     |
|--------------------------------|--------------------|-------------|----|-----|--------------------------|-------------|-----|-----|---------------------------------|-------------|-----|-----|
|                                | Impact             | p-value     | n0 | n1  | Impact                   | p-value     | n0  | n1  | Impact                          | p-value     | n0  | n1  |
| Target group 14-17 y.o.        |                    |             |    |     |                          |             |     |     |                                 |             |     |     |
| Calorie intake (Kcal)          | -115.25            | 0.07        | 38 | 76  | <b>-91.14</b>            | <b>0.00</b> | 502 | 249 | <b>-114.47</b>                  | <b>0.00</b> | 664 | 202 |
| Fat intake (g)                 | -3.53              | 0.21        | 38 | 76  | <b>-3.81</b>             | <b>0.00</b> | 502 | 249 | <b>-3.88</b>                    | <b>0.00</b> | 664 | 202 |
| Saturated fats intake (g)      | -2.25              | 0.11        | 38 | 76  | <b>-1.42</b>             | <b>0.02</b> | 502 | 249 | <b>-1.82</b>                    | <b>0.00</b> | 664 | 202 |
| Free sugar intake (g)          | -10.84             | 0.18        | 38 | 76  | <b>-10.32</b>            | <b>0.00</b> | 502 | 249 | <b>-11.71</b>                   | <b>0.00</b> | 664 | 202 |
| Sodium intake (mg)             | <b>-180.33</b>     | <b>0.03</b> | 38 | 76  | <b>-117.13</b>           | <b>0.00</b> | 502 | 249 | <b>-176.03</b>                  | <b>0.00</b> | 664 | 202 |
| Fats (% energy from)           | -0.60              | 0.89        | 34 | 56  | -5.57                    | 0.06        | 445 | 202 | -4.37                           | 0.08        | 664 | 202 |
| Saturated fats (% energy from) | -2.49              | 0.25        | 34 | 56  | -2.82                    | 0.07        | 445 | 202 | <b>-3.09</b>                    | <b>0.02</b> | 664 | 202 |
| Free sugar (% energy from)     | 2.23               | 0.79        | 34 | 56  | -1.54                    | 0.76        | 445 | 202 | -2.29                           | 0.58        | 664 | 202 |
| Target group 11-17 y.o.        |                    |             |    |     |                          |             |     |     |                                 |             |     |     |
| Calorie intake (Kcal)          | -57.63             | 0.14        | 81 | 113 | <b>-60.90</b>            | <b>0.01</b> | 624 | 386 | <b>-83.25</b>                   | <b>0.00</b> | 563 | 303 |
| Fat intake (g)                 | -1.10              | 0.53        | 81 | 113 | <b>-2.46</b>             | <b>0.02</b> | 624 | 386 | <b>-2.42</b>                    | <b>0.01</b> | 563 | 303 |
| Saturated fats intake (g)      | -0.94              | 0.28        | 81 | 113 | -0.81                    | 0.11        | 624 | 386 | -0.92                           | 0.05        | 563 | 303 |
| Free sugar intake (g)          | -5.55              | 0.26        | 81 | 113 | <b>-7.54</b>             | <b>0.00</b> | 624 | 386 | <b>-10.17</b>                   | <b>0.00</b> | 563 | 303 |
| Sodium intake (mg)             | -74.16             | 0.15        | 81 | 113 | <b>-94.62</b>            | <b>0.01</b> | 624 | 386 | <b>-116.66</b>                  | <b>0.00</b> | 563 | 303 |
| Fats (% energy from)           | 1.17               | 0.71        | 75 | 76  | -4.27                    | 0.09        | 563 | 303 | -1.69                           | 0.43        | 563 | 303 |
| Saturated fats (% energy from) | -0.91              | 0.58        | 75 | 76  | -1.88                    | 0.15        | 563 | 303 | -0.66                           | 0.55        | 563 | 303 |
| Free sugar (% energy from)     | 0.71               | 0.90        | 75 | 76  | -2.33                    | 0.58        | 563 | 303 | -2.18                           | 0.54        | 563 | 303 |

Note: Bold values indicate significance at the 95% confidence level

## V. DISCUSSION

This paper has brought some evidence on the impact of French policies targeted at improving school nutrition, with a special focus on isolating the effects of the vending machine ban. Despite the far from ideal availability of data, in absence of information on the use of vending machines at schools, and information limited to two points in time on different subjects, we have exploited different non-experimental policy evaluation methods to gather our outcome evaluations.

The application of multiple methods has given promising results. Despite differences imputable to the changes in benchmarks and sample sizes, results are highly consistent, especially when the focus is limited to a single eating occasion, the mid-morning break which we assume to be the most exposed to vending machine consumption.

On balance, we found significant, albeit small effects of the policy. These effects tend to disappear when the overall diet is considered, which could hide compensating behaviours or simply the fact that influencing the morning snack is not enough to improve the overall dietary quality. Further research on compensating pattern, considering school lunch and home dinners, will provide further evidence.

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