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# Vaccination take-up and health: evidence from a flu vaccination program for the elderly\*

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## Abstract

We analyze the effects of a vaccination program providing free flu vaccine to individuals aged 65 or more on take-up and hospitalization. By using linked patient-general practitioner (GP) data, we implement a regression discontinuity design around the threshold at age 65. We find that the program increases vaccination take-up by 6 percentage points, which corresponds to 75% of the take-up for non-eligible individuals, and reduces the probability of hospitalization by about 44%. We show that the effect on take-up is not entirely due to an income channel, and that the effect on health is mainly driven by patients with higher-quality GPs and emergency hospitalizations.

**JEL Classification:** I12, I18, J10

**Keywords:** vaccination, influenza, public health, health prevention policies

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# 1 Introduction

Seasonal influenza is a serious public health issue that causes severe illness and death in high-risk populations. Worldwide, these annual epidemics are estimated to result in about 3 million to 5 million cases of severe illness, and about 290,000 to 650,000 deaths ([WHO, 2017](#)).<sup>1</sup> The elderly are the individuals most affected by the influenza virus, and by the development of severe complications in case they are infected. In the latest influenza seasons in the United States, the influenza hospitalization rate of the elderly has been four times the overall hospitalization rate, and has more than doubled the hospitalization rate of the second most affected age group.<sup>2</sup> Similar figures emerge for Europe, where nearly half of the hospitalization and death cases refer to the oldest age group.<sup>3</sup>

The main strategy to protect the more vulnerable individuals has been to implement vaccination programs, especially targeted toward the elderly population.<sup>4</sup> In 2003, the World Health Organization (WHO) urged to increase vaccination coverage to 75% among older persons, and, in 2009, the European Union (EU) Council issued a recommendation encouraging Member States to implement policies aimed at reaching this target.<sup>5</sup> Even though the influenza vaccination remains non-mandatory, many countries have thus attempted to increase the coverage by offering the flu vaccine free to individuals above a certain age, which, depending on the country, ranges between 59 and 65 years.<sup>6</sup>

This paper assesses the effects of a flu vaccination program for the elderly, implemented in Italy, on vaccination take-up and health outcomes, measured by the hospitalizations occurred during the same flu epidemic season.<sup>7</sup> According to the program, the influenza vaccine is freely provided, during a single visit with the general practitioner (GP), to individuals aged 65 or more. The program is likely to affect the individual's propensity to get the shot, because it lowers both the monetary and nonmonetary time costs associated with the vaccination decision. We identify the effects of the program by adopting a regression discontinuity (RD) strategy around the threshold at 65 years of age, and by

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<sup>1</sup>Influenza epidemics also have substantial implications for the health sectors, as clinics and hospitals can be overwhelmed during illness periods ([WHO, 2017](#)), and for the overall society, as long as, through health, they may also affect human capital accumulation, labor force participation and, ultimately, economic growth ([Adda, 2016](#)).

<sup>2</sup>Data from the Center for Disease Control and Prevention (CDC). Website: <https://gis.cdc.gov/GRASP/Fluview/FluHospRates.html>.

<sup>3</sup>Data from the European Centre for Disease Control and Prevention (ECDC). See, for instance, [ECDC \(2018b\)](#).

<sup>4</sup>While antiviral drugs to treat the flu symptoms have been improved in the last decades, immunization has been found to be more effective and to have fewer adverse effects than the antivirals ([Stephenson and Nicholson, 2001](#)).

<sup>5</sup>Resolution WHA 56.19 and European Council Recommendation N. 2009/1019/EU.

<sup>6</sup>[ECDC \(2018a\)](#) provides an overview of these programs implemented in European countries. In the United States, flu vaccination is part of the preventive services to which individuals are entitled within Medicare Part B, for which they become eligible when they turn 65.

<sup>7</sup>In the rest of the paper, we will use interchangeably the term *flu vaccination* and *vaccination* to describe the vaccination against the seasonal influenza virus.

using administrative individual-level data from the metropolitan area of Milan, in the North of Italy, for the influenza vaccination campaign 2013.<sup>8</sup>

Our work relates to several strands of the literature. First, this paper is related to the literature which exploits eligibility rules based on age thresholds to assess the effects of health insurance, or free health provision, on health services consumption and health outcomes. [Card et al. \(2008; 2009\)](#) document that individuals eligible for Medicare from age 65 have higher use of medical services, and face a significant reduction in mortality. [Card et al. \(2008\)](#) also find that the effect is heterogeneous in the population, and that individuals without health insurance before age 65 increase more than the others the use of low-cost services, such as doctor's visits.<sup>9</sup>

This paper also relates to the economic and public health literature which assesses the effectiveness of vaccination programs, in terms of both vaccination take-up and health.<sup>10</sup> In the context of pediatric vaccinations, [Chang \(2016\)](#) estimates that state legislation mandating private insurers to cover pediatric immunizations increases the vaccination take-up rates substantially, suggesting that individuals are responsive to policies lowering the cost of immunization. [Ward \(2014\)](#) instead focuses on an influenza vaccination program expanding coverage to the entire population. She finds that when the free flu vaccination is provided also outside the typical target groups (i.e., children and individuals aged 65+), the vaccination rates of newly eligible age groups increase leading to health improvements, also for the older individuals.<sup>11</sup>

Finally, our study builds on the medical and economic studies which investigate the determinants of flu vaccination decisions. The medical literature suggests that demographic characteristics (such as gender and socio-economic status), as well as features of the health care system (such as vaccination cost) are strongly correlated with the flu vaccination decision ([Nagata et al., 2011](#); [Daniels et al., 2004](#)). Within the economic literature, [Mullahy \(1999\)](#) and [Schmitz and Wübker \(2011\)](#) analyze the microlevel determinants of flu vaccine take-up, and find that the most important correlates of individuals' flu vaccination decision are age, health status, and physicians' quality. [Mullahy \(1999\)](#) also suggests that, in addition to the out-of-pocket price of the vaccine, individuals may also respond to the nonmonetary time cost of getting the vaccination.

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<sup>8</sup>Metropolitan areas correspond to NUTS-3 level.

<sup>9</sup>For Italy, [Ponzo and Scoppa \(2016\)](#) evaluate the effects of cost-sharing exemption provision for individuals aged 65+ with a low income, on health services consumption and health outcomes. They report that individuals eligible for cost-sharing exemption have a higher consumption of drugs and specialist visits, while they do not detect any effects on health outcomes.

<sup>10</sup>Most of this literature considers policies recommending or mandating pediatric vaccinations before kindergarten or school entry ([Carpenter and Lawler, 2019](#); [Lawler, 2017](#); [Abrevaya and Mulligan, 2011](#)).

<sup>11</sup>There are also examples of vaccination programs assessment in the medical and epidemiological literature, such as [Hardelid et al. \(2011\)](#) and [Nichol et al. \(2007\)](#). However, these studies are based on observational analysis, and are thus very likely to suffer from bias and confounding factors. Randomized controlled trials, which are largely used in this literature, cannot be practically implemented in this setting, because influenza vaccination programs are already in place in most developed countries.

Our paper on the effects of universal access to free flu vaccination at age 65 makes four important contributions to the literature on the determinants of vaccination and health. First, our study provides new and clear evidence on the relationship between a specific health prevention policy, take-up and health outcomes, thereby improving our understanding of the implications of policies aimed at increasing vaccination rates. Unlike policies based on age-threshold studied by most prior work, that imply eligibility for insurance or free provision for a broad set of health services, the policy considered in this paper represents a particularly powerful intervention for the evaluation of vaccination programs, because eligibility for free vaccination is the only change occurring at the age threshold. Moreover, vaccination policies based on age-threshold eligibility are implemented in many developed countries, but very little is known about their actual effects on the individual’s decision to take up the shot. Figure 1 displays the age profile for the flu vaccination take-up, as reported in our data: while showing that take-up rises with age, the figure also documents that the most striking increase happens at age 65, suggesting that individuals react to the program at the moment they become eligible.

[Figure 1 about here]

Second, our analysis, based on individual-level data and a sound identification strategy, provides an estimate of the individual’s reaction to eligibility for free vaccination, which is not affected by other confounding factors. The individual-level dimension is particularly relevant in the context of flu vaccination for adult individuals. In fact, flu vaccination grants immunity only for the current flu season, and the decision to take the shot needs to be made every year. Nevertheless, in our data we observe a strong persistence in the vaccination decisions after age 65, which points to the importance of understanding the determinants of individuals’ decision to get the shot in the first place once they become eligible for free provision.<sup>12</sup>

Third, our paper focuses on a group of the population, i.e., the elderly, to whom health prevention policies are typically targeted. In addition to providing evidence on how older individuals respond to a policy lowering the costs associated with flu vaccination, our study also examines the health consequences of such program, thus contributing to a better understanding of the benefits associated with vaccination programs targeted toward the elderly population. In fact, the evidence on vaccine effectiveness is less robust for this age group (Lone et al., 2012), and also the vaccine per se is less effective because of immunity senescence (Simonsen et al., 2007). Because the flu vaccination only grants immunity for the current season, it is important that the focus of our analysis on health is on hospitalizations that occurred during an outcome period based on influenza surveillance

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<sup>12</sup>For instance, our data shows that about 80% of the 66-year-olds, in their second year of eligibility for the program, had the flu vaccination for the first time the year before.

data for the same flu epidemic season, so we can claim a clear link between the vaccination policy and the health outcomes.

Fourth, our analysis sheds light on potential heterogeneous responses to universal eligibility for free vaccination, in terms of both take-up and health. Importantly, the data allows us to observe not only individual characteristics that are likely to matter for the immunization decision (such as health status and income) but also the characteristics of the GP with whom each individual is registered, who may also play a role for the effectiveness of the program. This makes it possible not only to identify the subgroups of the population that comply more with the policy, but also to provide evidence on potential channels driving the effects on vaccination and health.

Our results show that universal eligibility for free vaccination increases the individual's vaccination take-up by 6 percentage points, corresponding to a 75% increase with respect to the average of 64-year-olds. We interpret this estimate as a local average treatment effect (LATE) of the vaccination program on the take-up. We show that this result is robust to a wide variety of specification choices and methodologies, and, importantly, we do not find any change in vaccination take-up at other ages before and after age 65. We show that the effect mainly comes from individuals with poor health and low income, as well as from individuals who are not eligible for cost-sharing exemptions within the Italian national healthcare system.

When evaluating the effect of the vaccination program on short-term health outcomes, we observe a reduction in the probability of hospitalization of about 44% compared to the average, even though the estimates are not always statistically significant at conventional levels. The reduction mainly refers to individuals registered with GPs with long experience and a high number of patients (that we interpret as being of a higher quality), as well as to emergency hospitalizations. The latter confirms the strong link between the influenza infection and the occurrence of complications that require emergency access to the hospital, especially for the elderly population. We interpret these changes in hospitalizations at age 65 as the intention-to-treat (ITT) effect of the vaccination program: in fact, the consequences that we observe on the health measures may be due to the increase in the individual's vaccination take-up, as well as to any changes in the individual's health behavior during the flu season or to spillover effects.

The rest of the paper is structured as follows. Section 2 gives an overview of the institutional background: Subsection 2.1 describes seasonal influenza and the vaccination programs implemented in most developed countries; Subsections 2.2 to 2.4 describe the flu vaccination program under study, the 2013 vaccination campaign, to which our data refers, and the Italian national healthcare system. Section 3 presents the identification strategy and discusses the main identification assumptions, while Section 4 describes the data. Section 5 presents the baseline results on vaccination take-up (Subsection 5.1), a number of robustness checks (Subsection 5.2) and heterogeneous effects (Subsection 5.3).

Section 6 presents the results on health outcomes, and Section 7 concludes.

## 2 Institutional background

### 2.1 Seasonal influenza and vaccination

Seasonal influenza is an acute and highly contagious infectious disease with mostly respiratory symptoms. It is caused by the influenza virus and is easily transmitted, predominantly *via* the droplet and contact routes and by indirect spread from respiratory secretions (WHO, 2017). Each year, influenza causes substantial morbidity and mortality, particularly in elderly individuals and those with poor or chronic health conditions, who face the highest risk of developing subsequent serious complications.

Vaccination is the safest and most recommended strategy to reduce the epidemics (WHO, 2017). For this reason, despite being typically non-mandatory, it is strongly recommended for elderly and high-risk individuals. In addition, in order to increase the vaccination coverage, countries have adopted different policies aimed at lowering the cost of immunization. In the United States, the Affordable Care Act (2010) provided that flu vaccination should be included in the preventive services covered by private insurance; the coverage becomes universal when individuals turn 65 and are eligible for Medicare. In Europe, the majority of countries provide free flu vaccination (either within the public national healthcare system or in a national health insurance scheme) to individuals who are above a certain age threshold, which, depending on the country, varies between 59 and 65 years.<sup>13</sup>

However, despite the elderly vaccination rate being typically higher than that of other age groups, it is still far from reaching the WHO target of 75% in many developed countries. For instance, in the 2013-2014 season, the vaccination rate of individuals above age 65 was around 65% in the United States, while in Europe it ranged from 75% in the UK and the Netherlands, to about 60% in central/Mediterranean countries, to 10% in Eastern Europe (ECDC, 2014).<sup>14</sup>

In the northern hemisphere, the influenza virus circulates during the winter, while the flu vaccination campaigns usually take place in the autumn. According to recommenda-

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<sup>13</sup>As of 2018, age 65 is the threshold for providing free flu vaccination used by the majority of the European countries with the exception of Germany, Greece, Hungary, Iceland, Portugal, and the Netherlands that use age 60, and Slovakia that uses age 59 as a threshold (ECDC, 2018a). Nevertheless, a relevant number of countries envisages forms of out-of-pocket payments, either in the cost of the shot or the injection (Belgium, Bulgaria, Cyprus, Estonia, Latvia, Iceland, Ireland, Luxembourg, Norway, Lithuania, Liechtenstein, Poland, Slovenia, Sweden) (ECDC, 2018a).

<sup>14</sup>In the United States, in the 2013-2014 flu epidemic season, the vaccination rate of individuals aged 50-64 was around 40%, and the rate of adults 18-49 was 32% (data from CDC, website: <https://www.cdc.gov/flu/fluview/trends/age-groups.htm>). In Europe, the vaccination rate of older individuals is significantly higher than the vaccination rate of individuals with chronic medical conditions (of any age), for whom the vaccine is still recommended (ECDC, 2017).

tions of the Center for Disease Control and Prevention (CDC) and the European Centre for Disease Prevention and Control (ECDC), the flu vaccination should be repeated every year because (i) the influenza virus constantly evolves, and (ii) the immunity elicited with the influenza vaccine is not as long-lived as the one following natural influenza infection, especially for elderly individuals. Every spring, WHO establishes the types of vaccines to be used in the next season, according to the predictions on the type of virus most likely to be circulating.<sup>15</sup>

## 2.2 The influenza vaccination program in Italy

In Italy, vaccination against seasonal influenza is regulated according to the National Plan for Preventive Vaccination (NPPV hereafter), which is established by the Italian Ministry of Health. The flu vaccination campaign starts in late October and finishes by the end of December, while the circulation of the influenza virus occurs between November and April of the following year ([ECDC, 2017](#)).

The NPPV establishes that flu vaccination shall be completely free for selected categories of individuals, who may be at risk of complications in case of flu infection.<sup>16</sup> The first category refers to the elderly: individuals are entitled to free vaccination from the calendar year in which they turn 65, regardless of their month and day of birth.<sup>17</sup> Other categories of individuals are offered a free flu vaccine, regardless of their age, because they may be at-risk of complications in case of contagion: (i) individuals aged less than 65 and affected by a certified chronic disease (especially those of the respiratory and cardiovascular systems), diabetes, or other diseases determining a weakening of the immune system; (ii) women in their second or third trimester of gestation; (iii) individuals institutionalized into nursing homes.

According to the NPPV regulations, individuals eligible for free flu vaccination get the immunization from the GP during one visit. More precisely, individuals eligible for free vaccination pay neither the vaccine shot, nor the injection nor the visit(s) from the GP, and thus face a zero out-of-pocket price. In order to increase the vaccination take-up in the at-risk categories above, the NPPV regulations also call for an active role of the GP, who should identify the eligible individuals among their patients who may be at higher risk of complications in case of flu infection, and actively offer them the vaccine ([Ministero della Salute, 2013](#)). In particular, individuals aged more than 65, who can be easily identified

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<sup>15</sup>There are two main types of influenza virus known as A and B, which are important in human disease ([WHO, 1980](#)). At any one time there is a mix of influenza viruses circulating. Influenza A and one or two strains of influenza B viruses (depending on the vaccine) are included in each year's influenza vaccine.

<sup>16</sup>As a preventive measure, the flu vaccine is also offered free to individuals working in the health, education or military sectors, care-takers of individuals at risk of complications, and individuals working in contact with animals ([Ministero della Salute, 2013](#)).

<sup>17</sup>This implies that e.g. individuals born in 1948, turning 65 in 2013, are eligible for free vaccination in the 2013 campaign (i.e. in preparation for the 2013-2014 flu epidemic season) but not in the 2012 campaign.

in the health records through their birth date, are offered the flu immunization at the beginning of any vaccination season.

All the individuals aged less than 65 and not included in any of the categories above have to get a prescription from their GP in order to buy the vaccine at the pharmacy and refer back to the doctor or to professional nurses to get the shot.<sup>18</sup> This implies that individuals not eligible for free vaccination bear not only the monetary cost of immunization,<sup>19</sup> but also a nonmonetary cost, mainly due to the time spent in the immunization process.

## 2.3 The 2013 flu vaccination campaign

For our analysis, we have access to data on the 2013 flu vaccination campaign, which lasted between October and December 2013. According to data from the Italian National Health Institute (NHI), which is in charge of documenting the vaccination coverage and the epidemiological characteristics of each flu seasonal epidemic, 15.6% of individuals of any age received the vaccination in the 2013 season, while the vaccination rate for individuals 65+ was 55.4%.<sup>20</sup> The rates are in line with the vaccination coverage rates in the adjacent campaigns, as shown in Appendix Figure A.1.

The laboratory analysis conducted for the virological surveillance of the 2013 campaign showed a good match between the vaccine composition and the virus actually circulating (Ministero della Salute, 2014).<sup>21</sup> The NHI also keeps track of the health consequences of the flu epidemic, by gathering data on the number of flu-related cases, as reported by GPs, and at attendance at the emergency rooms with respiratory symptoms. These data refer to influenza-like illness cases, based on both the symptoms and on a medical examination of the patient, but not on the analysis of biosamples. In the 2013-2014 epidemic season, the virus circulated between week 43 in 2013 (mid-October) and week 17 in 2014 (end of April). In this period, there were almost 4.5 million influenza-like illnesses (corresponding to about 7.5% of the Italian population), out of which about 100 were severe. Cases with respiratory or flu-like symptoms accounted for 9.4% of all attendances at the emergency rooms, and, of these, 20% ended up in a hospitalization (ISS, 2014). For our analysis on health outcomes, we use the definition of the outcome period from the epidemiological

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<sup>18</sup>The injection must be performed by a doctor or professional nurse, in order to check for potential side effects of the vaccine.

<sup>19</sup>The price of the vaccine shots sold in pharmacies might vary from 12 to 30 euros, depending on the year, type, and producer. The price for an injection can vary between 10 and 30 euros, depending on the doctor and on whether it is done at home or in the clinic.

<sup>20</sup>These rates include vaccinations performed either within or outside the NPPV. Website: <http://www.epicentro.iss.it/influenza/copertura-vaccinali>

<sup>21</sup>The vaccine used in the 2013-2014 season was trivalent, with two strains of influenza A and one of influenza B virus included (Ministero della Salute, 2014; WHO, 2014). An ECDC study (Valenciano et al., 2015), by using data on influenza virus cases registered in Germany, Hungary, Ireland, Portugal, Romania, and Spain estimates that the vaccine effectiveness against seasonal influenza in the 2013-2014 season has been 52.2% for the total population, and 49.1% for individuals aged more than 60.

study of the 2013-2014 season (ISS, 2014), and consider the hospitalizations that occurred during this time span.

## 2.4 The Italian healthcare system

The Italian national healthcare system (NHS hereafter) is mainly public and managed by the regional governments, while minimum quality standards are defined at the state level for all the regions.<sup>22</sup> Under the NHS, all residents can consult a free general practitioner (GP, often called a *family doctor*), who is responsible for prescriptions of drugs and requests for specialist visits. Hospitalizations (including accommodation and treatments) are also freely provided by the NHS to all residents. Cost-sharing is instead required for specialist visits, diagnostic checks, and drugs. Individuals are exempted from the cost-sharing in case of (i) poor health conditions (i.e. certified chronic disease or disability), (ii) low income, or (iii) a combination of both poor health and low income.<sup>23</sup> Cost-sharing exemptions for low income apply to individuals with income below a certain threshold, unemployed, or retired with a pension below a minimum level.<sup>24</sup>

Typically, the cost-sharing exemption due to chronic health conditions only allows the individual to gain free access to drugs and specialist visits related to the certified chronic disease. However, in case of extremely serious health conditions, the cost-sharing exemption is extended to all drugs and specialist visits. This implies that individuals with extremely poor health or certified chronic diseases do not enjoy any additional benefit, in terms of cost-sharing exemptions, from a low-income status. In our analysis, we shall use these cost-sharing exemption rules, based on certified health conditions and low-income status, to group individuals according to their poor health or income-related fragility.<sup>25</sup>

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<sup>22</sup>In Italy, there are 20 regions (NUTS2 level).

<sup>23</sup>Chronic diseases include, among others: cancer, diabetes, chronic renal insufficiency, heart and neurological diseases.

<sup>24</sup>Under (a) and (c) above, the cost-sharing exemption is automatically granted; under case (b) the unemployed should file the request. Exemptions due to low income are valid for one year only, and as long as the low-income condition applies.

<sup>25</sup>In our data, we observe whether the individual has a cost-sharing exemption due to (i) chronic disease or disability, (ii) low-income, or (iii) a combination of the above categories. It should be noticed that category (i) does not coincide with individuals aged less than 65 and eligible for free vaccination due to chronic health conditions, because eligibility for free vaccination mainly applies to individuals with diseases of the respiratory/cardiovascular system or diseases determining a weakening of the immune system (Ministero della Salute, 2013). This implies that the category of individuals exempted from cost-sharing because of poor health conditions overlaps but does not coincide with the category of individuals aged less than 65 and eligible for free vaccination, as defined in Subsection 2.2. See Section 4 for a more detailed description of the data.

### 3 Identification strategy

#### 3.1 The regression discontinuity design

The aim of this paper is to analyze the effect of universal eligibility for free flu vaccination on vaccination take-up and individuals' health. To this purpose, we exploit the fact that in Italy flu vaccination is free for all individuals aged 65+, and identify the effect of such age-related change in a RD framework. In practice, we use exact birth dates to determine individuals' assignment to the treatment (i.e., eligibility to free flu vaccination).

In the 2013 vaccination campaign, all individuals born before January 1 1949 are eligible for free flu vaccination under the NPPV; conversely those born after can be considered eligible only if belonging to any of the other categories listed in Section 2.2. This framework makes it possible to estimate the effects of the age-related change on vaccination take-up (and health outcomes), by comparing individuals who are essentially identical under all characteristics (observed and unobserved), but differ for being born in days close to the cutoff day, but on opposite sides. In order to make our comparison of eligible and non-eligible individuals credible, we focus the analysis on individuals born within 365 days from the cutoff birth date (January 1, 1949).

Let  $d_i$  (*running variable*) be the distance (in days) between the individual's date of birth and the cutoff point, such that it is positive for those born before the cutoff day (eligible for free vaccination), and negative for those born after (non-eligible). The baseline RD equation takes the following form:

$$Pr(V_i) = \alpha + ET_i(\beta_{RD} + f^R(d_i)) + (1 - ET_i)f^L(d_i) + \epsilon_i \quad (1)$$

where:  $ET_i$  is a dummy defining the eligibility for the treatment status (i.e. taking value 1 for those born before January 1 1949 and 0 otherwise);  $f^R$  and  $f^L$  are unknown smoothing functions of the running variable  $d_i$ , on the right and left hand side of the cutoff, respectively;  $V_i$  is a dummy indicating whether individual  $i$  got vaccinated in the 2013 campaign. Given that the assignment to the treatment is deterministic and based on the date of birth, which, in a sufficiently small neighborhood of the cutoff date, can be considered as-good-as random, the parameter  $\beta_{RD}$  is an estimate of the causal effect of universal free vaccination on the outcomes of interests:

$$\hat{\beta}_{RD} = \lim_{d_i \rightarrow 0^+} E(V_i|d_i) - \lim_{d_i \rightarrow 0^-} E(V_i|d_i) \quad (2)$$

Similarly, defining  $H_i$  as the health status of the individual during the flu disease spread, we use the same estimation framework to retrieve the short-term effects of vaccination on individual health. Notice that, while we interpret the effect on vaccination take-up as a local average treatment effect (LATE), the estimated effect on health shall

be interpreted as an intention-to-treat (ITT) effect. In the first case, we observe both the eligibility status (determined by the age threshold) and the individual’s direct compliance with the policy change; in the second case, instead, the effect of the policy change on health is likely to be influenced also by related changes in the individual’s health behavior or spillover effects.

### 3.2 Tests for the identifying assumptions

The identification of the effects of universal eligibility for free vaccination relies on a number of factors. First, the cutoff at age 65, after which free vaccination becomes universal, must generate a sizable variation in the vaccination take-up to allow identification of the effects. As we have seen from Figure 1, the largest increase in vaccination probability occurs at age 65. Figure 2 shows in details the discontinuous change in flu vaccination probability when comparing 64- and 65-year-olds: the average vaccination probability of 64-year-olds is 8%, while the average vaccination rate for 65-year-olds is 18%.

[Figure 2 about here]

Second, there should not be manipulation in the running variable. This assumption can be tested by investigating the presence of discontinuities in the density of the observations close to the cutoff (McCrary, 2008). Figure 3 reports the number of individuals born in each calendar day for the years 1948 and 1949, showing an unexpectedly high number of births on January 1, 1949. This pattern seems consistent with a framework where birth registers were manually filled, and parents retained some discretion when declaring the date of birth of their children.<sup>26</sup> The McCrary test, reported in Figure A.2, confirms that there is a statistically significant jump in the number of births at the cutoff date: the estimated discontinuity is -0.183 (0.029), with a  $t$ -statistics of 6.284. Thus, in order to provide conservative estimates of the causal effect under study, we adopt a *donut* specification (Barreca et al., 2016), by excluding from the analysis the individuals who are born exactly at the cutoff date and in the day before and after. In a later section we also show that the results are robust to using different *donut* specifications or the full sample.

[Figure 3 about here]

Third, the regression discontinuity design delivers an estimate of the effect of universal eligibility for free vaccination by comparing individuals aged 64 and 65 in the 2013 vaccination campaign, under the assumption that these two age groups do not differ in

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<sup>26</sup>In the years after World War II, it was standard to give birth at home and then declare the birth to the General Register Office of the municipality of residence in the days following the event.

any other observable or unobservable characteristic associated to the vaccination decision. To assess whether observable factors differ between the two groups, in Figure 4 we plot selected characteristics as a function of the individual’s birth date. In particular, we consider the share of females, the share of individuals living in urban areas and those with a certified cost-sharing exemption for chronic conditions (i.e. as a proxy for health status), as well as GP’s age, experience and number of patients.<sup>27</sup> The evidence reported in Figure 4 does not show any discontinuity in these variables close to the cutoff date. We also check this more formally, by estimating a non-parametric regression (similar to Equation (1)) using as dependent variables individuals’ and GPs’ characteristics. Results are presented in Table A.1 in the Appendix A and confirm the graphical evidence depicted in Figure 4.<sup>28</sup>

[Figure 4 about here]

Whilst other socio-economic characteristics may also be associated with the individual’s perceived benefits and costs of vaccination, the administrative data we use do not contain information such as education, employment or family composition. To check whether any of these characteristics also change around the cutoff date, we use an alternative source of data: the Italian Survey on Health (ISH). We select the 2013 wave and only consider 64- and 65-year-old individuals; due to the limited number of observations, we perform the analysis with the ISH survey on the whole Italy. We then specify and estimate non-parametric regressions, similar to Equation (1), using as dependent variables a set of dummies for specific individual characteristics, such as: female, certified chronic disease, high school diploma, retired status, working in public sectors (such as education, health or military services), marital status, living alone or living with son(s). The main results, reported in Table A.3 in the Appendix, confirm the absence of discontinuities at the cutoff date in gender and health status, as already documented with the administrative data, as well as in the other socio-economic characteristics.

Fourth, no other relevant policy change should affect the cohorts of individuals, at the threshold of age 65, considered in this study. Along this line, one first concern is related to the retirement age threshold as in 2013. Estimates in columns (7) and (8) of Table A.3 show that the proportion of retired individuals does not change discontinuously at the cutoff age. Indeed the retirement age, while being different across job types, in

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<sup>27</sup>More precisely, we define a dummy variable equal to 1 if the individual is female, a dummy variable equal to 1 if the individual lives in a urban area, and a dummy variable equal to 1 if the individual is exempted from the health cost-sharing rule because she has a chronic disease; regarding the GPs’ characteristics, these refer to the family doctor of each individual and represent the doctor’s age, experience and number of patients. Additional details on the definition of these variables are provided in Section 4.

<sup>28</sup>In Section 5, when presenting our results, we also show that these are robust to the inclusion and exclusion of these variables as covariates in the regressions. Table A.2 also shows that there are no discontinuities in the proportion of individuals entitled to exemption from cost-sharing because of health issues and low income, low income only or without exemptions.

no case in 2013 coincided with age 65.<sup>29</sup> A second concern is that individuals, when they turn 65 and have an income below 36,000 euro, become eligible for cost-sharing exemptions for specialist visits and diagnostic checks. Since at age 65 everyone is eligible for free vaccination, regardless of the income level, cost-sharing exemptions should not affect individuals' vaccination decision. Still, such rule may affect our analysis of health outcomes if individuals, due to cost-sharing exemption at 65, use more specialist visits which may improve their short-term health outcomes. To address this, we check whether the proportion exempted from cost-sharing because of low income changes discontinuously at the cutoff.<sup>30</sup> Results reported in Table A.2, columns (3) and (4), show that this is not the case.

Finally, the presence of spillover effects could represent an additional threat to our identification strategy if, when deciding whether to get the flu vaccination or not, individuals internalize the perceived level of herd immunity of one's peers (e.g. colleagues at work, neighbors or family members).<sup>31</sup> However, in our setup this can occur only if the level of herd immunity changes discontinuously at the cutoff date, which may happen if 65-year-olds expect to interact only with other eligible individuals – thus facing higher herd immunity among their peers – and not with 64-year-olds non-eligible for free vaccination. While we believe that such separation between 65- and 64-year-olds is rather unrealistic, such free-riding behavior is also strategically unsound since it would eventually drive vaccination take-up above 65 years of age to zero. In Tables A.1 and A.3, we show that there are no relevant discontinuities at the cutoff date along different peers clustering groups – such as urban or rural area, family composition and employment status – corroborating our claim that herd immunity does not follow specific patterns.

## 4 Data

### 4.1 Data and variables description

For our analysis we use administrative individual-level records of all residents aged 50 and more in the metropolitan area of Milan (Italy), which covers the municipality of Milan and 133 surrounding municipalities.<sup>32</sup> The data are provided by the Agency for Health

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<sup>29</sup>Retirement age in 2013 was regulated by Law 201/2011.

<sup>30</sup>In our data, we cannot identify the specific category of individuals exempted from cost-sharing due to age 65+ and low income. Instead we have information on any exemptions related to a low-income status. See Subsections 2.4 and 4.1.

<sup>31</sup>For *herd immunity* it is intended in the medical literature the protection against a certain disease that any individual gets as a spillover effect that comes from the fact that a substantial share of the population is immune to that disease because of the vaccination.

<sup>32</sup>The Milan metropolitan area corresponds to the NUTS level 3 and is located in the Lombardy region, in the north-west of the country. It includes approximately 3.2 millions inhabitants, and it represents the second largest metropolitan area in Italy, after Rome.

Protection, which is in charge of governing the healthcare sector in the area.<sup>33</sup>

The data include individual records from the *General Health Register* (GHR), containing demographic characteristics (gender, municipality of residence, and the date of birth), the exact date of flu vaccination (if any), and additional information on cost-sharing exemptions due to chronic health conditions and/or low income. The GHR also contains information about the GP assigned to each individual. The data covers the 2013-2014 flu epidemic season, from fall 2013 until spring 2014.

From the GHR we create a dummy variable ( $V_i$ ) which takes value 1 if the individual received the flu vaccination between October and December 2013, and zero otherwise. The date of birth of the individual is our running variable ( $d_i$ ). We use the information on cost-sharing exemptions to derive four dummy variables proxying for individuals' health and income status: (i) a dummy variable indicating exemption due to *chronic health conditions*; (ii) a dummy variable for individuals exempted from cost-sharing due to *poor health and low income*; (iii) a dummy variable indicating exemption for *low income only*; and (iv) a dummy variable indicating that the individual does *not have exemptions* of any sort. In the analysis, we control for the gender and place of residence of the individual, by defining a variable *Urban* equal to 1 if the individual lives in the municipality of Milan or the neighboring municipalities, 0 if instead lives in rural areas. We also control for the individual's health status, by including the dummy for cost-sharing exemption due to chronic health conditions, and for selected characteristics of the GP assigned to each individual (experience, age, and number of patients). Finally, we use the set of dummies on cost-sharing exemptions defined above to analyze heterogeneous effects.

We also merge the GHR with the register of *Hospitalization Records* (HR), reporting all hospitalizations that occurred in the territory of the Agency, and the duration of the attendance (in days). For the analysis of the effects of vaccination on health, we construct two variables based on the occurrence of hospitalization events, considering both the intensive margin (i.e., a dummy indicating whether or not at least one event occurred) and the extensive margin (i.e., the number of days of hospitalization). The information on hospitalizations refers to planned and emergency occurrences.<sup>34</sup> For the health outcomes, we consider the period when the influenza virus was circulating, from week 43 in 2013 until week 17 in 2014, according to the epidemiological report of the National Health Institute (NHI) (ISS, 2014). Note that for all vaccinated individuals, we exclude the hospitalizations occurred in the 14 days after the vaccination, as the immunization process takes at least 14 days to produce its effects (Russo, 2015).

A drawback of the information contained in the GHR is that only flu vaccinations provided within the NPPV are recorded. These include individuals (of any age) eligible

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<sup>33</sup> *Agenzia di Tutela della Salute* (ATS-Milan) in Italian.

<sup>34</sup> A hospitalization may be *planned* if, e.g., requested by the GP. *Emergency* hospitalizations, instead, occur after an access to the emergency rooms.

for free vaccination according to the categories listed in Section 2.2. Thus, in our data, we cannot observe whether individuals aged 64 – and not eligible for free vaccination – get the flu vaccine outside the NPPV and refer to a doctor for the injection. While official information on the number of individuals who receive the flu vaccine outside the NPPV (i.e., by paying for it) is not available, aggregate statistics from the National Health Institute indicate that, in the Lombardy region, the overall flu vaccination rate for the 45-64 age group is 3.7%. This figure is very close to the 3.6% vaccination rate recorded in the GHR data for the metropolitan area of Milan in the flu epidemic season under study, thus suggesting that flu vaccinations outside the NPPV are expected to be negligible. Moreover, in Section 5.2, we assess the importance of flu vaccinations outside the NPPV, by providing evidence from survey data, that report information on individuals who get the flu vaccine either under the NPPV or privately.

## 4.2 Sample selection and descriptive statistics

For the empirical analysis, as described in Section 3, we select individuals aged 64 or 65 in 2013 (i.e., born between January 1, 1948 and December 31, 1949), and exclude those born on the cutoff date (January 1, 1949), or on the day before or after (*donut* specification). We keep only individuals who get the flu vaccination until December 2013, or who did not get the flu vaccination in the 2013 campaign, and for whom we have reliable information on their GP.<sup>35</sup> In order to keep the individual’s vaccination decision as much homogenous as possible in the sample, we also exclude individuals with a certified disability or institutionalized in nursing homes.<sup>36</sup> The final sample consists of 68,962 individuals.

[Table 1 about here]

Table 1 reports the descriptive statistics of the variables used in the analysis. The variable *Treated* indicates individuals aged 65 in 2013 (i.e., born in 1948), who are 51% of the sample. In the 2013 campaign, 12% of individuals aged 64 or 65 got the flu vaccination, while 3% of individuals in the same age group experienced at least one hospitalization, for an average length of stay at the hospital of 0.36 days.<sup>37</sup> Females represent 54% of the sample, 60% live in a urban area, and 14% are eligible for cost-sharing exemption due to a chronic health status. In terms of GP’s characteristics, in our sample, the average age is

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<sup>35</sup>In the data, we drop individuals who got the flu vaccination in January or February 2014, which represent 0.11% of the population aged 64 or 65. Regarding the GPs’ characteristics, we drop 2.3% of the observations because the information on the GP was missing or unreliable.

<sup>36</sup>Individuals with a disability or institutionalized in nursing homes represent 9% of the entire population aged 64 or 65 years. For these individuals the flu vaccination decision is rather different, as they are likely to receive the vaccination at their home or at the nursing institution. However, our main results and conclusions hold when these individuals are included in the analysis. Results are available on request.

<sup>37</sup>The average length of stay for the hospitalized is around 10 days.

58, with an average of 24 years experience in the practice, and a total number of patients for each doctor close to 1,500.

## 5 Eligibility for free vaccination and take-up

### 5.1 Baseline results

Baseline estimates of the effect of universal eligibility for free flu vaccination on the vaccination take-up probability are reported in Table 2. We perform RD robust estimates following the non-parametric optimal bandwidth selection procedures suggested by [Calonico et al. \(2014\)](#) and [Calonico et al. \(2017\)](#), and use a triangular kernel and a coverage error rate (CER) bandwidth selector. The estimated parameter is around 6 percentage points in all specifications, regardless of whether we include additional controls, or whether we use a polynomial of order 0 or 1. The bandwidth used for the estimation ranges between 28 and 60 days from the cutoff date, meaning that for our estimates we are considering individuals born within one or two months from January 1, 1949.

[Table 2 about here]

Our estimate implies that the introduction of universal eligibility for free vaccination induces an increase in the likelihood of getting the flu vaccination by 6 percentage points, with the probability of getting a flu vaccine increasing up to 18% for those aged 65. Considering that the target vaccination rate for the 65+ group is 75%, one may be inclined to regard such effect as rather modest. However, if we compare the estimated parameter with the average vaccination rate of the 64-year-old (approximately 8% in our sample), a 6 percentage point increase corresponds to a 75% increase in vaccination take-up, which is a sizable effect.

[Table 3 about here]

Results from a parametric specification on vaccination take-up probability are reported in Table 3. All the parametric regressions use a triangular weight, which is decreasing in the distance from the cutoff, so that observations near the cutoff receive larger weight than do observations farther from the cutoff. Furthermore, we vary the bandwidth by using samples of individuals born within 1 month, 3 months, 6 months, or 12 months from the cutoff date. As expected, when increasing the bandwidth, and thus the number of observations, we prioritize precision over bias and the estimates become larger than the non-parametric ones. However, the estimates using a bandwidth of 1 month or 3 months are very similar to the ones presented in Table 2, and do not change substantially whether we include additional controls in the regression, or when a linear or a quadratic specification is used, with or without interaction terms between the treatment and the running variable.

## 5.2 Robustness checks

In the following analysis, we perform several robustness tests. First, we test for the occurrence of changes in vaccination take-up at different ages, by performing a placebo exercise. Second, we implement several specification checks, by focusing on three main dimensions: (i) the clustering of the standard errors, (ii) alternative *donut* specifications, (iii) the use of different bandwidth selector and kernel.<sup>38</sup> Finally, using complementary data from the Italian Survey on Health (ISH), we show that vaccinations taken outside the NPPV do not affect our baseline estimates.

**Placebo exercise.** To make sure that the estimated change in vaccination probability is due to the flu vaccination program at age 65, and not to underlying trends or other unknown factors, we replicate the baseline analysis using placebo age groups. We consider couple of adjacent cohorts not affected by the treatment in the campaign under study and assign the placebo treatment status to the older one. In practice, we consider two couples of cohorts before age 65 (i.e., the 64- and 63-year-olds, and the 63- and 62-year-olds), and two couples of cohorts after age 65 (i.e., the 66- and 65-year-olds, and the 67- and 66-year-olds).

[Table 4 about here]

Results reported in Table 4 show that in no case the placebo treatment matters for the individual's vaccination decision. Importantly, this placebo analysis confirms that the estimated change in vaccination probability that we document at age 65 is due to the introduction of universal eligibility for free vaccination, and not, for instance, to a natural increase in the vaccination propensity due to an older age.

**Sensitivity and specification checks.** In the baseline analysis standard errors are not clustered. In Table A.4 in the Appendix, we show that the baseline results do not change if we implement alternative clustering. First, given that our running variable is discrete, as suggested by Lee and Card (2008), we cluster standard errors by date of birth (our running variable). Then, to account for individuals sharing the same GP or living in the same municipality, we also cluster standard errors by GP and by municipality. In all cases, our main results are confirmed.

Furthermore, we check the sensitivity of our estimates with respect to the exclusion from the estimation sample of individuals born around the cutoff date. In Table A.5 in the Appendix, we report the results obtained from different samples: (i) *No Donut* with the entire sample, (ii) *Donut 0* where we drop individuals born on the cutoff date, (iii) *Donut 2* and *Donut 3* where we exclude individuals born on the cutoff date and those born 2 or 3 days immediately before or after. Results are unchanged.

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<sup>38</sup>We also check that the *parametric* estimates are robust to clustered standard errors (by cutoff date, by municipality of residence or by GP), or to different *donut* specifications. The results are very similar to the ones presented in Table 3, and are available upon request.

Finally, we test the robustness of the non-parametric results presented in Table 2 to the optimal bandwidth selector and to the kernel. While the baseline analysis is performed using the coverage error rate (CER) bandwidth selector and the triangular kernel, in Table A.6 in the Appendix we show that the results do not change if we instead use the mean square error (MSE) bandwidth selector or the uniform kernel.

***Flu vaccination outside the NPPV.*** An important issue concerns the extent to which individuals aged less than 65 get the flu vaccination outside the NPPV. As previously discussed, GHR data only provides information on flu vaccinations provided within the NPPV, thus neglecting individuals who purchase the vaccine at the pharmacy and refer to a doctor for the shot. While evidence from aggregate data suggests that the vaccination rate outside the NPPV is negligible (see the discussion in Section 4.1), we complement our analysis by replicating our baseline estimates on survey data drawn from the 2013 wave of the Italian Survey on Health (ISH), which asks individuals whether they received the flu vaccination in the 12 months before the interview, either within or outside the national vaccination program.

Hereafter, we discuss some caveats concerning the use of ISH data. First, with ISH data it is not possible to retrieve the exact date of birth of the respondents, since the age variable is coded as “age – in years – at the time of the interview”.<sup>39</sup> Second, it is not possible to retrieve the same territorial level as in the GHR data (i.e., Milan and its metropolitan area), as only a bigger (NUTS 2) geographical disaggregation (i.e., the Lombardy region) is available. Third, due to the wording of the question, respondents are asked to report flu vaccination decisions in the previous 12 months so that the information is likely to refer to the 2012 vaccination campaign (i.e., the campaign before the one considered in our analysis). Still, as shown in Appendix Figure A.1, the two campaigns had very similar vaccination rates: in the Lombardy region, the elderly vaccination rate was 48.2% in 2012 and 48.6% in 2013.<sup>40</sup>

In Table A.7 in the Appendix, we report the results we obtain replicating our baseline specification on the ISH data. Estimated effects, for the entire sample, on the vaccination take-up (reported in columns 1 and 2), show an increase in the take-up probability of about 7 percentage points (smaller for polynomial of degree one). The results appear less precisely estimated as we restrict the sample to geographical areas closer to the one covered by the GHR data, albeit always positive in sign and similar in magnitude. Overall, the results from this replication exercise confirm the existence of an increase in the take-up probability at age 65 and show that the magnitude of the effect is in line with our main findings with GHR data.

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<sup>39</sup>Interviews were performed in September and December 2012, and March and June 2013. In order to be as precise as possible in the attribution of the treatment status in the replication analysis below, we restrict the sample to individuals aged 65 or 64 and interviewed in the month of December 2012.

<sup>40</sup>Data from the NHI.

### 5.3 Heterogeneous effects

In this section, we analyze whether the flu vaccination program has heterogeneous effects on vaccination take-up depending on the individuals' characteristics and GPs' attributes, in order to shed light on the mechanisms driving the behavioral responses to free access to vaccination.

**Individuals' characteristics.** To investigate the role of individuals' characteristics on the vaccination decisions, we replicate our baseline analysis by splitting the sample according to the individual's health status and income.<sup>41</sup> Using the information on cost-sharing exemptions certified by the NHS, we identify four categories of individuals: (i) those affected by a chronic disease, (ii) those with poor health status and low income, (iii) those with a low income, and (iv) the remaining individuals with no certified exemptions. As mentioned in Section 2.4, since cost-sharing exemption associated with a chronic and severe health condition imply free access to a great proportion of specialist visits and drugs, we expect the cost-sharing exemption for low income to play no additional role, and thus interpret the four categories above as providing a ranking in the health-income space which improves from categories (i) to (iv).

[Table 5 about here]

Results are presented in Table 5. Panel A shows no effect of universal eligibility for free vaccination on take-up for individuals who have a certified chronic condition. While this result might seem counterintuitive, given that individuals in this group are characterized by the worst health status and potentially could benefit the most from flu vaccination, it should also be noted that they are likely to be eligible for free vaccination even before age 65, because of their chronic health condition, as outlined in Section 2.2. Thus, the absence of any effects for this category suggests that, even though the categories of individuals exempted from cost-sharing due to a chronic condition and those exempted from paying the flu vaccination do not perfectly coincide, there is a significant overlap between the two.

Panels B, C, and D report the effect of universal eligibility for free vaccination on individuals exempted from cost-sharing because of poor health status and low income (Panel B), low income only (Panel C), or without any exemptions (Panel D). We find that individuals characterized by both poor health and low income (Panel B), as well as individuals without any exemptions from cost-sharing (Panel D), are more resilient to free vaccination eligibility after 65, with an increase in the vaccination probability ranging between 7 and 9 percentage points. In the context of the flu vaccination program under study, it should be noticed that the age threshold induces a reduction in the monetary and nonmonetary time cost associated with the immunization. Individuals who are exempted

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<sup>41</sup>We do not find differences in the vaccination take-up across gender and place of residence; results are reported in Appendix Table A.8.

from cost-sharing because of low income, among which there are unemployed or employed with a minimum income level, may be more reactive to the reduction in monetary cost, even though this appears to be the case only if they also value the health benefits of not getting the flu, as in case of poor health conditions. On the contrary, the monetary cost of the vaccine (and its subsequent reduction induced by the program) is likely to matter less for individuals without any exemptions, who instead may value more the reduction in the nonmonetary costs associated with the flu immunization program. Furthermore, the increase in vaccination take-up that we document for individuals without exemptions seems in line with [Card et al. \(2008\)](#), who show that Medicare eligibility at age 65 matters especially for individuals without previous health insurance.

Summing up, this heterogeneity analysis points to the evidence that a pure income effect cannot be considered as the main driver of the decision of taking the vaccine shot, because low-income individuals only react to the policy if they have poor health conditions, and thus also value the expected benefits of vaccination. Individuals without any exemptions from cost-sharing also increase their take-up when becoming eligible: as this group may be less responsive to a change in the out-of-pocket price of the vaccine, we interpret this finding as evidence that the nonmonetary cost reduction implied by the program also plays a role for the vaccination decision.

***GPs' characteristics.*** Since eligible individuals typically receive the vaccine shot from their GP, the role of GPs may be important when assessing the individual's response to free vaccination. We thus check whether selected GPs' characteristics (experience and number of patients) matter for the individual's response to universal free vaccination at age 65. More precisely, we take experience (i.e., number of years of practice within the NHS) and the number of patients as proxies of GP's perceived quality. Results from this exercise are presented in Table 6. In general, we find that the magnitude of the effect on vaccination take-up is greater for higher-quality GPs (i.e., with more experience and a larger number of patients), even though the estimates are not statistically different.

[Table 6 about here]

## 6 Effects on health outcomes

In this section, we document the effects of universal access to free vaccination for individuals 65+, on health outcomes. We use as a measure of health the individual's hospitalization probability and hospitalization duration measured in the same 2013-2014 flu epidemic season (see Section 4 for details on the variables construction). We acknowledge that such health measures refer to quite serious outcomes, so that many minor illnesses, associated with the influenza virus, may end up undetected. However, the likelihood of hospitalization is the highest for the elderly population under study ([ECDC, 2018b](#)),

mainly because this age group is more likely to be affected by complications related to the influenza virus in case of contagion. Moreover, by focusing on hospitalization, which is a very costly treatment that in Italy is provided free to everyone by the NHS, we are able to better account for one of the main costs associated with the treatment of influenza.<sup>42</sup>

Furthermore, since the immunization induced by the flu vaccination is only valid for the same season, we restrict attention to the short-term effects on health in the weeks of the virus diffusion (i.e., between October 2013 and April 2014). We are confident that this allows us to claim a stronger link between the change in eligibility rules for the 65+ group and the individual’s health status in the forthcoming weeks. However, we cannot rule out that the observed health outcomes may be related to other factors, also changing as a consequence of the program, such as the individual’s health behavior, or the level of herd immunity in the population.<sup>43</sup> This implies that any potential health effect documented in this section should be interpreted as an intention-to-treat (ITT) effect of the flu vaccination program.

## 6.1 Baseline results and heterogeneous effects

Table 7 presents the main results of the effects of eligibility for free vaccination on hospitalization outcomes using a non-parametric analysis, while Table A.10 in the Appendix reports the results of the parametric analysis. In both cases, we find that eligibility for free vaccination does not induce any statistically significant improvement in hospitalization outcomes, neither at the intensive nor at the extensive margins.<sup>44</sup> The absence of any overall improvement in hospitalization outcomes for the whole sample of 64- and 65-year-olds, however, could hide the presence of heterogeneous effects. Thus, mirroring the analysis that we have performed on vaccination probability, we look at heterogeneous effects by individuals’ and GPs’ characteristics. Moreover, we exploit an additional feature of the hospitalization records, to look at the heterogeneous effects by hospitalization types.

[Table 7 about here]

***Heterogeneous effects by individuals’ characteristics.*** We focus on the subgroups defined according to the categories of cost-sharing exemptions described in Section

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<sup>42</sup>One day of hospitalization costs, on average, 674 euros to the NHS, while for an average length the cost may exceed 4,000 Euros (Ministero dell’Economia e delle Finanze, 2007). One emergency intervention costs on average 12,500 euros (Ministero della Salute, 2007).

<sup>43</sup>As shown in Section 3.2 we find no evidence of specific clustering in groups at the 65 cutoff, so we expect herd immunity to have only a second-order effect. On the other hand, it could be the case that eligible individuals not only get the free flu vaccination, but also are more exposed to information about (non-medical) preventive measures, such as washing hands, which may induce a change in their health behavior and, potentially, affect their short-term health status.

<sup>44</sup>We also repeat the same battery of robustness checks that we have performed for the baseline analysis on vaccination probability, and in all cases the absence of a statistically significant effect is confirmed. Results are available on request from the authors.

2.4.<sup>45</sup> The results are presented in Table 8 and show a small decline in the probability of hospitalization for selected groups of individuals, even though most estimates are generally not statistically significant. More precisely, individuals with a cost-sharing exemption for a chronic disease (Panel A) and those without any cost-sharing exemptions (Panel D) experience a reduction in the probability of hospitalization. It should be recalled that individuals with a cost-sharing exemption for poor health and low income (Panel B) and individuals with no exemptions (Panel D) were those who exhibit the largest increase in vaccination take-up. The results on health outcomes suggest that there are small health gains only for the latter group, and not for the former. One potential explanation could be that having a chronic health condition contributes to a less effective response to the vaccine (Restivo et al., 2018). Moreover, the reduction in the probability of hospitalization that we observe for individuals with chronic health conditions suggests that this group, despite not being directly affected by the vaccination program, may benefit from a higher vaccination rate in the population and thus from the spillover effects that the program generates.

[Table 8 about here]

***Heterogeneous effects by GPs' characteristics.*** Table 9 reports the results on health outcomes when we look at heterogeneous effects by GPs' characteristics. There is a statistically significant reduction in both the probability of hospitalization and the number of days at the hospital for individuals with GPs having a total number of patients above the median. Since GPs of higher perceived quality are likely to reach the maximum number of patients first, we interpret this result as an indication that physicians' quality matters for the individual's short-term health. Given that we did not detect significance differences in the vaccination take-up by GPs' characteristics, this result suggests that higher-quality physicians may be more convincing in advising patients not only about the flu vaccination but also about the health behavior to adopt in order to decrease the likelihood of infections or complications.

[Table 9 about here]

***Heterogeneous effects by type of hospitalization.*** As mentioned in Section 4, hospitalization records refer to both planned and emergency care. We thus replicate the analysis on these two alternative measures on both extensive and intensive margins. The results, presented in Table 10, show that the main effect comes from emergency hospitalizations. Given that the average probability of emergency hospitalization is 0.016, the estimated coefficients represent a reduction ranging between 44% and 94% from the baseline. This confirms that the influenza virus in the elderly population can lead to complications for which patients need immediate and intensive care.

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<sup>45</sup>As for the probability of vaccination, we find no differential effects for female or male individuals, or for individuals living in a urban rather than a rural area (see Appendix Table A.9).

[Table 10 about here]

## 7 Conclusions

In this paper, we analyze the effects of a vaccination program implemented in Italy, as in many other developed countries, which actively provides free flu vaccination to individuals aged 65 or more. The program implies a reduction not only in the out-of-pocket price of the vaccine, but also in the nonmonetary time cost associated with the vaccination, since eligible individuals can get it directly from their GP in a single visit.

We estimate that the vaccination take-up increases by 6 percentage points for those becoming eligible for the program: this effect is sizable, as it corresponds to 75% of the average vaccination rate of the non-eligible 64-year-olds. We do not find evidence of a strong income effect, because low-income individuals only react to the policy if they have poor health conditions, and thus also value the expected benefits of vaccination. Individuals without exemptions from cost-sharing also increase their vaccination rate, as a consequence of the policy: as these individuals may be less resilient to a change in the out-of-pocket price of the vaccine, we interpret this finding as evidence that the nonmonetary cost reduction implied by the program also matters for the vaccination decision.

We also evaluate the effects of the free vaccination program on individuals' short-term health status, measured by the hospitalization probability and duration, in the same flu epidemic season. We document a slight decline in the hospitalization probability of selected categories of individuals (those exempted from cost-sharing because of chronic diseases and those without exemptions), but the estimates are not always statistically significant at conventional levels. We find that the short-term health outcomes improve in case of high-quality GPs, indicating the importance of the GP's role not only for the decision to get the flu shot, but also for the health behaviors to adhere to in order to avoid the flu infection. Finally, we document a sizable reduction in the probability of emergency hospitalizations. Simple back-of-the-envelope calculations show that the monetary cost savings associated with the decrease in emergency hospitalizations would be enough to cover between one half and one third of the per-capita cost associated with an extension of the program to the closest non-eligible cohort (i.e., the 64-year-olds).<sup>46</sup>

Our work bears important policy implications for the effectiveness of flu vaccination programs. Given that the 75% WHO target is often not met in the elderly and high-

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<sup>46</sup>According to the estimates in Table 10, emergency hospitalizations decline by 0.7 to 1.5 percent. By applying this reduction to the group of 64-year-old untreated individuals, and considering that emergency hospitalizations have an average cost of about 12,500 euros (Ministero della Salute, 2007), back-of-the-envelope calculations show that per-capita savings would range between 2.8 and 1.5 euros. These should be compared with the per-capita cost of the immunization of the untreated group. In the Italian NHS context, regional governments buy the vaccine shots at a reduced price, through public auctions procedures, and the average price for a vaccine is around 5 euros (Casadei et al., 2009).

risk population, policymakers have debated over reducing the age for eligibility for free vaccination. Our estimates on vaccination take-up suggest that the individuals' reaction to an extension of free vaccination to the segment of the population close to the current age threshold would be sizable, and such measures may thus be effective in increasing the overall take-up. However, our results also indicate that the effect is hardly given by a pure income response, and thus, in addition to free provision, policymakers should look for other leverages in order to increase the take-up. For instance, this may involve widespread information campaigns, aimed at stressing the reduction in nonmonetary time cost associated with the program, or a more pro-active role of GPs in reaching the flu vaccination targets. The role of GPs seems particularly important in order to identify the segments of the eligible population who are more fragile also from a socio-economic point of view, because, as we have documented, individuals characterized by a poor health status are already likely to respond to vaccination programs.

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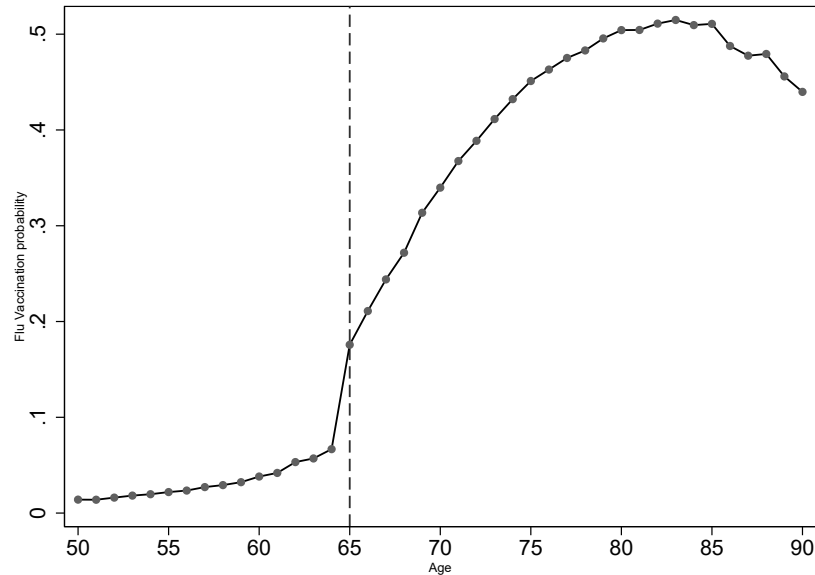
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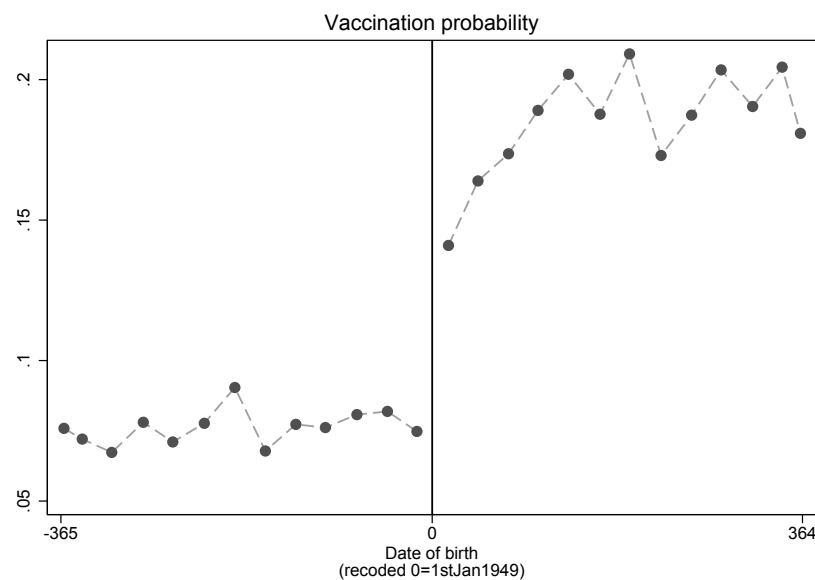
# Figures

Figure 1  
Flu vaccination probability: the age profile.



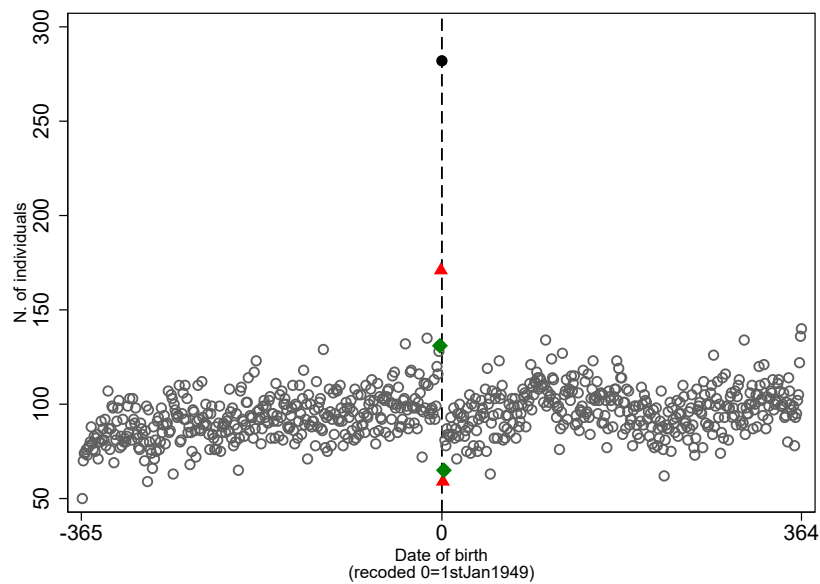
**Notes:** the figure shows the proportion of individuals who got vaccinated against the seasonal influenza in the 2013 campaign, by age; the vertical dashed line indicates the threshold at age 65, after which flu vaccination becomes recommended and free for the whole population. The sample is truncated at age 90 due to the very small number of individuals older than 90. **Source:** based on General Health Register, ATS-Milan.

Figure 2  
Change in probability of flu vaccination at age 65.



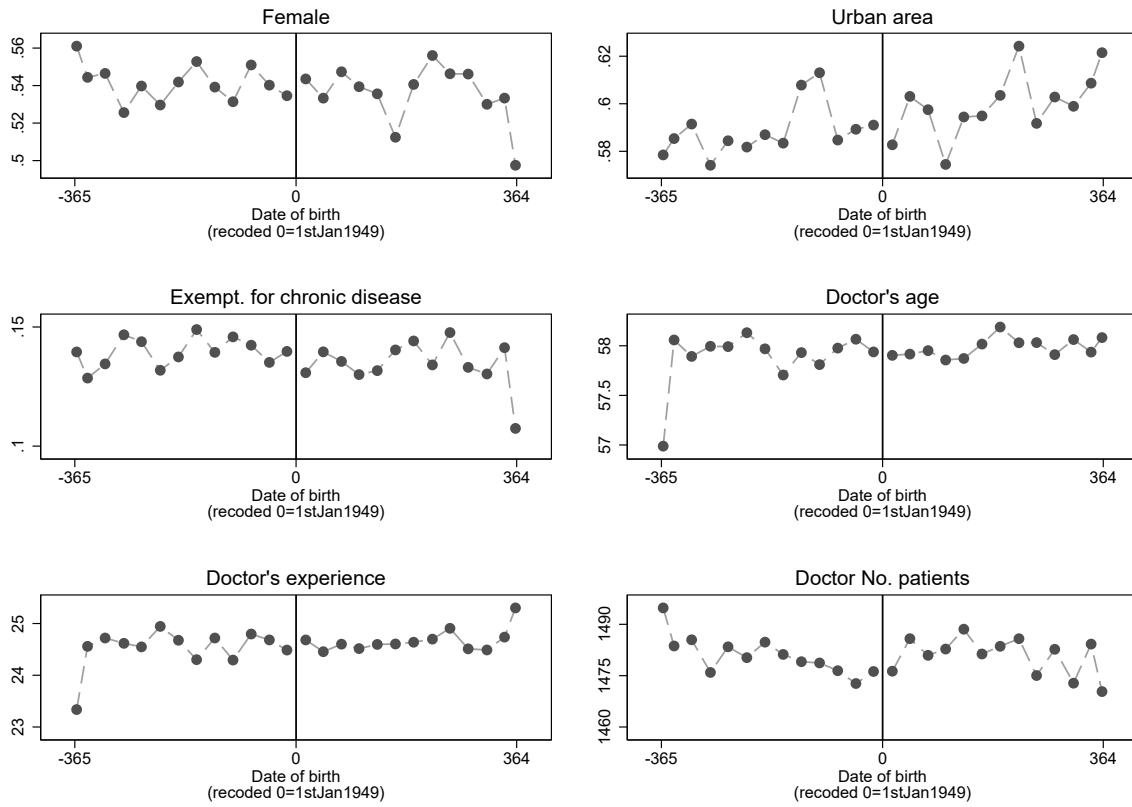
**Notes:** the figure plots the probability of getting a vaccination against the seasonal influenza in the 2013 campaign for individuals born in 1948 and 1949, with 24 bins (12 on each side of the discontinuity marked by the vertical line), where dots correspond to the mean value of the vaccination probability in each bin; the horizontal axis indicates the running variable (recoded so that the value 0 corresponds to the cutoff date of January 1 1949, the positive values to birth dates in 1948 and the negative values to birth dates in 1949). **Source:** based on General Health Register, ATS-Milan.

Figure 3  
Number of individuals born per calendar day.



**Notes:** the figure shows the number of individuals born in each calendar day of the years 1949 (i.e., aged 64 in 2013) and 1948 (i.e., aged 65 in 2013); the date of birth (horizontal axis) is recoded so that the value 0 corresponds to the cutoff date of January 1 1949, the positive values to birth dates in 1948 and the negative values to birth dates in 1949. The black dot indicates individuals born on January 1 1949, the triangles individuals born on January 2 1949 and December 31 1948, the diamonds individuals born on January 3 1949 and December 30 1948. **Source:** based on General Health Register, ATS-Milan.

Figure 4  
Continuity of observable characteristics at age 65.



**Notes:** the figure shows scatter plots with 24 bins (12 on each side of the discontinuity marked with the vertical line) where dots correspond to the mean value of each variable in each bin; the horizontal axis indicates the running variable (recoded so that the value 0 corresponds to the cutoff date of January 1 1949, the positive values to birth dates in 1948 and the negative values to birth dates in 1949). See Table 1 for definitions of the variables. **Source:** based on General Health Register, ATS-Milan.

# Tables

Table 1  
Descriptive statistics.

	mean	sd	min	max	N
Treated	0.514	0.500	0	1	68962
<i>Outcome variables:</i>					68962
Flu vaccination	0.123	0.328	0	1	68962
Prob. Hospitalization	0.037	0.188	0	1	68962
No. Of days at hospital	0.361	2.941	0	88	68962
<i>Covariates:</i>					68962
Female	0.539	0.498	0	1	68962
Living in urban area	0.594	0.491	0	1	68962
Exempted because of a chronic disease	0.138	0.345	0	1	68962
GP's age (years)	57.960	6.939	30	79	68962
GP's experience (years)	24.614	10.514	0	38	68962
GP's number of patients	1480.722	251.865	1	1975	68962

**Notes:** descriptive statistics performed on the sample of individuals born in 1948 or 1949; we exclude individuals with disability and those institutionalized in nursing homes; we further exclude those born on December 31st, 1948 and January 1st and 2nd, 1949. The variable *Treated* indicates individuals born in 1948 (i.e. those who are 65 years of age in 2013 and thus benefit from free vaccination); *Any hospitalization* indicates whether the individual got hospitalized at least once; *No. of days at hospital* indicates the number of days of hospitalization. The health outcomes variables are calculated in the observational period (which corresponds to the weeks of diffusion of the influenza virus, i.e. from 2013 week 42 to 2014 week 17). *Female* is a dummy equal to 1 for females; *Living in urban area* is a dummy equal to 1 for those who reside in the main city (Milan) and in its neighboring municipalities; *Exempted because of a chronic disease* is a dummy equal to 1 for individuals who are exempted from cost-sharing because of serious chronic diseases; *GP's number of patients* indicates the overall number of patients followed by each family doctor, while *GP's experience* indicates the number of years since the doctor started to work as family doctor. **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.

Table 2  
Eligibility for free vaccination at age 65 and take-up: non-parametric estimates.

	(1)	(2)	(3)	(4)
RD estimate	0.060*** (0.012)	0.059*** (0.012)	0.060*** (0.014)	0.059*** (0.014)
N.Obs.: total	68962	68962	68962	68962
N.Obs.: effective left	2807	2807	6212	5924
N.Obs.: effective right	2349	2349	5556	5260
BW	29	28	62	60
Order Loc. Poly. (p)	0	0	1	1
Covariates	✓		✓	

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register, ATS-Milan.

Table 3  
Eligibility for free vaccination at age 65 and take-up: parametric estimates.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. BW=1 month						
Treated	0.068*** (0.017)	0.068*** (0.018)	0.066*** (0.017)	0.068*** (0.017)	0.074** (0.030)	0.072** (0.030)
N	5618	5618	5618	5618	5618	5618
Panel B. BW=3 months						
Treated	0.060*** (0.009)	0.059*** (0.010)	0.059*** (0.009)	0.060*** (0.009)	0.054*** (0.015)	0.051*** (0.015)
N	17276	17276	17276	17276	17276	17276
Panel C. BW=6 months						
Treated	0.062*** (0.007)	0.062*** (0.007)	0.061*** (0.007)	0.062*** (0.007)	0.055*** (0.010)	0.055*** (0.010)
N	35398	35398	35398	35398	35398	35398
Panel D. BW=12 months						
Treated	0.080*** (0.005)	0.079*** (0.005)	0.079*** (0.005)	0.080*** (0.005)	0.058*** (0.008)	0.058*** (0.008)
N	68962	68962	68962	68962	68962	68962
Covariates		✓		✓		✓
<i>Specification:</i>						
(i) Linear						
(ii) Linear with interaction	✓	✓				
(iii) Quadratic			✓	✓		
(iv) Quadratic with interaction					✓	✓

**Notes:** parametric estimates with triangular weights and different bandwidths (BW): estimates in Panel A, B, C and D are performed on a sample including, respectively, individuals born one, three, six and twelve months before and after the cutoff date. The RD estimate is the coefficient of the variable *Treated*, which indicates individuals born in 1948 (i.e. those who are 65 years old in 2013 and thus benefit from the universal free vaccination). Linear and quadratic specifications with and without interactions are shown. For the list of covariates included and their definitions see Table 1. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register, ATS-Milan.

Table 4  
Placebo analysis on age groups before and after age 65.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A. Before age 65</i>	Age group 64-63				Age group 63-62			
RD estimate	-0.003 (0.007)	-0.003 (0.007)	-0.010 (0.011)	-0.011 (0.011)	0.006 (0.006)	0.006 (0.006)	0.008 (0.009)	0.007 (0.009)
N.Obs.: total	66949	66949	66949	66949	65552	65552	65552	65552
N.Obs.: effective left	5412	5689	5601	5504	6285	6383	6690	6472
N.Obs.: effective right	4521	4785	4703	4619	5550	5668	5921	5765
BW	54	56	55	55	65	66	69	66
<i>Panel B. After age 65</i>	Age group 66-65				Age group 67-66			
RD estimate	0.012 (0.012)	0.012 (0.012)	0.007 (0.016)	0.007 (0.016)	-0.001 (0.010)	-0.001 (0.010)	-0.002 (0.014)	-0.003 (0.014)
N.Obs.: total	71152	71152	71152	71152	72072	72072	72072	72072
N.Obs.: effective left	5921	6011	5921	5921	7185	7279	8881	8678
N.Obs.: effective right	5258	5351	5258	5258	6736	6836	8282	8078
BW	59	59	59	59	71	71	88	85
Order Loc. Poly. (p)	0	0	1	1	0	0	1	1
Covariates	✓				✓			

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth (BW) selector (Calonico et al., 2014; 2017) on samples constituted each time by two subsequent cohorts of individuals: the older cohort plays the role of the placebo treated group, the younger cohort that of the placebo control group. For example, the estimate for the *64-63 age group* is obtained treating the 64-year-olds as the treated group and the 63-year-olds as the control group. In all regressions, individuals born within a day from the cutoff date (i.e., between December 31 and January 2 of the following year) have been excluded. For the set of covariates included in the estimations and their definitions, see Table 1. **Source:** based on General Health Register, ATS-Milan.

Table 5

Effects of eligibility for free vaccination at age 65 on take-up by type of exemption from cost-sharing.

	(1)	(2)	(3)	(4)
<i>Panel A. Patients with exemption for chronic disease</i>				
RD estimate	0.024 (0.025)	0.019 (0.025)	0.019 (0.031)	0.013 (0.030)
N.Obs.: total	9502	9502	9502	9502
N.Obs.: effective left	592	592	1126	1126
N.Obs.: effective right	478	478	994	994
BW	43	42	82	82
Order Loc. Poly. (p)	0	0	1	1
Covariates		✓		✓
<i>Panel B. Patients with exemption for health conditions &amp; low income</i>				
RD estimate	0.076*** (0.016)	0.076*** (0.016)	0.094*** (0.026)	0.095*** (0.026)
N.Obs.: total	30375	30375	30375	30375
N.Obs.: effective left	2082	2082	2641	2556
N.Obs.: effective right	1836	1836	2379	2291
BW	47	48	61	58
Order Loc. Poly. (p)	0	0	1	1
Covariates		✓		✓
<i>Panel C. Patients with exemption for low income</i>				
RD estimate	0.024 (0.016)	0.024 (0.016)	0.024 (0.018)	0.024 (0.018)
N.Obs.: total	15419	15419	15419	15419
N.Obs.: effective left	465	448	1222	1222
N.Obs.: effective right	406	392	1062	1062
BW	21	21	54	54
Order Loc. Poly. (p)	0	0	1	1
Covariates		✓		✓
<i>Panel D. Patients without exemptions</i>				
RD estimate	0.072*** (0.013)	0.071*** (0.013)	0.067*** (0.023)	0.065*** (0.023)
N.Obs.: total	13666	13666	13666	13666
N.Obs.: effective left	1192	1169	1006	985
N.Obs.: effective right	1046	1026	873	854
BW	62	61	52	52
Order Loc. Poly. (p)	0	0	1	1
Covariates		✓		✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. Panel A reports the estimates for patients who are exempted from the general cost-sharing because of a chronic disease; Panel B reports the estimates for patients with exemption from the general cost-sharing because of a serious health condition and low income; Panel C reports the estimates for patients who are exempted from the general cost-sharing rule because of low income only; Panel D reports the estimates for patients who have no exemptions. Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register, ATIS-Milan.

Table 6  
Effects of eligibility for free vaccination at age 65 on take-up by GPs' characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A. Doctor's experience</i>	BELOW MEDIAN				ABOVE MEDIAN			
RD estimate	0.050*** (0.017)	0.049*** (0.017)	0.048*** (0.018)	0.047** (0.018)	0.065*** (0.013)	0.065*** (0.013)	0.066*** (0.019)	0.066*** (0.019)
N.Obs.: total	31077	31077	31077	31077	37885	37885	37885	37885
<i>Panel B. Doctor's No. of patients</i>	BELOW MEDIAN				ABOVE MEDIAN			
RD estimate	0.054*** (0.014)	0.054*** (0.014)	0.056*** (0.019)	0.056*** (0.019)	0.064*** (0.016)	0.062*** (0.016)	0.061*** (0.018)	0.059*** (0.018)
N.Obs.: total	34102	34102	34102	34102	34860	34860	34860	34860
Order Loc. Poly. (p)	0	0	1	1	0	0	1	1
Covariates		✓		✓		✓		✓

**Notes:** RD robust estimates with Triangular Kernel optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. The variable used for the sample split is excluded from the list of the covariates included in the corresponding specification. The sample splits according to the doctor's characteristics have been defined by using the median value of each variable: the median experience is 25 years, the median number of patients is 1548. Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register, ATS-Milan.

Table 7  
Eligibility for free vaccination at age 65 and hospitalization: non-parametric estimates.

	(1)	(2)	(3)	(4)
<i>Panel A. Prob. Hospitalization</i>				
RD estimate	-0.008 (0.006)	-0.007 (0.006)	-0.016* (0.010)	-0.015 (0.010)
N.Obs.: effective left	4041	4041	4707	4609
N.Obs.: effective right	3421	3421	4109	4009
BW	40	41	47	47
<i>Panel B. No. Of days at hospital</i>				
RD estimate	-0.147 (0.112)	-0.137 (0.111)	-0.180 (0.163)	-0.171 (0.162)
N.Obs.: effective left	3612	3744	4424	4509
N.Obs.: effective right	3055	3147	3815	3890
BW	37	37	45	45
N.Obs.: total	68962	68962	68962	68962
Order Loc. Poly. (p)	0	0	1	1
Covariates		✓		✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and the definitions of both the covariates and the outcome variables see Table 1. Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.

Table 8

Effects of eligibility for free vaccination at age 65 on hospitalization by type of exemption from cost-sharing.

	(1)	(2)	(3)	(4)
<i>Panel A. Patients with exemption for chronic disease</i>				
<i>a. Any hospitalization</i>				
RD estimate	-0.031 (0.020)	-0.027 (0.020)	-0.052** (0.025)	-0.049** (0.025)
<i>b. No. of days at hospital</i>				
RD estimate	-0.258 (0.433)	-0.206 (0.429)	-0.494 (0.579)	-0.450 (0.577)
<i>Panel B. Patients with exemption for health conditions &amp; low income</i>				
<i>a. Any hospitalization</i>				
RD estimate	0.012 (0.009)	0.013 (0.009)	0.006 (0.016)	0.007 (0.016)
<i>b. No. of days at hospital</i>				
RD estimate	-0.096 (0.159)	-0.085 (0.156)	-0.228 (0.244)	-0.222 (0.245)
<i>Panel C. Patients with exemption for low income</i>				
<i>a. Any hospitalization</i>				
RD estimate	-0.000 (0.008)	0.000 (0.008)	-0.006 (0.015)	-0.005 (0.015)
<i>b. No. of days at hospital</i>				
RD estimate	-0.007 (0.098)	-0.009 (0.097)	0.062 (0.170)	0.064 (0.171)
<i>Panel D. Patients without exemptions</i>				
<i>a. Any hospitalization</i>				
RD estimate	-0.019* (0.012)	-0.019 (0.012)	-0.024 (0.016)	-0.024 (0.016)
<i>b. No. of days at hospital</i>				
RD estimate	-0.113 (0.073)	-0.117 (0.073)	-0.148 (0.101)	-0.153 (0.101)
Order Loc. Poly. (p)	0	0	1	1
Covariates		✓		✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. Panel A reports the estimates for patients who are exempted from the general cost-sharing because of a chronic disease; Panel B reports the estimates for patients with exemption from the general cost-sharing because of serious health issues and low income; Panel C reports the estimates for patients who are exempted because of low income; Panel D reports the estimates for patients who have no exemptions. Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.

Table 9

Effects of eligibility for free vaccination at age 65 on hospitalization by GPs' characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A. Doctor's experience</i>	BELOW MEDIAN				ABOVE MEDIAN			
<i>a. Any hospitalization</i>								
RD estimate	-0.005 (0.008)	-0.004 (0.008)	-0.023 (0.015)	-0.023 (0.016)	-0.004 (0.009)	-0.003 (0.009)	-0.012 (0.013)	-0.011 (0.012)
<i>b. No. of days at hospital</i>								
RD estimate	-0.168 (0.146)	-0.162 (0.145)	-0.250 (0.191)	-0.245 (0.190)	-0.091 (0.142)	-0.086 (0.142)	-0.159 (0.215)	-0.148 (0.214)
N.Obs.: total	37885	37885	37885	37885	31077	31077	31077	31077
<i>Panel B. Doctor's No. Of patients</i>	BELOW MEDIAN				ABOVE MEDIAN			
<i>a. Any hospitalization</i>								
RD estimate	0.002 (0.007)	0.002 (0.007)	-0.006 (0.012)	-0.005 (0.012)	-0.018* (0.010)	-0.017* (0.010)	-0.027* (0.015)	-0.026* (0.015)
<i>b. No. of days at hospital</i>								
RD estimate	-0.080 (0.148)	-0.078 (0.149)	-0.047 (0.243)	-0.044 (0.243)	-0.247* (0.138)	-0.232* (0.137)	-0.348** (0.159)	-0.337** (0.160)
N.Obs.: total	34102	34102	34102	34102	34860	34860	34860	34860
Order Loc. Poly. (p)	0	0	1	1	0	0	1	1
Covariates		✓		✓		✓		✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. The variable used for the sample split is excluded from the list of the covariates included in the corresponding specification. The sample splits according to the doctor's characteristics have been defined by using the median value of each variable: the median age of doctors in the sample is 59 years, the median experience is 25 years, and the median number of patients is 1548. Significance level: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.

Table 10

Effects of eligibility for free vaccination at age 65 on hospitalization by hospitalization type.

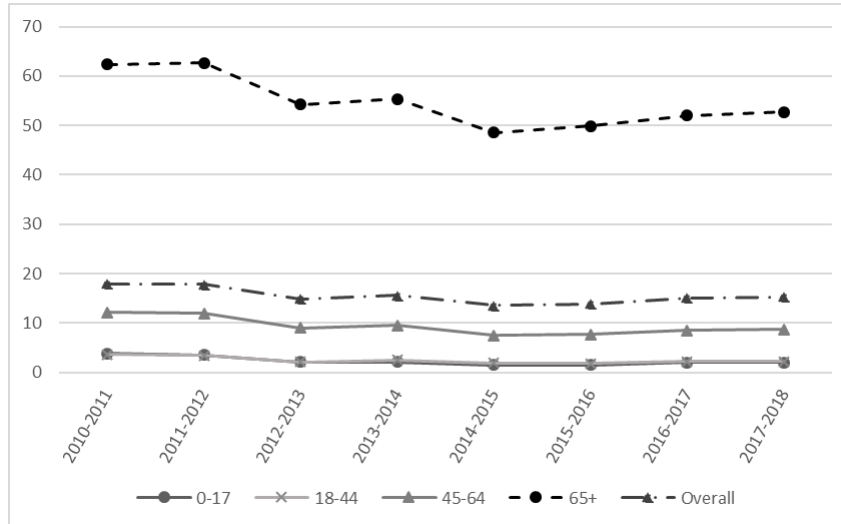
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Type of hospitalization:	PLANNED				EMERGENCY			
<i>Panel A. Prob. Hospitalization</i>								
RD estimate	-0.000 (0.005)	-0.000 (0.005)	-0.004 (0.007)	-0.003 (0.007)	-0.007* (0.004)	-0.007 (0.004)	-0.015** (0.006)	-0.015** (0.006)
<i>Panel B. No. Of days at hospital</i>								
RD estimate	-0.087 (0.072)	-0.084 (0.072)	-0.082 (0.106)	-0.077 (0.105)	-0.068 (0.069)	-0.060 (0.068)	-0.150 (0.098)	-0.141 (0.098)
N.Obs.: total	68962	68962	68962	68962	68962	68962	68962	68962
Order Loc. Poly. (p)	0	0	1	1	0	0	1	1
Covariates		✓		✓		✓		✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. Significance level: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.

## A Appendix: Additional Figures and Tables

Figure A.1

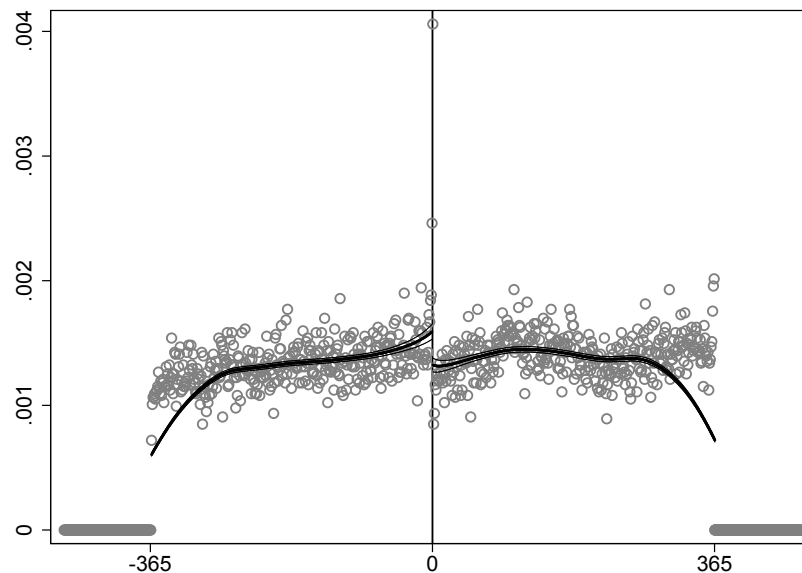
Proportion of individuals getting flu vaccination, by age group and flu epidemic season.



**Notes:** the figure shows the proportion of individuals who get vaccinated against the seasonal influenza by age group and by flu epidemic season. **Source:** own elaboration from data from the National Health Institute (NHI).

Figure A.2

McCrary test for the manipulation of the running variable



**Notes:** the figure depicts the McCrary test for the density of the running variable around the cutoff; the running variable is indicated on the horizontal axis (recoded so that the value 0 corresponds to the cutoff date of January 1 1949, the positive values to birth dates in 1948 and the negative values to birth dates in 1949). The test is performed on the overall sample, which does not exclude observations at the cutoff. The estimated discontinuity is -0.1835 (0.0292), with a  $t$ -statistics of 6.2842. **Source:** based on General Health Register, ATS-Milan and [McCrary \(2008\)](#).

Table A.1

Test of continuity of the observable characteristics at age 65: non-parametric estimates.

	(1)	(2)	(3)	(4)	(5)	(6)
Individual's charact.	FEMALE		URBAN AREA		CHRONIC DISEASE	
RD estimate	0.016 (0.016)	0.035 (0.022)	-0.004 (0.014)	-0.035 (0.025)	-0.004 (0.009)	-0.012 (0.013)
N.Obs.: effective left	4707	6610	6119	4924	7693	8249
N.Obs.: effective right	4109	5907	5475	4275	6955	7541
BW	48	66	61	50	78	84
N.Obs.: total	68962	68962	68962	68962	68962	68962
Order Loc. Poly. (p)	0	1	0	1	0	1
GP's charact.	AGE		EXPERIENCE		NUMB. PATIENTS	
RD estimate	-0.029 (0.199)	0.094 (0.343)	0.297 (0.314)	0.532 (0.543)	2.895 (7.116)	-2.248 (9.726)
N.Obs.: effective left	6402	5232	5530	4707	6402	7873
N.Obs.: effective right	5726	4566	4857	4109	5726	7134
BW	64	52	55	48	64	80
N.Obs.: total	68962	68962	68962	68962	68962	68962
Order Loc. Poly. (p)	0	0	1	1	0	0

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate optimal bandwidth selector (Calonico et al., 2014; 2017); for the the definition of the variables see Table 1. Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register, ATS-Milan.

Table A.2

Test of continuity in the proportions of individuals for each type of exemption from cost-sharing at age 65: non-parametric estimates.

	(1)	(2)	(3)	(4)	(5)	(6)
Type of exemption:	HEALTH & LOW INCOME		LOW INCOME		NOT EXEMPTED	
RD estimate	-0.008 (0.015)	-0.021 (0.022)	0.001 (0.013)	0.014 (0.018)	0.021 (0.014)	0.019 (0.021)
N.Obs.: total	68962	68962	68962	68962	68962	68962
N.Obs.: effective left	5423	6212	5315	6610	3239	4424
N.Obs.: effective right	4751	5556	4648	5907	2692	3815
BW	54	62	53	66	33	45
Order Loc. Poly. (p)	0	1	0	1	0	1

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate optimal bandwidth selector (Calonico et al., 2014; 2017); for the definition of the different groups, see the notes to Table 5. The test of continuity in the proportion of individuals with exemption because of a chronic disease is presented in Table A.1, Panel A, Columns (5) and (6). Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register, ATS-Milan.

Table A.3

Test of continuity of the observable characteristics at age 65: non-parametric estimates from the ISH survey data.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>Female</i>		<i>With chronic disease</i>		<i>High school diploma</i>		<i>Retired</i>	
RD estimate	0.009 (0.025)	0.044 (0.043)	-0.010 (0.034)	-0.024 (0.049)	-0.032 (0.033)	-0.018 (0.038)	-0.051 (0.043)	-0.028 (0.050)
N.Obs.: total	29169	29169	29169	29169	29169	29169	29169	29169
N.Obs.: effective left	2343	1977	823	1596	823	1977	411	1238
N.Obs.: effective right	2313	2009	1066	1706	1066	2009	772	1382
	<i>Work in Edu/Health sectors</i>		<i>Married</i>		<i>Living alone</i>		<i>Living with son(s)</i>	
RD estimate	0.022 (0.033)	0.044 (0.043)	-0.002 (0.033)	-0.017 (0.044)	0.033 (0.022)	0.043 (0.031)	-0.060 (0.039)	-0.046 (0.045)
N.Obs.: total	19717	19717	27685	27685	29169	29169	29169	29169
N.Obs.: effective left	710	1370	823	1596	1238	1596	411	1596
N.Obs.: effective right	889	1425	1066	1706	1382	1706	772	1706
Order Loc. Poly. (p)	0	1	0	1	0	1	0	1

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017). Covariates definitions: Female (1 if female), High school diploma (1 if got at least the High School Diploma), With chronic disease (1 if any chronic disease is declared), Retired (1 if retired or out of the labor force), Work in Edu/Health sectors (1 if individual works or has worked in the education, defense or health sectors), Married (1 if married), Living alone (1 if lives alone), Living with son(s) (1 if lives with at least one son). The estimation sample includes only individuals interviewed in the month of December 2012. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on Italian Survey on Health (ISTAT, 2013).

Table A.4

Robustness of estimates of eligibility for free vaccination at age 65 on take-up: clustering of the standard errors.

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A. Local polynomial of order zero</i>						
RD estimate	0.060*** (0.011)	0.059*** (0.011)	0.060*** (0.012)	0.059*** (0.012)	0.056*** (0.019)	0.056*** (0.015)
N.Obs.: effective left	3004	2905	3004	2905	5719	4041
N.Obs.: effective right	2523	2423	2523	2423	5034	3421
BW	30	30	30	30	58	41
Order Loc. Poly. (p)	0	0	0	0	0	0
<i>Panel B. Local polynomial of order one</i>						
RD estimate	0.056*** (0.012)	0.055*** (0.012)	0.058*** (0.013)	0.057*** (0.013)	0.057*** (0.019)	0.055*** (0.015)
N.Obs.: effective left	7778	7489	7086	6774	9733	8249
N.Obs.: effective right	7043	6761	6387	6101	9260	7541
BW	78	75	71	68	100	84
Order Loc. Poly. (p)	1	1	1	1	1	1
N.Obs.: total	68962	68962	68962	68962	68962	68962
Kernel Type	Triangular	Triangular	Triangular	Triangular	Triangular	Triangular
BW selector	CER	CER	CER	CER	CER	CER
Covariates		✓		✓		✓
<i>SE Clustered by:</i>						
Date of birth	✓	✓				
GP			✓	✓		
Municipality					✓	✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth (BW) selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. The different specifications cluster the standard errors, respectively, by date of birth (the running variable), GP, or municipality. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register, ATS-Milan.

Table A.5

Robustness of estimates of eligibility for free vaccination at age 65 on take-up: alternative *donut* specifications.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A. Local polynomial of order zero</i>								
RD estimate	0.047*** (0.011)	0.046*** (0.011)	0.057*** (0.011)	0.056*** (0.011)	0.063*** (0.012)	0.062*** (0.012)	0.062*** (0.012)	0.058*** (0.012)
N.Obs.: effective left	2600	2600	2978	2888	2774	2774	2548	2589
N.Obs.: effective right	2324	2324	2408	2303	2358	2358	2203	2163
BW	25	24	28	28	30	29	29	27
Order Loc. Poly. (p)	0	0	0	0	0	0	0	0
<i>Panel B. Local polynomial of order one</i>								
RD estimate	0.045*** (0.011)	0.044*** (0.012)	0.058*** (0.014)	0.057*** (0.014)	0.065*** (0.014)	0.064*** (0.015)	0.062*** (0.015)	0.057*** (0.015)
N.Obs.: effective left	6684	6573	5890	5805	5988	5690	5768	5796
N.Obs.: effective right	6161	6067	5093	4998	5410	5092	5219	5179
BW	65	64	58	56	61	58	61	59
Order Loc. Poly. (p)	1	1	1	1	1	1	1	1
N.Obs.: total	69474	69474	69192	69192	68766	68766	68557	68753
Kernel Type	Tri	Tri	Tri	Tri	Tri	Tri	Tri	Tri
BW selector	CER	CER	CER	CER	CER	CER	CER	CER
Covariates		✓		✓		✓		✓
<i>Specification:</i>								
(i) No donut	✓	✓						
(ii) Donut 0			✓	✓				
(iii) Donut 2					✓	✓		
(iv) Donut 3							✓	✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth (BW) selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. Specification (i) *No Donut* is performed including all individuals (i.e., also those born between December 31 and January 2); specification (ii) *Donut 0* is performed excluding only individuals born on January 1 (i.e. individuals for whom the running variable is equal to zero); specification (iii) *Donut 2* is performed excluding individuals born between December 30 and January 3 (i.e. individuals for whom the running variable takes values between  $\pm 2$ ); specification (iv) *Donut 3* is performed excluding only individuals born between December 29 and January 4 (i.e. individuals for whom the running variable takes values between  $\pm 3$ ). Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register, ATS-Milan.

Table A.6

Robustness of estimates of eligibility for free vaccination at age 65 on take-up: bandwidth selector and kernel.

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A. Local polynomial of order zero</i>						
RD estimate	0.070*** (0.013)	0.068*** (0.013)	0.060*** (0.012)	0.059*** (0.012)	0.070*** (0.013)	0.068*** (0.013)
N.Obs.: effective left	1841	1730	2807	2807	1841	1730
N.Obs.: effective right	1443	1343	2349	2349	1443	1343
BW	18	17	29	28	18	17
Order Loc. Poly. (p)	0	0	0	0	0	0
<i>Panel B. Local polynomial of order one</i>						
RD estimate	0.055*** (0.014)	0.054*** (0.014)	0.057*** (0.011)	0.056*** (0.012)	0.055*** (0.011)	0.054*** (0.011)
N.Obs.: effective left	4924	4924	10603	10110	8608	8526
N.Obs.: effective right	4275	4275	10244	9693	7939	7840
BW	50	49	109	104	87	86
Order Loc. Poly. (p)	1	1	1	1	1	1
N.Obs.: total	68962	68962	68962	68962	68962	68962
Kernel Type	Uniform	Uniform	Triangular	Triangular	Uniform	Uniform
BW selector	CER	CER	MSE	MSE	MSE	MSE
Covariates		✓		✓		✓

**Notes:** RD robust estimates with Triangular or Uniform Kernel and Mean Square Error (MSE) or Coverage Error Rate (CER) optimal bandwidth (BW) selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . **Source:** based on General Health Register, ATS-Milan.

Table A.7

Eligibility for free vaccination at age 65 and take-up: non-parametric estimates using the ISH survey data.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RD estimate	0.068** (0.033)	0.071** (0.032)	0.074 (0.048)	0.042 (0.064)	0.053 (0.038)	0.060 (0.038)	0.103 (0.068)	0.035 (0.078)
N.Obs.: total	29169	29169	6487	2976	29169	29169	6487	2976
N.Obs.: effective left	411	411	208	136	1596	1596	372	305
N.Obs.: effective right	772	772	238	140	1706	1706	399	280
Order Loc. Poly. (p)	0	0	0	0	1	1	1	1
Covariates		✓	✓	✓		✓	✓	✓
<i>Sample:</i>								
Italy	✓	✓			✓	✓		
North-West regions			✓				✓	
Lombardy region				✓				✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017). Covariates included: gender (1 if female), education level (1 if the individual has at least a high school education level (ISCED 3 or more)), chronic disease (1 if any chronic disease is declared), retirement status (1 if retired or out of the labor force). The estimation sample includes only individuals interviewed in the month of December 2012; North-West regions include: Lombardy, Piedmont, Aosta Valley and Liguria. Survey weights applied. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on Italian Survey on Health (ISTAT, 2013).

Table A.8

Eligibility for free vaccination at age 65 and take-up: heterogeneous effects by individuals' gender and place of residence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A. Gender of patient</i>	FEMALE				MALE			
RD estimate	0.068*** (0.014)	0.066*** (0.015)	0.065*** (0.017)	0.062*** (0.017)	0.048*** (0.016)	0.048*** (0.015)	0.050** (0.019)	0.050*** (0.019)
N.Obs.: total	37157	37157	37157	37157	31805	31805	31805	31805
<i>Panel B. Patient living in urban/rural area</i>	URBAN				RURAL			
RD estimate	0.076*** (0.014)	0.075*** (0.014)	0.072*** (0.018)	0.071*** (0.018)	0.031* (0.016)	0.030* (0.017)	0.029 (0.020)	0.027 (0.019)
N.Obs.: total	40967	40967	40967	40967	27995	27995	27995	27995
Order Loc. Poly. (p)	0	0	1	1	0	0	1	1
Covariates		✓		✓		✓		✓

**Notes:** RD robust estimates with Triangular Kernel optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. The variable used for the sample split is excluded from the list of the covariates included in the corresponding specification. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register, ATS-Milan.

Table A.9

Eligibility for free vaccination at age 65 and hospitalization: heterogeneous effects by individuals' gender and place of birth.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A. Gender of patient</i>	FEMALE				MALE			
<i>a. Any hospitalization</i>								
RD estimate	-0.010 (0.008)	-0.008 (0.008)	-0.011 (0.010)	-0.010 (0.010)	-0.001 (0.009)	-0.001 (0.009)	-0.022 (0.014)	-0.022 (0.014)
<i>b. No. of days at hospital</i>								
RD estimate	-0.067 (0.107)	-0.056 (0.106)	-0.146 (0.237)	-0.128 (0.234)	-0.188 (0.156)	-0.189 (0.156)	-0.249 (0.172)	-0.256 (0.172)
N.Obs.: total	37157	37157	37157	37157	31805	31805	31805	31805
<i>Panel B. Patient living in urban/rural area</i>	URBAN				RURAL			
<i>a. Any hospitalization</i>								
RD estimate	-0.006 (0.009)	-0.005 (0.008)	-0.009 (0.012)	-0.007 (0.012)	0.002 (0.008)	0.003 (0.007)	-0.018 (0.012)	-0.019 (0.012)
<i>b. No. of days at hospital</i>								
RD estimate	-0.159 (0.156)	-0.134 (0.154)	-0.212 (0.224)	-0.189 (0.221)	-0.075 (0.103)	-0.072 (0.100)	-0.149 (0.182)	-0.139 (0.182)
N.Obs.: total	40967	40967	40967	40967	27995	27995	27995	27995
Order Loc. Poly. (p)	0	0	1	1	0	0	1	1
Covariates		✓		✓		✓		✓

**Notes:** RD robust estimates with Triangular Kernel and Coverage Error Rate (CER) optimal bandwidth selector (Calonico et al., 2014; 2017); for the list of covariates included and their definitions see Table 1. The variable used for the sample split is excluded from the list of the covariates included in the corresponding specification. Significance level: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.

Table A.10

Effects of eligibility for free vaccination at age 65 on hospitalization: parametric estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Bandwidth size:	BW=1m				BW=3m				BW=6m				BW=12			
<i>Panel A. Prob. Hospitalization</i>																
Treated	-0.013 (0.011)	-0.014 (0.011)	-0.013 (0.011)	-0.013 (0.018)	-0.003 (0.006)	-0.003 (0.006)	-0.003 (0.006)	-0.017* (0.009)	0.004 (0.004)	0.005 (0.004)	0.004 (0.004)	-0.003 (0.006)	0.002 (0.003)	0.002 (0.003)	0.002 (0.003)	0.005 (0.005)
<i>Panel B. No. Of days at hospital</i>																
Treated	-0.102 (0.178)	-0.104 (0.176)	-0.102 (0.177)	0.041 (0.279)	-0.085 (0.097)	-0.084 (0.096)	-0.085 (0.097)	-0.196 (0.151)	0.008 (0.063)	0.010 (0.063)	0.009 (0.063)	-0.082 (0.101)	-0.010 (0.048)	-0.010 (0.048)	-0.010 (0.048)	0.015 (0.073)
N	5618	5618	5618	5618	17276	17276	17276	17276	35398	35398	35398	35398	68962	68962	68962	68962
Covariates	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
<i>Specification:</i>																
(i) Linear	✓				✓				✓				✓			
(ii) Linear with interac		✓				✓				✓				✓		
(iii) Quadratic			✓				✓				✓				✓	
(iv) Quadratic with interac				✓				✓				✓				✓

**Notes:** parametric estimates with triangular weights and different bandwidths (BW): estimates are performed on a sample including, respectively, individuals born one, three, six and twelve months before and after the cutoff date. The RD estimate is the coefficient of the variable *Treated*, which indicates individuals born in 1948 (i.e. those who benefit from the free access to the vaccination). Linear and quadratic specifications with and without interactions are shown. For the list of covariates included and their definitions see Table 1. Significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. **Source:** based on General Health Register and Hospitalizations records, ATS-Milan.



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6. P. Bingley, L. Cappellari, *Correlation of Brothers Earnings and Intergenerational Transmission*, novembre 2013.
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