Journal of Population Economics (2023) 36:2549–2580
https://doi.org/10.1007/s00148-023-00942-4

ORIGINAL PAPER

Vaccination and risky behaviors: evidence from the hepatitis B vaccination campaign in China

Chen Huang[1] · Cong Li[2] · Feng Liu[3] · Ruofei Xu[2]

Received: 21 July 2022 / Accepted: 3 February 2023 / Published online: 10 March 2023

Abstract

Understanding the causal relationship between vaccination and individuals' risky behavioral responses has important policy implications as it affects the ultimate effectiveness of increasing access to vaccination. This paper examines the causal effects of vaccination on risky behaviors by exploring the 1992 hepatitis B vaccination campaign in China. Our empirical strategy exploits variations in age at the campaign as well as the pretreatment infection risks across provinces. Using a large cross-section of individuals born between 1981 and 1994, we find that more exposure to the hepatitis B vaccination leads to lower alcohol use during adulthood, and such impacts are almost entirely driven by men. Individuals from more educated families and people who live in urban areas tend to react more. Improved educational attainment and dissemination of related knowledge are important contributors. Our results uncover an unexpected benefit of promoting access to vaccination.

Keywords Hepatitis B · Vaccination · Risky behaviors · Alcohol consumption

JEL I12 · I18 · H51

Responsible editor: Xi Chen

✉ Feng Liu
LiuFeng@cuhk.edu.cn

Chen Huang
chenhuang@cufe.edu.cn

Cong Li
li.cong@mail.shufe.edu.cn

Ruofei Xu
ruofeihsu@163.sufe.edu.cn

[1] Center for Human Capital and Labor Market Research, Central University of Finance and Economics, Beijing 100081, China

[2] School of Economics, Shanghai University of Finance and Economics, Shanghai 200433, China

[3] School of Humanities and Social Science, Chinese University of Hong Kong, Shenzhen 518172, Guangdong, China

1 Introduction

Vaccination is one of the most effective ways to contain infectious disease outbreaks and protect people from serious vaccine-preventable illnesses. However, the causal relationship between vaccination and individuals' risky behavioral responses has been understudied in the literature, and the existing evidence is mixed.[1] Such a relationship raises questions about the ultimate effectiveness of increasing access to vaccination. Take the COVID-19 vaccines as an example: if people continue taking precautions or become even more careful after receiving the COVID-19 vaccines, such responses are likely to reinforce the positive effects of the vaccination, and we would expect long-term benefits on public health. However, if individuals stop taking precautions after being vaccinated, the benefits of such vaccination are likely mitigated in the long run.

This paper examines the causal relationship between vaccination and individual's risky behaviors by exploring the hepatitis B vaccination campaign in China in 1992. Hepatitis B is one of the most important infectious diseases around the world, and it is of particular interest to the policy makers in developing countries because of the high prevalence of chronic hepatitis B virus (HBV) infection (Kane 1995). Chronic HBV infection can lead to cirrhosis and hepatocellular carcinoma (McMahon 2009), imposing a heavy burden for low-income countries, and it is responsible for nearly 900 deaths per day worldwide (World Health Organization 2014).

The hepatitis B vaccination campaign was carried out by the Ministry of Health of China in 1992 in response to the high prevalence of HBV infection. A routine HBV immunization was recommended, and priorities were given to the infants and children at preschool age. We are particularly interested in the vaccination effects on individuals' alcohol use during adulthood.

A priori, how anti-HBV vaccination affects drinking behavior is unclear. First, alcohol consumption is highly discouraged for people with chronic HBV infection due to the harmful effects of alcohol on the liver. According to the Center for Disease Control and Prevention (CDC), alcohol use of more than 25–30 mL per day is associated with the progression of HBV-related liver disease (CDC 2008). As a result, vaccines that protect people from being infected with HBV might increase individuals' alcohol use because the cost of drinking alcohol is substantially reduced. This is consistent with the concept of a moral hazard effect that has been widely studied in the context of health insurance.[2]

Second, alcohol use may decline if vaccination generates gains in human capital. The long-run impacts of early-life health interventions on educational attainment have been extensively studied in the literature (e.g., Chay et al. 2009; Bharadwaj

[1] For example, Brewer et al. (2007) show that individuals who had undergone human papillomavirus (HPV) vaccination were less likely to engage in risky behaviors than those not vaccinated. Sadler et al. (2015) find similar results for women in the UK. Moghtaderi and Dor (2021) further confirm that the HPV vaccination causally promotes women's participation in Pap tests. However, Donken et al. (2018) fail to find any evidence that HPV vaccination affects young women's sexual behavior in the Netherlands, which is further confirmed by Ogilvie et al. (2018) in British Columbia and Frio and França (2021) in Brazil.

[2] See a review of this literature in Einav and Finkelstein (2018).

et al. 2013; Miller and Wherry 2019; Brown et al. 2020). There is also a growing number of studies that focus on early-life vaccination and find significantly positive effects on education (Baranov and Kohler 2018; Oskorouchi et al. 2020; Kuecken et al. 2021; Zhang et al. 2021; He et al. 2022). Given the strong evidence that education is negatively associated with alcohol consumption (e.g., Murakami and Hashimoto 2019; Crum et al. 1993; Liu et al. 2020), improved educational attainment as a result of the vaccination might reduce regular alcohol use. Furthermore, alcohol consumption may also be reduced if the vaccination campaign equips people with better knowledge about the risk factors for HBV-related infection.

Finally, the theory of competing mortality risks outlined by Dow et al. (1999) implies that a particular health policy does not only change the probability of death from the targeted disease but also increases one's incentive to invest in preventing other causes of death. Based on this theory, people who have been exposed to the anti-HBV vaccination might have strong incentives to increase other health investments so as to reduce alternative causes of death.

To identify the vaccination effects on individuals' risky behaviors, we use the cohort difference-in-differences (DD) strategy following Zhang et al. (2021), who study the same vaccination campaign and its impacts on individuals' investments in human capital. This strategy exploits two sources of variation. The first variation is the age when the campaign was launched. According to the medicine literature, unlike most adults who recover spontaneously from acute HBV infection (e.g., Gitlin 1997; Peters 2009), the chronicity risk of HBV infection is strikingly high among infants and younger children since they usually do not have sufficient immune response to clear the virus once exposed.[3] This chronicity risk declines with age at which one was exposed, and according to the medicine literature, it dramatically drops to almost zero if exposed at age 5 (e.g., Coursaget et al. 1987; Cui and Zhuang 2016; Zu et al. 2017; Torres-Cornejo and Lauer 2017) because now most people can spontaneously clear their infection (e.g., Prescott et al. 1999; Mysore and Leung 2018).[4] Moreover, an estimated one-third of individuals with chronic HBV infection ultimately develop a long-term consequence of the disease, such as cirrhosis, end-stage liver disease, and hepatocellular carcinoma (e.g., McMahon 2009; Liang 2009).[5]

Given the above evidence, we believe that the anti-HBV vaccination is more useful for children under age 5 because they face substantially higher chronicity risk and more detrimental long-term consequences of HBV infection than their older counterparts. Older children and adults may not benefit from being vaccinated as much since they either have already developed chronic HBV infection so that vaccination would not work anymore, or they mostly can recover spontaneously from an acute infection without vaccines. In particular, we choose the age cutoff at 4 years,

[3] People who test positive for the hepatitis B virus for more than 6 months (after their first blood test result) are diagnosed as having a chronic infection (Krajden et al. 2005).

[4] Specifically, the risk of developing chronic HBV infection if exposed is about 90% for neonates and children younger than 1 year and about 30% for infections in early childhood between 1 and 4 years. In contrast, the chronicity risk of HBV infection in older children and adults is as low as 3%.

[5] To the contrary, acute liver failure is very rare among patients with acute hepatitis B, accounting for approximately 1%.

or equivalently the birth-year cutoff at 1988, and consider those no more than 4 years old at the time of the campaign as the treatment group. Applying the 4-year-old cutoff is equivalent to restricting the coefficients for children aged 5 and above in 1992 to be zero and as suggested in Duflo (2001), this is empirically testable using cohort-by-cohort estimation. Therefore, we follow Duflo (2001) and Nunn and Qian (2011), and further confirm that this chosen age cutoff is in line with the data. We also consider the variation in the number of years one is exposed to the vaccine, as opposed to the binary exposure, for robustness tests.

The second variation comes from the regional differences in the pre-campaign HBV infection risks. It can be used to proxy for the intensity that a given area was treated based on the evidence that provinces that had higher initial infection rates experienced larger declines in the hepatitis B surface antigen (HBsAg) seroprevalence. We construct the vaccination exposure variable by combining the above two sources of variation. Our identification comes from the comparison in the cohort trends in alcohol use between individuals born in the areas with higher pre-campaign HBV infection risks and those born in the areas that were less risky, within and beyond the age range for the hepatitis B vaccination.

This identifying strategy does not assume exogenous cross-provincial variation in the pretreatment risk levels, but it relies on the assumption of parallel trends: in the absence of the vaccination campaign, alcohol use behaviors follow common cohort trends across places with different pre-campaign HBV infection risks. In other words, the cohort trends in regular alcohol use should not be correlated with the initial risk levels if there were no vaccination campaigns. Based on the cohort-by-cohort estimation, we confirm that there are no heterogeneous preexisting cohort trends in alcohol use between high- and low-risk provinces. We further include a series of pre-campaign provincial characteristics and allow these effects to vary across cohorts to control for the potentially confounding factors that are correlated with the initial HBV infection risk levels.

Using the China Family Panel Studies (CFPS) data in 2018, we find that more exposure to the anti-HBV vaccination campaign leads to lower alcohol use during adulthood. An increase of 1-percentage-point in the exposure intensity, measured as the initial HBV infection risk, reduces the likelihood of regular alcohol drinking by about 0.91 percentage points, which is equivalent to a decline of approximately 6.89%. Such negative effects only appear among men, while the vaccination impacts on women's alcohol use are neither statistically nor economically significant. The estimates are robust to a variety of tests that account for different choices of sampling cohorts, alternative control groups and treatment measures, inter-provincial migration, sample selection, etc.

Apart from the gender differences in the treatment effect, there are also some heterogeneous vaccination effects that tend to be larger for individuals from more educated families and people who live in urban areas. We discuss two potential mechanisms. First, we find that more exposure to the vaccination campaign improves educational attainment, which in turn reduces regular alcohol use. Second, the reduction in regular alcohol consumption among high-educated fathers associated with the vaccination provides suggestive evidence of knowledge dissemination due to the campaign among the high-educated families.

Our findings contribute to the literature in three ways. First, our paper adds to the small but growing literature that examines individuals' behavioral responses to medical innovations. Existing associational and causal studies have looked into medical innovations, including the HPV vaccines (Brewer et al. 2007; Moghtaderi and Dor 2021; Frio and França 2021), the human immunodeficiency virus (HIV) test and treatment (Wilson et al. 2014; Gong 2015; Delavande and Kohler 2016; Friedman 2018), diabetes treatment (Klick and Stratmann 2007), statin use (Kaestner et al. 2014), and the coronary artery disease (CAD) treatment (Margolis et al. 2014). Despite the great importance of hepatitis B and its vaccines, the causal relationship between hepatitis B vaccination and individual risky behaviors has received little attention in the economics literature.

The behavioral changes associated with the vaccination against hepatitis B are likely different from responses to the other medical innovations that have been studied in the literature for two reasons. For one thing, unlike diabetes and CAD, which are noncommunicable, hepatitis B is highly infectious and can cause long-term damage to the liver.[6] Therefore, people might react to the anti-HBV vaccines differently from the treatments for non- or less-infectious diseases. For another, in addition to the cost of medical treatment for HBV infection, HBV carriers in China usually have to bear great costs associated with discrimination at school, in employment, in relationships, and even within families (Yang and Wu 2011). It was very common for employers and schools to turn down those who tested positive for HBV, which highlights the poor knowledge about HBV transmission routes (Kan et al. 2015). Facing such high costs, people who have been vaccinated might exert more effort in maintaining their health in the context of hepatitis B.

Second, because most HBV infections occur through perinatal transmission from mother to child, the vaccination against HBV is routinely given to newborns and infants (Abbas and Siddiqui 2011). This provides us with the opportunity to study the long-run behavioral responses to vaccination, while the existing literature has primarily focused on the short-run effects.

Finally, our results shed light on the literature about the effect of early-life shocks on later-life outcomes.[7] Existing studies have largely reached a consensus that early-life health interventions have both short-run and long-run impacts on a variety of outcomes, such as health, education, and labor earnings (Smith 2009; Currie et al. 2010; Currie and Vogl 2013; Adhvaryu et al. 2019). However, the role played by children's long-run behavioral responses to these shocks remains unclear. There is a growing literature studying parental responses to children's endowment (Fan and Porter 2020) and children's early health shocks (Yi et al. 2015), but their own behavioral responses could be very different from parental reactions because they have heterogeneous goals: parents aim to find the optimal solution to the intra-household resource allocation problem, while children ought to maximize their own utility.

The paper is organized as follows: Section 2 provides the background of China's hepatitis B vaccine campaign. Section 3 describes the data used in the analyses.

[6] Hepatitis B is known to be 50 to 100 times more infectious than HIV (Juszczyk 2000).

[7] A review of this literature can be found in Almond and Currie (2011).

Section 4 discusses the empirical strategy. Section 5 presents the baseline results, the heterogeneity results, and robustness checks. Section 6 discusses the mechanisms. Section 7 finally concludes.

2 Context

China was a hyperepidemic area of HBV infection (Lei et al. 1999). According to the second National Viral Hepatitis Seroepidemiological Survey, the HBsAg seroprevalence[8] among the population aged 1–59 years was 9.75% in 1992. In most developed countries, the prevalence of chronic HBV infection is only 1% (Abbas and Siddiqui 2011). It is estimated that 120 million people in China were HBV carriers (Xia et al. 1996), and almost 300,000 died annually of HBV-induced liver diseases (Zhuang 2004). Due to the high HBV endemicity, China's health authorities prioritized the prevention of HBV infection. In fact, China is known to be one of the two first countries in the developing world to attempt to control HBV infection by mass immunization of hepatitis B vaccines (Gust 1996; Zhou et al. 2008).

In 1986, a locally produced plasma-derived hepatitis B vaccine that uses HBsAg from the blood of people with chronic HBV infection was licensed and produced. The supplies of the carrier plasma were inadequate, and as a result, the production was insufficient and very costly (Guo et al. 1999; Zhou et al. 2008). With the availability of mammalian cell culture technologies, in 1992, recombinant hepatitis B vaccines using Chinese hamster ovary cells were licensed and put into mass production.[9]

In the meantime, the Ministry of Health of China initiated the hepatitis B vaccination campaign. It formulated the "National Hepatitis B Immunization Plan" in January 1992 and published the guideline in April 4, 1992. The state-owned company China Biological Products was the only supplier of the vaccine, and local health departments were responsible for making the purchase and distributing the vaccines to local healthcare facilities. The goal of this campaign was that by 1994, the vaccination coverage rate should reach 85% for all neonates and preschool-age children in the urban areas, about 60% for newborns in relatively more developed rural areas, and 40% for neonates in less developed regions.

According to the Plan, the vaccination for neonates should follow the "0–1–6" rule: receiving the first dose within 24 h of birth and subsequent doses at ages 1 and 6 months (Wang et al. 2016). For preschool-age children, three doses of catch-up vaccines were given. At the beginning of the campaign, vaccines were not free of

[8] HBsAg seroprevalence is believed to be a more appropriate measure for the hepatitis B infection than clinical disease outcomes because the transmission of HBV among infants and young children is usually asymptomatic, and reduction in the incidence of cirrhosis or hepatocellular carcinoma often takes many years to observe (World Health Organization 2014).

[9] Later in 1996, Chinese vaccine makers were granted to produce recombinant vaccines using HBsAg derived from yeast cells, a technology shared by the Merck & Dohme Company, and the vaccine production was as high as about 60 million doses per year. In June 1998, the production of plasma-derived vaccine was suspended and was eventually abandoned in 2000 (Zhuang 2004).

charge. It cost about 29 yuan for neonates born to mothers with chronic HBV infection and about 18 yuan for infants whose mothers were not HBV carriers and all preschool children (Hu 1992). Given that the yearly disposable income was about 1826 yuan among urban workers and around 784 yuan among rural workers (National Bureau of Statistics of China 1993), the vaccines accounted for no more than 1.6% and 3.7% of annual income among urban and rural workers, respectively.

With the hepatitis B vaccination program, vaccine coverage among children has significantly increased. It was less than 8% at the time when the campaign was launched, and by 1994, it had substantially increased to about 95.09% in the cities, 78.24% in the suburbs, and less than 50% in rural areas (Jia et al. 1999).[10] Although the immunization coverage was not full, the rate of HBsAg seropositivity among children considerably reduced as a result of the vaccines. At the beginning of the campaign, the HBsAg seroprevalence was 10.7% among boys aged no more than 4 years and 8.5% among girls within the same age range (Zhou et al. 2008), and it had declined to about 2.28% by 1994 (Jia et al. 1999). In 2002, the health authorities integrated the hepatitis B vaccine into the National Expanded Program on Immunization (EPI) and canceled all charges in May 2005. According to the most recent Seroepidemiological Survey of Hepatitis B Virus Infections in 2014, the HBsAg seroprevalence among children under age five dropped to about 0.32% in China (United Nations Children's Fund 2018).

3 Data

3.1 HBV-infection risk

The pre-campaign HBV-infection risks at the province level come from the 1992 National Viral Hepatitis Seroepidemiological Survey. The survey was led by the Ministry of Health of China and carried out by local health departments in June 1992. The survey randomly selected 145 national disease surveillance points (DSPs) across 30 provinces,[11] covering a total of 67,017 individuals aged 1–59 years from 22,949 households. It collects serum specimens from all subjects who were interviewed, except those who had already been vaccinated, to detect HBsAg, total hepatitis B core antibody (anti-HBc), and hepatitis B surface antibody (anti-HBs). Since the survey was conducted around the same time when the campaign was just initiated, about 92% of all subjects had never received anti-HBV vaccination.

Figure 1 plots the geographical distribution of the HBsAg seroprevalence in June 1992. Consistent with existing studies (e.g., Bersohn et al. 1974; Orito et al. 2001; Roman et al. 2014), the prevalence of HBsAg carriers has strong geographical

[10] The immunization coverage was not universal, possibly due to the lack of public awareness. Moreover, before the introduction of the out-of-the-cold-chain (OCC) strategy, vaccines should be stored and transported using a cold chain. The lack of cold-chain infrastructure further hampers immunization coverage, especially in remote areas (Wang et al. 2007).

[11] The municipality of Chongqing was not separated from Sichuan province until March 1997, and Taiwan was not surveyed.

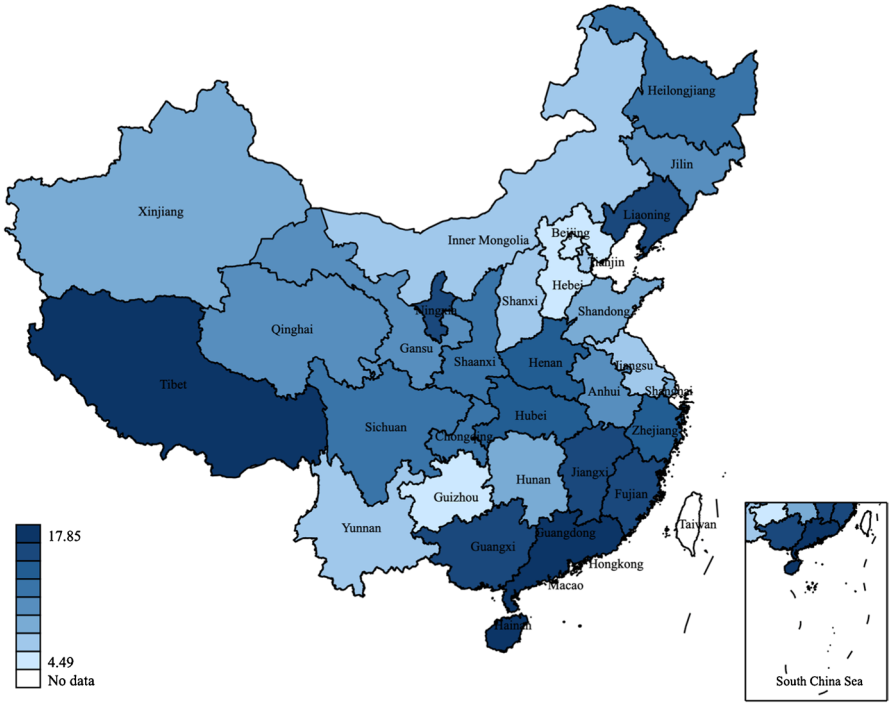


Fig. 1 Geographical Distribution of the HBsAg seroprevalence in 1992. Notes: This figure plots the geographical distribution of the HBsAg seroprevalence across provinces in June 1992. Data source: the 1992 National Viral Hepatitis Seroepidemiological Survey

patterns. The share of people with chronic HBV infection in the southern areas is generally higher than that in northern China, and the average prevalence rates in the coastal areas are typically higher than those in inland China.[12]

More importantly, the pre-campaign HBsAg seroprevalence is strongly related to the effectiveness of the vaccines, measured as a reduction in the province-level HBV infection rates. Figure 2 plots the province-level HBsAg seroprevalence in 1992 against the percentage-point decline in the HBsAg carrier rates between 1992 and 2006 based on both waves of the National Viral Hepatitis Seroepidemiological Survey. We find a strong and positive correlation with a slope of 0.311 (s.e. 0.106), indicating that provinces that had higher HBV infection rates experienced larger declines in the HBsAg seroprevalence.[13] We thus assign the pre-campaign HBV

[12] We confirm no evidence of a strong correlation between the initial risk levels and the of pretreatment local economic development. There is a weak correlation between the logarithm of province-level GDP per capita in 1992 and the province-level HBsAg carrier rates in the same year, with a slope of −0.903 (p-value = 0.546).

[13] We note that there are four provinces whose HBsAg carrier rates increased between 1992 and 2006. We confirm that excluding these outliers yields a slightly smaller slope at about 0.206 (s.e. 0.095), and the statistical significance remains.

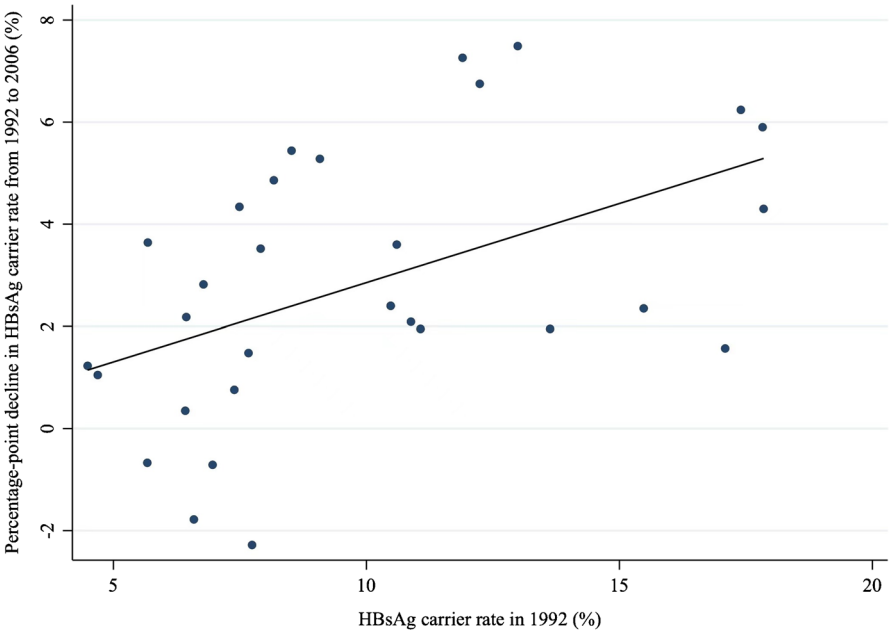


Fig. 2 Decline in the province-level HBV-infection risks associated with initial risk levels. Notes: This figure is a scatter plot with the province-level HBsAg carrier rates in 1992 on the horizontal axis and percentage-point declines in the HBsAg carrier rates from 1992 to 2006 on the vertical axis. The data is collected from the two waves of the National Viral Hepatitis Seroepidemiological Survey in 1992 and 2006. The fitted line is obtained from linear regression, and the slope is 0.311 (s.e. 0.106)

infection risk to each individual based on one's province of birth so as to describe the intensity that one is exposed to the vaccination.

3.2 Alcohol use

The key outcome of interest is individual's regular alcohol use collected from the CFPS. The CFPS is a nationally representative longitudinal social survey project conducted by the Institute of Social Science Survey of Peking University, with rich information on education, health, and income, among many others, at individual, household, and community levels. The national baseline survey was launched in 2010 and interviewed 16,000 households in 25 provinces in China. There are then bi-yearly follow-up surveys in 2012, 2014, 2016, 2018, and 2020.

We use the 2018 survey for our analyses, and the reasons are twofold. First, since we focus on individuals born around the campaign year 1992, many of them were too young in the earlier waves of the survey to drink alcohol regularly.[14] Second, we do not use the most recent wave of the CFPS surveyed in 2020 because

[14] According to Li et al. (2011), only about 5.8% of men aged 18–24 years frequently drink alcohol in China, while 14% of males aged 25–34 are regular alcohol users.

we are concerned that the COVID-19 pandemic might change individuals' alcohol use behaviors. If its impacts vary across cohorts, our estimates will be biased.[15] We define the outcome variable as an indicator of whether one is a regular alcohol user based on the survey question: "Did you drink alcohol at least 3 times a week in the past month?" We assign the value of 1 if the individual answers "yes" to this question and consider them as regular alcohol drinkers, and the value of 0 if the answer is "no".

To arrive at our baseline sample, we make two restrictions. First, we exclude people whose alcohol-drinking behaviors are not allowed or strictly regulated, including full-time students[16] and Hui and Islam individuals who are forbidden from consuming alcohol due to religious rules. Second, we limit the sample to individuals born between 1981 and 1994 who were in their late 20 s and early 30s when they were surveyed. We do not include cohorts born beyond 1994 in concern of potential sample selection since many are likely in school.[17] Our baseline sample includes 5570 individuals. Among cohorts born before 1988, the difference in regular alcohol drinking between the high- and low-risk areas is about 0.001 (s.e. 0.013) and statistically insignificant. The difference turns − 0.026 (s.e. 0.012) for the treated cohorts born in and after 1988 and becomes statistically significant at the 5% level. More summary statistics of the demographic characteristics can be found in Table 1.

4 Empirical strategy

To gauge the causal effect of the anti-HBV vaccination on individual alcohol use, we adopt the cohort difference-in-differences (DD) approach specified below:

$$y_{iptm} = \alpha + \beta \text{Risk}_p \times \text{post1988}_i + X_{iptm}\gamma + \left(W_p\eta_t\right)\delta + \theta_p + \eta_t + \omega_m + \varepsilon_{iptm} \quad (1)$$

where y_{iptm} is the regular alcohol drinking status of individual i born in province p in year t surveyed in month m. The variable $Risk_p$ is the initial HBV-infection risk level, measured as the HBsAg carrier rate in province p in 1992, and $post1988_i$ is an indicator that equals 1 if individual i was born in or after 1988 and 0 if individual i was born before 1988. X_{iptm} is a series of individual and household characteristics including gender, ethnicity, health endowment measured as one's birth weight, hukou type at birth, and three indicators for household age composition, i.e., shares of household members who are aged 0–6, 7–24, and 25–55. We include a vector of pretreatment characteristics at the province level measured in 1990, denoted by W_p

[15] We also note that the publicly available version of the CFPS 2020 is currently incomplete. For example, it does not include family relations, so we are unable to control for family characteristics.

[16] In China, the majority of university students live on campus, and their activities in dormitories are often strictly regulated (Mou and Lin 2020). For example, student parties cannot involve alcohol consumption on campus. They may still be able to consume alcoholic beverages outside the campus, but they are rarely regular drinkers (Ji 2010).

[17] We further removed 72 respondents whose provinces of birth were beyond the 25 provinces surveyed in the baseline CFPS in concern of the singleton problem (Correia 2015).

Table 1 Summary statistics

	Birth cohorts ≥ 1988						Birth cohorts < 1988					
	High-risk areas			Low-risk areas			High-risk areas			Low-risk areas		
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Regular alcohol use	1311	0.098	0.298	1351	0.124	0.330	1438	0.152	0.359	1470	0.151	0.358
HBV-infection risk in 1992	1311	13.060	2.701	1351	6.842	1.233	1438	13.07	2.712	1470	6.852	1.250
Gender (male = 1)	1311	0.527	0.499	1351	0.506	0.500	1438	0.513	0.500	1470	0.531	0.499
Birth year	1311	1991	1.993	1351	1991	1.972	1438	1984	2.058	1470	1984	2.066
Ethnicity (Han = 1)	1311	0.910	0.286	1351	0.908	0.289	1438	0.916	0.278	1470	0.907	0.291
Normal birth weight	1311	0.505	0.500	1351	0.530	0.499	1438	0.483	0.500	1470	0.503	0.500
Macrosomia	1311	0.066	0.249	1351	0.070	0.255	1438	0.054	0.227	1470	0.053	0.224
Hukou type at birth (urban = 1)	1311	0.157	0.364	1351	0.117	0.321	1438	0.140	0.348	1470	0.119	0.324
Shares of household members who are aged:												
0–6	1311	0.139	0.156	1351	0.141	0.151	1438	0.132	0.142	1470	0.131	0.137
7–24	1311	0.124	0.199	1351	0.121	0.197	1438	0.183	0.159	1470	0.182	0.156
25–55	1311	0.631	0.254	1351	0.633	0.245	1438	0.514	0.192	1470	0.513	0.179

This table reports summary statistics for the main outcome and demographic variables used in the baseline analyses. Provinces with HBsAg seroprevalence higher than the median level are considered high-risk areas, and those with lower-than-median HBsAg seroprevalence rates are considered low-risk areas. A birth weight between 2.5 and 4 kg is considered normal birth weight. Babies with a birth weight higher than 4 kg are considered macrosomia. Here, we only report the proportion of the ethnic majority group (the Han people), but we note that in the estimation, we control for a series of ethnic group indicators

.[18] Following Duflo (2001), Alsan (2017), and Kuecken et al. (2021), we interact W_p with indicators for birth cohorts η_t to allow these effects to vary across cohorts. We further include province-of-birth fixed effects θ_p and birth cohort (or equivalently birth year) fixed effects η_t. We also control for the survey month fixed effects ω_m to capture the seasonal patterns in alcohol drinking. Following Kuecken et al. (2021), we add an interaction term between birth cohort indicators η_t and regional averages of the outcome variable to control for the potential mean reversion in the alcohol drinking behaviors. Standard errors are clustered at the place-of-birth level.

Our identification relies on the parallel trend assumption: the cohort trends in alcohol use are not related to the initial HBV-infection risks, so the evolvement of alcohol use among cohorts born in the low-risk areas provides valid counterfactuals. In Fig. 3, we separately plot the fractions of regular alcohol drinkers for each birth cohort between 1981 and 1994 for the high-risk areas and low-risk areas determined by the median risk level. For earlier cohorts born before 1988, there are no apparent differences in the cohort trends of shares of regular alcohol drinkers between the high-risk areas and the low-risk areas. The spatial distribution of HBV infection is largely determined by climatic characteristics (Yin et al. 2021),[19] which likely contributes to the common cohort trends prior to the campaign. The fractions of regular alcohol drinkers for cohorts born after 1988, however, immediately drop and remain low. Moreover, provinces that had higher initial infection risks experienced a larger reduction in the fraction of alcohol drinkers. Taken together, Fig. 3 suggests that cohort trends in alcohol use prior to the campaign are similar across areas with different initial risk levels. It also indicates that alcohol use behaviors are quite different for cohorts on the opposite sides of the birth-year cutoff.

We further follow Duflo (2001) and Nunn and Qian (2011) and generalize Eq. (1) to a fully flexible cohort-by-cohort estimation as below

$$y_{iptm} = \alpha + \sum_{k=1981}^{1994} \beta_k \text{Risk}_p \times I_i^k + X_{iptm}\gamma + \left(W_p \eta_t\right)\delta + \theta_p + \eta_t + \omega_m + \varepsilon_{iptm} \tag{2}$$

Specifically, we interact the pre-campaign risk level $Risk_p$ with a series of birth-year indicators I_i^k that equal 1 if individual i was born in year k. All other variables are defined in the same way as those used in Eq. (1). By writing the regression model in this way, we are able to obtain a battery of cohort-specific estimators β_k for the vaccination effects, except for the cohort born in 1987, which is used as the reference group. Therefore, each coefficient β_k is interpreted as the estimated impact of the vaccination campaign for a given cohort k relative to the reference cohort.

[18] Specifically, W_p includes the logarithm of per capita consumption, number of hospital beds per 1000 people, the share of people with at least middle-school education, and four variables that describe local population demographics, i.e., shares of people who are urban hukou owners, male, aged 0–6, and Tibetan or Zhuang ethnicity. The latter two variables are collected from the fourth population census data, and the rest are from the 1991 China Statistical Yearbook.

[19] For example, Yin et al. (2021) show that warm and humid weather both aggravates the development of hepatitis B disease and is not conducive to the recovery of liver disease.

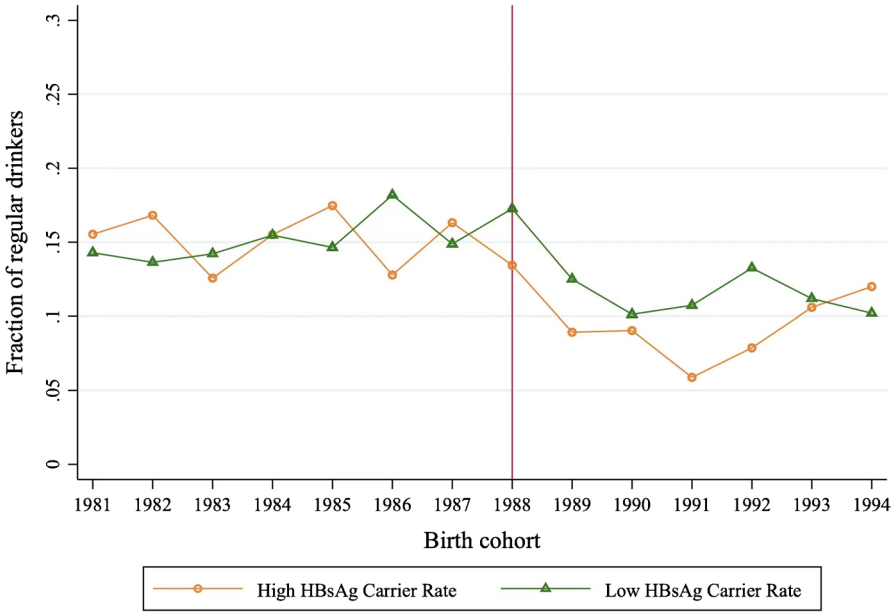


Fig. 3 Fraction of regular alcohol drinkers by birth cohorts and pre-campaign HBsAg carrier rates. Notes: This figure compares the fractions of regular alcohol drinkers for different birth cohorts between high-risk areas and low-risk areas. We consider provinces where HBsAg carrier rates were higher than the median level as the high-risk areas and those with lower-than-median HBsAg prevalence rates as the low-risk areas. Data source: CFPS 2018 and the 1992 National Viral Hepatitis Seroepidemiological Survey

Estimates of Eq. (2) are reported in Table 2 and plotted in Fig. 4. They lend strong support to the parallel-trend assumption. For all cohorts born before 1988, the vaccination effects on individual alcohol use are statistically insignificant and very close to zero. Moreover, the responses to regular alcohol drinking are significant among people born in and after 1988.[20] When we divide the sample based on gender, the same patterns hold for men, while the vaccination effects are indistinguishable from zero for all female birth cohorts. This dynamic pattern does not only provide convincing evidence that the parallel-trend assumption is likely to hold, but it also justifies our choice of 1988 as the birth-cohort cutoff.

A remaining concern comes from the potentially confounding impacts of other vaccines scheduled for infants and established over the early 1980s. In 1978, the state council passed a law that required the establishment of a national EPI. The program requires all infants to receive Bacille-Calmette-Guérin (BCG), oral poliovirus

[20] We note that the significant negative effects do not appear to hold for the youngest cohorts born in 1993 and 1994. One possible explanation is that the sample restriction that excludes full-time students is likely to be more binding for these birth cohorts than their older counterparts; thus, the sample of these two cohorts is subject to more selection.

Table 2 Cohort-by-cohort vaccination effects on the incidence of regular alcohol use

	All	Male	Female
	(1)	(2)	(3)
Risk × birth1981	0.0001	−0.0002	−0.0005
	(0.0044)	(0.0099)	(0.0029)
Risk × birth1982	0.0024	0.0020	−0.0012
	(0.0036)	(0.0066)	(0.0038)
Risk × birth1983	0.0018	0.0011	0.0008
	(0.0067)	(0.0131)	(0.0025)
Risk × birth1984	−0.0051	−0.0054	0.0001
	(0.0033)	(0.0069)	(0.0035)
Risk × birth1985	0.0048	0.0111	0.0033
	(0.0071)	(0.0119)	(0.0048)
Risk × birth1986	−0.0046	−0.0063	0.0006
	(0.0056)	(0.0105)	(0.0041)
Risk × birth1988	−0.0119***	−0.0251***	0.0012
	(0.0037)	(0.0082)	(0.0033)
Risk × birth1989	−0.0091**	−0.0186***	0.0021
	(0.0033)	(0.0047)	(0.0036)
Risk × birth1990	−0.0062***	−0.0103**	−0.0004
	(0.0016)	(0.0037)	(0.0026)
Risk × birth1991	−0.0099***	−0.0207***	0.0007
	(0.0035)	(0.0058)	(0.0020)
Risk × birth1992	−0.0176***	−0.0350***	0.0010
	(0.0032)	(0.0067)	(0.0031)
Risk × birth1993	−0.0043	−0.0079	0.0018
	(0.0032)	(0.0067)	(0.0047)
Risk × birth1994	−0.0038	−0.0056	0.0003
	(0.0045)	(0.0071)	(0.0051)
Mean dependent variable	0.132	0.237	0.020
Observations	5570	2891	2679

This table estimates the vaccination campaign impacts on the incidence of individual regular alcohol use based on Eq. (2). All specifications shown include birth cohort indicators interacted with regional averages of the outcome variable and pretreatment provincial measures, individual and family characteristics, and province, birth cohort, and survey month fixed effects. Results on demographic and provincial characteristics are not reported. Standard errors are in parentheses and clustered at the place-of-birth level. $p<0.1$; ** $p<0.05$; *** $p<0.01$

(OPV), diphtheria-pertussis-tetanus (DPT), and measles vaccines, which is also known as the "Four vaccines, Six diseases" campaign (Yu et al. 2018). Since the EPI was initiated around a similar time period when the anti-HBV vaccination was launched, our estimates might be biased if the coverages of these other vaccines are correlated with the pre-campaign HBV infection risks and vary across cohorts.

However, we believe that this is less of a concern because the take-up rates of these other vaccines were already high prior to the anti-HBV vaccine campaign. In particular, the first nationwide coverage survey conducted in 1989 documents that the coverage of all recommended BCG, OPV, DPT, and measles doses by 12 months of age was about 75–85% in 1987 and had reached 95–98% by 1989 (Yu et al. 2018). Given that the majority of children were covered by the EPI at the time when the anti-HBV vaccination was initiated, the potential impacts of the four major vaccines are likely canceled out in the DD approach.

Finally, it is noteworthy that we do not observe whether one has been vaccinated; hence, this identification strategy that is based on the exposure intensity estimates the intention-to-treat (ITT) rather than the average treatment effect on the treated (ATT). Understanding the ITT is as well important since the effect of the vaccination campaign on individual risky behaviors does not always rely on individuals being vaccinated. People who were not vaccinated might also be affected by the availability of vaccines through positive externality (Kim 2006). Moreover, if the vaccine campaign encourages the dissemination of HBV-related knowledge and greater awareness that alcohol use could induce liver diseases, unvaccinated individuals who face a high risk of HBV infection might also reduce their alcohol use as a result of the campaign. We will test this mechanism in Sect. 6.

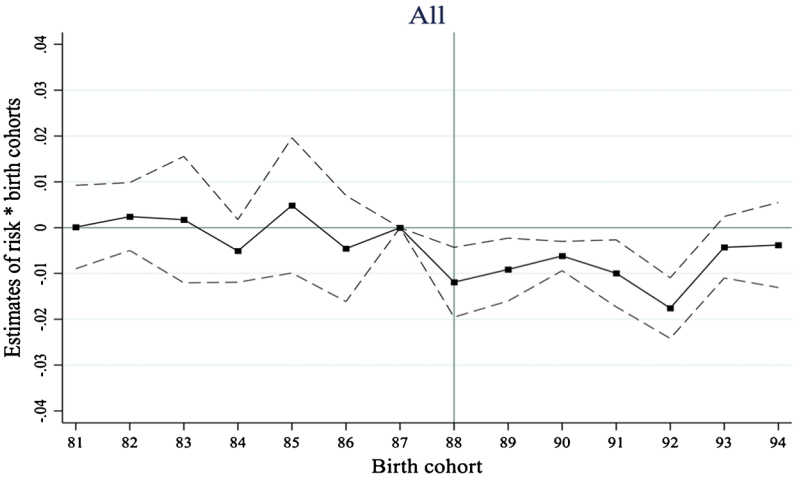
5 Results

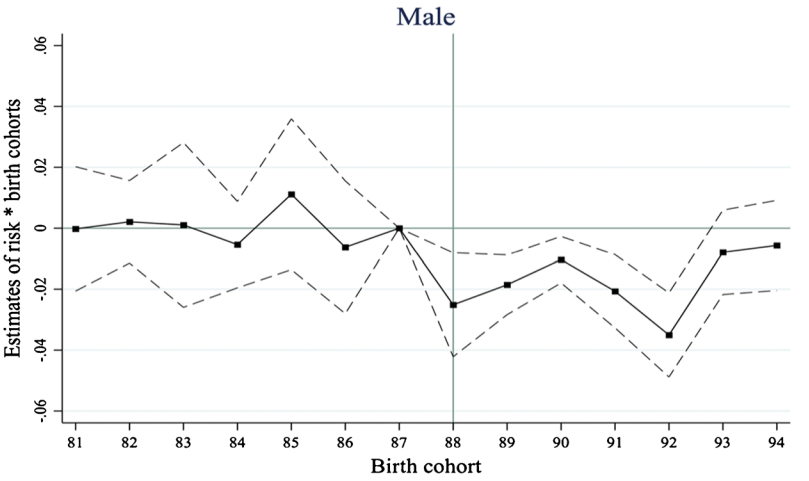
5.1 Baseline results

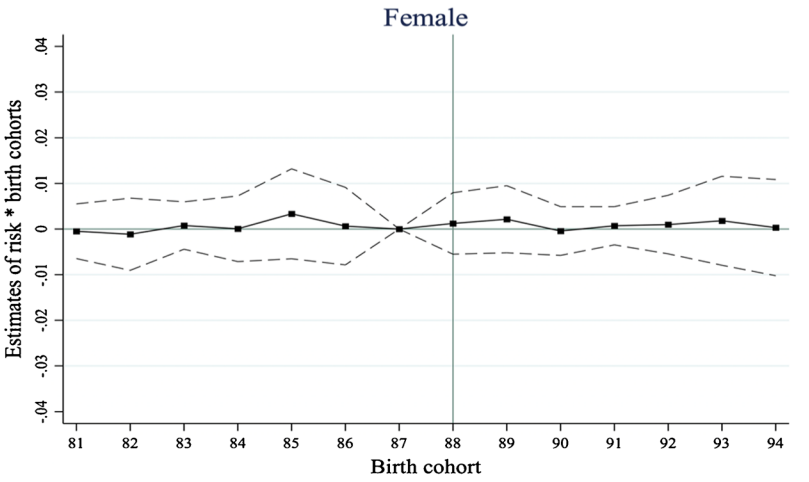
The estimated results of Eq. (1) are reported in Table 3. We start with the specification that only controls for a set of fixed effects. Column 1 shows that more exposure to the vaccination tends to reduce the likelihood of regular alcohol drinking among men but not for women. Specifically, a 1-percentage-point increase in the exposure intensity, measured as the pre-campaign HBV infection risks, reduces the probability of regular drinking by 0.43 percentage points for all, but such an effect is statistically insignificant.

When the sample is restricted to men, we find a significant reduction in their likelihood of regular drinking at 1.05 percentage points. Given the sample average of regular drinking at 23.7% for men, this translates the vaccination effects to a decline in the probability of regular alcohol use at about 4.43% (= 1.05/23.7). For women, the campaign effects are neither statistically nor economically significant, which is somewhat unsurprising since very few women are regular alcohol users. Since the likelihood of regular drinking among the majority of women is already at the corner solution in absence of vaccines, the vaccination can no longer reduce their drinking, and the effect is expected to be small. On the contrary, as the interior solution is optimal for men on average, the exposure to vaccination would potentially drive some to the corner solution, leading us to find significant results.

The province-of-birth fixed effects absorb all provincial characteristics that do not vary across cohorts. However, concerns remain if the initial HBV infection risks are


All
Estimates of risk * birth cohorts
.04
.03
.02
.01
0
-.01
-.02
-.03
-.04
81 82 83 84 85 86 87 88 89 90 91 92 93 94
Birth cohort


Male
Estimates of risk * birth cohorts
.06
.04
.02
0
-.02
-.04
-.06
81 82 83 84 85 86 87 88 89 90 91 92 93 94
Birth cohort


Female
Estimates of risk * birth cohorts
.04
.03
.02
.01
0
-.01
-.02
-.03
-.04
81 82 83 84 85 86 87 88 89 90 91 92 93 94
Birth cohort

◂ **Fig. 4** Cohort-by-cohort vaccination effects on the incidence of regular alcohol use. Notes: This figure plots the estimation based on Eq. 2 for all and also separately for men and women. The markers show the coefficients reported in Table 2, with the cohorts born in 1987 omitted as the reference group. The dashed lines indicate the 95% confidence intervals around the point estimates, with the standard errors clustered at the place-of-birth level

correlated with some cohort-variant factors at the province level. For example, areas that experience economic downturns might have worsened healthcare systems and hence higher infection risks for later cohorts. To address this concern, we include the interaction terms between a battery of pretreatment provincial characteristics and birth cohort indicators in column 2 of Table 3. We find a slightly larger vaccination effect at about 1.5 percentage points (or equivalently 6.33%) for men and 0.65 percentage points (or 4.92%) for all.

In column 3, where we further control for a set of individual and household characteristics, we consistently find a significant reduction in individual alcohol use associated with vaccination exposure. Adding the mean-reversion term in column 4 yields a statistically significant estimate of − 0.0183 for men and − 0.0091 for all. The results suggest that a 1-percentage-point increase in vaccine exposure reduces the probability of regular alcohol drinking by about 1.83 percentage points or equivalently 7.72% for men and 0.91 percentage points or approximately 6.89% for both genders combined. By multiplying these estimates by the average level of initial HBV infection risk at 0.099, we find that the resulting elasticity is − 0.76 for men and − 0.68 for all.

Our baseline estimation uses the birth cohorts born between 1981 and 1994. In concern that the results are sensitive to the choices of sampling cohorts, we gradually restrict the sample by removing 1 year at a time from each side of the birth-year cutoff and re-estimate Eq. (1). Results are reported in Table 4. We consistently find reduced alcohol use associated with more exposure to the vaccination campaign across all columns, especially for men. The statistical significance maintains even in the last column, where we only include the two birth cohorts born in 1987 and 1988 who were respectively five and four years old at the time of the campaign, and the magnitudes of the vaccine effects are slightly larger than the baseline results. One percentage-point increase in vaccine exposure reduces the probability of regular alcohol use by about 1.29 percentage points (or 8.43%) for all and 2.47 percentage points (or 8.64%) for men. Overall, the estimates are robust to different choices of sampling birth cohorts.[21]

Alternatively, we redefine the treatment group to include cohorts born in 1986 and 1987, as they were both at preschool age and hence well targeted by the vaccination campaign. Results in the first two columns of Table A1 remain statistically significant and are slightly smaller than the baseline results in magnitude. In particular, the average reduction in regular alcohol use drops from 0.91 percentage points to 0.82 percentage points for all individuals and from 1.83 percentage points to 1.57 percentage points for men. The results are also robust to the exclusion of the above two cohorts, as shown in the last two columns of Table A1.

[21] We note that our estimates are also robust to the adoption of a probit model and the inclusion of the CFPS sampling weights.

Table 3 Vaccination effects on the incidence of regular alcohol use

	(1)	(2)	(3)	(4)
All				
Risk × post1988	−0.0043	−0.0065**	−0.0074***	−0.0091***
	(0.0030)	(0.0024)	(0.0024)	(0.0019)
Mean dependent variable	0.132	0.132	0.132	0.132
Observations	5570	5570	5570	5570
Male				
Risk × post1988	−0.0105**	−0.0150***	−0.0154***	−0.0183***
	(0.0044)	(0.0039)	(0.0041)	(0.0030)
Mean dependent variable	0.237	0.237	0.237	0.237
Observations	2891	2891	2891	2891
Female				
Risk × post1988	−0.0001	0.0008	0.0006	0.0006
	(0.0007)	(0.0008)	(0.0009)	(0.0008)
Mean dependent variable	0.020	0.020	0.020	0.020
Observations	2679	2679	2679	2679
Birth cohort × avg. alcohol use	No	No	No	Yes
Individual and family characteristics	No	No	Yes	Yes
Birth cohort × 1990 province characteristics	No	Yes	Yes	Yes

This table estimates the vaccination campaign impacts on the incidence of individual regular alcohol use based on Eq. (1). All specifications shown include province, birth cohort, and survey month fixed effects. Results on demographic and provincial characteristics are not reported. Standard errors are in parentheses and clustered at the place-of-birth level. $p<0.1$; ** $p<0.05$; *** $p<0.01$

5.2 Heterogeneity

Our baseline results reveal that vaccination exposure tends to reduce alcohol use, especially for men. In this section, we discuss the potential heterogeneity therein. We first divide the sample based on family educational background. Specifically, we consider families as being highly educated if the average parental education levels are at least middle school. Results in the first two columns of Table 5 suggest that more exposure to the anti-HBV vaccination reduces the likelihood of regular alcohol drinking for people from both educational backgrounds. In particular, a 1-percentage-point increase in vaccination exposure reduces the likelihood of regular alcohol use by about 1.28 percentage points or 10.4% for individuals from more educated families, while the effects are much smaller at about 0.55 percentage points or equivalently 3.85% for the less educated group. Consistent with our baseline results, the significantly negative impacts only appear among men.

Table 4 Vaccination effects on the incidence of regular alcohol use based on alternative choices of birth cohorts

	81–94	82–93	83–92	84–91	85–90	86–89	87–88
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
All							
Risk × post1988	−0.0091***	−0.0095***	−0.0101***	−0.0086***	−0.0096***	−0.0099***	−0.0129***
	(0.0019)	(0.0024)	(0.0027)	(0.0023)	(0.0029)	(0.0031)	(0.0042)
Mean dependent variable	0.132	0.132	0.132	0.134	0.138	0.143	0.153
Observations	5570	4887	4170	3466	2758	1922	1012
Male							
Risk × post1988	−0.0183***	−0.0199***	−0.0219***	−0.0191***	−0.0203***	−0.0202***	−0.0247**
	(0.0030)	(0.0036)	(0.0044)	(0.0034)	(0.0047)	(0.0047)	(0.0102)
Mean dependent variable	0.237	0.239	0.241	0.246	0.256	0.262	0.286
Observations	2891	2523	2147	1788	1409	983	514
Female							
Risk × post1988	0.0006	0.0002	−0.0003	−0.0004	−0.0007	0.0005	0.0011
	(0.0008)	(0.0008)	(0.0010)	(0.0013)	(0.0014)	(0.0022)	(0.0030)
Mean dependent variable	0.020	0.019	0.016	0.015	0.016	0.017	0.016
Observations	2679	2364	2023	1678	1349	939	496

This table uses different sampling cohorts to examine the vaccination campaign impacts on the incidence of individual regular alcohol use based on Eq. (1). All specifications shown include birth cohort indicators interacted with regional averages of the outcome variable and pretreatment provincial measures, individual and family characteristics, and province, birth cohort, and survey month fixed effects. Results on demographic and provincial characteristics are not reported. Standard errors are in parentheses and clustered at the place-of-birth level. $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 5 Heterogeneous vaccination effects on the incidence of regular alcohol use

	By average parental education		By place of residence	
	Lower than middle school	At least middle school	Urban	Rural
	(1)	(2)	(3)	(4)
All				
Risk × post1988	−0.0055**	−0.0128***	−0.0104***	−0.0085***
	(0.0024)	(0.0034)	(0.0029)	(0.0024)
Mean dependent variable	0.143	0.123	0.121	0.147
Observations	3136	2347	2988	2470
Male				
Risk × post1988	−0.0098**	−0.0280***	−0.0203***	−0.0200***
	(0.0044)	(0.0052)	(0.0048)	(0.0043)
Mean dependent variable	0.245	0.225	0.211	0.269
Observations	1704	1174	1528	1296
Female				
Risk × post1988	0.0009	0.0003	−0.0007	0.0020**
	(0.0009)	(0.0018)	(0.0012)	(0.0008)
Mean dependent variable	0.0209	0.0205	0.0274	0.0111
Observations	1432	1173	1460	1172

This table estimates the heterogeneous vaccination campaign impacts on the incidence of individual regular alcohol use by average education levels of both parents and type of residential place. All specifications shown include birth cohort indicators interacted with regional averages of the outcome variable and pretreatment provincial measures, individual and family characteristics, and province, birth cohort, and survey month fixed effects. Results on demographic and provincial characteristics are not reported. Standard errors are in parentheses and clustered at the place-of-birth level. $p<0.1$; ** $p<0.05$; *** $p<0.01$

The larger vaccination impacts for men from families with better educational backgrounds are likely driven through two channels. First, parents with higher educational attainments are more likely to educate their children with the HBV-related knowledge that they acquired from the campaign, which in turn leads their children to drink less when they grow up. Second, children from more-educated families have a better chance of being vaccinated since their parents are likely more aware of the importance of the vaccine.

Next, we discuss the heterogeneous treatment effects between urban and rural regions. We consider the urban–rural classification based on one's place of residence.[22] Results are reported in the last two columns of Table 5. We find that the impacts on individual alcohol use associated with the anti-HBV vaccination are

[22] We are unable to examine the heterogeneous treatment effects based on one's place of birth because the CFPS does not provide information on the urban/rural classification for one's birthplace. To mitigate concerns about endogenous sampling, we run baseline regressions with the type of residential place as the outcome variable. We confirm small and insignificant results overall and among men, but we cautiously note that there appears to be some sorting in the rural area among women.

rather comparable between the two groups of people. In particular, a 1-percentage-point increase in vaccination exposure reduces the incidence of regular drinking by about 0.85 percentage points or 5.83% for people living in rural areas, and the effects are larger at about 1.04 percentage points or 8.57% for people living in urban areas. Similar results are found for men.

When we restrict the sample to rural women, we find that they exhibit an ex-ante moral hazard effect in the sense that they are more likely to drink alcohol associated with more exposure to vaccination. We think that this could be driven by the son preference that has long been prevalent among rural households. Li (2004) finds that being female substantially reduces the probability of receiving necessary vaccinations and leads to less child healthcare utilization in rural areas. If the preference toward sons being vaccinated is particularly strong in the high-risk areas, we might expect the vaccination effect on alcohol use flips the sign for rural women.

5.3 Robustness checks

5.3.1 Placebo tests

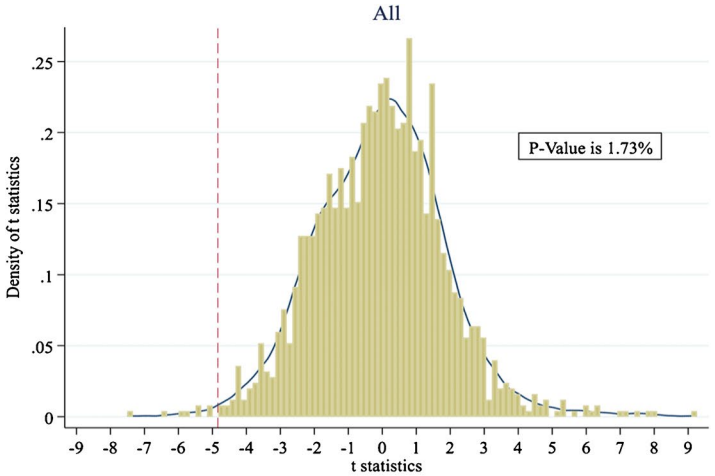
To address the concern that our estimator may pick up the impact of some unobserved province-level characteristics omitted from our regressions, we perform two placebo tests. First, we estimate Eq. (1) based on placebo campaign years in Table A2. We find insignificant effects in all placebo tests and confirm that our baseline estimates are unlikely driven by some unobserved confounders.

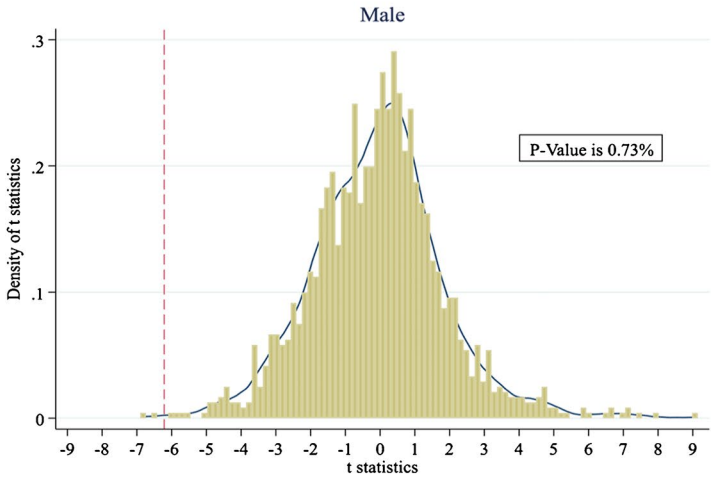
Second, we follow Chetty et al. (2011) and Tang et al. (2019) and perform a placebo test by randomizing the initial risk levels. We repeat this procedure 1500 times and depict the distribution of the t statistics of the 1500 placebo estimates with the kernel density denoted by the solid curves in Fig. 5. We confirm that the vaccination campaign leads to a large decline in the incidence of regular alcohol use, especially for men. This implies that the significant negative effects of the anti-HBV vaccination campaign on individual alcohol use are unlikely obtained by random chance.

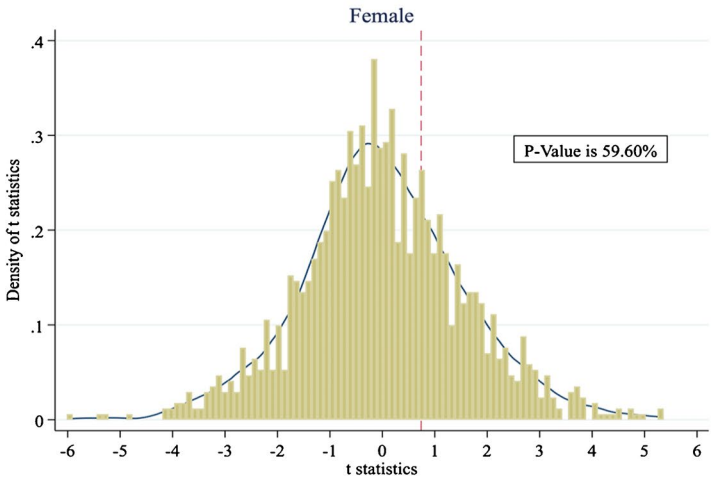
5.3.2 Alternative treatment measures

In the concern that our baseline estimates might suffer from the measurement error problem if the initial HBV-infection risk levels were misreported, we replace the initial HBsAg seroprevalence with alternative measures.

First, we replace the risk levels with a binary variable based on the median level of the initial HBsAg carrier rates in the first panel of Table A3. Second, we replace the amount of HBsAg carrier rates with their rank orders in panel B. We further use the quantiles of the initial infection risk and report the estimates in panel C. We confirm that the significant reduction in the likelihood of regular alcohol use, especially for men, holds across all three specifications.


All
Density of t statistics
.25
.2
.15
.1
.05
0
P-Value is 1.73%
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9
t statistics


Male
Density of t statistics
.3
.2
.1
0
P-Value is 0.73%
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9
t statistics


Female
Density of t statistics
.4
.3
.2
.1
0
P-Value is 59.60%
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
t statistics

◂**Fig. 5** Placebo test by randomly assigning initial risk levels. Notes: This figure runs the placebo tests by randomizing the initial HBsAg carrier rates. We repeat this procedure 1500 times and depict the distribution of the *t* statistics of the 1500 placebo estimates with the kernel density denoted by the solid curves. The vertical dashed lines present the *t* statistics of our baseline results shown in the last column of Table 3. The *p*-value is the proportion of placebo *t* statistics that are, in absolute value, no less than the baseline *t* statistics

Furthermore, it is likely that individuals at different ages when the vaccination campaign was launched were exposed to a different extent, even if they face the same levels of infection risks. To this end, we replace the treatment group indicator with a non-dichotomous variable to further differentiate the treatment group by the number of years an individual was exposed to the vaccination campaign. We interact this variable with the continuous risk levels and present the results in panel D, and we combine it with the binary risk variable described above and re-estimate Eq. (1) in panel E. Overall, the baseline results are robust to all of the alternative treatment measures and unlikely attenuated.

5.3.3 Alternative control groups

In the baseline analyses, we use those who were aged at least 5 years at the time of the campaign as the control group because the vaccines are unlikely effective for these people. We pick cohorts born between 1981 and 1987, but technically, any cohorts born before 1988 could serve as the comparison group. To examine whether the baseline results are sensitive to the choices of the control group, we use a variety of alternative birth cohorts as a comparison, as demonstrated in the column heads of Table A4. We consistently observe significant negative effects on the likelihood of alcohol use during adulthood associated with more exposure to the vaccination.

5.3.4 Confounding effects

First, in concern that our baseline results might pick up the confounding effects of poor health, we restrict the sample to individuals with good health status and re-estimate Eq. (1) in Table A5. The estimated impacts are very similar to the baseline estimates and remain statistically significant. In particular, a 1-percentage-point increase in the initial infection risk reduces the incidence of regular alcohol use by approximately 0.8 percentage points or 6% for all and about 1.63–1.8 percentage points (or equivalently 6.9–7.6%) for men.

Second, we address the concern of confounding vaccination effects with the impacts of parental risk preference by controlling for own and/or parental degree of risk aversion based on the five hypothetical questions regarding one's risk preference in the CFPS. In the survey, respondents are asked to compare receiving a fixed amount of money for sure and participating in a lottery with a certain amount of prize. Based on these questions, we construct an ordered variable ranging from 1 to 6, with a higher value representing a higher degree of risk aversion,

and include it in the regression as five indicators.[23] In Table A6, we first control for parental risk preference and further add children's own risk preference to the regression. The estimates are very similar to our baseline results.

Finally, the 9-year compulsory education law (CEL) took effect on July 1, 1986; hence, all cohorts in the baseline sample were affected. But due to the staggered enforcement of the CEL at the province level, there might be heterogenous effects across cohorts, which then confound the estimated vaccination effects. To mitigate this concern, we use two ways to exclude its potential effects in Table A7. Results confirm that the baseline estimates are insensitive to the inclusion of the CEL.

5.3.5 Sample selection

The sample selection problem could arise on two occasions. First, people might migrate across provinces for health concerns. Therefore, we restrict the analytic sample to the non-migrants whose provinces of residence are the same as their birthplaces. Results in Table A8 are almost identical to the baseline estimates.

Second, our baseline sample only includes individuals who survived in the long run. This is unlikely a concern for the sampling cohorts since HBV infections often manifest after middle age, especially post-40 years old (Kao and Chen 2002; Zu et al. 2017). Nonetheless, we examine this selection problem in two ways. We use the annual average mortality per 100,000 people shown in Table A9 and back out the number of observations that are potentially missing due to selection.[24] We find that the sample selection problem is trivial. Only two people were selected for liver cancer, accounting for merely 0.04% of our baseline sample size, and about 29.5 were selected by all-cause disease mortality, which is only about 0.53% of the baseline sample size.[25]

We also utilize the birth information collected for all members in the baseline households regardless of whether they were alive, which is only available in the CFPS 2010 data. It enables us to locate all individuals born between 1981 and 1994 whose households were surveyed by the CFPS. By replacing the dependent variable in Eq. 1 with the indicator for whether one has died by 2010, we find in Table A10 that the vaccination effects are neither statistically nor economically significant. Overall, we confirm that sample selection is negligible.

[23] Specifically, the variable equals 1 if one consistently chooses the lottery; 2 if one stops preferring the lottery when the safe price raises to 150 yuan; 3 if one stops preferring the lottery when the safe price is 120 yuan; 4 if one begins to prefer the lottery when the safe price is 80 yuan; 5 if one begins to prefer the lottery when the safe price is 50 yuan; 6 if one consistently chooses the safe price over the lottery.

[24] We impute the survival function at age t as $S = \Pr(T \geq t) = \sum_{k=t}^{\infty} f_k = 1 - \sum_{k=1}^{t} f_k$ where $f_k = \Pr(T = k)$ with $k = 1, 2, \ldots$ Dividing the number of observations within each birth cohort by the survival rate S then yields the complete cohort sizes. We then multiply the imputed cohort sizes with the probability of dying any time between age 1 and age t, denoted by $\sum_{k=1}^{t} f_k$, and repeat this process for all baseline birth cohorts. We note that the survival rate for a given cohort is imputed based on the mortality at the age when they were surveyed by the CFPS in 2018, i.e., $S = 1 - tf_t$. Since children are much less likely to die from liver cancer than adults, our estimated size of selection is possibly the upper bound.

[25] Admittedly, the average annual mortality rates are imputed based on the time period after 2004, not exactly the entire time period our baseline cohorts have experienced. This may lead us to understate the size of the selection problem if earlier periods have higher mortality rates.

6 Mechanisms

In the previous sections, we find robust evidence that more exposure to the anti-HBV vaccination leads to a reduced probability of regular alcohol use during adulthood. To rationalize this negative effect, we consider two mechanisms.

6.1 Human capital

There is empirical evidence suggesting that vaccination improves the accumulation of human capital, and the literature has also discovered some channels through which education is affected. For example, Baranov and Kohler (2018) find that antiretroviral therapy (ART), a treatment for HIV, significantly increases household expenditures on education and children's schooling, and they find that the extended life expectancy and positive income effect through saved healthcare costs are important contributors; Oskorouchi et al. (2020) show long-run positive impacts of childhood vaccinations on education and cognitive skills; Kuecken et al. (2021) find that the anti-malaria campaigns in Sub-Saharan Africa lead to an increase in children's years of schooling since reducing malaria improves learning through biological means; Zhang et al. (2021) explore the anti-HBV vaccination campaign in China and find significant increases in children's educational attainments due to longevity gains; and He et al. (2022) show that children's human capital benefits from the introduction of Meningitis vaccines in China.

In Table 6, we examine whether individual educational attainment is affected by the anti-HBV vaccination for our analytic sample. Results suggest that more exposure to vaccination improves men's education but has null effects on the education among their female counterparts. This is consistent with Driessen et al. (2015), who also find gender disparity in the childhood measles vaccination effects on schooling in Bangladesh, possibly due to son preference. Specifically, we find that a 1-percentage-point increase in the exposure raises the likelihood of completing at least primary school and middle school education by about 0.25 and 0.42 percentage points, respectively, while such positive effects do not occur at the high-school margin. Given the strong evidence that education is negatively associated with alcohol drinking (e.g., Murakami and Hashimoto 2019; Crum et al. 1993; Liu et al. 2020), the reduction in individual alcohol use could be driven by improved educational attainment as a result of the vaccination.

In addition, since existing literature has found strong evidence of a causal link between education and the majority of health outcomes (e.g., Brunello et al. 2016; Hamad et al. 2018), the educational gains associated with the vaccination program may lead to significant improvements in other health outcomes as well. To this end, we extend our baseline analysis to other health outcomes, including self-assessed health, overweight status, incidence of inpatient care, medical expenditures, current life expectancy, and cigarette smoking behavior. Details can be found in Appendix B.

Table 6 Vaccination effects on individual educational attainment

	All	Male	Female
	(1)	(2)	(3)
At least complete primary school			
Risk × post1988	−0.0001	0.0025*	−0.0025
	(0.0009)	(0.0015)	(0.0018)
Mean dependent variable	0.959	0.972	0.943
Observations	5708	3203	2505
At least complete middle school			
Risk × post1988	0.0015	0.0042**	−0.0006
	(0.0021)	(0.0019)	(0.0050)
Mean dependent variable	0.872	0.884	0.858
Observations	5708	3203	2505
At least complete high school			
Risk × post1988	−0.0027	−0.0034	−0.0043
	(0.0037)	(0.0044)	(0.0048)
Mean dependent variable	0.507	0.500	0.515
Observations	5708	3203	2505

This table estimates the vaccination campaign's impacts on individual educational attainment. All specifications shown include birth cohort indicators interacted with regional averages of the outcome variable and pretreatment provincial measures, individual and family characteristics, province, birth cohort, and survey month fixed effects. In this table, we further control for an individual's number of siblings so as to alleviate the confounding effect of quality-quantity tradeoff and parental educational attainment, which are perceived as a kind of social-economic background affecting children's attitudes toward the importance of education. Because we have included the mean-reversion term, the estimations do not control for the interaction between the provincial shares of people with at least middle-school education and birth cohort dummies. Results on demographic and provincial characteristics are not reported. Standard errors are in parentheses and clustered at the place-of-birth level. $p<0.1$; ** $p<0.05$; *** $p<0.01$

6.2 Dissemination of knowledge

According to the "National Hepatitis B Immunization Plan," local health departments are also responsible for educating the public with HBV-related knowledge. For example, in Anhui, local experts and healthcare workers showed up on TV promoting anti-HBV vaccines, and there were approximately 400 news articles related to hepatitis B in 1992 (Chen et al. 1993). Therefore, it is likely that people benefit from the vaccination campaign not only through them being vaccinated but also through their dissemination of related knowledge.

To test this channel, we face two challenges. First, the dissemination of information is hard to measure. Second, children who were prioritized in the vaccination campaign were too young at the time to be directly educated, and thus, they

Table 7 Vaccination effects on the incidence of father's regular alcohol use

	(1)	(2)	(3)	(4)	(5)	(6)
Risk × post1988	0.0024	0.0021	0.0047	0.0048	0.0010	0.0010
	(0.0029)	(0.0028)	(0.0035)	(0.0034)	(0.0029)	(0.0029)
Risk × post1988 × 1(edu$_f$ ≥ highschool)			−0.0109*	−0.0128**		
			(0.0061)	(0.0055)		
Risk × post1988 × 1(edu$_m$ ≥ highschool)					−0.0170***	−0.0165***
					(0.0054)	(0.0055)
Effect on the higher-educated			−0.0062	−0.0080*	−0.0160***	−0.0155***
Mean dependent variable	0.315	0.318	0.315	0.318	0.312	0.314
Observations	6519	6084	6519	6084	5448	5106
Children characteristics	No	Yes	No	Yes	No	Yes

This table estimates the vaccination campaign impacts on the incidence of father's regular alcohol use based on Eq. (1). We control for children's characteristics including gender, education level indicators, marital status indicators, and current hukou type in columns 2, 4, and 6. Other covariates are defined the same as in Eq. 1. In columns 3 and 4, we interact the treatment variable with the indicator for whether father's education level is at least high school. In the last two columns, we interact the treatment variable with the indicator for whether mother's education level is at least high school. All specifications shown include birth cohort indicators interacted with regional averages of the outcome variable and pretreatment provincial measures, individual and family characteristics, province, birth cohort, and survey month fixed effects. Results on demographic and provincial characteristics are not reported. Standard errors are in parentheses and clustered at the place-of-birth level. $p<0.1$; ** $p<0.05$; *** $p<0.01$

probably obtained the relevant knowledge through someone else, possibly their parents. In this case, parents were educated during the campaign and passed the information onto their children later on, and if parents are indeed the "messengers," we might expect their own risky behaviors to be changed. Since older children and adults were not the targeted population of the 1992 vaccination campaign, we believe that the dissemination of knowledge is plausibly limited among parents of older and even adult children.

Results in Table 7 are obtained by estimating Eq. 1 based on the father's current alcohol use behaviors. We include the father's marital status and indicators for the father's age groups, with other covariates defined the same as in the baseline analyses. To mitigate the concern that fathers' drinking may be affected by their adult children, we add children's characteristics, such as their gender, educational attainment, marital status, and hukou type to the regression. Overall, we find null campaign effects on fathers' alcohol use in the first two columns.

We further consider the potential heterogeneity by parental education since parents with higher education might process the information better than their less-educated counterparts and are also more likely to educate their children. Specifically, in columns 4 and 5, we interact the campaign variable with the indicator for whether father's education level is at least high school. Its coefficient thus reflects the difference in the campaign effects between high- and low-educated fathers. Consistent with our prediction, the statistically significant interaction term (e.g., Risk × post1988 × 1(edu$_f$ ≥ high school)) implies that the information channel differs

between the two groups. We further confirm that this channel only exists among the higher-educated by adding up the coefficient of the reference group (Risk × post1988) with that of the interaction term (e.g., Risk × post1988 × 1(edu$_f$ ≥ high school)). This difference is even larger in the last two columns, where we examine the effects based on whether the spouse's education level is at least high school.

We would not expect that the reaction of the father's alcohol use to the vaccination campaign is driven by direct vaccination since adults were not even eligible for the vaccination during the campaign, and neither are they likely to be affected through positive externality. Therefore, the father's drinking behavior likely reflects health knowledge. The significant interaction term (e.g., Risk × post1988 × 1(edu$_f$ ≥ high school)) is also useful in explaining the heterogenous effects in Table 5, where individuals from higher-educated families are much less likely to be regular drinkers (−0.0128) compared with their less-educated counterparts (−0.0055). Since this information channel is significantly different between people from higher-educated and less-educated families, it may lead us to find different results on their alcohol use.

7 Conclusion

This paper examines the causal effect of vaccination on an individual's risky behaviors. We pay particular attention to individual alcohol use during adulthood and exploit the introduction of the hepatitis B vaccination campaign in China in 1992. This is essential for policy evaluation since an individual's behavioral responses could reinforce or compromise the ultimate effectiveness of the vaccination.

Using the cohort DD approach based on a cross-section of individuals born between 1981 and 1994, we find that more exposure to the anti-HBV vaccines has unexpected benefits. Specifically, a 1-percentage-point increase in the vaccination exposure intensity, measured as the initial infection risks, reduces the likelihood of regular alcohol drinking by about 6.89% and as large as 7.72% among men. These results are robust to a series of tests. We further find some heterogeneous effects: individuals from more educated families and people who live in urban areas experience a larger decline in the likelihood of being regular alcohol users. Human capital accumulation and dissemination of related knowledge are potential contributors to the reduction in regular alcohol use. A back-of-the-envelope calculation suggests that for every yuan spent on the anti-HBV vaccination, the health benefits amount to 41.68 yuan (see Appendix C). This is very close to the benefit–cost ratio of 39.41 estimated by Jiang et al. (2003) based on a sample of about 2800 workers in a particular steel corporation in China.

Our findings should inform the policymakers, especially the developing countries where the uptake of the vaccine remains low, such as India (Khan et al. 2019) and the African region (World Health Organization 2017). In these countries, health infrastructure is relatively weak, healthcare insurance is often insufficient, and people with chronic HBV infection have to bear large medical costs themselves since the treatments are usually not included in the insurance plans.

Our findings suggest that promoting vaccination during early life is likely to have long-term health benefits since people respond to the vaccination by reinforcing the effectiveness of the vaccines through reduced risky behaviors. We cautiously note that the evaluation of the effectiveness of vaccines might be needed on a case-by-case basis. Nonetheless, the results that people take up more precautions suggest that there are likely large benefits of adding and strengthening policy interventions in vaccination coverage.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00148-023-00942-4.

Acknowledgement We thank the Editor, Xi Chen, and three anonymous referees for their very helpful comments. We also thank participants at the 20th Quarterly Conference of the China Labor Economists Forum, the 9th Conference on Asia and Pacific Economies, and CHLR Applied Microeconomics seminar for their comments and discussions.

Author contribution All authors have contributed equally.

Funding This research is supported by the National Science Foundation of China (grant nos. 71873080 and 72273076).

Data Availability The main dataset used in this study is available to the public at China Family Panel Studies website: http://isss.pku.edu.cn/cfps/en/index.htm.

Declarations

Conflict of interest The authors declare no competing interests.

References

Abbas Z, Siddiqui AR (2011) Management of hepatitis B in developing countries. World J Hepatol 3(12):292–299

Adhvaryu A, Fenske J, Nyshadham A (2019) Early life circumstance and adult mental health. J Polit Econ 127(4):1516–1549

Almond D, Currie J (2011) Human capital development before age five. In: Card D, Ashenfelter O (ed) Handbook of Labor Economics, 1st edn. Elsevier, California, pp 1315–1486

Alsan M (2017) The gendered spillover effect of young children's health on human capital: evidence from Turkey. Working paper 23702. Natl Bureau Econ Res. https://doi.org/10.3386/w23702

Baranov V, Kohler HP (2018) The impact of AIDS treatment on savings and human capital investment in Malawi. Am Econ J Appl Econ 10(1):266–306

Bersohn I, Macnab GM, Pyzikowska J et al (1974) The prevalence of hepatitis B (Australia) antigen in Southern Africa. S Afr Med J 48(5):941–944

Bharadwaj P, Løken KV, Neilson C (2013) Early life health interventions and academic achievement. Am Econ Rev 103(5):1862–1891

Brewer NT, Cuite CL, Herrington JE et al (2007) Risk compensation and vaccination: can getting vaccinated cause people to engage in risky behaviors? Ann Behav Med 34(1):95–99

Brown DW, Kowalski AE, Lurie IZ (2020) Long-term impacts of childhood Medicaid expansions on outcomes in adulthood. Rev Econ Stud 87(2):792–821

Brunello G, Fort M, Schneeweis N et al (2016) The causal effect of education on health: what is the role of health behaviors? Health Econ 25(3):314–336

Centers for Disease Control and Prevention (2008) Recommendations for identification and public health management of persons with chronic hepatitis B virus infection. Morb Mortal Wkly Rep 57(No. RR-8):1–20

Chay K, Guryan J, Mazumder B (2009) Birth cohort and the black-white achievement gap: the roles of access and health soon after birth. Working paper 15078. Natl Bur Econ Res. https://doi.org/10.3386/w15078
Chen Y, Zu G, Chen X et al (1993) Evaluation on the health education of the hepatitis B immunization plan. Chin J Health Ed (in Chin) 9(2):21–23
Chetty R, Friedman JN, Hilger N et al (2011) How does your kindergarten classroom affect your earnings? Evidence from Project STAR. Quart J Econ 126(4):1593–1660
Correia S (2015) Singletons, cluster-robust standard errors and fixed effects: a bad mix. Duke University, Technical Note
Coursaget P, Yvonnet B, Chotard J et al (1987) Age-and sex-related study of hepatitis B virus chronic carrier state in infants from an endemic area (Senegal). J Med Virol 22(1):1–5
Crum RM, Helzer JE, Anthony JC (1993) Level of education and alcohol abuse and dependence in adulthood: a further inquiry. Am J Public Health 83(6):830–837
Cui F, Zhuang H (2016) Hepatitis B control in China: progress, challenges and strategies. Chin J Viral Dis (in Chin) 6(2):81–87
Currie J, Vogl T (2013) Early-life health and adult circumstance in developing countries. Annu Rev Econ 5(1):1–36
Currie J, Stabile M, Manivong P et al (2010) Child health and young adult outcomes. J Human Resour 45(3):517–548
Delavande A, Kohler HP (2016) HIV/AIDS-related expectations and risky sexual behaviour in Malawi. Rev Econ Stud 83(1):118–164
Donken R, Tami A, Knol MJ et al (2018) Changes in (risk) behavior and HPV knowledge among Dutch girls eligible for HPV vaccination: an observational cohort study. BMC Public Health 18(1):837
Dow WH, Philipson TJ, Sala-i-Martin X (1999) Longevity complementarities under competing risks. Am Econ Rev 89(5):1358–1371
Driessen J, Razzaque A, Walker D et al (2015) The effect of childhood measles vaccination on school enrolment in Matlab, Bangladesh. Appl Econ 47(55):6019–6040
Duflo E (2001) Schooling and labor market consequences of school construction in Indonesia: evidence from an unusual policy experiment. Am Econ Rev 91(4):795–813
Einav L, Finkelstein A (2018) Moral hazard in health insurance: what we know and how we know it. J Eur Econ Assoc 16(4):957–982
Fan W, Porter C (2020) Reinforcement or compensation? Parental responses to children's revealed human capital levels. J Popul Econ 33(1):233–270
Friedman WH (2018) Antiretroviral drug access and behavior change. J Dev Econ 135(November 2018):392–411
Frio GS, França MTA (2021) Human papillomavirus vaccine and risky sexual behavior: regression discontinuity design evidence from Brazil. Econ Human Biol 40(January 2021):100946
Gitlin N (1997) Hepatitis B: diagnosis, prevention, and treatment. Clin Chem 43(8):1500–1506
Gong E (2015) HIV testing and risky sexual behaviour. Econ J 125(582):32–60
Guo X, Yi Z, Bi J (1999) Hepatitis B and anti-HBV vaccination in China. Dis Surveill (in Chin) 14(4):150–153
Gust ID (1996) Epidemiology of hepatitis B infection in the Western Pacific and South East Asia. Gut 38(Suppl 2):S18–S23
Hamad R, Elser H, Tran DC et al (2018) How and why studies disagree about the effects of education on health: a systematic review and meta-analysis of studies of compulsory schooling laws. Soc Sci Med 212(2018):168–178
He F, Huang W, Wang J (2022) Vaccination, human capital investment, and economic growth. Paper presented at the 20th Quarterly Meeting of the China Labor Economists Forum, Guangdong, March 26, 2022
Hu S (1992) Discussions about the implementation of the "National Hepatitis B Immunization Plan." Chin J Public Health Manag (in Chin) 8(1):34–35
Ji C (2010) Prevalence of binge drink in Chinese college students. Chin J School Health (in Chin) 31(10):1157–1160
Jia Z, Wu G, Su C et al (1999) An investigation on hepatitis B vaccination of newborns in four provincial capital cities and suburbs. Chin J Vaccines Immunization (in Chin) 5(5):258–261
Jiang D, Liu A, Tan H et al (2003) Health-economics study of hepatitis B vaccination in adults. Chin J Vaccines Immunization (In Chin) 9(3):157–160
Juszczyk J (2000) Clinical course and consequences of hepatitis B infection. Vaccine 18:S23–S25

Kaestner R, Darden M, Lakdawalla D (2014) Are investments in disease prevention complements? The case of statins and health behaviors. J Health Econ 36(July 2014):151–163
Kan Q, Wen J, Xue R (2015) Discrimination against people with hepatitis B in China. The Lancet 386(9990):245–246
Kane M (1995) Global programme for control of hepatitis B infection. Vaccine 13(Suppl 1):S47–S49
Kao JH, Chen DS (2002) Global control of hepatitis B virus infection. Lancet Infect Dis 2(7):395–403
Khan J, Shil A, Mohanty SK (2019) Hepatitis B vaccination coverage across India: exploring the spatial heterogeneity and contextual determinants. BMC Public Health 19(1):1–14
Kim SY (2006) Economic evaluation of vaccination programs: cost-effectiveness, externalities, and affordability of hepatitis B vaccination. Dissertation, Harvard University
Klick J, Stratmann T (2007) Diabetes treatments and moral hazard. J Law Econ 50(3):519–538
Krajden M, McNabb G, Petric M (2005) The laboratory diagnosis of hepatitis B virus. Can J Infect Dis Med Microbiol 16(2):65–72
Kuecken M, Thuilliez J, Valfort MA (2021) Disease and human capital accumulation: evidence from the roll back malaria partnership in Africa. Econ J 131(637):2171–2202
Lei X, Shigeko N, Deng X et al (1999) Prevalence of hepatitis C virus infection in the general population and patients with liver disease in China. Hepatol Res 14(2):135–143
Li J (2004) Gender inequality, family planning, and maternal and child care in a rural Chinese county. Soc Sci Med 59(4):695–708
Li Y, Jiang Y, Zhang M et al (2011) Drinking behaviour among men and women in China: the 2007 China chronic disease and risk factor surveillance. Addiction 106(11):1946–1956
Liang TJ (2009) Hepatitis B: the virus and disease. Hepatology 49(S5):S13–S21
Liu Z, Luo R, Fu R et al (2020) The influences of impulsivity and education levels on severity of alcohol dependence. Front Psych 11:737
Margolis J, Hockenberry J, Grossman M et al (2014) Moral hazard and less invasive medical treatment for coronary artery disease: the case of cigarette smoking. Working paper 20373. Natl Bureau Econ Res. https://doi.org/10.3386/w20373
McMahon BJ (2009) The natural history of chronic hepatitis B virus infection. Hepatology 49(S5):S45–S55
Miller S, Wherry LR (2019) The long-term effects of early life Medicaid coverage. J Human Resour 54(3):785–824
Moghtaderi A, Dor A (2021) Immunization and moral hazard: the HPV vaccine and uptake of cancer screening. Med Care Res Rev 78(2):125–137
Mou Y, Lin CA (2020) Consuming alcohol to prepare for adulthood: An event history analysis of the onset of alcohol use among Chinese college students. SAGE Open 10(3):1–11
Murakami K, Hashimoto H (2019) Associations of education and income with heavy drinking and problem drinking among men: evidence from a population-based study in Japan. BMC Public Health 19(1):1–9
Mysore KR, Leung DH (2018) Hepatitis B and C. Clin Liver Dis 22(4):703–722
National Bureau of Statistics of China (1993) China Statistical Yearbook 1993. China Stat Press, China
Nunn N, Qian N (2011) The potato's contribution to population and urbanization: evidence from a historical experiment. Quart J Econ 126(2):593–650
Ogilvie GS, Phan F, Pedersen HN et al (2018) Population-level sexual behaviours in adolescent girls before and after introduction of the human papillomavirus vaccine (2003–2013). CMAJ 190(41):E1221–E1226
Orito E, Ichida T, Sakugawa H et al (2001) Geographic distribution of hepatitis B virus (HBV) genotype in patients with chronic HBV infection in Japan. Hepatology 34(3):590–594
Oskorouchi HR, Sousa-Poza A, Bloom DE (2020) The long-term cognitive and schooling effects of childhood vaccinations in China. Working paper 27217. Natl Bureau Econ Res. https://doi.org/10.3386/w27217
Peters MG (2009) Special populations with hepatitis B virus infection. Hepatology 49(S5):S146–S155
Prescott SL, Macaubas C, Smallacombe T et al (1999) Development of allergen-specific T-cell memory in atopic and normal children. The Lancet 353(9148):196–200
Roman S, Jose-Abrego A, Fierro NA et al (2014) Hepatitis B virus infection in Latin America: a genomic medicine approach. World J Gastroenterol 20(23):7181–7196
Sadler L, Roberts SA, Hampal G (2015) Comparing risk behaviours of human papillomavirus-vaccinated and non-vaccinated women. BMJ Sex Reprod Health 41:243–244

Smith JP (2009) The impact of childhood health on adult labor market outcomes. Rev Econ Stat 91(3):478–489
Tang C, Zhao L, Zhao Z (2019) Does free education help combat child labor? The effect of a free compulsory education reform in rural China. J Popul Econ 33(2):601–631
Torres-Cornejo A, Lauer GM (2017) Hurdles to the development of effective HBV immunotherapies and HCV vaccines. Pathog Immun 2(1):102–125
United Nations Children's Fund (2018) An atlas of social indicators of children in China. https://www.unicef.cn/en/atlas-2018-en. Accessed 3 Mar 2023
Wang L, Li J, Chen H et al (2007) Hepatitis B vaccination of newborn infants in rural China: evaluation of a village-based, out-of-cold-chain delivery strategy. Bull World Health Organ 85:688–694
Wang S, Smith H, Peng Z (2016) Increasing coverage of hepatitis B vaccination in China: a systematic review of interventions and implementation experiences. Medicine 95(19):e3693
Wilson NL, Xiong W (2014) Mattson CL (2014) Is sex like driving? HIV prevention and risk compensation. J Dev Econ 106:78–91
World Health Organization (2014) Hepatitis B control through immunization: a reference guide. WHO Regional Office for the Western Pacific. https://apps.who.int/iris/handle/10665/208163. Accessed 3 Mar 2023
World Health Organization (2017) Global hepatitis report 2017. WHO. https://www.who.int/publications/i/item/9789241565455. Accessed 3 Mar 2023
Xia G, Liu C, Cao H et al (1996) Prevalence of hepatitis B and C virus infections in the general Chinese population: results from a nationwide cross-sectional sero epidemiologic study of hepatitis A, B, C, D, and E virus infections in China, 1992. Int Hepatol Commun 5(1):62–73
Yang T, Wu M (2011) Discrimination against hepatitis B carriers in China. The Lancet 378(9796):1059
Yi J, Heckman JJ, Zhang J et al (2015) Early health shocks, intra-household resource allocation and child outcomes. Econ J 125(588):F347–F371
Yin Y, Li G, Wang Y et al (2021) Analysis of the characteristics of hepatitis B in various regions of China from 2009 to 2011 and the analysis of TCM diagnosis and treatment plans. In: 2021 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). IEEE, Houston, Texas, USA, 3912–3918
Yu W, Lee LA, Liu Y et al (2018) Vaccine-preventable disease control in the People's Republic of China: 1949–2016. Vaccine 36(52):8131–8137
Zhang H, Qian L, Zhou K (2021) Disease prevention and human capital investments. Paper Presented Appl Econ Workshop, Shanghai, June 18–19, 2021
Zhou YH, Wu C, Zhuang H (2008) Vaccination against hepatitis B: the Chinese experience. Chin Med J 121(1):98–102
Zhuang H (2004) Epidemiology of hepatitis. Chin J Vaccines Immunization (in Chin) 10(3):180–181
Zu J, Zhuang G, Liang P et al (2017) Estimating age-related incidence of HBsAg seroclearance in chronic hepatitis B virus infections of China by using a dynamic compartmental model. Sci Rep 7(1):1–12