Environment, Public Policy and Human Capital

Human Capital Effect of a Hepatitis B Vaccination Program

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Hepatitis B

- Infectious disease arising from the hepatitis B virus (HBV) that cause acute or chronic liver diseases
- Potentially life-threatening.
- Some new HBV infections become chronic infections, while others evolve towards spontaneous clearance of the virus.
- Risk of developing chronic infection with HBV is highest among children.
- Those infected with HBV are not aware of their disease, unless they are tested and diagnosed, while inflammation progresses in the liver.

Chronic Hepatitis B

- Hepatitis B infection may be acute and an infected individual achieves complete immune clearance of virus yielding lifelong immunity
- The likelihood of chronic hepatitis B is higher if infected perinatally (90%) compared to those infected in adulthood (1%).
- Chronic hepatitis B - HBsAg remains detectable for life, titers of viral DNA tend to decline overtime.
  - Usually asymptomatic
  - Common symptom: Fatigue
  - Other symptoms: Sleep disorders, difficulty concentrating, and upper right quadrant pain.
  - Flare - ongoing immune attack on infected cells in the liver.
  - Exacerbation of hepatitis in patients with chronic hepatitis B virus infection

Hepatitis B virus - Global health problem

- HBV infection has been a global health problem.
- Around a third of the world population have been infected with hepatitis virus.
- 257 million of them are chronic carriers of the virus, and 1.34 million deaths in 2015 (WHO 2017).
- The prevalence rate HBV infection is especially high in South East Asia, Africa, and sourthern Europe, and Latin America.
- The prevalence of HBV infection has been low in developed countries and they adopt a strategy of immunizing high risk individuals (e.g., neonates of infected mothers, households or sexual contacts of individuals infected with HBV, injecting drug users, hemodialysis patients, hemophiliacs).
- The prevalence rate of HBV infection was high in developing countries and the heavy burden caused by hepatitis B virus has prompted the implementation of mass vaccination programs in Asia in the 1980s.

Public health literature on HBV vaccinaton programs

- Numerous studies on the efficacies of HBV vaccination programs
- Reduction in the HBV infection prevalence rate or liver diseases
  - Lao et al. (2013) look at the programto immunize neonates in Hong Kong in 1983.
  - Chang et al. (1997) investigate the effect of the 1984 universal vaccination programon the incidence of hepatocellular carcinoma in children in Taiwan.
  - Liang et al. (2009) examine the impact of universal HBV vaccination, launched since 1992, on the prevalence of hepatitis B survance antigen.

Economics literature on vaccination

- Focus on the behavioral aspects
- They examine on how different factors affect individuals' vaccination decisions.
  - Philipson (1996) and Oster (2018) look at individuals' response to prevalance rates.
  - Anderberg et al. (2011) look at individuals' response to prices.
  - Chang (2016), Lawler (2017) and Abrevaya and Mulligan (2011) examine response to mandates.

HBV vaccination program in Taiwan

- Launched on July 1, 1984, the program in Taiwan has two phaces
  - Initially only newborns with a HBsAg-carrier mother were given vaccines free of charge.
  - Extended to all newborns on July 1, 1986.
- Affected high-risk individuals born after July 1, 1984 and all other individuals born after July 1, 1986.

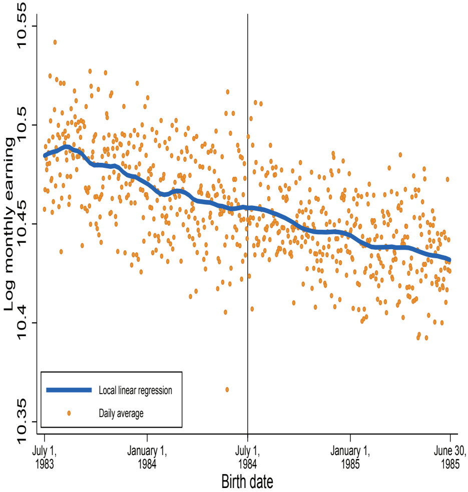
Data

- Administrative records of Taiwan's National Health Insurance (NHI).
- We use the NHI data in an on-site facility maintained by Ministry of Health and Welfare (MOHW).
- All individuals covered by NHI.
- Our analysis includes only workers covered by Labor Insurance
  - Exclude: government employees, self-employed, farmers, and fishermen - income is not accurate.
- Information on individuals' income and sector of employment recorded because an individual's NHI premium varies with them.
- Look at 2013-2016 income.
- Link with 2000 Population Census
  - Parental income & education (for heterogenous effects analysis) and county of birth (as controls).

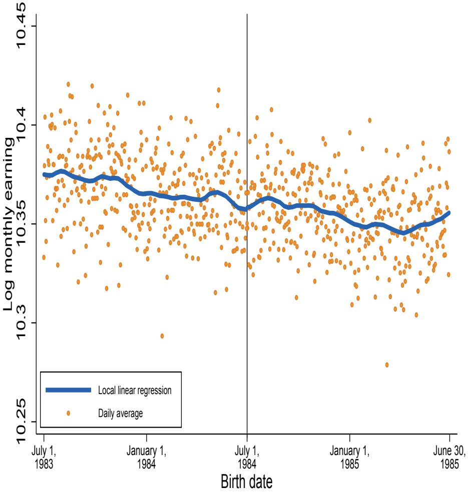
Exploratory Analysis

Private sector workers - born before and after July 1, 1984

Men

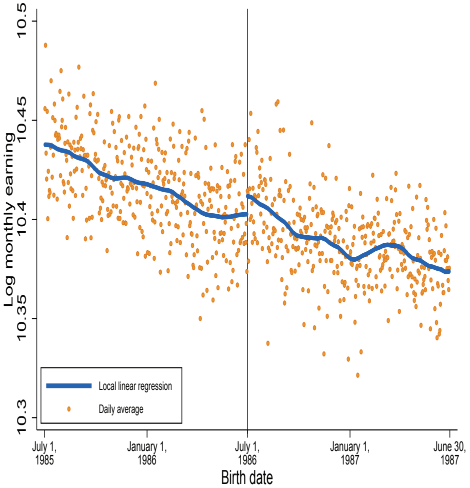


Women

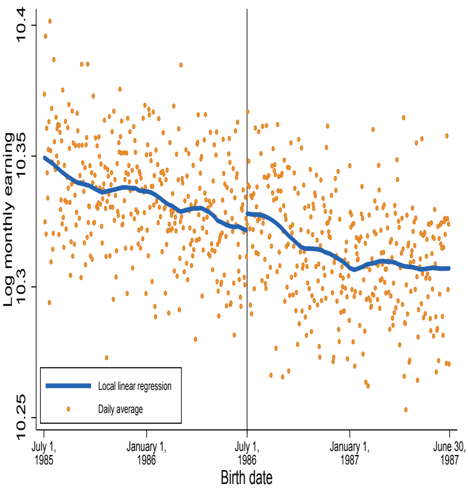


Exploratory Analysis
Private sector workers - born before and after July 1, 1986

Men

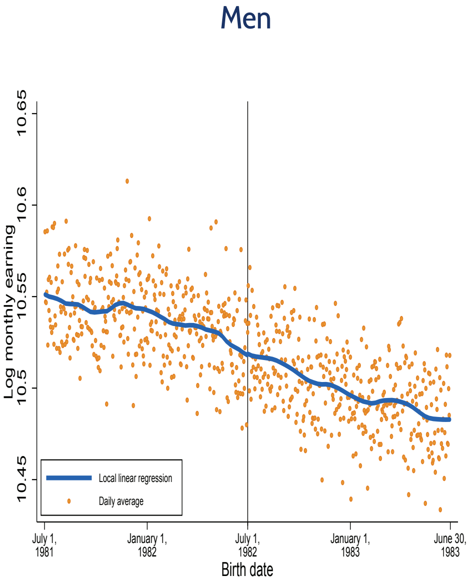


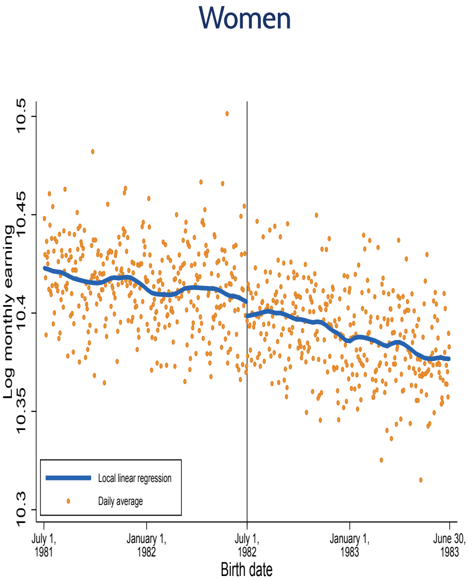
Women



Exploratory Analysis

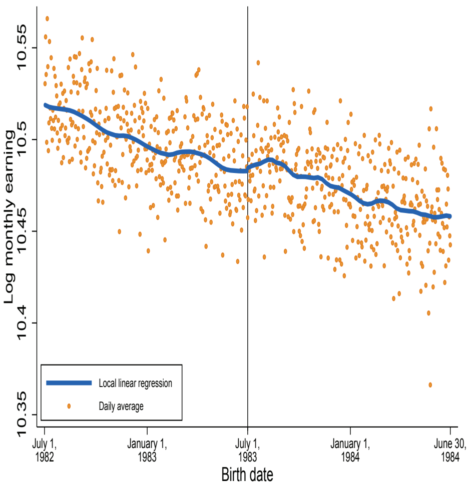
Private sector workers - born before and after July 1, 1982



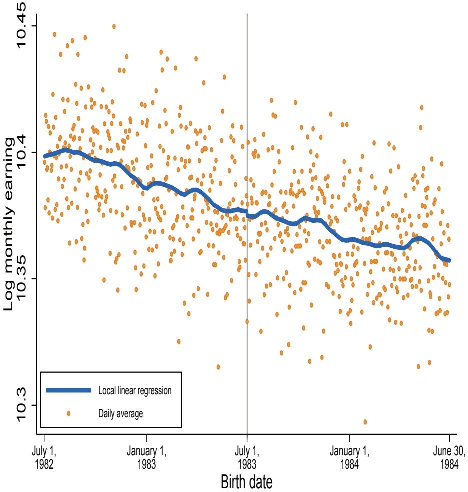


Exploratory Analysis
Private sector workers - born before and after July 1, 1983

Men



Women



Identification Strategy

- Sharp regression discontinuity design (SRDD), with the local linear regression.

$$
\begin{aligned}
y_{it} &= \alpha_0 + \alpha_1^p D_i^p + + \alpha_2^p R_i^p + \alpha_3^p D^p \times R_i^p + \alpha_4^p S_i + \alpha_5^p S_i \times R_i^p \\
&\quad + \alpha_6^p \boldsymbol{X}_i + \epsilon_{it}^p, \qquad (1)
\end{aligned}
$$

where $y_{it} =$ log monthly salary; $t = 2013\text{–}2016$; $p = 1984, 1986.$

$D_i^p =$ dummy - exposed to the year p vaccination program,

$\boldsymbol{X}_i =$ demographic characteristics (e.g., county of birth),

$R_i^p =$ number of days born after the launch of the program,

$S_i =$ dummy - born after September 1.

$\epsilon_{it}^p =$ error term,

- The triangular kernel for the local linear regression.
- Bandwidth - Imbens & Kalyanaraman (2012)
- s.d. clustered at the individual level.
- Parameter of interest α_1^p
    - Effect of year p's vaccination program on income

1984 Phase of the Program

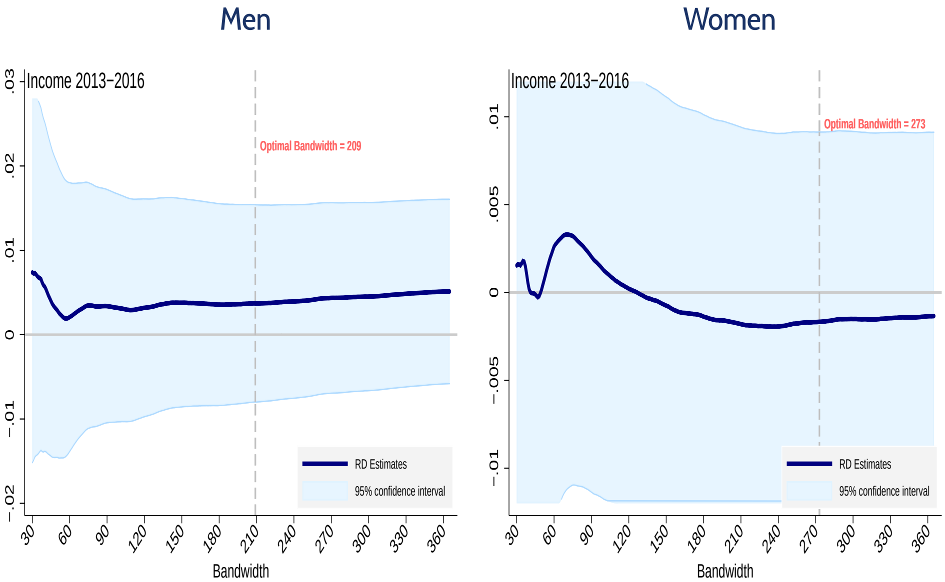
Table: Effect of the 1984 Phase of the HBV Vaccination Program†

	Private Sector	
	Men [1]	Women [2]
Bandwidth	209	273
Born after 1984/7/1	0.0037 (0.0060)	-0.0017 (0.0055)
R^2	0.0178	0.0219
Observations	431319	489304
Mean Monthly Income	10.4563 (0.3687)	10.3606 (0.3359)

† The triangular kernel is used. Bandwidths choosen for mortality by the method proposed by Imbens and Kalyanaraman (2012). Standard errors in parentheses.

Effect of the 1984 phase of the program

Private sector workers



1986 Phase of the Program

Table: Effect of the 1986 Phase of the HBV Vaccination Program†

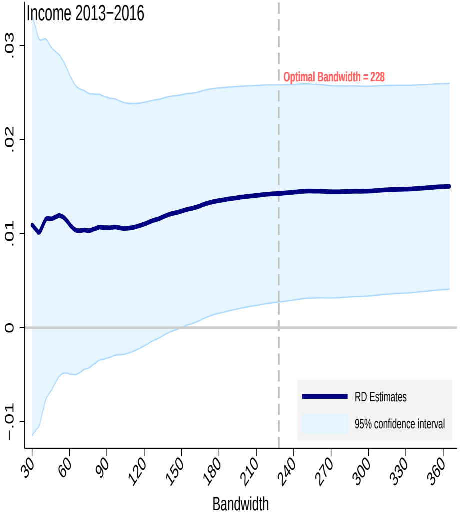
	Private Sector	
	Men	Women
	[1]	[2]
Bandwidth	228	181
Born after 1986/7/1	0.0143*** (0.0059)	0.0086 (0.0060)
R^2	0.0235	0.0244
Observations	386873	272215
Mean Monthly Income	10.4018 (0.3459)	10.3235 (0.3169)

† The triangular kernel is used. Bandwidths choosen for mortality by the method proposed by Imbens and Kalyanaraman (2012). Standard errors in parentheses.

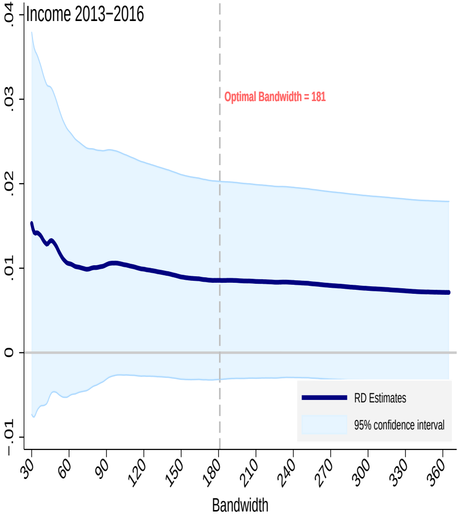
Effect of the 1986 phase of the program

Private sector workers

Men



Women



Placebo Test

Table: Placebo test: Assuming 1982 as the Launch Year†

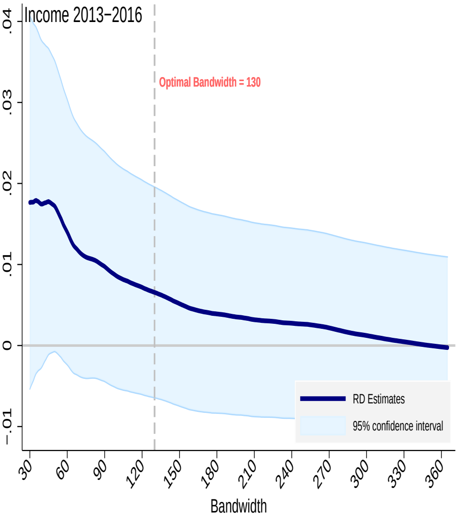
	Private Sector	
	Men	Women
	[1]	[2]
Bandwidth	130	178
Born after 1982/7/1	0.0066	-0.0089
	(0.0066)	(0.0061)
R^2	0.0154	0.0246
Observations	294109	342907
Mean Monthly Income	10.5198	10.4027
	(0.3937)	(0.3600)

† The triangular kernel is used. Bandwidths choosen for mortality by the method proposed by Imbens and Kalyanaraman (2012). Standard errors in parentheses.

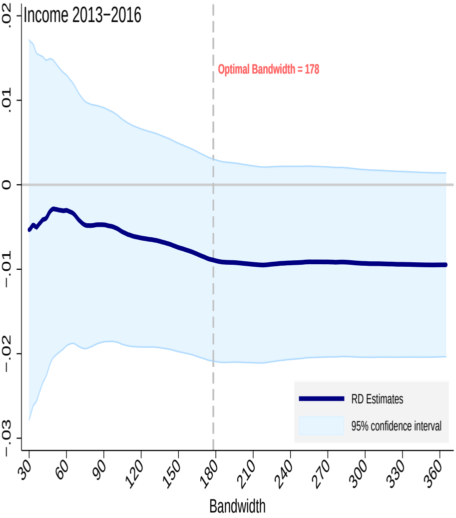
Placebo test - 1982

Private sector workers

Men



Women



Placebo Test

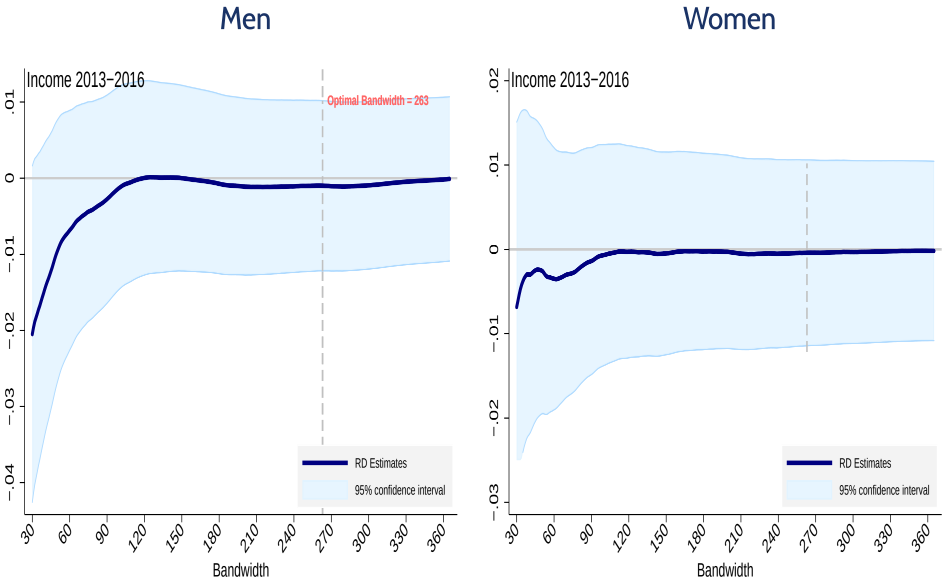
Table: Placebo test: Assuming 1983 as the Launch Year†

	Private Sector	
	Men [1]	Women [2]
Bandwidth	263	365
Born after 1982/7/1	-0.0010 (0.0057)	-0.0002 (0.0054)
R^2	0.0176	0.0240
Observations	568681	671814
Mean Monthly Income	10.4853 (0.3794)	10.3793 (0.3475)

† The triangular kernel is used. Bandwidths choosen for mortality by the method proposed by Imbens and Kalyanaraman (2012). Standard errors in parentheses.

Placebo test - 1983

Private Sector workers



1986 Phase of the Program - Heterogeneous Effects

- Different effect for individuals of different SES?
  - Parental education:

$$y_{it} = \alpha_0 + \alpha_1^p D_i^p + \alpha_{1e}^p D_i^p \times E_p + \alpha_2^p R_i^p + \alpha_3^p D^p \times R_i^p + \alpha_4^p S_i + \alpha_5^p S_i \times R_i^p + \alpha_4^p \mathbf{X}_i + \alpha_4^p E_p + \epsilon_{it}^p, \quad (2)$$

where $E_p = 1$ if at least one parent is univerity graduate.

  - Parental income:

$$y_{it} = \alpha_0 + \alpha_1^p D_i^p + + \alpha_{1t}^p D_i^p \times Inc_{top} + \alpha_{1b}^p D_i^p \times Inc_{bottom} + \alpha_2^p R_i^p + \alpha_3^p D^p \times R_i^p + \alpha_4^p S_i + \alpha_5^p S_i \times R_i^p + \alpha_6^p \mathbf{X}_i + \alpha_7^p Inc_{top} + \alpha_8^p Inc_{bottom} + \epsilon_{it}^p, \quad (3)$$

where $Inc_{top} = 1$ if parental income is top 25%.
$Inc_{bottom} = 1$ if parental income is bottom 25%.

- Linking children-parents using 2000 Census.

The 1986 Program - The role of parental education

Table: Effect of the 1986 Phase of the HBV Vaccination Program†

	Private Sector	
	Men	Women
	[1]	[2]
Bandwidth	342	201
Born after 1986/7/1	0.0078* (0.0046)	0.0091 (0.0058)
Parent's education	0.0767*** (0.0029)	0.0813** (0.0038)
Born after 1986/7/1 × parent's education	0.0010 (0.0042)	0.0019 (0.0052)

† The triangular kernel is used. Bandwidths choosen for mortality by the method proposed by Imbens and Kalyanaraman (2012). Standard errors in parentheses.

The 1986 Program - The role of parental income

Table: Effect of the 1986 Phase of the HBV Vaccination Program†

	Private Sector	
	Men [1]	Women [2]
Bandwidth	208	192
Born after 1986/7/1	0.0116** (0.0054)	0.0099* (0.0054)
Parent's income top 25%	0.0781*** (0.0050)	0.0707*** (0.0051)
Born after 1986/7/1 × parent's income top 25%	-0.0021 (0.0070)	-0.0018 (0.0071)
Parent's income bottom 25%	-0.0306*** (0.0040)	-0.0431*** (0.0039)
Born after 1986/7/1 × parent's income bottom 25%	0.0005 (0.0055)	0.0009 (0.0054)

Implications

Cost-Benefit Analysis:

- Compare the benefit (i.e., exposed individual vs. non-exposed individual) with the cost:
$$Y_i^1 - Y_i^0 \text{ vs. } C \quad (4)$$
  - Present value of life-time income
$$Y_i^0 = \sum_{t=25}^{60} \frac{M_t^0}{(1+r)^{t-25}}, \quad Y_i^1 = \sum_{t=25}^{60} \frac{M_t^0 \times (1+\alpha_1)}{(1+r)^{t-1}} \quad (5)$$
    where M_t^0 = annual income of non-exposed individuals and $M_t^0 \times (1+\alpha_1) = M_t^1$ exposed individuals.
  - $\alpha_1 = 0.0146$ (men), 0.0086 (women), our estimates
  - C =NT$250–500 (vaccination costs, 1984-1986 prices)
  - Y_i = NT$12, 948, 788 (RMB 2,861,547); NT$11, 380, 879 (RMB 2,515,056)
  - $Y_i^1 - Y_i^0$ =NT$185,168 (RMB 41,779) (men), NT$86,131 (RMB 21,629) (women)

$\Longrightarrow Y_i^1 - Y_i^0 > C$

Computation of life-time income

$$Y_i = \sum_{a=25}^{60} M_{a,t} \times \left(\frac{1+g}{(1+f)(1+r)} \right)^{a-25} \tag{6}$$

$M_{a,t}$ = annual income at age a
t = year (2011 data)
g = income growth rate (past 10 years' average, g=0.00754)
f = inflation rate (past 10 years' average, f=0.01001)
r = interest rate (1.5%, r=0.015)

The 1986 Program

Effect on Education

Table: University Entrance Examination Scores (學科能力測驗)†

	3 Subjects		5 Subjects	
	Men [1]	Women [2]	Men [3]	Women [4]
Bandwidth	165	125	175	129
Born after 1982/7/1	-0.0112 (0.0093)	0.0014 (0.0084)	-0.0088 (0.0070)	0.0025 (0.0066)
R^2	0.0012	0.0008	0.0008	0.0007
Observations	38766	29144	41250	30169
Mean	3.2359 (0.2864)	3.2622 (0.2540)	3.8553 (0.2169)	3.8502 (0.2022)

More work to be done

- Health/Medical costs