Health in China: Impacts of Nutrition, Pollution and Education

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I Lei Lu hereby declare that Chapters 2 and 3 of this thesis are entirely my own. Chapter 1 is based on a collaboration with Dr. Melanie Luhrmann. My contribution to the joint work has been in preparing the data for analysis, performing all steps of the empirical analysis and writing the main part of the paper. I have also participated in discussions to exchange research ideas. Where I have consulted the work of others, this is always clearly stated.

Lei Lu

Abstract

This thesis explores issues related to health in China by looking at three different issues.
The first chapter investigates the role of nutrition as one of the major determinants of bodyweight and estimates the income effects on individual nutritional intakes using China Health and Nutrition Survey from 1989-2006 and finds hump-shaped Engel curves in calories for both non-agricultural and agricultural households.
The second chapter looks at the long-run impact of the Cultural revolution and finds that it has induced the treated cohorts to obtain significantly more years of primary education, adopt healthier consumption habits and engage more actively in the labor market,though with a mixed health impact.
Thethird chapter aims to evaluate and compare the health impact of two air quality regulations in China. It finds that being more regulated by the FYP was inversely associated with significantly higher incidences of pollution-related illnesses.To explain this perverse health-policy relationship, this chapter suggests that the FYP did not succeed in inducing pollution-heavy industries to substantially alter their pollution control technologies and may have caused heavy polluters to relocate from more to less regulated areas, leading to persistently worse ambient air quality in High provinces and larger pollution increases in Low provinces over the regulation period.

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Introduction

The first chapter investigates the role of nutrition as one of the major determinants of bodyweight and estimates the income effects on individual nutritional intakes using China Health and Nutrition Survey from 1989-2006. It explicitly accounts for the problem of endogenous income when obtaining the nutrition-income relationship and distinguishes between incomes from agricultural sources and those earned from non-agricultural activities. In practice, the impact of the former is identified from variation in weather shocks and the impact of the latter is identified from institutional changes in marginal tax rates. This chapter finds hump-shaped Engel curves in calories for both non-agricultural and agricultural households. Women were more income elastic towards both total calorie intakes and more specific macro-nutrient intakes (fats, proteins and carbohydrates). There may also be a shift in women's diet pattern away from a more traditional and carbohydrate rich one while no such pattern can be found for men. Also, couples were the least income elastic towards calories and other nutrition intakes in the non-agricultural sector, but they appear to be the most income elastic in the agricultural sector.

The second chapter provides new evidence for the long-term impact of early educational interventions on a wide range of individual adulthood outcomes, including educational attainment, health, health-related consumption habits and labor supply. The education intervention is the 1968-1976 Cultural Revolution education system that almost universalized primary education among school-aged kids and improved primary school quality. Policy intensity varied by year-of-birth in terms of when the intervention was introduced and place-of-birth in terms of its quantitative and qualitative relevance. Specifically, the treated cohorts consist of those born in 1955-1970 while the control is those born in 1949-1954. The More Rural cohorts (born in rural-villages or suburban areas) benefited much more than the More Urban cohorts (born in rural-towns or cities) from the Cultural Revolution. Exploiting both the More Rural and year-of-birth differentials, this study finds that the Cultural Revolution has induced the treated cohorts to obtain significantly more years of primary education, adopt healthier consumption habits and engage more actively in the labor market, though with a mixed health impact. The estimates can be viewed as reliable since they remain stable across various robustness checks. Then to better understand the estimated results, this chapter provides evidence suggesting the existence of two potential pathways through which the impact of the Cultural Revolution may have operated, that is, by shaping individual preferences and influencing individual investment in education. The dataset used is from China Health and Nutrition Survey for years 2000-2009.

The third chapter aims to evaluate and compare the health impact of two air quality regulations in China. The two air quality regulations, the 10th Five-Year Plan (2001-2005) and the 11th Five-Year Plan (2006-2010), asked for nationwide reductions in pollutant discharges of sulfur dioxide and Total Suspended Particulates. Due to the lack of direct measures for regulatory pressure, existing evidence on their health effectiveness remains limited. This analysis proposes using province High and Low pollution status to proxy for province High and Low FYP regulatory pressure. Because first there was geographical variation in province ambient air quality before each FYP and second after each FYP the High provinces experienced larger pollution reductions than the Low provinces. The health impact is then estimated by comparing pre-post FYP changes in individual health in High provinces to the corresponding changes in in Low provinces, using China Health and Nutrition Survey from 2000-2006. This chapter finds that being more regulated by the FYP was inversely associated with significantly higher incidences of pollution-related illnesses. This perverse finding is insensitive to attempts made to deal with the limitations of the province High/Low, alternatives measures of health and regulation relevance and remains stable across different socioeconomic subgroups. To explain this perverse health-policy relationship, this chapter suggests that the FYP did not succeed in inducing pollution-heavy industries to substantially alter their pollution control technologies and may have caused heavy polluters to relocate from more to less regulated areas, leading to persistently worse ambient air quality in High provinces and larger pollution increases in Low provinces over the regulation period.

Chapter 1 The Impact of Chinese Income Growth on Nutritional Outcomes

1 Introduction

In recent years, obesity and overweight arose as one of the most prevalent health risks in modern society. While obesity and overweight levels are especially high in developed countries like the US and the UK (Bleich et al., 2008), overweight prevalence is with 22% comparatively low in emerging economies like China (Figure 1). However, countries such as China and India face a double challenge with respect to weight: A relatively persistent fraction of the population which is underweight and in parallel a fast rising fraction which is overweight or obese. Furthermore, obesity levels are rising fast.

Both these health risks – under- and overweight- are related to diet, as individual bodyweight evolves through the (im)balance between calorie intake (Chou et al., 2004; and Bleich et al., 2008) and occupational and other physical activity (Lakdawalla et al., 2007; Ng et al., 2009). According to Ng et al. (2011), around 5% of weight gain can be attributed to declines in occupation and/or home activities and around 3% of weight gain in China results from dietary changes between 1991 and 2006.

The two main economic factors determining such dietary changes are incomes and prices. This paper investigates the role of income changes in altering diets based on a sample of Chinese men and women from 1989 to 2006. China has experienced an unprecedented period of strong economic growth and a large economic transition over the last decades. Figure 2A showsthe massive individual income (at 2009 price) growth in China of around 259% for males and 204% for females - resulting in increasesin household income (at 2009 yuan) of around 181% for singles, 248% for couples, and 162% for larger households (see Figure 2B).

In face of these strong rises in incomes, we estimate income elasticities in nutrients, in particular those for calories, carbohydrates, fats and proteins. These can help explain the evolution and dispersion of healthy lifestyles. Knowledge of income elasticities for different nutrients further allows anticipating the impact of policy changes involving income transfers on diet and yields a better understanding of the efficiency of such policies in regulating bodyweight. Existing empirical evidence on the effect of public policies using transfers, e.g. food stamps,is mixed (Alaimo et al., 2002; Whitmore, 2002; Krueger, 2004; and Kaushal, 2007). However, these studies have focused on conditional cash or in-kind programs.

Unconditional income transfers like welfare benefit programs may have a different effect on nutritional intake and consequently recipients' health status.

Policy interventions may alternatively target food prices. Goldman et al. (2010) focus on the role of food prices in contributing to weight gains using the Chinese Health and Nutrition Survey from 1991 to 2006. They find that decreases in the price of energy-dense foods have consistently led to elevated body fat. For body weight, however, they get mixed results. Their reduced form approach does not establish the transmission channel between food prices and body fat.

Our study contributes to the literature in several ways: first, there are few studies that focus on income effects on calorie intake in a country with strong income growth, China. One of the reasons for this gap in the literature is the difficulty of identifying income effects due to the lack of suitable instruments for endogenous individual or household income which biases conventional estimates. We propose an innovative instrumentation strategy that exploits changes in income tax rates as well as bracket creep, i.e. tax increases resulting from inflation leading to higher nominal incomes and higher marginal taxation due to nominally fixed tax brackets. Our instrumentation strategy carefully distinguishes between households working in the agricultural and non-agricultural sector, reflecting the fact that the former group are food consumers and producers at the same time, while the latter consume food only. The instrumentation strategy is applied for the non-agricultural sector which is liable to income taxes, while instruments for the agricultural sector are based on weather shocks that have been shown to explain income variation in this group (Wolpin, 1982; Paxson et al., 1992; Maccini et al., 2009).

Second, we test the theoretical predictions on the correlation between food consumption and individual income from the model in Lakdawalla et al. (2002), which establishes a non-linear relationship between food consumption and its nutrient content, e.g. calorie intake and income.

Lakdawalla et al. (2002 and 2005) develop a theoretical model of obesity that takes into account individual preferences for weight, food and leisure consumption. They postulate an inverted U-shaped relationship between food consumption and individual income within countries, conditional on occupational physical activity. Conditional on physical activity, calorie intake is increasing in individual income for countries with low per capita income and high food production costs, and calorie intake is decreasing in individual income for countries with high per capita income and low food production costs in their model. We test whether the postulated non-monotonic relationship between calorie intake and individual income is observable in our data.

We find evidence of calorie income profiles that are hump-shaped for both non-agricultural and agricultural households. Unexpectedly, people from non-agricultural and agricultural background have similar attitudes towards calorie consumption: similar income elasticities that are around 0.093 for non-agricultural and 0.082 for agricultural households are estimated. Females are more income elastic towards calorie and other nutrient consumption than males in both sectors. Males from a non-agricultural background are more income elastic towards fat consumption at low income levels. Couples are the least income elastic towards calorie and other nutrient intakes in the non-agricultural sector, but they are the most income elastic in the agricultural sector. Agricultural households of various types do not have different tastes for fat consumption when their incomes reach a certain level (around 35,000 at 2009 prices in the sample). In contrast, singles with an agricultural background have opposite protein intake pattern to that of couples and people from larger households.

The remainder of this study is structured as follows. Section 2 briefly summarizes the theoretical model in Lakdawalla (2002 and 2005). Section 3 describes the data. Section 4 discusses the empirical model. The identification strategy, choice of instruments, and first stage results are presented in Section 5. Section6presents the main results and robustness checks. Section 7concludes.

2 Theoretical Model

We base our analysis of income effects on bodyweight on a model developed by Lakdawalla et al. (2002 and 2005). Agent's period utility $U(F, C, W)$is a function of food consumption (F), consumption of other goods (C), and current weight (W). Utility is increasing in the consumption of food and other goods, and it is non-monotonic in bodyweight.

Bodyweight depends on the (im)balance between energy ingested and energy spent on physical activity. Every agent has an ideal weight (W_0). She prefers to gain weight if her weight is below her ideal weight, and she prefers to lose weight if her weight is above her ideal weight. Lakdawalla et al. (2002 and 2005) express utility as a quadratic function of bodyweight with the ideal weight as the bliss point.

Food consumption and consumption of other goods are not substitutes. The marginal utility of food consumption is non-decreasing in consumption of other goods ($U_{FC} \geq 0$.

An agent manages her weight by solving a dynamic problem in which her weight is the state variable. Weight is a capital stock that depreciates over time[1], and can be accumulated by eating and de-cumulated throughphysical activity. The transition equation for weight can be written as

$$W' = (1 - \delta)W + g(F, S)$$

Where the depreciation rate is $0 < \delta < 1$, and g is a continuous and concave function that is increasing in food consumption ($g_F > 0$) and decreasing in physical activity ($g_S < 0$). Sisa composite of the durationand strenuousness of physical activity. Hence, weight is increasing in food consumption ($W'_F > 0$) and decreasing in physical activity ($W'_S < 0$).

The associated value function for an agent is given by[2]

$$V(W) = max_{F,C,W'}\{U(F, C, W) + \beta V(W')\}(1)$$

$$s.t.: pF + C \leq Y \qquad (2)$$

$$W' = (1 - \delta)W + g(F, S)(3)$$

where$Y$ is agents' income, and p is the price of food. The price of other consumption goods is normalised to one.

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[1]The depreciation rate is defined by the basal metabolic rate which is the energy the body uses to maintain metabolic functioning.

[2]The model assumes separability of leisure and ignores the impact of choices made on physical activities during leisure time. All physical activities an agent engages in are summarized in the strenuousness variable.

Provided that the utility function is continuous, strictly concave, differentiable, and bounded, and that the transition function is continuous and concave, the first-order and envelope conditions could be obtained as

$$U_F(F, Y - pF, W) + \beta V'(W')g_F = pU_C(F, Y - pF, W)(4)$$

$$V'(W) = U_W(F, Y - pF, W) + \beta V'(W')(1 - \delta)(5)$$

Equation (4) implies that the marginal utility of consumption of other goods is equal to the marginal utility of food consumption. The latter is the sum of the direct marginal utility of food consumption, i.e. the joy of eating, and the marginal value of the weight change induced by food consumption. Equation (5) implies that the long-run marginal value of weight is equal to the marginal utility of current weight plus the discounted future marginal value of weight.

Equation (4) and equation (5) together yieldthe unique and stable steady-state equilibrium food consumption ($F^*(p, Y, S)$) and weight ($W^*(p, Y, S)$).

If we further allow occupational physical activity, S(Y),to vary with income to reflect the more sedentary nature of high-skilled (and paid) jobs, the effect of income on steady-state equilibrium food consumption and weight can be written as

$$\frac{\partial F^*(p, Y, S)}{\partial Y} = F_Y^* + F_S^* \cdot S_Y(Y)(6)$$

$$\frac{\partial W^*(p, Y, S)}{\partial Y} = W_Y^* + W_S^* \cdot S_Y(Y)(7)$$

Under the assumptions imposed by Lakdawalla et al. (2002 and 2005), the model implies an inverted U-shaped relationship between food consumption and income, conditional on occupational physical activity. That is, for steady-state equilibrium food consumption, it is increasing in income when an agent is below her ideal weight (Lakdawalla et al., 2002) or if she is poor (Lakdawalla et al., 2005); and it is decreasing in income when an agent is above her ideal weight (Lakdawalla et al., 2002) or if she is rich (Lakdawalla et al., 2005), conditional on occupational physical activity (see Figure 3).

In the following, we examine and test the hypothesis of a quadratic relationship between income and food consumption, and extend our analysis to the estimation of Engel curves in nutrients other than calories. An Engel curve shows how the consumer's demand for one particular commodity varies with his/her income, with prices and other factors affecting demand (such as consumer preferences and demographics etc.) held constant.

To test if the inverted U-shaped Engel curve derived by Lakdawalla et al. (2002 and 2005) also applies to the Engel curve with daily calorie intake in place of food consumption, the functional form specification for the Engel curve should, among other things, be as consistent with equation (6) as possible[3].

3 Data

This paper uses a representative sample of working males and females aged 18 to 60[4]from the China Health and Nutrition Survey (CHNS) for the years 1989 to 2006. The panel survey was designed to examine the effects of health, nutrition, and family planning policies and programs implemented by national and local governments in China. Itcontains rich health and nutrition information of the Chinese population during a period of rapid economic transition.

4,400 households with a total of 19,000 individuals from nine provinces[5], which vary in geography, economic development, public resources, and health indicators, are surveyed over three consecutive days which start at a random weekday. During this time, daily calorie intakeswere obtained from a household dietary survey[6]recording detailed information on household food production and consumption. Since surveys that directly record calorie intake by asking individuals what they ate are subject to non-negligible reporting biases (Bingham et al., 1995;Briefel et al., 1997; Rennie et al., 2007), household food consumption in the CHNS was calculated using reports on food purchases, initial and final food stocks and reports on food waste. Household nutrient intakes were then computed by CHNS using quantities of food consumed in a household and the nutrition content table provided by the National Institute of Nutrition and Food Safety (NINF). Individual nutrition intake was household nutrition intake averaged over the number of household members, data on which were also collected in the household dietary survey.

We use a sample of working males and females aged 18 to 60 from 1989 to 2006. We abstract from modelling labour force participation as China has the highest labour force participation rates for males and females worldwide – at 67% for women aged 15-65 and

[3]The Engel curve specification should also, ideally, be as consistent with consumer demand theory and/or consumer expenditure data as possible. Many studies have been searching for the best functional form specification for Engel curves, either in terms of goodness-of-fit for the consumer expenditure data (Working, 1943; Leser, 1963), or in terms of consistency with consumer demand theory (Deaton et al., 1980; Blundell et al., 1993; Banks et al., 1997).

[4] The standard retirement age is at 55years for females and around 60years for males.

[5]These are: Liao Ning, HeiLongjiang, Jiang Su, Shan Dong, He Nan, Hu Bei, Hu Nan, Guang Xi, and Gui Zhou

[6]The household survey was carried out by CHNS field workers who were trained nutritionists.

above 80% for men in the same age group. After dropping extreme outliers with daily working hours greater than 24 hours and the upper 1% of the individual income distribution as well as the top 1% of the wave-specific calorie intake distribution, the resulting sample has a total of 31,699 observations, with an average of around 4,600 observations per wave.

Additional information on food price indices, progressive individual income tax rates, and weather variation is obtained from two external data sources: NBSC (National Bureau of Statistics of China) and CSAT (China State Administration of Taxation).For more information on all three sources of data, please refer to appendix A.

3.1. Variable Definition and Trends in Variables

We use four measures to capture some main components of diet composition: calories as a measure of the intake level, and the macronutrients fat, carbohydrates, and proteins as compositional measures. We convert intakes of fats, carbohydrates and proteins into calorie units using the following conversion factors: 1 gram fat equals 9 kcal, 1 gram carbohydrate equals 4 kcal, and 1 gram protein equals 4 kcal. Individual daily total calorie intake is the sum of daily fat, carbohydrate, and protein intake. For males, calories declined strongly by 24% between 1989 and 2006 (Figure 4), composed of declines in calories from fats by 13%, those from carbohydrates by 30% and calories from proteins by 15%; females experienced a similar decline in calories (25%)and similar trends in its decomposition.

Caloric imbalance and weight growth do not only arise from eating patterns but also from the intensity of physical activity (Lakdawalla et al., 2002, 2005, and 2007; and Philipson et al., 2008). Several papers argue that technological innovation, i.e. a shift to sedentary occupations, is a driver of underlying changes in calorie intake and bodyweight (Lakdawalla et al., 2002, 2005, and 2007; Bleich et al., 2008; and Philipson et al., 2010). Hence, we control for the largest source of physical activity (or lack thereof) in the most time-intensive activity – work –by conditioning on occupational physical activity.Self-reported occupational physical activity is measured on a 1 to 5 scale, which we collapse to three categories: sedentary (=1 if 1 or 2), moderate (=1 if 3) and heavy (=1 if 4 or 5)occupational activity. Figure 5 shows the large shift in activity over the sample period: there was an around 14% decline in the percentage of males with a moderately active occupation and an increase in the percentageof workers in sedentary occupations of about 16%; we see a similar increase in sedentary occupations among females, and a larger decline of the fraction working in moderately active occupations of around 20%.

The CHNS records individual income from three sources: earnings, household businesses, and agricultural activities (farming, fishing, raising livestock, and gardening), and does not include individual income from subsidies (such as subsidies for health, one-child, food, and utilities) or income from sources not mentioned above (such as gifts, rents, and other in-kind payments). Individual earnings include on-the-job bonuses, other cash income, and value of non-cash income. Income is measured as net (after tax) income in the previous year.[7] Table 2 shows that around 12% of individuals receive income from household business, 44% are wage earners, and 59% have income from agricultural activities.Figure 2A shows the strong real income (in 2009 prices) growth in China of around 259%for males, and around 204% for females.

Household income is comprised of the sum of individual incomes plus pensions, subsidies, and income from sources not mentioned (such as rents and other in-kind payments). It is measured as net (after tax) income in the previous year.[8] Growth in real household income can be seen in Figure 2B: around 181% for singles, 248% for couples, and 162% for larger households.

Due to the presence of economies of scale in household food consumption (Deaton et al., 1998; Vernon, 2005), we use equivalised household income. What constitutes a proper equivalence scale is intensively discussed in the literature. Goldman et al. (2010) uses household income per capita, while Meng et al. (2004) use more equivalence scale adjustments with different weights for adults, children and elderly[9]. Our equivalised income measure is based on the square root of household size (Buhrmann et al., 1988; Atkinson et al., 1995) which gives a weighting similar to that of the also widely used modified OECD scales. We performed a robustness check using per-capita income which assumes no economies of scale, and find very similar results.

[7]Negative individual incomes from agricultural activities and/or household business were recoded to 0, with a corresponding dummy variable generated (=1 if recoded). Percentage with 0 individual income was around 2% in 1989, 3% in 1991, 3% in 1993, 1% in 1997, 1% in 2000, 1% in 2004, and 1% in 2006, respectively. Results are virtually unchanged when we drop observations with negative individual income.

[8] Same as individual income, there are also observations with negative household income in the sample. Similarly, they were recoded to 0, with a corresponding dummy variable generated (=1 if recoded). Percentage with 0 household income was around 0.8% in 1989, 0.4% in 1991, 0.4% in 1993, 0.4% in 1997, 0.1% in 2000, 0.1% in 2004, and 0.1% in 2006, respectively. Results are virtually unchanged when we drop observations with negative household income.

[9] These weights are: 0.35 for infants (0-2y), 0.5 for children (3-14y) and elderly (above 65y). Alternatively, they attach an equivalence scale of 0.5 to infant and a weight of 0.75 to children and the elderly.

Retail food price indices (relative to 1989 retail food prices) are obtained from NBSC, and the food price indices are those of grain, non-staple food, fresh vegetables, meat, and fish. There was an upward trend in all the food price indices from 1989 to 2006.

Individual characteristics are captured using educational attainment (dummies for primary, low middle and high middle/technical school degree; college degree or higher), household size, gender and age. We alsocontrol for community level characteristics using 11 indicators (capturing differences and trends in population density and diversity, economic conditions, education standards, quality of housing, health services and sanitation, traditional market, modern market, and the quality of transportation and communication infrastructure). They allow us to control for systematic regional differences in calorie intake patterns, and for community level differences in income[10]. A high index value (with a range between 0 and 10) of each community-level covariate indicates better quality of institutions/infrastructure and better economic conditions.Descriptive statistics for individual- and community-level characteristics are summarized in Table 1, and more information on these indices can be found in the data appendix A.

4 Empirical Model

Equation (8) in Section 2 describes the Engel curve specification for daily calorie intake:

$$(8)\quad kcal_{ict} = \alpha + f(x_{ict};\beta) + \delta_1 light_{ict} + \delta_2 moderate_{ict} + rpi'_{ct}\gamma + Z^{1\prime}_{ict}\theta_1 + Z^{2\prime}_{ct}\theta_2 + \tau_t + \varepsilon_{ict}$$

where$kcal_{ict}$ is daily calorie intake of individual i in community c at time t. The inverted U-shaped Engel curve derived by Lakdawalla et al. (2002 and 2005) is obtained after conditioning on occupational physical activity ($light_{ict}$ and $moderate_{ict}$,) in equation (8). $f(x_{ict};\beta)$ is a smooth function of incomex_{ict}(deflated to 2009 Yuan). rpi_{ct} is a vector of community-level retail food price indices (grain, non-staple food, fresh vegetables, meat, and fish). Z^1_{ict} is a vector of individual-level covariates and Z^2_{ct} is a vector of community level covariates. τ_t is a time trend, and α is a constant. ε_{ict} is the idiosyncratic error term. $(\gamma', \beta', \delta_1, \delta_2, \theta'_1, \theta'_2)'$ is a vector of parameters.

[10]For example, the correlation between community economic condition and individual income is around 0.38, the correlation between community education and individual income is around 0.31, and the correlation between community housing quality and individual income is around 0.39.

Following Lakdawalla and Philipson, we start with a 2nd order polynomial in income, i.e.$f(x_{ict};\beta)=\beta_1 x_{ict}+\beta_2 x_{ict}^2$. Consequently, we will test for functional form using higher order polynomials, e.g.$f(x_{ict};\beta)=\beta_1 x_{ict}+\beta_2 x_{ict}^2+\beta_3 x_{ict}^3$.

4.1. Identification and instruments

Pooled OLS estimation of specification (8) is only valid under the assumption:

$$E(W'_{ict}\varepsilon_{ict})=0$$

where $W_{ict}=(x_{ict},x_{ict}^2,light_{ict},moderate_{ict},rpi'_{ct},Z_{ict}^{1\prime},Z_{ct}^{2\prime},\tau_t)'$.

However, unobserved heterogeneity may be present which is correlated with income. Sources of unobserved heterogeneity could be genetic factors, innate ability, family background, eating habits and food preferences, time discounting, and individual perceptions of ideal weight or heterogeneous social norms. Unobserved heterogeneity could bias our estimated income parameters in both directions: If daily calorie intake is decreasing in smoking (Chou et al., 2004) and individuals with higher educational attainment and income smoke less (Autor et al., 2005; Cutler et al., 2006), there will be an upward bias. If daily calorie intake is increasing in the discount rate (Ikeda et al., 2010), and higher income individuals have a lower discount rate, our estimates will be biased downwards.[11] Following Behrman and Deolalikar (1990), we present individual-level rather than community-level fixed effects estimates to address this issue.

However, unobserved heterogeneity is not necessarily time-constant. Unobserved social network and contextual characteristics are likely to change over time, e.g. individual eating habits (Yaniv et al., 2009), social norms of thinness and individual perceptions of ideal weight (Levy, 2002; Trogdon et al., 2008). The assumption of time-invariant unobserved heterogeneity seems particularly problematic given the massive growth and major transitions in economic structure and lifestyles in China. For example, the availability of fast and junk food (Currie et al., 2009; Anderson et al., 2011) may change individual food preferences. In spite of controlling for time-constant individual heterogeneity and controlling for the accessibility of supermarkets, traditional markets and cafes through the community-level indices, estimates may still be biased. In addition, simultaneity bias may arise. Lecocq et al. (2006) and Deaton (1997) argue in an agricultural context that common shocks determine

[11]Based on evidence by Cawley (2004), we hypothesize a downward bias resulting from social norms and perceptions of bodyweight (Dragone et al., 2011).

both daily calorie intake and individual income. Other studies emphasizethe role of technological innovationswhichinduce a simultaneous change in individual food consumption patterns and income (Lakdawalla et al., 2002, 2005, and 2007; Philipson et al., 2008, 2010; Bleich et al., 2008; Ng et al., 2009). Households in transition economies face high levels of economic uncertainty, as market infrastructure and economic institutions in these countries are often underdeveloped (Stillman, 2001). Also, (im)balances between calorie intakes and physical activity can affect the earnings potential of individuals and thus incomes (Register et al., 1990; Behrman et al., 2001; Cawley, 2004; and Morris, 2006).

5 Identification

We explore exogenous variation in income induced by Chinese tax reforms as well as spatial and temporal variability in environment (2SLS) to identify income effects on daily calorie intake. To our knowledge, the set of instruments exploiting variation in taxation has not been used in the context of estimating Engel curves.In fact, many studies ignore the potential endogeneity of their income measures and do not seek to employ instrumental techniques at all (Lakdawalla et al., 2002; Chou et al., 2004; Goldman et al., 2010). Valid instrumental variables (z) for endogenous income should, among other things, satisfy two conditions: they are uncorrelated with unobserved idiosyncratic error term ($E(z'_{ict}\varepsilon_{ict}) = 0$), which includes unobserved heterogeneity ($\varepsilon_{ict} = \eta_i + \epsilon_{ict}$)[12], and they are partially correlated with income. We use two sets of instruments to reflect the different income sources: weather shocks identify income effects among agricultural businesses and propose variation in marginal income tax rates to be used as instruments for income generated outside of agriculture.

5.1. Instrument I: Weather shocks

Weather shocks have been shown to be correlated with agricultural income and used as instruments for income in other studies. Maccini et al. (2009) find that rainfall variation across space and time in Indonesia generates variation in agricultural output and thus household income. Wolpin (1982), Paxson et al. (1992) and Jacoby et al. (1998) use weather shocks and unusual village level rainfall to examine consumer behaviour of agricultural

[12] $\eta_i$is unobserved heterogeneity, and ϵ_{ict} is another idiosyncratic error term.

households in rural India.The dimensions of weather variation across provinces and time used in the literature are: monthly temperatures, rainfall levels and hours of sunshine.[13]

We exploit variation in average monthly levels of all three weather dimensions in spring across provinces and time using data from the National Bureau of Statistics of China (NBSC). We measure weather shocks at the province level and define them as deviations from their long-run average. The choice of spring weather dimensions only is first to avoid multicollinearity and second, statistics published by Ministry of Agriculture of the People's Republic of China show that in 2006 the majority of grain products (accounted for almost 35% of total agricultural products) were harvested in autumn. Liu et al. (2004) point out that spring drought frequently happens in China, with adverse impacts on harvests. Hence, we focus on capturing weather shocks in the growing season (i.e. in spring). Panel B in Table 3 shows the considerable variation across provinces and time in all of the weather dimensions.

5.2. Instrument II: Variation in marginal tax rates

For non-agricultural income sources, we exploit changes in marginal income tax rates[14]. Income taxation in China applies to individual income and includes exemption amounts and several tax brackets so that marginal tax rates vary across the population. Two tax reforms during our sample period--31st October 1993, and 27th October 2005--give us additional exogenous time-series variation in the marginal tax rates an individual faces.[15] Figure 6illustrates the tax schedules applicable at different points in time, and Panel A of Table 3 summarizes thetime series variation in earnings tax rates. We construct instruments for household income using the following strategy: first, we compute marginal tax rates based on individual income. Three dummies for the applicability of tax brackets--5%, 10 to 15%, and 20% to 35%[16]--are generated. Since we observe net but not gross incomes, we cannot always

[13] Other instrumental variables such as educational attainment of the head of household and the partner (if present), widow status and gender of the head of household, and log household income (and squared) (Kalwij et al., 2007), and characteristics of cities (densities, population, distance to the dynamic center of the county, average wage level, and average wage level squared) have also been used(Azzoni et al., 2008), but they are likely to be correlated with unobserved heterogeneity in this study.

[14]Other instruments used in the literature are Social Security contributions (Parker, 1999), income tax refunds (Souleles 1999) and extra wage payments (Browning et al., 2001).

[15]Since there was no variation in the individual income tax law on income from household business, we include a dummy variable which is equal to 1 if individual income was earned from a household business. This group accounts for around 18% of the sample and hence is a relatively small proportion.

[16]Percentage of tax payers falling into each tax bracket is around 9% for 0.05, 4% for 0.1, 0.2% for 0.15, 1% for 0.2, 0.04% for 0.25, 0.08% for 0.3, and 0.04% for 0.35. No one was paying a tax rate higher than 0.35. As few observations fall into a tax bracket higher than 0.2, we summarized these observations into one single bracket [0.2, 0.35], similarly for the tax brackets 0.1 and 0.15.

match net individual incomes and applicable tax brackets (and thus rates) uniquely. However, as Figure 7 shows by plotting net and corresponding gross incomes, the area of ambiguity is negligibly small.

Next, we construct instruments for equivalised household income. These are the shares of tax payers falling into each tax bracket within a household over time.

5.3. Instrument III: Variation in marginal tax rates and bracket creep

The validity of tax rules as income instrument has been criticized by Lindsey (1987) and Feldstein (1995) who point out that existing tax rules provide substantial opportunity for individuals to reduce their taxable income by adjusting their income and expenses in response to high marginal tax rates. For example, individuals can vary their labour supply by varying their work effort, their location and the types of jobs they accept. They can also choose forms of compensation that are untaxed or subject to lower effective tax rates. Further, changes in tax rate policies aimed at reducing income inequality resulting from technological change, declining union membership, increasing import competition, lessening of government pressure to increase minority employment, increasing immigration, and changing supplies of college workers can also lead to endogenous individual income tax rates in the income-tax rate equation (Auten et al., 1999).

Hence, while large tax reforms (such as the one used here) are natural experiments that create exogenous variation in incomes, individual income tax rates could still be correlated with the error term in the income-tax rate equation (Saez, 2003). This concern is supported by discrepancies between studies (Lindsey, 1987; Feldstein, 1995; Sammartino et al., 1997; and Goolsbee, 2000) that use the U.S. tax reforms of 1981, 1986, and 1993 to estimate taxpayers' responses.

However, tax reforms can still provide good instruments due to an additional source of variation which results from tax schedules that are fixed in nominal terms and highly progressive.In a study of the response of taxpayers to changes in marginal tax rates using the University of Michigan tax panel 1979, 1980, and 1981, Saez (2003) notices high inflation during the sample period (around 10%). Due to the nominal tax schedule, a taxpayer near the top-end of a bracket was likely to creep to the next bracket even at constant real income, while taxpayers far from the top-end of a bracket were less likely to experience an increase in the marginal rates. This characteristic of "bracket creep" allows him to construct instruments for endogenous marginal tax rates.

We exploit this additional variation in our study as inflation in China was high (around 5% on average from 1989 to 2006) during the sample period and tax schedules are fixed in nominal terms and highly progressive. Hence, we construct taxpayer's predicted annual tax rates using initial individual income in the first survey year, inflated to corresponding nominal income in the same wave[17]:

$$Predicted\ individual\ income_{it} = 1st\ Individual\ income_i * Inflate_t{}^{18}$$

Instrumental variables are then dummies for the applicability of predicted tax brackets (5%, between 10% and 15%, and between 20% and 35%) and predicted shares of tax payers falling into each tax bracket within a household over time. The raw correlation between individual income tax rates and predicted individual income tax rates is around 0.71.

5.4. Instrumenting for individual financial control

As existing empirical investigations have found that intra-household allocation of consumption depends on the financial control of the household members (Lee, 2004), we additionally include the ratio of individual income relative to household income (unequivalised) in each regression, and use the household member's computed marginal tax rate to instrument for it.

6 Results

6.1. First stage results

In Table 4, we show the first stage results of our IV estimation. We split the sample into households without (Columns 1 and 2) and with (Columns 3 and 4) an agricultural background . In Columns 1 and 3, the share instruments are separately and jointly significant at the 1% level. The magnitude of the tax effects is larger among non-agricultural households as expected, but significant throughout.[19] Agricultural equivalised household income is also

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[17] For example, if an individual entered the CHNS survey for the first time in 1989 and remained in the survey till 1991. His predicted tax rate in 1991 is the tax rate under the 1991 individual income tax law using his 1989 income inflated to corresponding 1991 nominal income. Inflation data was obtained from National Bureau of Statistics of China (NBSC).

[18] $Predicted\ individual\ income_{it}$ is individual i's predicted income in year t. $1st\ Individual\ income_i$ is individual i's income in the first survey year. $Inflate_t$ is the inflation rate taking the first survey year as the base year.

[19] This may be due to the fact that individuals are classified as agricultural in the CHNS as long as they have any income from agricultural activities. They may however receive income from other sources as well: for example,

affected by unusual variation in weather conditions, measured as deviations from long-run trend. Temperature is statistically significant at the 1% level for agricultural and non-agricultural individuals separately and negatively related to income. This may in part be due to earnings from other weather-sensitive occupations like construction or some areas of retail business. In contrast, rainfall only has a significant and negative impact on incomes from agricultural activities. In Columns 2 and 4, the two tax bracket dummies are significant at the 1% level and hence are correlated with individuals' relative income in a household.

Results for the alternative set of tax instruments including bracket creep are reported in the first stage estimates in Table 5. Our new set of instruments is statistically significant at the 1% significance level, and hence highly correlated with income.

We first estimate income effects on daily calorie intake using the quadratic functional form postulated by Lakdawalla et al. (2002 and 2005) for the Engel curve. Table 6 reports Ordinary Least Squares (OLS) estimates in Column 1 and Fixed-Effects (FE) estimates in Column 2. Two-Stage-Least-Squares (2SLS) estimates based on the first stage from Table 4 are reported in Column 3.

The OLS and FE estimates of income coefficients differ statistically from the 2SLS results at the 5% level, which suggests a downward bias in these estimates due to endogeneity of equivalised household income. In Column 3, income is significant and positively correlated with calorie intake, and the non-linear relationship between calorie intake and income is confirmed. We find a hump-shaped calorie income profile for both non-agricultural (Panel A) and agricultural (Panel B) households (see Figure 8). The negative correlation between calorie intake and income at higher income levels could be due to two reasons. First, as incomes rise, people's diets may shift from quantity towards higher quality foods that are low in calories. Second, wealthier people may be more concerned about their health and thus choose healthier lifestyles that include healthier diets (Philipson and Posner, 2010). In this sense, without other effects operating at the same time, income growth can make obesity growth self-limiting (by lowering calorie intake).

Unexpectedly, people from non-agricultural and agricultural background have similar income elasticities in calories at their respective median incomes (which are almost double as high

9% of the sample had income from both employment and agricultural activities, and around 6% of the sample had income from both household business and agricultural activities.

among individuals working in the non-agricultural sector: these are around 0.093 for non-agricultural and 0.082 for agricultural households.

We further find that individuals in sedentary occupations reduce their calorie intake, pointing to a downward adjustment of calories in reaction to a less active lifestyle. We additionally estimated a specification in which we do not condition on physical activity – and find very similar income elasticities. In consequence, it seems that the potential positive correlation between a sedentary occupation and income is not biasing our results.[20] We further add our more sophisticated instruments using the bracket creep, and investigate whether our results are sensitive to the choice of instruments. Results are reported in Column 4 of Table 6. Income coefficients in Column 4 do not differ statistically from those in Column 3, at the 5% level. Income is significant and positively correlated with calorie intake, and the quadratic income measure further captures non-linearity in the calorie-income relationship. They also imply an almost identical calorie income profile (see Figure 9). The implied income elasticities are somewhat larger, however, around 0.152 and 0.119, for non-agricultural and agricultural households, respectively. As our bracket creep instruments capture income dynamics to a larger extent, they are likely to provide a refined estimate of the Engel curves.

We further examine the sensitivity of our choice of equivalence scale and use per capita income instead of dividing by the square root of household size. There is no statistical difference between the two sets of results for agricultural households at the 5 percent level, while parameter estimates change for the non-agricultural sector – however, with very little impact on the Engel curves. Detailed results can be found in appendix B, Figure 20 and Table 12.

A study related to ours is Meng et al. (2004) who examine income elasticities of calorie consumption of urban households in China between 1986 and 2000. Their results range from 0.322 to 0.719. Using the same Engel curve specification but restricting to urban households, we get much lower calorie income elasticities that are around 0.084 (actual tax rates as instruments) and 0.187 (predicted tax rates as instruments). Apart from different functional form specification and the use of equivalent household income, two other factors may explain these large differences. First, the lack of instruments in their study can lead to an upward bias in income effects (Behrman and Deolalikar, 1990), which aligns with the fact that our income effects are smaller. Second, we use more recent waves and income elasticities decline

[20] The results can be found in appendix B.

significantly over time, as is pointed out by Meng et al. (2004). All in all, our low incomeelasticities are consistent with earlier findings in, for example, Behrman and Deolalikar (1990) for India.

6.2. Engel Curves in Calorie and other Nutrients by Gender

Due to differences in height and body composition, recommended calorie intake levels for men and women differ. We control for this by always including gender dummies in our estimations. Furthermore, males and females have different preferences for particular types of commodities (Anderson and Balland, 2002; and Doepke et al., 2011), including different dietary preferences. In this section, we thus allow Engel curves in calories and other nutrients to differ by gender. Results are reported in Table 7.[21]Female calorie intake is more income elastic than that of males in both sectors, as is reflected by a more steeply hump-shaped income profile (see Figure 10). However, the income-gender interaction term is only significant and positively correlated with calorie intake in agricultural households in Column 1. Again, results obtained using more sophisticated instruments in Column 2 do not differ statistically from those in Column 1, at the 5% level. F-tests of the joint significance of the two gender-specific income terms point to gender differences in Engel curves in the non-agricultural sector, while we the F-tests are not statistically significant in the agricultural sector. Since families in the agricultural sector work and live together and are hence likely to share all meals and eat out less, this effect is not surprising. Furthermore, the concept of individual income of household members in a common agricultural business is probably less clear cut than in the non-agricultural sector with a higher fraction of partners working for different employers. In the non-agricultural sector, females' income elasticity of calorie intake is around 104% larger than that of males. This difference reduces to around 39% when more sophisticated instruments are used. (see Table 9).

Males from non-agricultural background are more income elastic towards fat intake at low income levels (see Figure 11), with their income elasticity of fat intake being around 13% larger than that of females. What should also be noted is the gender differential in carbohydrate consumption of agricultural individuals. Rather than having a hump-shaped income profile, males' carbohydrate intake becomes almost linearly increasing in income,

[21]We present income effects obtained using more sophisticated instruments for calorie intake. Results based on the other set of instruments are available upon request.

indicating substantial gender differences in carbohydrate consumption at high income levels (see Figure 13). Females are generally more income elastic towards the consumption of other nutrients.

As existing empirical investigations have found that intra-household bargaining power depends on the household members' control over financial resources (Lee, 2004), we follow Behrman and Deolalikar (1990) and include the ratio of individual income relative to household income (unequivalised) in each regression, but in contrast to their approach, we use computed (individual) marginal tax rates to instrument for it. Female control over financial resources has been found to be associated with different expenditures compared to male income control (Haddad et al., 1994; Duflo, 2003; and Duflo et al., 2004). Duflo (2003) finds that pensions received by females had a large impact on the anthropometric status (weight-for-height and height-for-age) of girls but little effect on that of boys; no effect is found for pensions received by males.

We find that females' relative income is always significantly and positively correlated with their calorie and other nutrient intakes in the agricultural sector. For females in non-agricultural settings, calorie and protein intakes also increase significantly with their relative income share. Hence, females spend more on calories when they have more control over financial resources, a result that is consistent with earlier findings in the literature.

6.3. Engel Curves in Caloriesand other Nutrients by Household Type

Banks et al. (1997) find shifts in Engel curves for food in the UK as household size varies. Beneito (2003) and Rajapakse (2011) emphasize the importance of the effect of household size on household consumption pattern. In this section, we investigate whether Engel curves in calories differ by household size and also extend this comparison to other nutrient intakes. Results are reported in Table 8. Similarly, we present income coefficients based on predicted marginal tax rates for calorie intake only. As can be seen in Columns 1 and 2, significant differences between the two sets of estimated income effects are not detected.[22]

We find substantial household size differential in calorie Engel curves in the non-agricultural sector, in spite of generally insignificant household size interaction terms. Single households' calorie income profiles are U-shaped, that of couples is almost flat with a slightly downward

[22]Results for other nutrients are the same and available upon request.

trend, and the calorie Engel curve of larger households is hump-shaped (see Figure 13), suggesting that couples are the least income elastic towards calorie consumption. Couples' income elasticity of calories is around 85% (or 90%) smaller than that of singles and 75% (or 86%) smaller than that of people from larger households. Non-agricultural individuals' calorie income profiles diverge at low income levels, gradually converge up to an income level of around 20,000 (at 2009 price), and again diverge afterwards.

In contrast, couples from agricultural background are the most income elastic towards calorie intake, and calorie Engel curves are hump-shaped across all household types. Couples' income elasticity of calorie intake is around 51% (or 24%) larger than that of singles and 71% (or 63%) larger than that of people from larger households. It is also worth noting that agricultural households' calorie income profiles only diverge at high income levels. We still do not find significant household size interaction terms in the agricultural sector.

For other nutrients, agricultural households' Engel curves in calories from fat converge (not diverge) at high income levels (see Figure 15), suggesting that households of various types do not have different tastes for fat consumption when their incomes reach a certain level (around 35,000 at 2009 prices in the sample). Agricultural singles have opposite protein intake pattern to that of couples and people from larger households: their protein consumption decreases with income till around 10,000 (at 2009 price) and steadily increases with income afterwards. This contrast is also reflected by significant income-household size interaction terms for protein (for the resulting Engel curves, see Figure 16). In general, non-agricultural couples are the least and agricultural couples are the most income elastic towards the intakes of other nutrients.

6.4. *Choice of Functional Form*

So far, we have postulated the functional form derived from the model by Lakdawalla et al. (2002 and 2005). We now test our choice of functional form by allowing for higher order polynomials. Table 10 shows results for daily calorie intake using 3^{rd} and 4^{th} order polynomials of income. For non-agricultural individuals, we find empirical evidence of the existence of a 3rd order polynomial: it is significant at the 5% level in Column 1. However, as Figure 18A shows, the 3^{rd} order Engel curve is hump-shaped over most of the relevant support of the data. For individuals from the agricultural sector, we also find little empirical evidence supporting the inclusion of higher order polynomials. Despite that the 3^{rd} and

4^{th}order polynomial terms are significant separately at the 1% level in Column 4, Figure 18B again shows that the higher order income profiles are hump-shaped over most of the relevant support of the data and increases strongly only among very high incomes (4th order). In summary, we find little evidence that would be inconsistent with the theory proposed by Lakdawalla et al. (2002 and 2005).

7 Conclusions

This paper investigates the role of income in altering diets. China has experienced an unprecedented period of strong growth and a large economic transition over the last decades. Figure 2A showsthe massive individual income growth in China of around 259% for males and 204% for females (see Figure 2B). In face of these strong rises in incomes, we estimate income elasticities in nutrients, in particular those for calories, carbohydrates, fats and proteins.

We find evidence supporting the hypothesis of biased OLS and FE estimates due to omitted variables and simultaneity bias. Exploiting exogenous changes in Chinese tax system and weather shocks, we find a hump-shaped calorie income profile for both non-agricultural and agricultural households. Unexpectedly, people from non-agricultural and agricultural backgrounds have similar attitudes towards calorie consumption: similar income elasticitiesthat are around 0.093 for non-agricultural and 0.082 for agricultural households are found. Our more sophisticated instruments using bracket creep confirms the exogeneity of marginal tax rates. The implied income elasticities are somewhat larger, however, around 0.152 and 0.119, for non-agricultural and agricultural households, respectively. Females are more income elastic towards calorie consumption than males in both sectors. In the non-agricultural sector, females' income elasticity of calorie intake is around 104% larger than that of males. This difference reduces to around 39% when more sophisticated instruments are used. In the agricultural sector, females' calorie income elasticity is around 266% (or 146%) larger than that of males, depending on which set of instruments is used.

Extending to other nutrient intakes, males from non-agricultural background turn out to be more income elastic towards fat consumption at low income levels, with their income elasticity of fat intake being around 13% larger than that of females. Notably, rather than having a hump-shaped income profile, males' carbohydrate intake becomes almost linearly increasing in income, indicating substantial gender difference in carbohydrate consumption at high income levels. Females are more income elastic towards the consumption of other nutrients.

Lastly, we find differences in calorie Engel curves by household size, especially for those not in agriculture. In the non-agricultural sector, single households' calorie income profile is U-shaped, that of couples is almost flat with a slight downward trend, and the calorie Engel curve of larger households is hump-shaped, suggesting that couples are the least income elastic towards calorie consumption. Couples' income elasticity of calories is around 85% (or 90%) smaller than that of singles and 75% (or 86%) smaller than that of people from larger households. Non-agricultural individuals' calorie income profiles diverge at low income levels, gradually converge up to an income level of around 20,000 (at 2009 price), and again diverge afterwards.

In contrast, couples from agricultural background are the most income elastic towards calorie intake, and calorie Engel curves are all hump-shaped across household types. Couples' income elasticity of calorie intake is around 51% (or 24%) larger than that of singles and 71% (or 63%) larger than that of people from larger households. Agricultural households' calorie income profiles only diverge at high income levels.

For other nutrients, agricultural households' fat Engel curves converge (not diverge) at high income levels, suggesting that households of various types do not have different tastes for fat consumption when their incomes reach a certain level (around 35,000 at 2009 price in the sample). Agricultural singles have opposite protein intake pattern to that of couples and people from larger households: their protein consumption decreases with income till around 10,000 (at 2009 price) and steadily increases with income afterwards. In general, non-agricultural couples are the least while agricultural couples are the most income elastic towards the intakes of other nutrients.

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Tables and Figures

Figure 1: Time trends in bodyweight by weight group and gender ,1989 to 2006

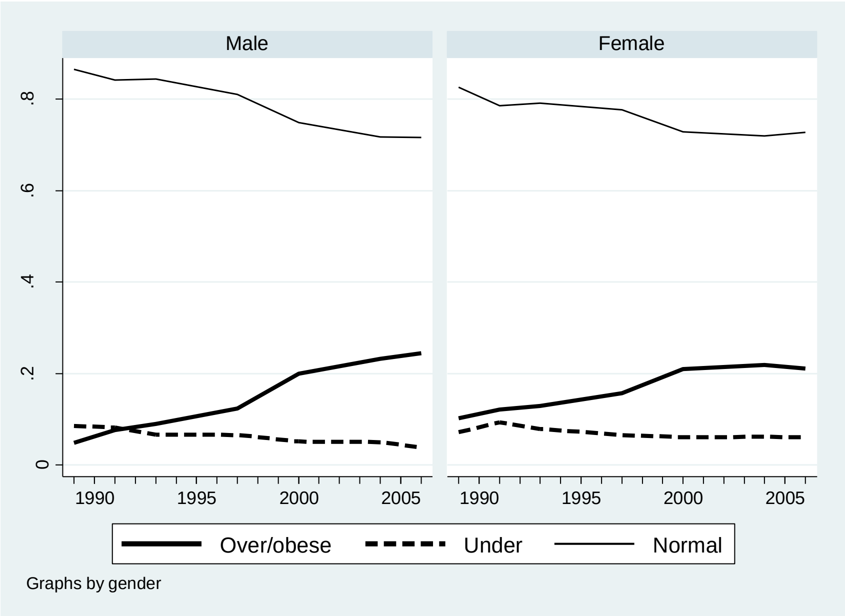
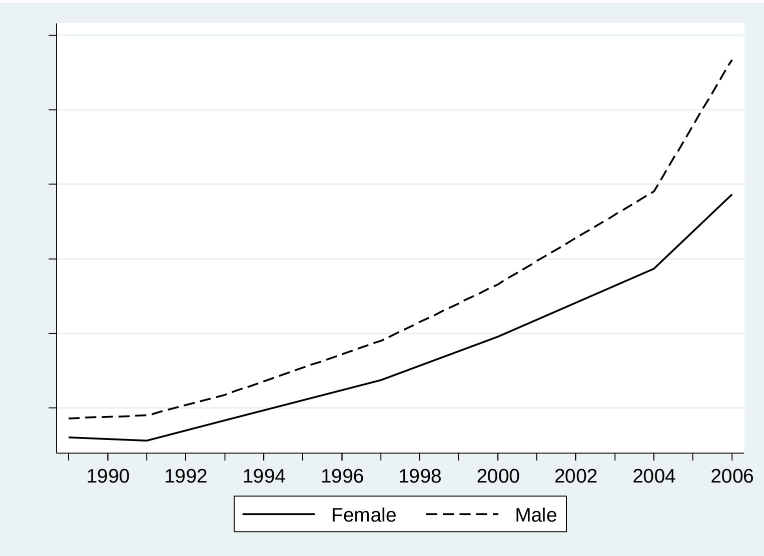


Figure 2: Time trend in individual income (deflated to 2009 Yuan)

A. Individual income by gender



B. Household income by household size

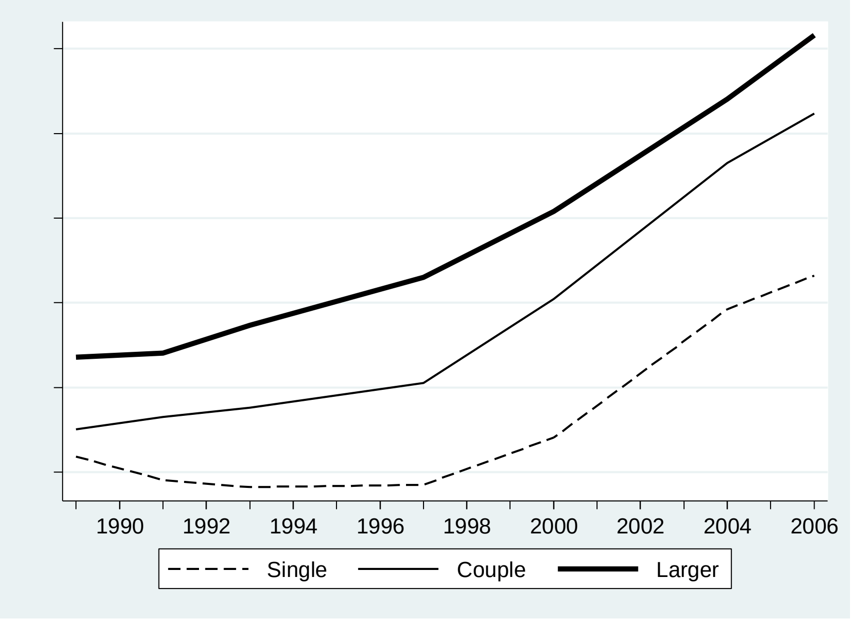
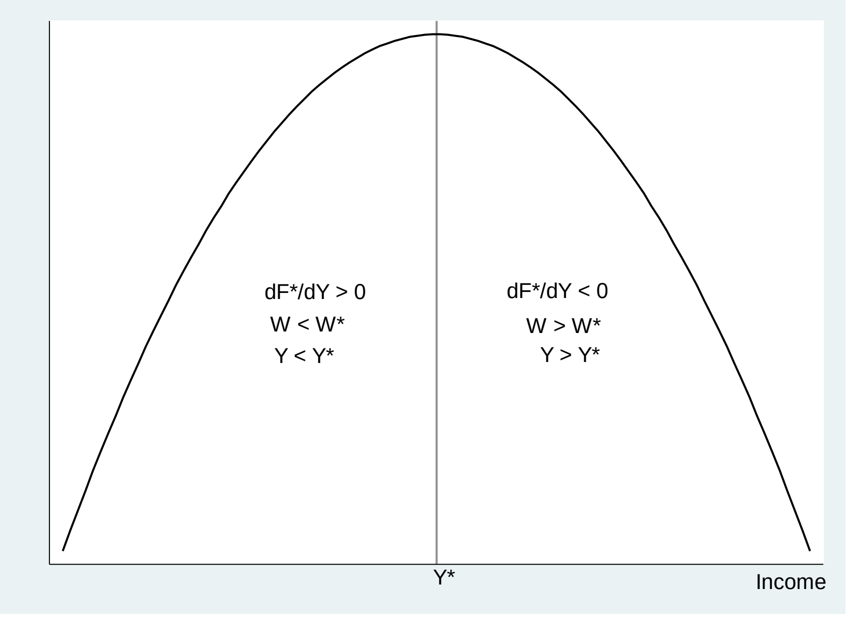


Figure 3: Steady-state equilibrium food consumption and individual income



Source: Lakdawalla et al. (2002)

Figure 4: Time trends in daily intakes of calories, fat, carbohydrates, and proteins, by gender

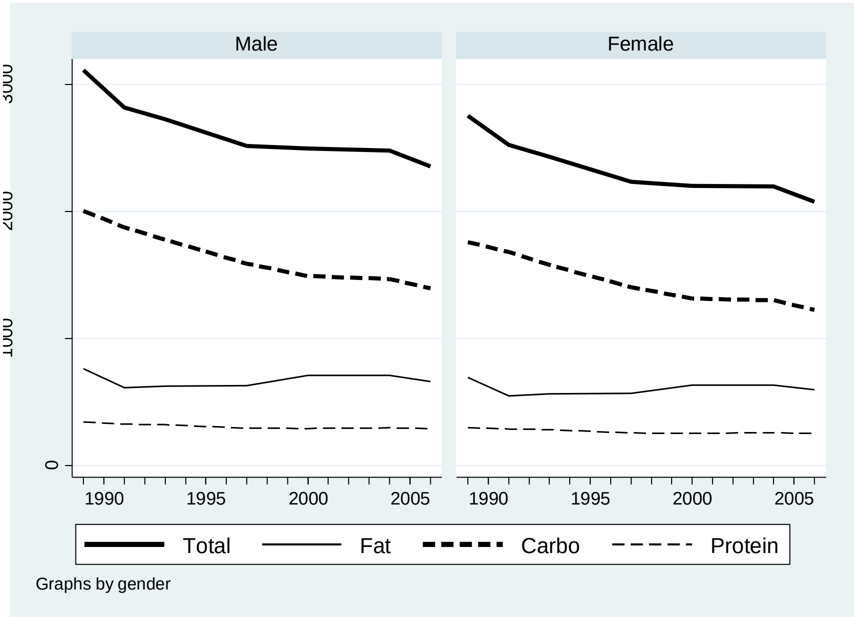


Figure 5: Time trends in self-reported strenuousness of occupation (in % of working population), by gender

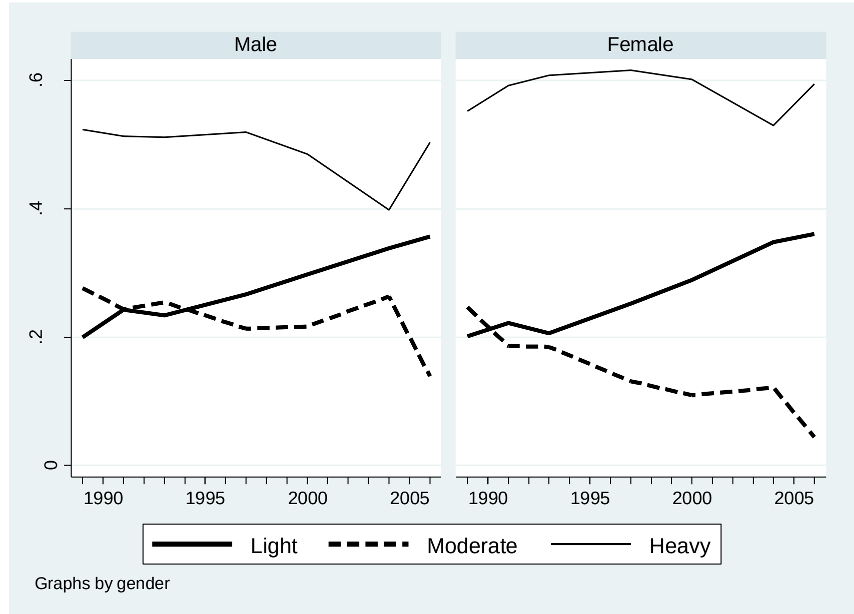


Table 1: Sample mean and standard deviation of individual and community level covariates

Variable	1989	1991	1993	1997	2000	2004	2006
Panel A: Individual level covariates							
Primary schoo degree (=1 if yes)	0.232	0.227	0.236	0.249	0.238	0.217	0.175
	(0.422)	(0.419)	(0.425)	(0.432)	(0.426)	(0.412)	(0.380)
Low middle school degree (=1 if yes)	0.33	0.308	0.327	0.324	0.344	0.345	0.351
	(0.470)	(0.462)	(0.469)	(0.468)	(0.475)	(0.475)	(0.477)
High middle/technical school degree (=1 if yes)	0.18	0.153	0.162	0.186	0.209	0.255	0.247
	(0.384)	(0.360)	(0.368)	(0.389)	(0.407)	(0.436)	(0.431)
College degree or higher (=1 if yes)	0.023	0.023	0.017	0.029	0.046	0.054	0.078
	(0.151)	(0.150)	(0.129)	(0.167)	(0.210)	(0.225)	(0.268)
Household size (unit)	4.416	4.468	4.493	4.186	4.03	3.861	3.804
	(1.437)	(1.441)	(1.488)	(1.335)	(1.328)	(1.366)	(1.408)
Female (=1 if yes)	0.524	0.528	0.526	0.507	0.508	0.487	0.488
	(0.499)	(0.499)	(0.499)	(0.500)	(0.500)	(0.500)	(0.500)
Age	31.76	36.518	37.429	38.132	39.829	41.422	42.509
	(7.049)	(11.112)	(11.000)	(10.648)	(10.366)	(10.042)	(9.789)
Panel B: Community level covariates (0-10)							
Population density	5.78	5.782	5.779	5.478	5.568	5.751	5.562
	(1.281)	(1.306)	(1.326)	(1.528)	(1.589)	(1.480)	(1.567)
Population diversity	3.82	3.727	3.896	4.109	4.418	4.589	5.064
	(1.039)	(0.971)	(0.970)	(0.935)	(1.089)	(1.163)	(1.185)
Economic condition	2.938	2.544	2.743	3.844	4.288	5.569	6.18
	(1.670)	(1.913)	(1.737)	(3.012)	(3.179)	(3.192)	(3.046)
Education	2.449	2.472	2.592	2.816	3.273	3.286	3.357
	(1.287)	(1.257)	(1.193)	(1.291)	(1.442)	(1.459)	(1.547)
Housing quality	2.992	3.557	3.984	5.027	5.776	6.415	6.812
	(2.580)	(2.518)	(2.509)	(2.652)	(2.652)	(2.456)	(2.236)
Health-care service quality	5.655	5.568	5.385	5.537	5.434	5.075	4.811
	(2.004)	(2.026)	(2.182)	(2.160)	(2.180)	(2.290)	(2.330)
Sanitation	4.991	5.065	4.89	5.338	5.519	6.155	6.317
	(3.110)	(3.233)	(3.199)	(3.299)	(3.191)	(3.019)	(2.960)
Traditional market quality	4.531	4.493	4.267	4.967	5.7	4.681	4.675
	(3.040)	(3.137)	(3.292)	(3.476)	(3.529)	(3.661)	(3.863)
Modern market quality	3.638	3.692	4.115	3.977	4.465	4.582	4.512
	(2.991)	(3.206)	(3.083)	(3.202)	(3.328)	(2.933)	(2.872)
Transportation	4.108	4.763	4.937	5.251	5.564	5.712	5.725
	(2.603)	(2.965)	(2.614)	(2.654)	(2.585)	(2.535)	(2.497)
Communication	2.755	3.831	4.139	4.559	4.755	5.643	6.126
	(1.640)	(1.418)	(1.487)	(1.311)	(1.198)	(1.527)	(1.388)
Observations	3,695	5,716	5,189	5,006	4,963	3,485	3,645

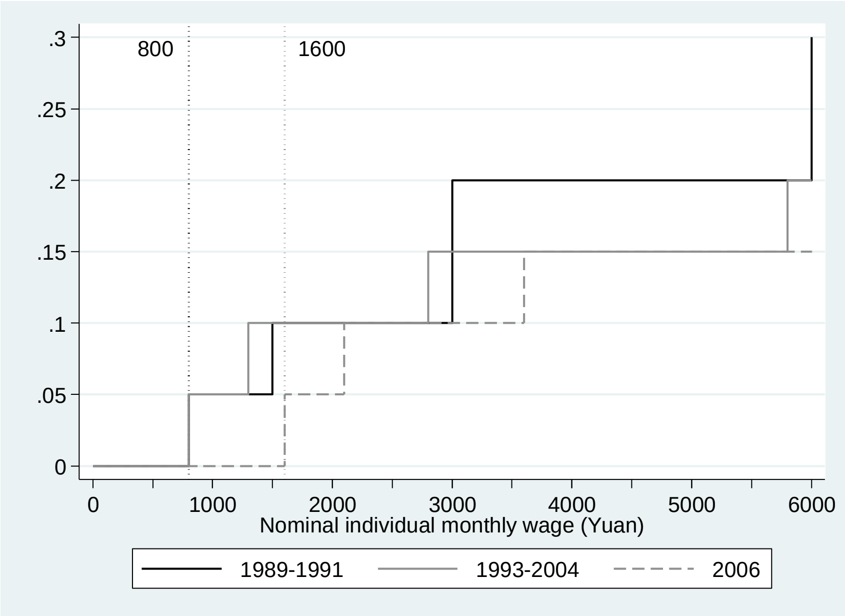
Table 2: Percentage with income from labour market, household business, and agricultural activities

Income source	Percentage	Liability for income tax
% With income from household business	12%	Yes
% With income from labour market	44%	Yes
% With income from agricultural activities	59%	No

Table 3: Variation in instrumental variables

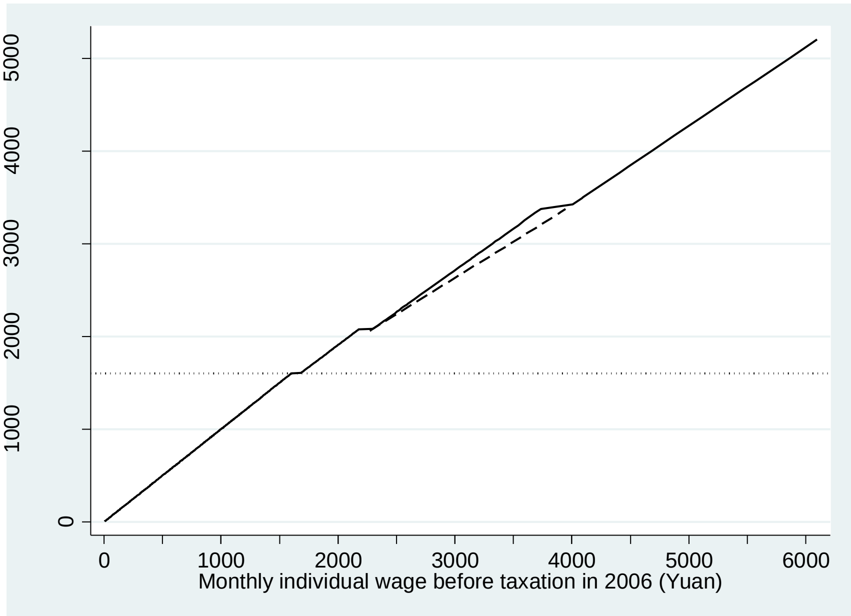
Variable		Std. Dev.
Panel A: Individual income tax rates		
Tax bracket 1: tax rate 0.05	Across individuals	0.231
	Across time	0.202
Tax bracket 2: tax rate [0.1,0.15]	Across individuals	0.162
	Across time	0.139
Tax bracket 3: tax rate [0.2,0.35]	Across individuals	0.108
	Across time	0.083
Panel B: Weather variation		
Lagged spring temperature shock	Across provinces	0.542
	Across time	1.153
Lagged spring rainfall shock	Across provinces	549
	Across time	917
Lagged spring sunshine hour shock	Across provinces	238
	Across time	519

Figure 6: Time series variation in the income tax schedule across three tax regimes



Notes: the exemption amount of monthly individual wage was 800 Yuan before 2005, and it rose to 1,600 Yuan after 2005. The 1999 tax reforms did not change regulations related to this current study, and hence the tax schedules in 1993-1999 and 1999-2004 are the same.

Figure 7: Mapping between (unobserved) gross and (observed) net monthly earnings in 2006



Notes: the solid line shows the relationship between monthly individual wage after taxation (Yuan) and monthly individual wage before taxation in 2006 (Yuan), using the tax rates adopted in estimation. Due to the lack of individual income data before taxation, there is not a one-to-one link between monthly individual wage after taxation and monthly individual wage before taxation in 2006. The dashed line shows alternative possible values of monthly individual wage before taxation using tax rates that are also possible for that range of monthly individual wage after taxation. The dotted line shows the exemption amount (1,600 Yuan).

Table 4: First stage using actual marginal tax rates

	(1)	(2)	(3)	(4)
	Non-agri		Agri	
Variable	Income	Ratio	Income	Ratio
Marginal tax rate:0.05	1,010***	0.141***	-483.2*	0.0536**
	(295.2)	(0.00982)	(293.6)	(0.0220)
Marginal tax rate:[0.1,0.15]	2,466***	0.271***	381.3	0.228***
	(419.0)	(0.0139)	(400.5)	(0.0300)
Marginal tax rate:[0.2,0.35]	5,503***	0.345***	1,232**	0.318***
	(761.6)	(0.0253)	(620.9)	(0.0464)
Lagged spring temperature shock	-280.3***	-0.00244	-159.4***	-0.000629
	(50.77)	(0.00169)	(38.70)	(0.00289)
Lagged spring rainfall shock	0.0211	3.92e-06**	-0.123***	9.28e-06***
	(0.0511)	(1.70e-06)	(0.0355)	(2.66e-06)
Lagged spring sunshine hour shock	0.0868	3.45e-06	0.109	1.42e-05**
	(0.110)	(3.66e-06)	(0.0825)	(6.17e-06)
Share 1	4,173***	-0.0939***	2,330***	-0.0874***
	(259.5)	(0.00864)	(186.8)	(0.0140)
Share 2	7,230***	-0.152***	4,388***	-0.152***
	(386.3)	(0.0129)	(270.1)	(0.0202)
Share 3	7,413***	-0.179***	6,977***	-0.211***
	(717.6)	(0.0239)	(437.7)	(0.0327)
Observations	12,698	12,698	18,654	18,654
R-squared	0.456	0.332	0.293	0.087

Notes: *** indicates being statistically significant at the 1 percent level. ** indicates being statistically significant at the 5 percent level. * indicates being statistically significant at the 10 percent level. Share 1=number of tax payers paying 0.05/total number of tax payers in a household. Share 2=number of tax payers paying [0.1,0.15]/total number of tax payers in a household. Share 3=number of tax payers paying [0.2,0.35]/total number of tax payers in a household. Ratio=individual income/household income. Additional individual level covariates are educational attainment dummy variables (primary school degree, low middle school degree, high middle/technical school degree, and college degree or higher), a dummy variable equal to 1 if income was from household business, female (=1 if yes), household size, age (and age squared), and rural (=1 if living in rural areas). Additional community level covariates are population density, population diversity, educational level, economic condition, traditional market condition, modern market condition, transportation quality, communication quality, housing quality, sanitation quality, and health-care service quality. Controls for provincial food retail prices are retail price indices of grain, non-staple food, fresh vegetables, meat, and fish (relative to food retail prices in 1989). Also included is a set of time dummy variables from 1991 to 2006.

Table 5: First stage using predicted marginal tax rates

	(1)	(2)	(3)	(4)
	Non-agri		Agri	
Variable	Income	Ratio	Income	Ratio
Predicted marginal tax rate:0.05	-328.4	0.0850***	-889.0***	0.0288*
	(307.3)	(0.00984)	(213.2)	(0.0157)
Predicted marginal tax rate:[0.1,0.15]	284.0	0.184***	-478.6	0.121***
	(484.4)	(0.0155)	(383.1)	(0.0282)
Predicted marginal tax rate:[0.2,0.35]	2,699***	0.205***	-1,301*	0.170***
	(757.9)	(0.0243)	(672.0)	(0.0495)
Lagged spring temperature shock	-235.3***	-0.00239	-134.3***	-0.00120
	(53.46)	(0.00171)	(39.40)	(0.00290)
Lagged spring rainfall shock	0.00570	3.31e-06*	-0.132***	9.73e-06***
	(0.0538)	(1.72e-06)	(0.0362)	(2.66e-06)
Lagged spring sunshine hour shock	-0.0244	2.21e-06	0.105	1.45e-05**
	(0.116)	(3.70e-06)	(0.0840)	(6.19e-06)
Predicted share 1	2,919***	-0.0757***	726.3***	-0.0623***
	(270.4)	(0.00866)	(164.0)	(0.0121)
Predicted share 2	4,730***	-0.110***	2,436***	-0.102***
	(448.2)	(0.0144)	(288.7)	(0.0213)
Predicted share 3	5,293***	-0.118***	5,638***	-0.141***
	(694.7)	(0.0222)	(494.5)	(0.0364)
Observations	12,698	12,698	18,654	18,654
R-squared	0.397	0.314	0.268	0.082

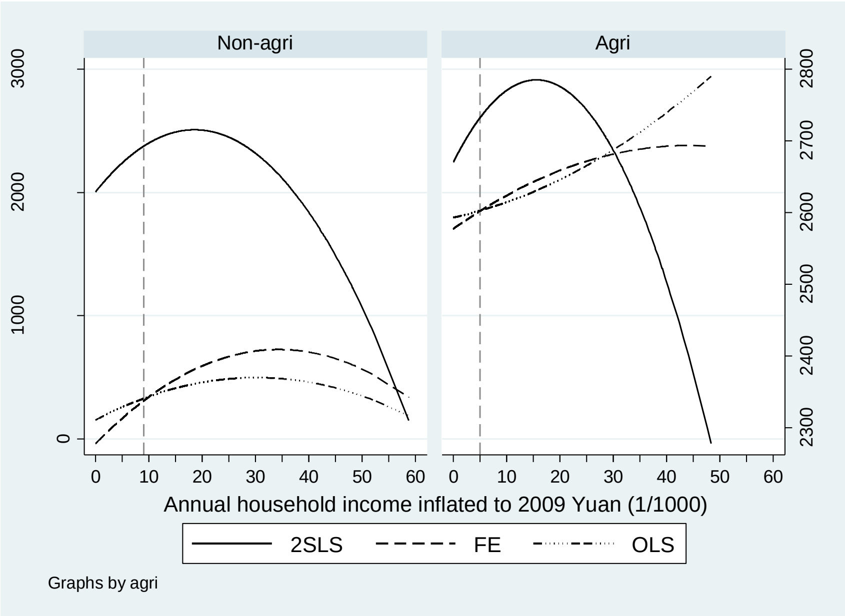
Notes: *** indicates being statistically significant at the 1 percent level. * indicates being statistically significant at the 10 percent level. Predicted share 1=number of predicted tax payers paying 0.05/total number of predicted tax payers. Predicted share 2=number of predicted tax payers paying [0.1,0.15]/total number of predicted tax payers. Predicted share 3=number of predicted tax payers paying [0.2,0.35]/total number of predicted tax payers. Additional individual and community level covariates are the same as those in Table 4.

Table 6: OLS, FE, and 2SLS estimates

Variable	(1) OLS	(2) FE	(3) 2SLS	(4) 2SLSP
Panel A: Non-agricultural individuals				
Household income	0.00392	0.00765**	0.0543**	0.0866**
	(0.00239)	(0.00386)	(0.0232)	(0.0340)
Household income^2	-6.52e-08	-1.12e-07	-1.46e-06**	-2.20e-06**
	(5.98e-08)	(9.08e-08)	(6.46e-07)	(8.99e-07)
Ratio	-8.997	12.35	240.7	390.7*
	(29.33)	(49.65)	(146.5)	(208.5)
Light	-53.78**	-11.40	-61.51**	-76.08***
	(25.05)	(46.38)	(26.10)	(28.16)
Moderate	-22.23	56.44	-30.57	-44.29
	(25.57)	(46.10)	(26.49)	(28.28)
Observations	12,698	12,698	12,698	12,698
R-squared	0.163	0.098	0.125	0.074
Panel B: Agricultural individuals				
Household income	0.00163	0.00526*	0.0856**	0.128**
	(0.00238)	(0.00303)	(0.0372)	(0.0535)
Household income^2	5.05e-08	-5.95e-08	-2.75e-06**	-4.60e-06**
	(8.71e-08)	(1.07e-07)	(1.37e-06)	(2.03e-06)
Ratio	56.13***	4.698	857.4***	1,007***
	(14.00)	(16.08)	(200.8)	(276.7)
Light	-127.1***	-66.80**	-175.3***	-177.3***
	(21.66)	(32.52)	(29.09)	(35.42)
Moderate	-161.6***	-64.99**	-245.7***	-263.8***
	(20.93)	(31.36)	(36.94)	(46.95)
Observations	18,654	18,654	18,654	18,654
R-squared	0.188	0.142	0.009	NR

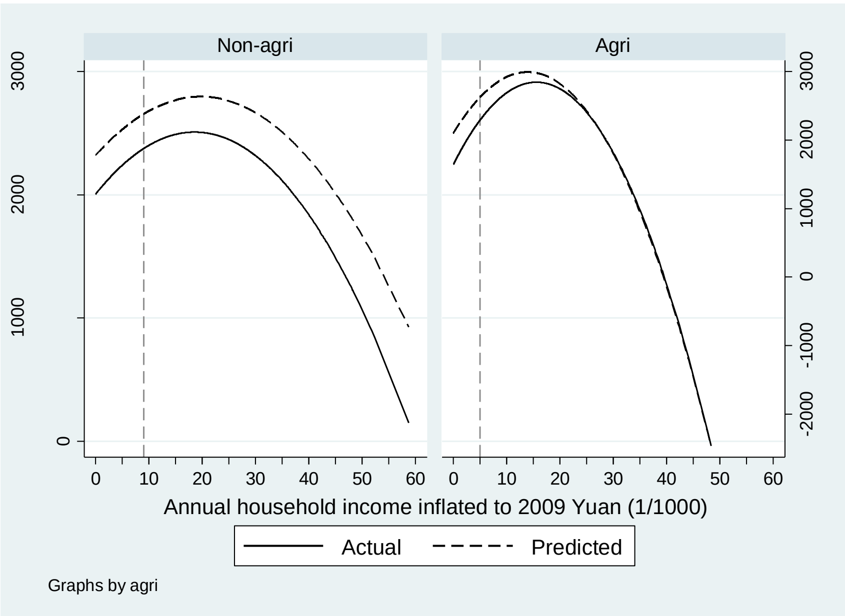
Notes: *** indicates being statistically significant at the 1 percent level. ** indicates being statistically significant at the 5 percent level. * indicates being statistically significant at the 10 percent level. Additional individual and community level covariates are the same as those in Table 4. NR denotes Not Reported.

Figure 8: OLS, FE, and 2SLS Engel curves in calories



Notes: The left-hand-side denotes 2SLS predicted daily calorie intake, and the right-hand-side denotes OLS and FE predicted daily calorie intake. The dashed x-line indicates median income among non-agricultural/agricultural individuals

Figure 9: Predicted V.S. actual marginal tax rates



Notes: The left-hand-side denotes predicted calorie intake using actual tax rates, and the right-hand-side denotes predicted calorie intake using predicted tax rates.

Table 7: 2SLS by gender

Variable	(1) Calories	(2) Calories-P	(3) Fat	(4) Protein	(5) Carbohydrate
Panel A: Non-agricultural individuals					
Household income	0.0386	0.0713*	0.0237*	0.00685*	0.00811
	(0.0260)	(0.0372)	(0.0141)	(0.00368)	(0.0165)
Household income^2	-9.75e-07	-1.74e-06*	-5.61e-07	-1.42e-07	-2.73e-07
	(7.29e-07)	(1.01e-06)	(3.96e-07)	(1.03e-07)	(4.63e-07)
Household income*Female	0.0441	0.0318	-0.000348	0.00263	0.0418*
	(0.0398)	(0.0547)	(0.0216)	(0.00563)	(0.0253)
Household income^2*Female	-1.35e-06	-9.53e-07	-6.08e-08	-8.01e-08	-1.21e-06*
	(1.14e-06)	(1.55e-06)	(6.19e-07)	(1.61e-07)	(7.24e-07)
Ratio	244.0	346.5*	121.6	37.06*	85.36
	(151.0)	(210.3)	(82.02)	(21.37)	(95.95)
Light	-63.42**	-76.94***	15.19	-8.840**	-69.77***
	(26.33)	(28.17)	(14.30)	(3.727)	(16.73)
Moderate	-31.30	-43.85	-4.134	-7.647**	-19.52
	(26.71)	(28.22)	(14.51)	(3.781)	(16.97)
Observations	12,698	12,698	12,698	12,698	12,698
R-squared	0.111	0.075	0.068	0.082	0.207
Panel B: Agricultural individuals					
Household income	0.0352	0.0660	0.0281	0.00453	0.00261
	(0.0435)	(0.0657)	(0.0199)	(0.00532)	(0.0298)
Household income^2	-8.12e-07	-2.45e-06	-9.26e-07	-8.36e-08	1.97e-07
	(1.75e-06)	(2.66e-06)	(8.00e-07)	(2.14e-07)	(1.20e-06)
Household income*Female	0.0952*	0.0838	0.0298	0.00850	0.0570
	(0.0567)	(0.0713)	(0.0259)	(0.00693)	(0.0388)
Household income^2*Female	-3.48e-06	-2.79e-06	-1.10e-06	-3.05e-07	-2.08e-06
	(2.41e-06)	(3.05e-06)	(1.10e-06)	(2.95e-07)	(1.65e-06)
Ratio	1,060***	1,151***	389.4***	79.92***	591.1***
	(208.5)	(255.3)	(95.16)	(25.49)	(142.7)
Light	-174.2***	-163.9***	10.41	-9.465***	-175.1***
	(29.99)	(35.34)	(13.69)	(3.668)	(20.54)
Moderate	-235.6***	-237.9***	-34.92**	-20.58***	-180.1***
	(36.02)	(45.70)	(16.44)	(4.405)	(24.66)
Observations	18,654	18,654	18,654	18,654	18,654
R-squared	NR	NR	NR	0.033	0.153

Notes: *** indicates being statistically significant at the 1 percent level. ** indicates being statistically significant at the 5 percent level. * indicates being statistically significant at the 10 percent level. Additional individual and community level covariates are the same as those in Table 4.

Figure 10: Calorie intake by gender

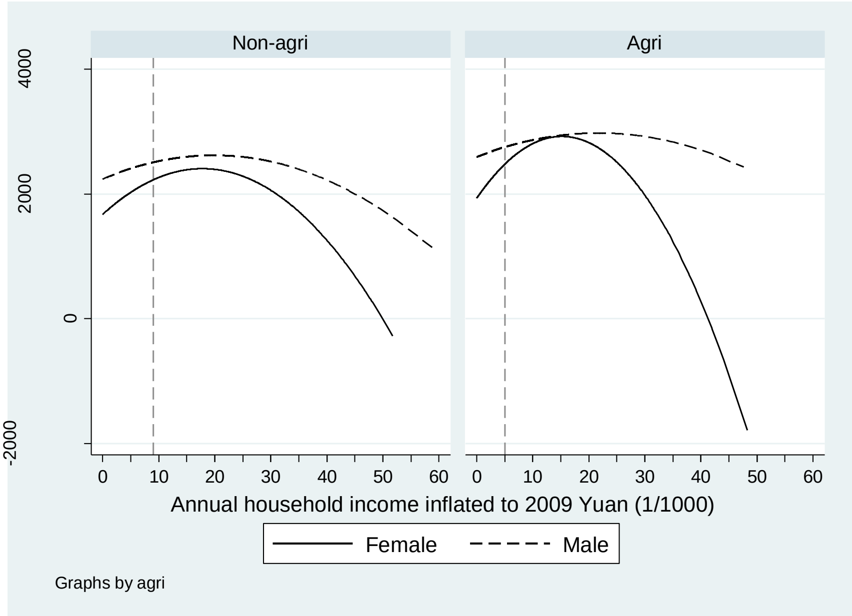


Figure 11: Fat intake by gender

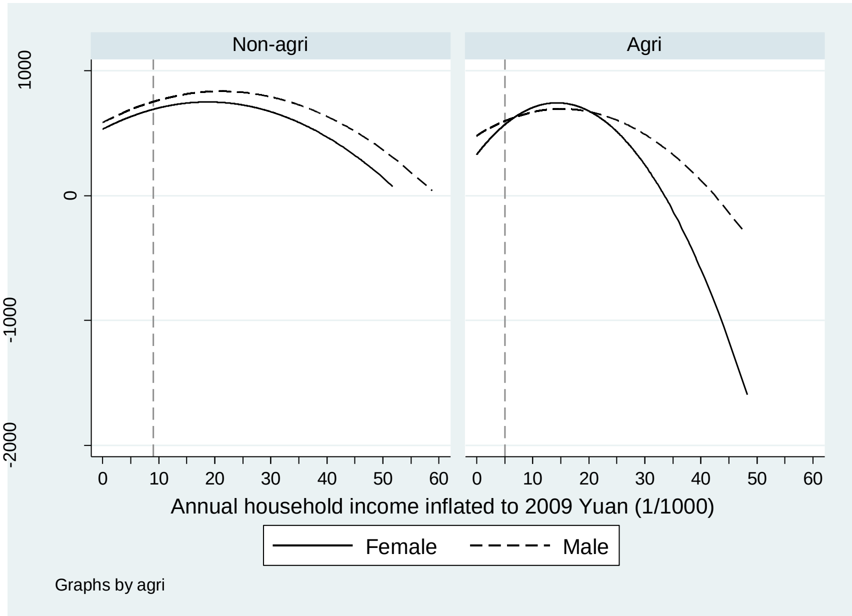


Figure 12: Protein intake by gender

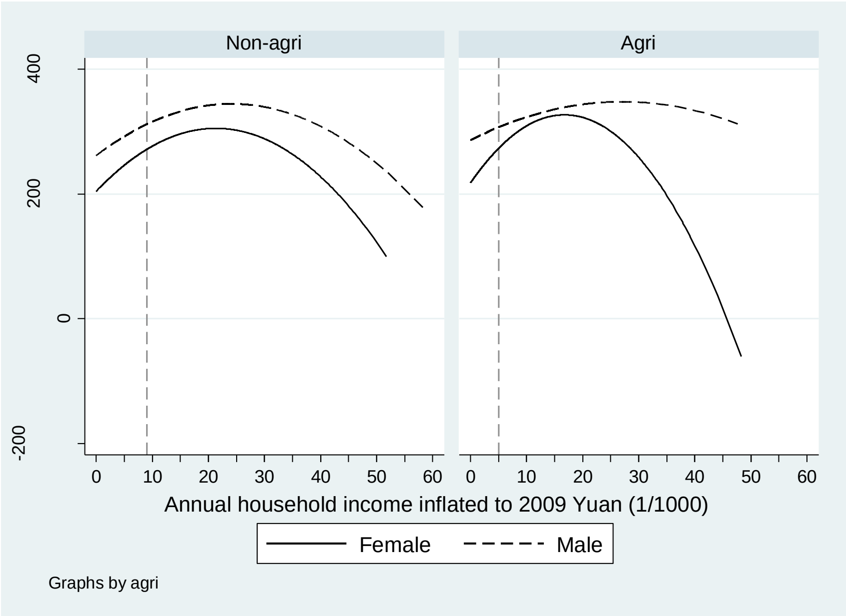


Figure 13: Carbohydrate intake by gender

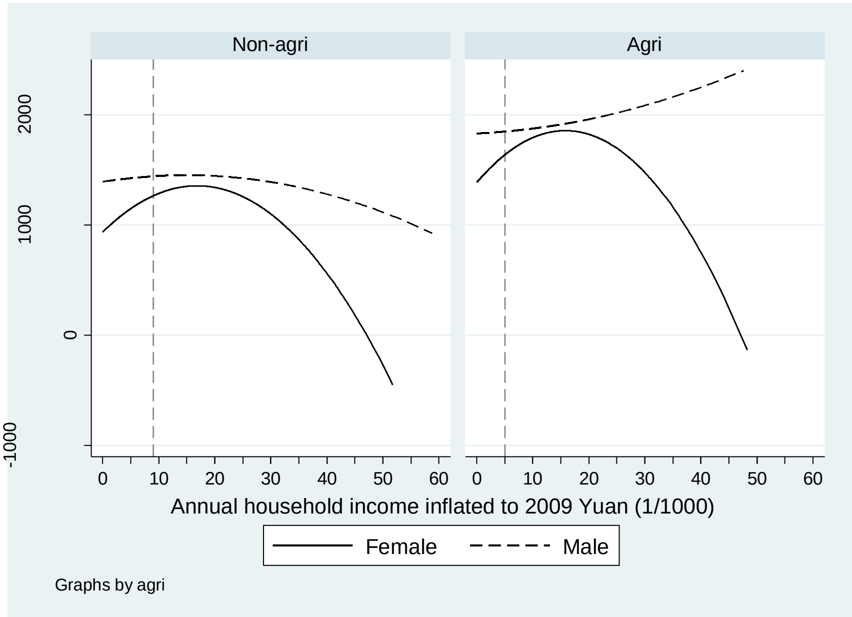


Table 8: 2SLS by household size

Variable	(1) Calories	(2) Calories-P	(3) Fat	(4) Protein	(5) Carbohydrate
Panel A: Non-agricultural individuals					
Household income	-0.0587	-0.0978	-0.0265	-0.00856	-0.0237
	(0.0530)	(0.0653)	(0.0292)	(0.00756)	(0.0337)
Household income^2	1.37e-06	2.24e-06	3.84e-07	2.75e-07	7.12e-07
	(1.37e-06)	(1.62e-06)	(7.53e-07)	(1.95e-07)	(8.68e-07)
Household income*Couple	0.0534	0.0868**	0.0174	0.0104*	0.0256
	(0.0380)	(0.0440)	(0.0210)	(0.00543)	(0.0242)
Household income^2*Couple	-1.34e-06	-1.91e-06	-1.72e-07	-3.17e-07**	-8.49e-07
	(1.10e-06)	(1.20e-06)	(6.05e-07)	(1.56e-07)	(6.97e-07)
Household income*Three	0.101	0.184**	0.0400	0.0137	0.0476
	(0.0682)	(0.0850)	(0.0376)	(0.00973)	(0.0433)
Household income^2*Three	-2.53e-06	-4.46e-06**	-6.87e-07	-3.71e-07	-1.47e-06
	(1.80e-06)	(2.15e-06)	(9.93e-07)	(2.57e-07)	(1.14e-06)
Ratio	267.8**	476.2**	161.4**	47.45**	58.89
	(134.2)	(188.5)	(74.03)	(19.15)	(85.27)
Light	-57.01**	-74.98***	19.33	-8.143**	-68.20***
	(26.00)	(28.49)	(14.35)	(3.712)	(16.52)
Moderate	-28.70	-45.99	-2.070	-7.399**	-19.23
	(26.40)	(28.60)	(14.57)	(3.769)	(16.78)
Observations	12,698	12,698	12,698	12,698	12,698
R-squared	0.135	0.078	0.064	0.091	0.228
Panel B: Agricultural individuals					
Household income	0.0902	0.156	0.0377	-0.0125	0.0650
	(0.104)	(0.124)	(0.0500)	(0.0132)	(0.0724)
Household income^2	-2.14e-06	-3.50e-06	-1.16e-06	7.12e-07	-1.69e-06
	(3.83e-06)	(4.18e-06)	(1.84e-06)	(4.86e-07)	(2.67e-06)
Household income*Couple	0.0194	-0.00500	0.0209	0.0192*	-0.0207
	(0.0789)	(0.0903)	(0.0379)	(0.0100)	(0.0549)
Household income^2*Couple	-2.21e-06	-1.86e-06	-7.78e-07	-1.06e-06***	-3.73e-07
	(3.21e-06)	(3.40e-06)	(1.54e-06)	(4.07e-07)	(2.24e-06)
Household income*Three	-0.0215	-0.0484	0.00831	0.0191	-0.0489
	(0.116)	(0.146)	(0.0558)	(0.0147)	(0.0809)
Household income^2*Three	1.26e-08	-3.83e-07	-4.65e-07	-8.78e-07	1.36e-06
	(4.32e-06)	(5.16e-06)	(2.08e-06)	(5.48e-07)	(3.01e-06)
Ratio	752.4***	820.3***	344.1***	46.73*	361.6**
	(203.7)	(252.5)	(97.84)	(25.81)	(141.7)
Light	-170.2***	-170.8***	10.80	-8.679**	-172.4***
	(29.26)	(34.58)	(14.05)	(3.708)	(20.35)
Moderate	-237.1***	-252.4***	-36.82*	-20.38***	-179.9***
	(39.68)	(48.88)	(19.06)	(5.029)	(27.61)
Observations	18,654	18,654	18,654	18,654	18,654
R-squared	0.049	NR	NR	0.094	0.237

Notes: *** indicates being statistically significant at the 1 percent level. ** indicates being statistically significant at the 5 percent level. * indicates being statistically significant at the 10 percent level. Additional individual and community level covariates are the same as those in Table 4. Couple is a dummy equal to 1 if household size is 2. Three is a dummy equal to 1 if household size is greater than or equal to 3.

Figure 14: Calorie intake by household size

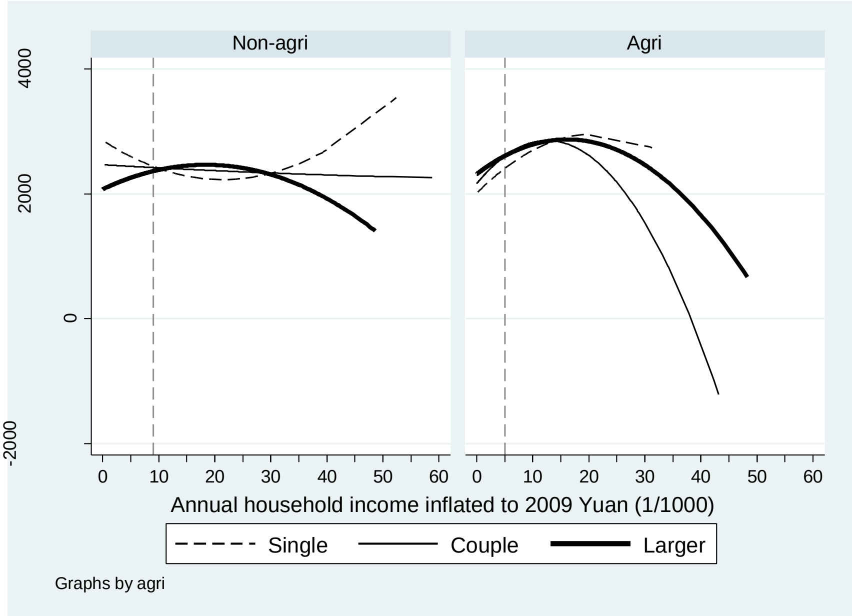


Figure 15: Fat intake by household size

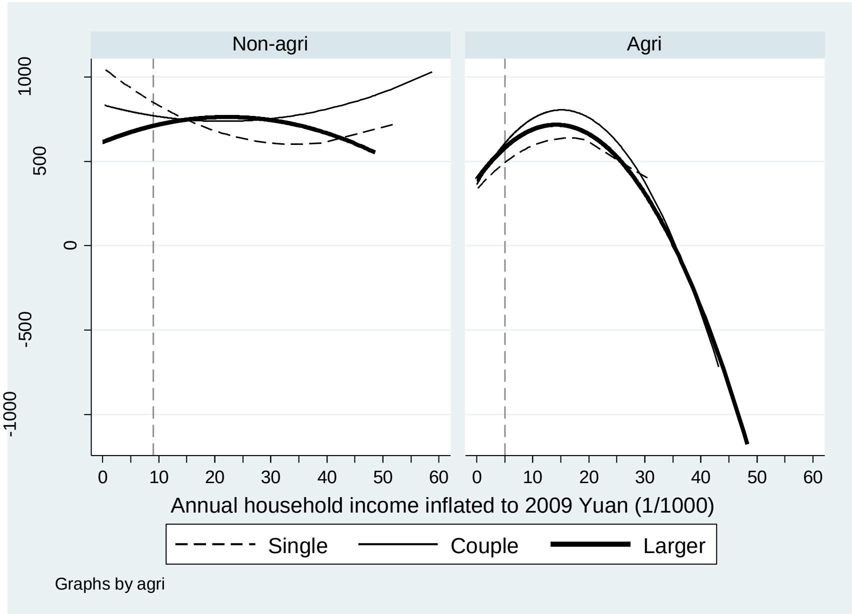


Figure 16: Protein intake by household size

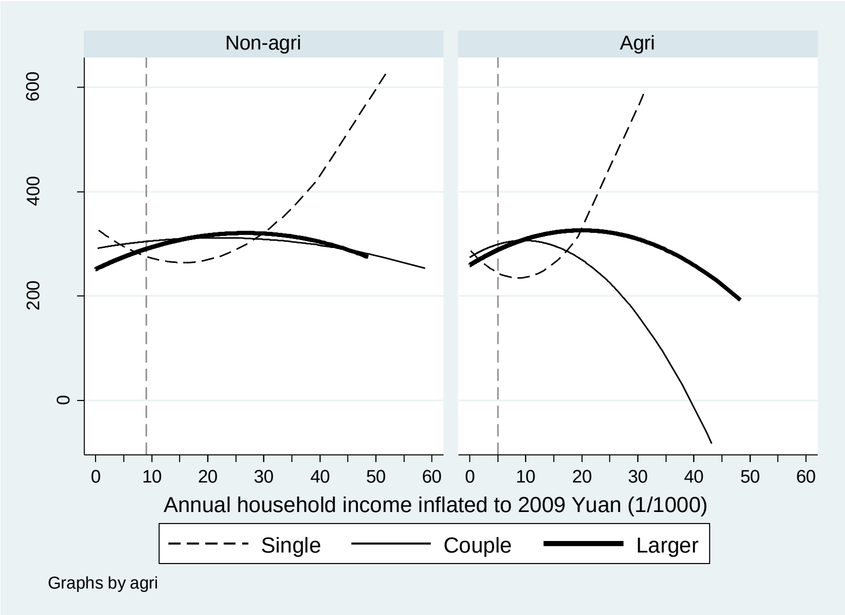


Figure 17: Carbohydrate intake by household size

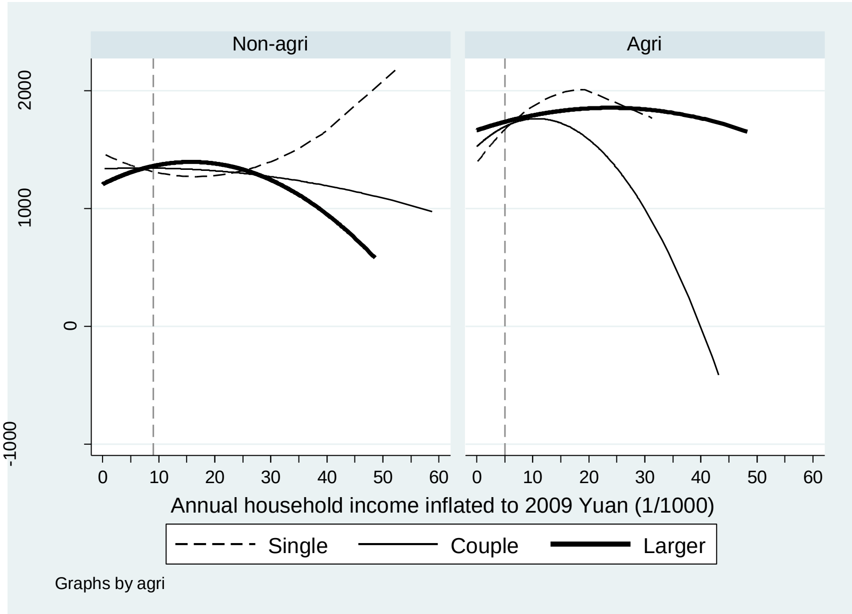


Table 9: Income elasticities in Tables 6-8

	(1)	(2)	(3)	(4)	(5)	(6)
	All	Female	Male	Single	Couple	Larger
Panel A: Non-agricultural individuals						
Calories	0.093	0.139	0.068	-0.118	-0.018	0.072
	[0.152]	[0.178]	[0.128]	[-0.198]	[-0.020]	[0.148]
Fat		0.134	0.151	-0.201	-0.063	0.084
Protein		0.137	0.106	-0.123	0.034	0.080
Carbohydrate		0.146	0.021	-0.074	-0.003	0.066
Panel B: Agricultural individuals						
Calories	0.082	0.128	0.035	0.075	0.113	0.066
	[0.119]	[0.145]	[0.059]	[0.131]	[0.163]	[0.100]
Fat		0.273	0.130	0.135	0.261	0.213
Protein		0.120	0.042	-0.077	0.056	0.061
Carbohydrate		0.090	0.007	0.082	0.070	0.025

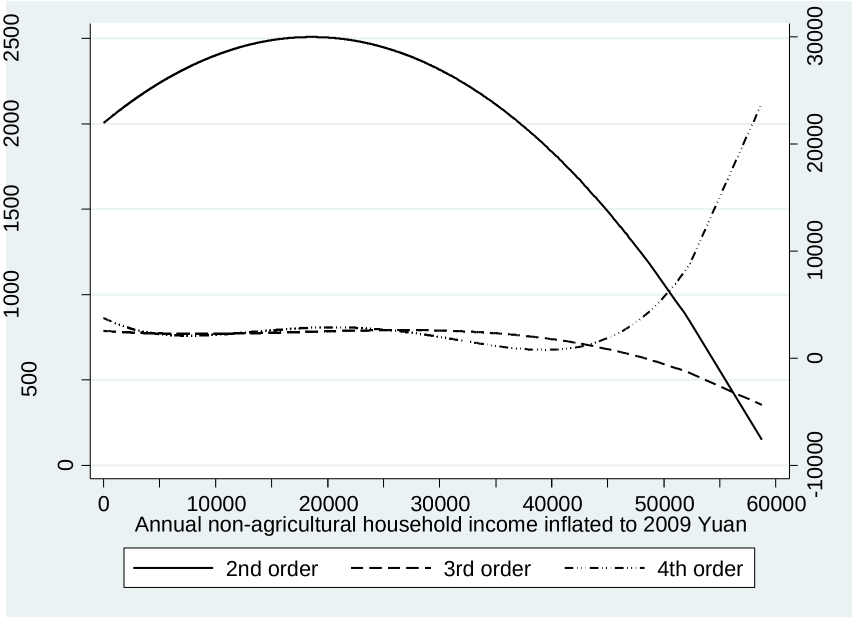
Notes: All income elasticities are evaluated at median income and nutrient intakes. Income elasticities obtained when predicted tax rates are used are in the brackets.

Table 10: Robustness check for higher order functional form

	(1)	(2)	(3)	(4)
	Non-agri		Agri	
Variable	3rd order	4th order	3rd order	4th order
Household income	-0.0735	-0.522	-0.00559	-0.519**
	(0.0658)	(0.469)	(0.0674)	(0.209)
Household income^2	5.85e-06	5.37e-05	4.87e-06	7.51e-05***
	(3.58e-06)	(4.95e-05)	(4.91e-06)	(2.73e-05)
Household income^3	-1.13e-10**	-1.91e-09	-1.65e-10	-3.54e-09***
	(5.41e-11)	(1.86e-09)	(1.02e-10)	(1.29e-09)
Household income^4		0		0***
		(0)		(0)
Ratio	322.1**	301.5*	725.3***	339.5
	(155.3)	(181.1)	(215.5)	(279.6)
Light	-41.50	-63.88	-158.0***	-94.47**
	(28.44)	(40.22)	(30.80)	(41.73)
Moderate	-14.58	-38.95	-217.9***	-186.3***
	(28.23)	(41.24)	(40.51)	(46.33)
Observations	12,698	12,698	18,654	18,654
R-squared	0.079	NR	0.023	NR

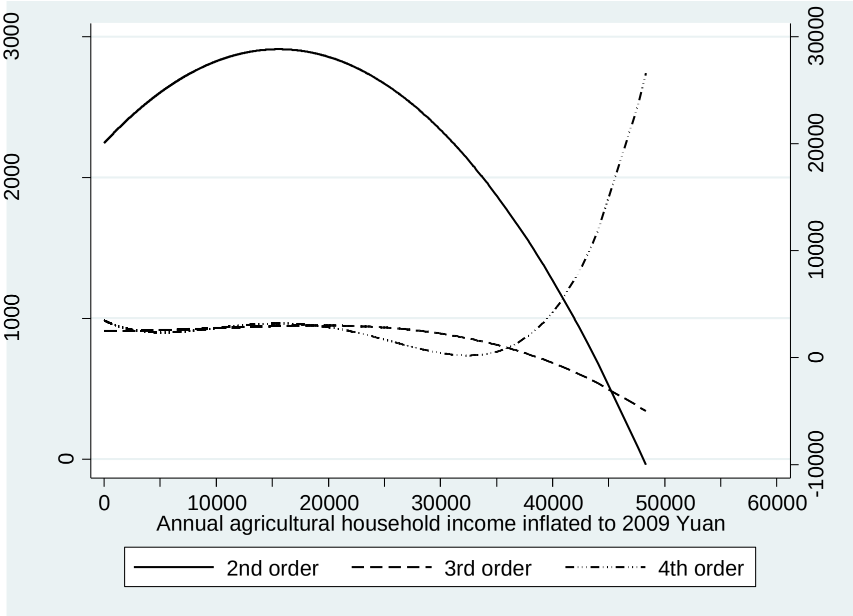
Notes: *** indicates being statistically significant at the 1 percent level. ** indicates being statistically significant at the 5 percent level. * indicates being statistically significant at the 10 percent level. Additional individual and community level covariates are the same as those in Table 4.

Figure 18A: Higher order Engel curves in the non-agricultural sector



Notes: The left-hand-side uses 2nd order specification, and the right-hand-side uses 3rd and 4th order specifications.

Figure 18B: Higher order Engel curves in the agricultural sector



Notes: The left-hand-side uses 2nd order specification, and the right-hand-side uses 3rd and 4th order specifications.

Appendix A: Data

A.1. China Health and Nutrition Survey (CHNS)

CHNS is an ongoing international collaborative project between the Carolina Population Center (UPC) at the University of North Carolina (UNC) and the National Institute of Nutrition and Food Safety (NINFS) at the Chinese Center for Disease Control and Prevention (CCDCP). This survey was designed to examine the effects of the health, nutrition, and family planning policies and programs implemented by the national and local governments, and to analyze how the social and economic transformation is affecting its population's health and nutritional status.

The survey was performed by an international team of researchers whose backgrounds include nutrition, public health, economics, sociology, Chinese studies, and demography. And it took place over a 3-day period using a multistage, random cluster process to draw a sample of about 4,400 households with a total of 19,000 individuals in nine provinces, which vary in geography, economic development, public resources, and health indicators. Counties in the nine provinces were stratified by income (low, middle, and high), and a weighted sampling scheme was used to randomly select four counties in each province. The provincial capital and a lower income city were selected when feasible. Villages and townships within the counties, and urban and suburban neighborhoods within the cities, were selected randomly.

The survey collects information on household and individual economic activities (such as occupational activity, farming, and household business), time allocation (such as shopping, cooking, and child care), insurance coverage, use of health facilities, individual lifestyle (such as smoking, and drinking etc.), household asset ownership, individual health status, marriage and birth history. Furthermore, it includes anthropometric measures (such as weight, height, and arm circumference) and information on community level economic conditions, such as health service quality, infrastructure availability etc. was collected in the community survey.

CHNS constructed a separate longitudinal data file with community level covariates, using established scaling procedures and CHNS community level data collected in the community survey. A higher value (0-10) of each community level covariate indicates a higher degree of urbanization/quality. The community level covariates are population density, population diversity, economic condition, education, housing quality, health service quality, sanitation, traditional market, modern market, transportation, and communication.

Community population density was constructed as the ratio between total population of the community and community area (from official records). Community population diversity was constructed using information on the variation in educational attainment and income level within the community. Community economic condition was constructed using information on typical daily wage for an ordinary male worker and percentage of non-agricultural labour force. Community education was constructed using information on average educational attainment among adults aged over 21y. Community housing quality was constructed using information on access to electricity and access to gas etc. within a community. Community health service quality was constructed using information on number and type of health-care facilities within 12 km within the community. Community sanitation was constructed using information on proportion of households with treated water etc. within the community.

Community traditional market was constructed using information on traditional markets (such as distance to a traditional market etc.). Community modern market was constructed using information on number of supermarkets, cafes, internet cafes etc. within the community. Community transportation was constructed using information on type of road, distance to the closest bus stop etc. within the community. Community communication was constructed using information on availability of a cinema, availability of postal service, percentage of households with a television etc. within the community.

A.2. National Bureau of Statistics of China (NBSC) and China State Administration of Taxation (CSAT)

NBSC provides China Statistical Yearbook (CSY) for each year (CSY 1989), which is an annual statistical publication and covers very comprehensive data in each year and some selected data in historically important years and the most recent 20 years at national level and local levels of province, autonomous region, and municipality directly under the central government, reflecting various aspects of China’s social and economic development. CSAT is a ministerial-level department within the government of the People’s Republic of China. It is under the direction of the State Council, and is responsible for the collection of taxes and enforces the state revenue laws. CSAT is responsible for, among other things, drafting tax laws and regulations, formulating detailed implementation rules for tax laws and regulations, and putting forward suggestions on tax policies.

Appendix B: Additional results

B.1. *Robustness Check I: Calories and Physical Activity*

Calorie intake and physical activity determine the evolution of body weight. Increases in bodyweight consequently result from eating too much given the level of physical activity the individual engages in. Hence, we control for one important dimension of physical activity, which is occupational physical activity. However, it is likely that the control variables for occupational physical activity (sedentary occupation and moderate occupation) are also endogenous. On the one hand, occupational type is likely to be correlated with unobserved heterogeneity such as innate ability, family background, and/or time discounting. For example, if daily calorie intake is increasing in the strenuousness of occupational physical activity, and if individuals with a lower discount rate are more likely to have a sedentary occupation (Murphy et al., 2005), the correlation between daily calorie intake and the strenuousness of occupational physical activity will be biased upward. On the other hand, since there also exists common shocks (for example, technological innovation) that affect both daily calorie intake and the strenuousness of occupational physical activity (Lakdawalla et al., 2002, 2005, and 2007; Philipson et al., 2008 and 2010; Bleich et al., 2008; and Ng et al., 2009), endogeneity of occupational type in turn is due to simultaneity bias instead of omitted variables bias.

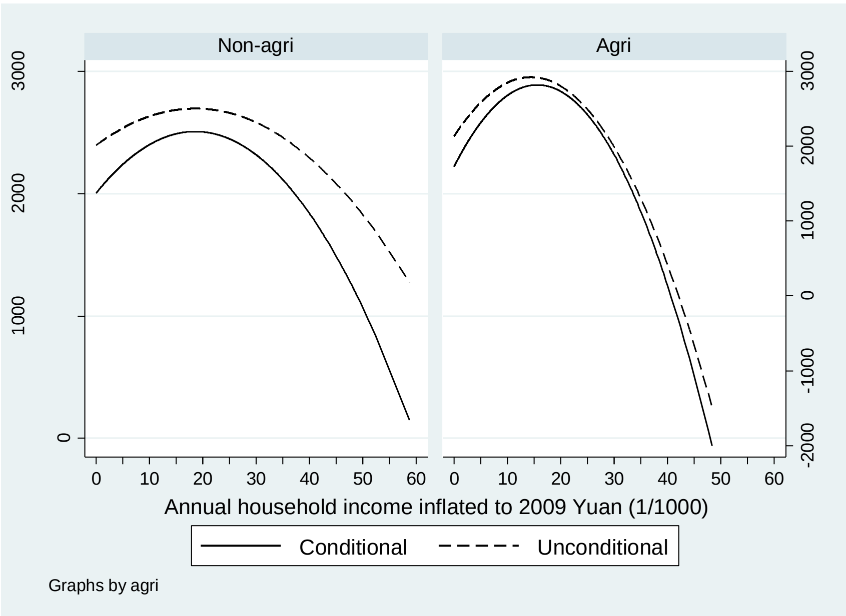
Table 11 shows results for daily calorie intake with and without conditioning on occupational physical activity, for both non-agricultural (see Columns 1 and 2) and agricultural (see Columns 3 and 4) individuals. We find very similar coefficient estimates for the income profiles in both specifications, in spite of significant and negative effects of occupational physical activity among individuals from both sectors. These negative effects indicate that calorie intake is adjusted according to daily energy expended. The resulting Engel curves (Figure 19) are almost identical and differ only at very high incomes.

Table 11: Robustness check for endogeneity of physical activity

	(1)	(2)	(3)	(4)
	Non-agri		Agri	
Variable	Conditional	Unconditional	Conditional	Unconditional
Household income	0.0543**	0.0531**	0.0856**	0.109***
	(0.0232)	(0.0231)	(0.0372)	(0.0399)
Household income^2	-1.46e-06**	-1.43e-06**	-2.75e-06**	-3.81e-06**
	(6.46e-07)	(6.44e-07)	(1.37e-06)	(1.48e-06)
Ratio	240.7	231.9	857.4***	811.4***
	(146.5)	(146.1)	(200.8)	(199.2)
Light	-61.51**		-175.3***	
	(26.10)		(29.09)	
Moderate	-30.57		-245.7***	
	(26.49)		(36.94)	
Observations	12,698	12,698	18,654	18,654
R-squared	0.125	0.125	0.009	NR

Notes: *** indicates being statistically significant at the 1 percent level. ** indicates being statistically significant at the 5 percent level. Additional individual and community level covariates are the same as those in Table 4.

Figure 19: Conditional V.S. unconditional Engel curves



Notes: The left-hand-side denotes conditional Engel curves, and the right-hand-side denotes unconditional Engel curves.

B.2. Robustness Check II: Equivalence Scale Adjustment

What constitutes a proper equivalence scale is intensively discussed in the literature. Goldman et al. (2010) uses household income per capita, while Meng et al. (2004) use more equivalence scale adjustments with different weights for adults, children and elderly[23]. Our equivalised income measure is based on the square root of household size (Buhrmann et al., 1988; Atkinson et al., 1995) which gives a weighting similar to that of the also widely used modified OECD scales. We performed a robustness check using per-capita income which assumes no economies of scale, and find very similar results.

Results obtained under the alternative measure are reported in Columns 2 and 4 of Table 12. For comparison, income effects obtained under the original square root measure are shown in Columns 1 and 3.

There is no statistical difference between the two sets of results for agricultural households at the 5 percent level, while significant differences are detected for people from non-agricultural background. But as Figure 20 shows, there is little change in the calorie income profile of non-agricultural households, and their income elasticity of calories under the alternative equivalence scale adjustment is around 0.139, similar that predicted in Table 6 (0.093). Therefore, our results are robust to the use of different equivalence scale adjustments.

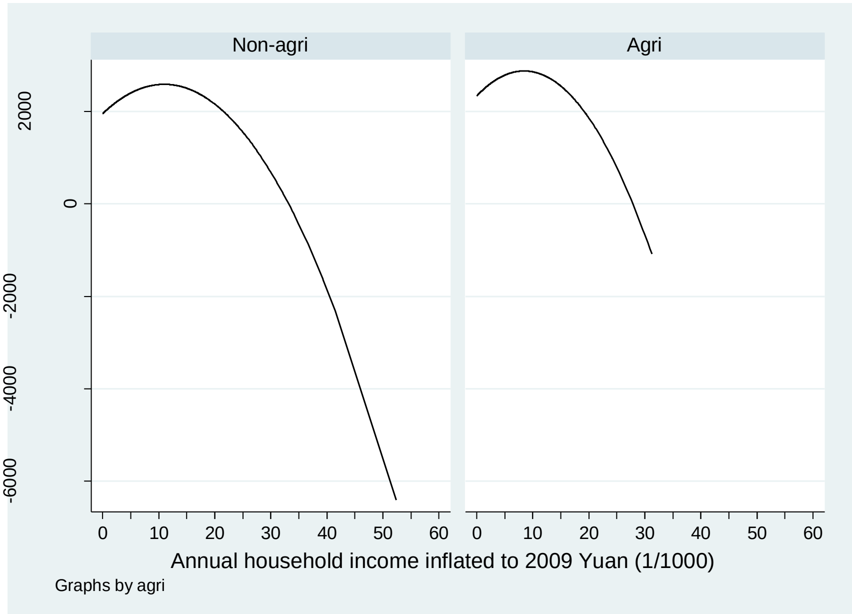
[23] These weights are: 0.35 for infants (0-2y), 0.5 for children (3-14y) and elderly (above 65y). Alternatively, they attach an equivalence scale of 0.5 to infant and a weight of 0.75 to children and the elderly.

Table 12: Square root of household size V.S. household size

	(1)	(2)	(3)	(4)
	Non-agri		Agri	
Variable	Size^1/2	Size	Size^1/2	Size
Household income	0.0543**	0.116***	0.0856**	0.129**
	(0.0232)	(0.0370)	(0.0372)	(0.0518)
Household income^2	-1.46e-06**	-5.26e-06***	-2.75e-06**	-7.63e-06**
	(6.46e-07)	(1.71e-06)	(1.37e-06)	(3.62e-06)
Ratio	240.7	393.3**	857.4***	793.3***
	(146.5)	(168.0)	(200.8)	(184.7)
Light	-61.51**	-58.59**	-175.3***	-169.1***
	(26.10)	(27.10)	(29.09)	(27.72)
Moderate	-30.57	-30.02	-245.7***	-226.5***
	(26.49)	(27.56)	(36.94)	(30.91)
Observations	12,698	12,698	18,654	18,654
R-squared	0.125	0.047	0.009	0.034

Notes: *** indicates being significant at the 1 percent level. ** indicates being significant at the 5 percent level. Additional individual and community level covariates are the same as those in Table 4.

Figure 20: Engel curves: household size adjusted income



Chapter 2 When Culture Dictates: The Long-term Impact of the Chinese Proletarian Cultural Revolution (1966-1976)

1. Introduction

The role of education interventions has been a basic concern for economists for some time. One central motivation behind various education interventions is that increased schooling may pay off in the long-term (Currie 2009; Oreopoulos and Salvanes 2011). In particular, the health returns to education have been attracting increasingly more attention from the academic circle. As Kenkel, Lillard and Mathios (2006) noted: "the positive association between schooling and health has been called one of the strongest generalisations to emerge from empirical research on health in the United States". Yet so far existing evidence on the health impact of education interventions (or education) has been mixed. On the one side, education interventions have proved to positively influence health (Currie and Moretti 2003; Lleras-Muney 2005; Oreopoulos 2006). On the other, scepticisms have also been cast on the potential health benefits of further expenditures on education (Heckman 2000; McCrary and Royer 2011; Clark and Royer 2013). One reason for this inconclusiveness is that individuals who are affected by education interventions may differ systematically from those who are not, in terms of initial endowment (Behrman and Rosenzweig 2004), innate ability (Card 2001), preferences (Butcher and Case 1994) and parental characteristics (Oreopoulos, Page and Stevens 2006). Since health is one of the most important human capitals (Grossman 1972) and education policies have long been perceived as a cost-effective way to improve health (Devereux and Hart 2010), more empirical estimates of the health impact of education policies are warranted. This analysis aims to add more insight into this ongoing literature by taking advantage of a nationwide education expansion campaign in China that may overcome some of the selection problems highlighted by previous studies. It also examines how this education campaign has altered individual health behaviours and labour supply, as they are two of the well-established correlates of health (Arendt 2005; Chavas 2013).

The education intervention examined in this study is the Chinese proletarian Cultural Revolution. The Cultural Revolution created a once-and-for-all education system, i.e. change that lasted from 1968-1976 and had no counterpart in the education history of China (Pepper 1991; Lin 1997; Song 2009). Since both the onset and termination of the Cultural Revolution were unexpected, abrupt and comprehensive (Harding 1991; MacFarquhar 1991; Pepper 1991), the education system ensued from it can be used as a quasi-experiment for better understanding the health-policy relationship. In particular, one major feature of the Cultural

Revolution education system was the nationwide expansion of primary education. This analysis examines the long-term impact of this feature of the Cultural Revolution on individual health and health-related outcomes. The dataset used is China Health and Nutrition Survey (CHNS) panel, which has rich information on various measures of health.

The Cultural Revolution education policies almost universalised primary education among school-aged children, as a result of a wider availability of primary schools across the country and the abolition of various entrance exams used to restrict grade progression (Andreas 2004; Deng and Treiman 1997; Hannum 1999). But evidence on how education quality was affected by the Cultural Revolution has been mixed. On the one hand, because the Cultural Revolution overstretched limited school resources (to meet the demand by newly constructed schools), shortened primary school length (from 6 to 5 years), simplified teaching curricula (from academic to vocational) and lowered study morale (future career opportunities no longer linked to academic performance), it was blamed for leading to a disastrous decline in education standard (Deng and Treiman 1997; Wu 2008; Hannum 1999; Andreas 2004). On the other, Meng and Gregory (2002 and 2007) and Zhang, Liu and Yung (2007) observed that there was a gradual return to normalcy in the primary school system since around 1969. Statistics from the Ministry of Education suggest that during the Cultural Revolution the number of full-time teachers in primary schools increased, there were more teachers with better teaching qualifications (teacher-training and academic senior-middle school graduates), the student-to-teacher ratio declined and there was little change in class-size (Table 1). These seem to suggest that primary school quality may have suffered little or even improved.

Specifically, these policy implications varied by both cohort year-of-birth and place-of-birth. Time-wise, the expansion of primary education affected only those cohorts who were at primary school age during the Cultural Revolution: Cohorts born in 1955-1970 (-1 to 14 years old in 1968) were potentially exposed to the revolution while cohorts born in 1949-1954 (15 to 20 years old in 1968) were not. In addition, policy intensity also differed by urban and rural place-of-birth. Before the Cultural Revolution, children with rural place-of-birth had more limited access to primary education than children with urban place-of-birth. The revolution education policies explicitly favoured rural children, leading to a relative increase in education quantity among them, compared to their urban counterparts (Deng and Treiman 1997; Hannum 1999; Lu and Treiman 2008). There may also be a relative increase in education quality received by rural children, although the overall impact of the Cultural Revolution on education quality is not clear. Giles, Park and Wang (2008) and Meng and

Gregory (2002 and 2007) found that school life for rural children was likely less disrupted than that for urban children (e.g. the student-teacher movements seemed mainly concentrated in the cities). Andreas (2004) suggested that the expansion policies made basic education available to some village youth for the first time, leaving no scope for decline in education quality. Thirdly, the problem of teacher shortage may also be less acute for primary schools in rural areas. Because statistics from the Ministry of Education show that rural primary schools hired more teachers than urban primary schools between 1965 and 1976 (Table 1). Andreas (2004) noted that village youth graduating from teacher-training schools were required to return to their villages of origin during the Cultural Revolution. And the various rustication programs (targeted at urban middle school graduates and other academic professionals) put forward by the revolution authority may avail rural primary schools of more teachers (Hou and Zhou 1999). Interestingly, available evidence also appears to suggest that, within rural cohorts, those with rural-village (More Rural) place-of-birth may likewise have benefited more from the Cultural Revolution than those with rural-town (More Urban) place-of-birth, in terms of both education quantity and quality (Section 2).

Exploiting both the year-of-birth and More Rural-More Urban place-of-birth differentials in treatment intensity, this study identifies the policy parameter of interest using difference-in-differences. Using the More Rural-More Urban differential instead of the urban-rural differential helps minimise confounding due to the forced Rustication Program (middle school graduates were forced to the countryside to engage in agricultural labour) that was also part of the Cultural Revolution and may have long-term implications for cohort health. But since CHNS contains only information on cohort rural-village (More Rural) and rural-town (More Urban) place-of-residence (instead of place-of-birth) and since place-of-residence can well differ from place-of-birth due to migration (Mullan et al. 2010), this study uses and compares four alternative definitions of More Rural and More Urban which differ by how rural-village and rural-town are classified, as an attempt to provide more reliable estimates of interest.

Yet it is still likely that changes in the health (or health-related outcomes) of the More Rural cohorts would not have been the same as the changes in the health of the More Urban cohorts even without the Cultural Revolution. This study therefore re-estimates the baseline specification on a more comparable discontinuity sample of the More Rural and More Urban cohorts created by one institutional feature of the revolution education agenda. Second, since the treatment group includes those who were in school at the beginning (the 1955-1960 cohorts) and the end (the 1966-1970 cohorts) of the Cultural Revolution, it is possible that the baseline results are picking up the effects of events other than the education policy occurring during the especially turbulent years of the revolution (beginning and end). This study next restricts the treatment group to those who started and completed primary education within the revolution decade (the 1961-1965 cohorts), the cohorts who may be less affected by events that occurred either before or after they were at primary school age. Thirdly, cohorts may differ systematically in their demand for education due to e.g. changing attitudes toward education. This study then examines whether the baseline is sensitive to controlling for cohort pre-treatment difference in education attainment. Fourth, a similar difference-in-differences is applied to the control (the 1949-1954 cohorts) in order to see if a significant policy impact can be found where it is not expected. Lastly, the comparison of outcomes of the urban and rural cohorts is likely plagued by non-random rural-to-urban migration. This study uses exogenous shocks to agricultural labour supply to model individual decisions to move and correct for potential selection bias caused by endogenous migration.

This study builds upon and contributes to three strands of existing literature. First, it adds more information to an emerging literature that focuses on the long-term impact of the Cultural Revolution[24]. The most related are Giles, Park and Wang (2008) and Meng and Gregory (2002; 2007) who also exploited the education policies during the Cultural Revolution. Both these two studies noticed that the Cultural Revolution caused substantial education disruptions by closing schools at its onset (1966-1968) and simplifying school curricula. Meng and Gregory (2007) asked how these education disruptions affected cohorts' later education and earnings. The urban youth with disturbed school years (the 1947-1961 cohorts) were significantly less likely than their undisturbed counterparts (the 1942-1946 and the 1962-1966 cohorts) to have a senior-high school and college degree, by 17 and 7 percentage points. The cohorts with interrupted education also earned significantly less, by 6%. Giles, Park and Wang (2008) used the Cultural Revolution as an instrument for education and estimated the earnings return to education. They argued that the extent to which education was interrupted differed by parental education and occupation. Using this within-cohort variation and controlling for unobserved cohort differences, they found that the disrupted urban cohorts (disrupted secondary education: the 1948-1963 cohorts; disrupted college education: the 1945-1963 cohorts) with more educated fathers were less likely to

[24]Harmel and Yeh (2013), Gong, Lu and Xie (2014), Li, Rosenzweig and Zhang (2008), Giles, Park and Wang (2008) and Meng and Gregory (2000 and 2007). Among them, Harmel and Yeh (2013), Gong, Lu and Xie (2014) and Li, Rosenzweig and Zhang (2008) were interested in the rustication program instead of the education system during the Cultural Revolution. All the three studies found a significant long-term impact of the rustication program.

graduate from colleges (1-4 percentage points; 5-22%) and high schools (2 percentage points; 3%). Though intended as a placebo test, an additional finding in Giles, Park and Wang (2008) is that the Cultural Revolution seems not significantly related to individual health. This study differs from theirs by focusing on a different aspect of the Cultural Revolution, i.e. the restoration and expansion of the school system during the later consolidation phase of this movement (1968-1976).

This study is also related to an extensive literature that uses supply-side features of the school system as exogenous determinants of individual education and estimates returns to education[25]. Specifically, Maurin and McNally (2008) is related to this study in that the education intervention exploited is essentially a historical event (the May 1968 student riots in France that abandoned normal examination procedures and enabled a fair proportion of students to pursue more years of higher education than would otherwise have been possible). Angrist and Lavy (1999), Krueger (1999) and Krueger and Whitmore (2001) are related because they used education policies targeted at primary schools (specifically class-size in primary schools) to estimate the impact of school quality on student performance. Duflo (2001) is the most relevant. The setting is in a developing country (Indonesia) and the education intervention is a primary school construction program. Between 1973 and 1978, more than 61,000 primary schools (two schools per 1,000 children aged 5-14 in 1971) were built up in Indonesia. Duflo observed that program intensity differed by both individual year-of-birth in terms of when the program was implemented and region-of-birth in terms of the number of schools constructed. Exploiting both these two differentials, her estimates suggest that each primary school constructed (per 1,000 children) led to an average increase of 0.12-0.19 years of education and 1.5-2.7% increase in wages. This study contributes to this literature by asking how education intervention in a setting with low levels of education may have shaped individual health outcomes. Relatively few studies have considered the health returns to education policy in a developing background (Currie and Moretti 2003; Oreopoulos 2006).

Thirdly, this study adds some new insight into an ongoing literature that more closely examines the intermediate pathways linking education policies or education to health[26]. For

[25] For example, for school availability, see Card (1995), Currie and Moretti (2003) and Duflo (2001); for compulsory schooling laws, see Oreopoulos (2006), Angrist and Krueger (1991) and Chou (2007); for education benefits, see Stanley (2003) and Lemieux and Card (1998); for examination procedure, Maurin and McNally (2008); for class-size, see Angrist and Lavy (1999), Krueger (1999) and Krueger and Whitmore (2001).

[26] For example, Currie and Moretti (2003), Clark and Royer (2013), de Walque (2007), Lleras-Muney (2005), Grimard and Parent (2007) and Kenkel, Lillard and Mathios (2006).

example, Currie and Moretti (2003) found that, after obtaining estimates suggesting that college openings in a mother's county-of-birth at age 17 significantly increased her education and improved child health, a higher number of colleges was associated with a higher probability that a new mother was married and higher husband education, reduced parity, increased prenatal care usage and reduced smoking. They interpreted this as suggesting that these aspects are important pathways for the ultimate effect on health. Clark and Royer (2013) estimated the education impact on smoking to better understand their results of a mild relationship between increased secondary education (induced by the 1947 and 1972 British compulsory schooling laws) and health. Their results seem not point to smoking as a strong health mediator. These two studies and others also noted that education may affect individuals' health by influencing their health knowledge and perceptions of health-related risks. This contention is supported by a few studies summarised in Grimard and Parent (2007) and Kenkel, Lillard and Mathios (2006).

This study exploits rich data from the CHNS and asks whether the health impact of the Cultural Revolution may operate through its impact on individual health-related preferences or through the possibility that increased education induced individuals to adopt health-improving behaviours (e.g. medical care utilisation).

This study finds that the Cultural Revolution significantly increased primary education obtained by the treated More Rural (the cohorts with More Rural place-of-residence who were affected by the expansion of primary education). In particular, the full-treat More Rural (the cohorts with More Rural place-of-residence who began and finished their primary schooling during the Cultural Revolution) and partial-after More Rural (the cohorts with More Rural place-of-residence who began their primary schooling during the Cultural Revolution but were still in school at the end of it) seem have benefited more from the Cultural Revolution in terms of education attainment. The results also suggest that the the education estimates are not sensitive to various robustness checks.

Yet the long-term impact of the Cultural Revolution on cohort health is more mixed. While the Cultural Revolution seems have significantly reduced underweight among the treated More Rural, by 4.5-5.6 percentage points or 123-153% (based on sample means), reduced self-reported poor health, by 11.3-23.5 percentage points (33-68%), it seems have significantly increased the incidence of high blood pressure, by 6.9-7.6 percentage points (107-117%). Results for overweight are also inconclusive with flipping signs. Further exploring the impact of the Cultural Revolution on the two health correlates – health behaviours and labour supply – leads to estimates suggesting that the treated More Rural was more likely to have medical insurance (15-59%), less likely to smoke (31-43%) and more likely to take physical activities (137%), while working more actively (19%) and having a higher income (34.2-120.5%). (The labour supply results are only for the partial-after More Rural.) The difference-in-differences estimates also tend to suggest that the more treated (in terms of education), the healthier the health behaviours and the more active the labour supply.

Lastly, the Cultural Revolution is estimated to have a significant impact on cohort health-related lifestyle and consumption preferences and the preference results seem able to explain those obtained for its long-term impact. For example, the lower prevalence of underweight among the treated More Rural cohorts may be explained by their higher likelihood of liking less healthful foods (fast foods, salty snacks and soft drinks) and sedentary activities (watching TV, playing computer and reading), while the higher tendency for the full-treat More Rural to take physical activities and consume a fatty diet may be explained by this group's preferences for active activities (walking, sports and body-shaping) and similarly less healthful foods. Moreover, more primary schooling (induced by the Cultural Revolution) seems have increased medical insurance ownership (20-49%), reduced smoking (33%), increased exercising (103-166%), led to higher probability of working (22%) and increased income (38.1-116.8%), within the study sample. It therefore seems that the long-term impact of the Cultural Revolution may come from its influence on cohort health-related preferences and the positive correlation between education and health outcomes.

This study is structured as follows: Section 2 outlines the historical and theoretical setup for the current study. Section 3 describes in detail the research design. More information on the China Health and Nutrition Survey data is in Section 4. Section 5 presents the education results for the Cultural Revolution, which is followed by some robustness checks in Section 6. Results for the health impact of the Cultural Revolution are in Section 7. Section 8 exploits the mechanism and Section 9 concludes.

2. Historical and Theoretical Setup

2.1 The Cultural Revolution Education System (1968-1976)

This section briefly summarises the educational aspect[27] of the Chinese proletarian Cultural Revolution. The radical Cultural Revolution education campaign was carried out in order to "drag out the academic power holders and bourgeois intellectual authorities who presided over the breeding ground for intellectual aristocrats" (Pepper 1991). It went through two phases. During the first mobilisation phase (1966-1967), the pre-revolution education system was turned over by students and teachers as a result of a series of student-teacher movements and day to day management of schools was severely disrupted. Normal school life was gradually resumed during the second consolidation phase (1968-1976) when the Cultural Revolution education system was nationally institutionalised (Lin 1997; Song 2009). This revolution education system was then abruptly and comprehensively dismantled in 1977, after the official's denunciation and termination of the broader Cultural Revolution.

One major feature of the Cultural Revolution education system was the nationwide expansion of primary[28][29] education. In fact, part of the education policy was also designed to promote secondary and college education, but since identifying the policy impact of the former is much more difficult[30] and only around 6% of the study sample had some college education[31], this study leaves this aspect of the Cultural Revolution for future research (Appendix B provides a brief description of the revolution education policies at the secondary and tertiary levels). Specifically, the Cultural Revolution education policies at the primary level had three implications for the affected cohorts. First, quantitatively, primary education was almost universalised among school-aged kids. This can be explained by a wider availability of primary schools and the fact that exams previously used to determine grade progression were abolished[32] (Andreas 2004; Deng and Treiman 1997; Hannum 1999).

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[27] A more comprehensive description (including non-educational aspects) of the Chinese proletarian Cultural Revolution is given in The Cambridge History of China edited by MacFarquhar and Fairbank (1991).

[28] To be more specific, the major feature of the Cultural Revolution education policies should be the nationwide expansion of basic education (including both primary and secondary education). But since this current analysis does not examine the policy impact of the expansion of secondary education, the main text is somewhat vague about this point.

[29] In fact, it should be primary education obtained from regular schools. But since all the primary schools were regular, the main text is also vague about this point.

[30] This is because among the sampling cohorts, those born between 1949 and 1970, there does not exist a group of cohorts who was neither affected by the expansion of secondary education nor affected by the expansion of primary education, i.e. there does not exist a clean control group for the treatment in terms of secondary education.

[31] This is consistent with previous findings in e.g. Lin (1997).

[32] Before 1966, admission examinations were required for progressing onto each higher level, starting with junior middle schools. In the revolution decade, more emphasis was placed instead on student family class

Figure 1A plots trend in enrolment rate of school-aged kids in primary schools from 1952-1983. Around the onset of the Cultural Revolution education system (in 1965), roughly 84.7% of total school-aged children were enrolled in primary schools; this number rose to about 96% at the end of it. Including both school-aged and non-school-aged kids, Figure 1B shows a similar upward trend in both primary school enrolment and graduation over the period when the revolution system was in existence. From 1968-1976, there was an around 50% (10036.3 ten thousand in 1968) and 74% (1428.2 ten thousand in 1968) increase in primary school enrolment and graduation, respectively.

Second, existing evidence on the qualitative impact of the Cultural Revolution is mixed. On the one hand, the Cultural Revolution education policies have been blamed for leading to a disastrous decline in education standards. The rapid expansion of education likely lowered teaching quality substantially because it made the problem of limited school resources and qualified teachers more acute (Deng and Treiman 1997). Primary school length was reduced from 6 years in the pre-system to 5 years (Wu 2008). School curricula were simplified and became more practical: Before the revolution academic curricula coexisted with rural-oriented (or vocational) curricula, with the former emphasising education quality and the latter focusing on popularising education among workers and peasants; the Cultural Revolution made all the curricula rural-oriented (Hannum 1999). In addition, the Cultural Revolution also abolished the pre-revolution examination system in which students competed in exams to enter a hierarchy of increasingly selective middle schools and (ultimately) colleges. This undermined student motivation to study: Success in the old meritocratic system was closely correlated with future job opportunities in state sectors, while the elimination of it blocked this route (Andreas 2004).

Conversely , researchers (Meng and Gregory 2002 and 2007; Zhang, Liu and Yung 2007) observed that academic curricula were restored in primary schools since around 1969 and there was a gradual return to normalcy in the entire education system throughout the 1970s. Statistics from the Ministry of Education show that the number of full-time teachers in primary schools rose by around 37% from 1965-1976. Over the same period, there were more teachers from teacher-training and academic senior middle schools (top two teacher credentials)[33], by around 724% and 1337%, respectively. The student-to-teacher ratio

origin and his/her political loyalty. This criterion favoured children of workers and peasants who were less academically successful and hence positively improved their educational opportunities.

[33]It should be noted that direct official statistics on types of primary school teachers are not available. Hence teacher type here is approximated by number of graduates from institutions including teacher-training middle

declined by around 6%. And little change in class-size occurred (Table 1). These descriptive statistics then suggest that primary school quality may have improved over the revolution decade. Lastly, though post-revolution education officials made explicit effort to retrench the provision of secondary education in order to restore education quality (by cutting down the number of secondary schools), no comparable effort could be observed for primary education, suggesting (indirectly) that primary school quality may suffer less than secondary school quality because of the Cultural Revolution (Knight and Shi 1996).

Thirdly and most importantly, the Cultural Revolution education policies seem to have relatively increased both education quantity and quality in rural areas, compared to urban areas. Before the Cultural Revolution, rural children had more limited access to primary education. The Cultural Revolution policies instead favoured children from rural families and hence narrowed the urban-rural differential in education quantity (Deng and Treiman 1997; Hannum 1999; Lu and Treiman 2008). For example, the abolition of various entrance examinations made progression onto higher levels of the education ladder easier for rural kids who were in general less academically successful. More direct evidence is given in Figure 4A, which shows that while the number of students in urban primary schools declined by around 35% from 1965-1976, that for rural primary schools rose by 38% over the same period. Likewise in Figure 4B, there was a disproportionate increase in the number of primary school graduates in rural areas from 1965-1976, i.e. 330% in rural versus 85% in urban.

Moreover, education quality in rural primary schools may also have improved relative to that in urban primary schools. First, day-to-day management of primary schools in the countryside was likely to be less disrupted by the Cultural Revolution, according to Giles, Park and Wang (2008) and Meng and Gregory (2002 and 2007). Second, Andreas (2004) suggested that the radical policies made basic education available to some village youth for the first time (leaving no scope for decline in education quality). Meanwhile, the problem of teacher shortage may be less severe in rural primary schools during the Cultural Revolution. Official statistics suggest that rural primary schools recruited more teachers between 1965 and 1976 than their urban counterparts, i.e. an increase of around 43% compared to a decline of about 7% (Figure 4C). The revolution government required village youth graduating from teacher-training schools to return to their villages of origin. And the various rustication programs (targeted at urban middle school graduates and other academic professionals) could

schools, academic senior middle schools and academic junior middle schools. These three types of graduates formed the major part of primary school teachers over the revolution decade.

avail schools in the countryside of more teachers (Hou and Zhou 1999). It also seems that while the elimination of the examination system led urban students to lose interest in study (academic performance was no longer tied to career opportunities in state sectors), rural students were less discouraged because the rural-oriented curricula made rural education remain directly connected with future work in the villages (Andreas 2004); besides, the recommendation procedure which replaced all the entrance exams gave priority to children with agricultural background (Wu 2008).

Interestingly, for rural children from the same county (administrative level equivalent to city and immediately below province in China), those with More Rural (i.e. rural village in a county) place-of-birth also turn out to be more likely to be enrolled in and graduate from primary schools during the Cultural Revolution, compared to those with More Urban (i.e. rural town in a county) place-of-birth. This can be seen from Figures 5A and 5B. Data compiled by the Ministry of Education suggest that the number of More Rural kids enrolled in primary schools was around 41% higher in 1976 than in 1965; the corresponding figure for More Urban kids was lower, of around 3%. In Figure 5B, while primary school graduates became about 355% more prevalent in More Rural areas from 1965-1976, the upward trend was (comparatively) milder for More Urban areas with a magnitude of about 166%. Similarly for education quality, Figure 5C shows that the number of full-time teachers in More Rural primary schools rose by around 45% in 1965-1976, which was about 34 percentage points higher than the corresponding increase in More Urban primary schools. It may also be assumed that the More Rural-More Urban contrast in other dimensions of school quality resembled its rural-urban counterpart described in the previous paragraph. Therefore, the Cultural Revolution education system, with its explicit goal of narrowing any urban-rural (or class) difference in educational attainment, likely also has benefited the More Rural kids more than the More Urban kids, with respect to both education quantity and quality.

As will become clearer later, this last feature of the Cultural Revolution is crucial for the empirical analysis of this study, which is intended to estimate the long-term impact of the Cultural Revolution on individual adulthood health and health-related outcomes. What also remains unclear is why individual health (and health-related outcomes) could be affected by the Cultural Revolution and through what channels. Hence, before giving more details on the empirical design, the next section first uses the life-cycle model developed in Heckman, Stixrud and Urzua (2006) to illustrate some hypothesised effects of the Cultural Revolution on health.

2.2 A Life-cycle Model

Although the life-cycle model in Heckman, Stixrud and Urzua (2006) is about explaining the role of cognitive and non-cognitive abilities, it can also be used to ground the theoretical foundation for this current study in the light of the development of human capital. Assume that utility at period t (U_t) is derived from consumption c_t and labour supply l_t:

$$U_t = U(c_t, l_t; \eta)$$

whereη is a preference parameter. Consumption is a vector and includes a variety of health behaviours such as diet and physical activity. The agent discounts utility at time preference rate ρ. Wages at period t (Y_t) are given by human capital h_t and productivity traits θ:

$$Y_t = R(h_t; \theta)$$

Human capital h_t itself is produced by the human capital production function:

$$\dot{h}_t = \varphi(h_t, I_t; \tau)$$

whereτ is a productivity parameter, I_t is investment at t and $\dot{h}_t$ denotes the rate of change of the human capital stock. The initial condition is given by h_0. Assuming perfect credit markets at interest rate r, given initial condition A_0 and ignoring taxes, the law of motion for assets at period t (A_t) is

$$\dot{A}_t = Y_t h_t l_t - P_t' c_t + r A_t$$

whereP_t denotes the market prices of the consumption goods (c_t).

The agent maximises

$$\int_0^T exp(-\rho t) U(c_t, l_t; \eta) dt$$

over time horizon T subject to the law of motion for human capital ($\dot{h}_t$) and that for assets ($\dot{A}_t$).

So why could health (and health-related) outcomes be affected by the Cultural Revolution and through what channels, based on this life-cycle model? The centrepiece of the Cultural Revolution education policies is the nationwide expansion of primary education. Hence in the first place, this supply-side shock may influence individual investment in education I_t, then via the human capital production function ($\dot{h}_t = \varphi(h_t, I_t; \tau)$), the outcome human capital h_t (e.g. health) may then be linked to the Cultural Revolution. Because human capital is an input for the production of wages Y_t ($Y_t = R(h_t; \theta)$), and both human capital h_t ($\dot{h}_t = \varphi(h_t, I_t; \tau)$) and wages Y_t ($\dot{A}_t = Y_t h_t l_t - P_t' c_t + r A_t$) influence an agent's available resources with which she chooses consumption c_t (e.g. health behaviours) and labour supply l_t to maximise her utility, this means that the Cultural Revolution may also affect two of the well-established health correlates – health behaviours (i.e. c_t) and labour supply (i.e. l_t) – by changing cohort investment in education.

Alternatively, this life-cycle model also implies that the Cultural Revolution may influence health (and health-related) outcomes by shaping cohort preferences and productivity (the preference/productivity mechanism). That is, if more education (due to easier access to education) enhances human capital productivity τ, then via the human capital production function ($\dot{h}_t = \varphi(h_t, I_t; \tau)$), human capital h_t (e.g. health) can be alternatively linked to the Cultural Revolution through human capital productivity τ (instead of investment in education I_t). Similarly, if education shapes individual preferences (η) and time-discounting traits (ρ) that could be determinants of his/her consumption (e.g. health behaviours) and labour supply, then rather than through the budget constraint (or investment in education), health behaviours (i.e. c_t) and labour supply (i.e. l_t) can be instead linked to the Cultural Revolution via the consumption (i.e. η) and time-discounting (i.e. ρ) preference parameters.

Therefore, this study examines the long-term impact of the Cultural Revolution on individual health, health behaviours (i.e. medical care utilisation, smoking, dietary pattern and physical activity) and labour supply (i.e. labour force participation, occupation and income), after establishing its relevance for cohort educational attainment (i.e. both channels rely on the education impact of the Cultural Revolution). The next section lays out the research design used for the empirical analysis.

3. Research Design

The Cultural Revolution education system (1968-1976) was a national intervention that had profound implications for the educational attainment of the affected cohorts (Pepper 1991; Lin 1997; Song 2009). One major feature of it was the nationwide expansion of primary education. This study examines the long-term impact of this feature of the Cultural Revolution on a wide range of individual outcomes, including educational attainment (primary education in particular), health, health behaviours and labour supply. The dataset used is taken from China Health and Nutrition Survey (CHNS), which is an unbalanced panel that provides detailed information on various outcome measures. This section explains in more detail the empirical framework within which the policy parameters of interest are identified.

3.1 Treatment and Control: The Cultural Revolution Generation

The Cultural Revolution generation, i.e. the cohorts whose primary education may be affected by the revolution education policies, can be determined using year-of-birth. Kids normally started primary education when reaching 7-8[34] years old (Zhang, Liu and Yung 2007). Since primary school length was reduced to 5 years during the Cultural Revolution (Andreas 2004; Deng and Treiman 1997; Hannum 1999) and enrolment to primary schools may be postponed for cohorts reaching primary school age in 1966-1967 (Deng and Treiman 1997; Hannum 1999), the Cultural Revolution generation, or the treatment group, should be composed of the cohorts born between 1955[35] and 1970 (or -1-14 years old in 1968). The non-Cultural Revolution generation, or the control group, should be the cohorts born in 1949-1954 (or 15-20 years old in 1968). It turns out that in the CHNS sample the Cultural Revolution generation indeed had around 34% (p-value: 0.000) more years of primary schooling and was around 45% (p-value: 0.000) more likely to have a primary school degree, compared to the control (Figure 2).

This dichotomous treatment and control classification masks important variations in treatment intensity within the Cultural Revolution generation, i.e. years (potentially) exposed differed among the treated cohorts. This can be demonstrated by Figure 3, which computes for each treated cohort for how long they may have stayed in the revolution education system. Treatment intensity is calculated based on school enrolment age (7-8 years old) and school length during the Cultural Revolution (5 years). In Figure 3, those who were born between 1959 and 1965[36] can spend a maximum of 5 years in primary schools operating under the revolution education agenda, implying that they were the potentially fully exposed cohorts. By contrast, those who were born before (the 1955-1958 cohorts) or after (the 1966-1970 cohorts) should have spent fewer than 5 years in the revolution primary system, meaning that

[34]This is based on the Law of Compulsory Education passed by the People's Congress in 1986. Before then, there was no formal legislation stipulating age eligibility for primary education. So this study assumes that the 7-8 age eligibility imposed by the 1986 Law of Compulsory Education can also be applied to the pre-1966 and Cultural Revolution education systems. Age is calculated according to the formula: Age = Year – Cohort + 1 (1 year old at time of birth).

[35]It is calculated based on cohorts who were 7-10 years old in 1968 (expansion) and who were 7-8 years old in 1977 (termination).

[36]The 1966 cohort is not included because they can still be in school at the end of the Cultural Revolution.

they were the potentially partially exposed cohorts. In this regard, the empirical specification explicitly takes into account this heterogeneity in treatment exposure (below).

3.2 Geographic Treatment Dispersion: rural and urban differences

The expansion of primary education was accompanied by a series of other radical events that occurred during the early stages of the communist regime (Tables A1- A3). This means that directly comparing adulthood outcomes of the Cultural Revolution generation to those of the non-Cultural Revolution generation is unlikely to correctly inform the long-term impact of the Cultural Revolution, i.e. estimates from treatment-control comparisons can be well biased by unobserved cohort-specific characteristics correlated with individual outcomes. The previous section shows that, in addition to year-of-birth, treatment intensity also varied by place-of-birth (i.e. rural-urban or More Rural-More Urban). Hence, this analysis takes advantage of both the variation in treatment intensity by year-of-birth in terms of when the Cultural Revolution was introduced and the variation in treatment intensity by place-of-birth in terms of its relative quantitative and qualitative relevance to identify the policy parameter of interest. That is, in a difference-in-differences framework that uses both the year-of-birth and place-of-birth differentials. One advantage of this research design is that the effects of any unobserved cohort-level confounders can be controlled for by including a set of cohort fixed effects in the difference-in-differences specification.

Specifically, the place-of-birth differential in treatment intensity means the More Rural-More Urban contrast in the relevance of the Cultural Revolution in the current context. Although the quantitative and qualitative impact of the Cultural Revolution education policies also differed by urban and rural place-of-birth, this dimension of treatment intensity cannot be used because of the well-documented Forced Rustication Program (Whyte 1991; Zhou and Hou 1999; Li, Rosenzweig and Zhang 2008). The Forced Rustication Program (FRP) was a part of the Cultural Revolution and lasted from 1968-1979. Its intended goal was to relocate urban youth (mostly 16-19 years old) to the countryside and let them engage in manual labour and learn from the farmers; around 17 million urban youth were rusticated between 1967 and 1978 (Zhou and Hou 1999). Due to the then substantially inferior living conditions in rural areas, this program created a group of urban youth who was systematically different from their rural counterparts in terms of later development such as health. Further, Zhou and Hou (1999) reported that around 19.3% of their youth sample stayed in the countryside for more than 10 years, 39.3% for 5-10 years and 41.1% for at most 5 years, implying that intensity of the FRP likely varied over time[37]. Therefore, to minimise confounding due to the FRP, this study stratifies the estimating sample by urban and rural place-of-birth (Section 4), meaning that the urban-rural differential in the Cultural Revolution intensity cannot be used.

To be clearer about the definitions of More Rural and More Urban. For individuals with rural place-of-birth (the rural sample), those with rural-village residence are classified as More Rural and those with rural-town residence are classified as More Urban. For individuals with urban place-of-birth (the urban sample), those with suburban residence are classified as More Rural and those with city centre residence are classified as More Urban. It should be noted that the More Rural and More Urban are defined using individual place-of-residence (instead of place-of-birth), because information on respondent More Rural and More Urban place-of-birth is not available from CHNS. This implies that if for the study sample place-of-residence differs from place-of-birth, the classification of More Rural and More Urban and hence the resulting difference-in-differences estimates can be misleading. Given that rural-to-urban migration has been an increasingly common phenomenon in China after the Cultural Revolution, from around 16 million in the 1980s to around 145 million by the end of 2009 (Mullan et al. 2010; Jiang et al. 2012; Hu 2012), this source of measurement error seems more likely for the current study. As a result, this analysis further restricts the estimating sample to either rural non-migrants (those with rural place-of-birth and rural place-of-residence) or urban non-migrants (those with urban place-of-birth and urban place-of-residence), since for non-migrants place-of-birth is likely to be the same as place-of-residence. Most of the study sample can be viewed as non-migrants, 60% for the urban sample and 85% for the rural sample, implying that this migration restriction may not produce an endogenous sample of non-migrants. As robustness checks, a Heckman two-step procedure is also used to correct for potential non-random migration; the implied estimates remain virtually unchanged.

Another source of measurement error in the More Rural and More Urban comes from the possibility that locations that were rural-village or suburban during the Cultural Revolution decade had become rural-town or city centre till the CHNS survey as a result of changing administrative definitions of rural-village and suburban, e.g. because of land re-allocation for urbanisation (Mullan et al. 2011). Similarly because of data limitation, this

[37] Implementation of RP varied over the course of the Cultural Revolution. After intensive mobilisations in the first few years, the leadership allowed one child per family to stay in the cities after graduating from middle schools.

possibility cannot be safely ruled out. This study therefore uses and compares four alternative definitions of More Rural and More Urban, which differ by how individual residential places are defined as rural-village or suburban. The classifications of rural-village or suburban based on the four More Rural can be shown to be largely time-invariant, implying that the second source of measurement error in the More Rural variables may also be less worried about for this study (Section 4). The regression specification that exploits both the More Rural and year-of-birth variations in the relevance of the Cultural Revolution education system is given in the section that follows.

3.3 Baseline Model: Difference-in-Differences

Equation 1 gives the baseline specification used by the study to identify the long-term of the Cultural Revolution education policies:

$$Y_{icp} = \alpha + \delta_1(F_c * R) + \delta_2(PB_c * R) + \delta_3(PA_c * R) + \theta_1 F_c + \theta_2 PB_c + \theta_3 PA_c + \gamma R + X'_{icp}\beta + \varepsilon_{icp} \quad (1)$$

whereY_{icp} is the outcome of individual i born in year c living in province p (e.g. education and health). Equation 1 allows for heterogeneous treatment effect: F_c is equal to 1 if cohort c was potentially fully exposed to the Cultural Revolution education policies (full-treat); PB_c and PA_c correspond to the potentially partially exposed cohorts, with PB_c equal to 1 for those who were older than the fully exposed cohorts (partial-before) and PA_c equal to 1 for those who were younger (partial-after). Rmeasures More Rural and is equal to 1 if i was More Rural and 0 otherwise. Thus, the coefficients of interest are δ_1, δ_2 and δ_3, which are in front of the three interaction terms $F_c * R$, $PB_c * R$ and $PA_c * R$. $X_{icp}$is a vector of other observed covariates: A set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 (distinct survey design) and two individual-level variables including a female dummy (equal to 1 if female and 0 otherwise) and age (and its square). $\alpha$is a constant. $\varepsilon_{icp}$is an error term that is allowed to be arbitrarily correlated within and across cohorts. Equation 1 is estimated on urban or rural non-migrants (above).

The parameters of interest (δ_1, δ_2 and δ_3) are identified from within cohort variation in treatment intensity (i.e. the More Rural differential in policy intensity), conditional on all the other observables (X_{icp}). In addition, they may credibly inform the long-term impact of the Cultural Revolution. The identifying assumption is that the underlying trend in the outcomes of the More Rural cohorts would have been parallel to that for the More Urban cohorts, absent the Cultural Revolution. The cohort fixed effects (F_c, PB_c and PA_c) absorb any unobserved characteristics unique to each cohort group that may also be correlated with Y_{icp}. This is important given the presence of numerous other radical events that were hallmarks of the early stages of the communist regime and that may also have influenced Y_{icp}. The More Rural fixed effect (R) is intended to control for unobserved factors that may make the More Rural cohorts persistently different from their More Urban counterparts (e.g. health conditions between More Urban and More Rural areas). Then the province and quarter-of-birth fixed effects by the same token should be able to capture any province and quarter-of-birth specific confounders that may come from e.g. the diverse economic conditions across provinces in China (Chow and Shen 2006; Wu 2010; Shi 2012) and school enrolment policies (Angrist and Krueger 1991). Age (and its square) and the gender dummy are used to control for any inherent and systematic life-cycle pattern and gender differences in Y_{icp}.

Besides, one might also be worried about the catastrophic incident of the Great Leap Forward (GLF) and the economic depression that ensued from it (1958-1962). The well-documented GLF effectively shattered China's economy and generated the most severe famine in its modern history (Madsen 1991; Whyte 1991). Official statistics suggest that agricultural output in 1960 was 75.5 percent of that in 1958, down by another 2.4 percent in 1961. Output of the light industry decreased by 9.8 percent in 1960, by 21.6 percent in 1961 and by another 8.4 percent in 1962. Heavy industry output declined by 46.6 percent from 1960-1961 and by another 22.2 percent from 1961-1962. The cumulative result (coupled with bad weather) was a surge in mortality rates of around 129 percent from 1957 (11.1 per thousand) to 1960, accompanied by a drop in birth rates of around 45 percent from 1957 (33 per thousand) to 1961. To ameliorate this type of concern, Equation 1 includes polynomial terms in cohort size, which presumably should be able to reflect well the most traumatic effects of the GLF. The flexible cohort trend (also in Equation 1) can in addition serve to capture any other smooth cohort-specific effects on the outcomes.

Furthermore, elementary schooling obtained by the study sample (the 1949-1970 cohorts) should remain broadly insulated from later educational interventions initiated after the Cultural Revolution (Law and Pan 2009; Zhang and Zhao 2006; Zhao and Qiu 2012). These later interventions included the 1980 reform that once more attempted to universalise primary education. Then in 1986 the Law of Compulsory Education was passed, which made nine-year primary and junior middle schooling[38] mandatory for age eligible kids (7[39]-8 years old by each new school year[40]). But the youngest cohort in the sample, the 1970 cohort, was already 11 years old by the time of the first reform, and Andreas (2004) found that these later efforts were slow getting started and made little headway for more than a decade in most parts of China.

Therefore, the difference-in-differences estimates of δ_1, δ_2 and δ_3 may be viewed as credible, since they are identified from within cohort variation in treatment intensity. But admittedly, the identifying assumption underlying difference-in-differences is strong. It requires that changes in the potential outcomes of the More Rural cohorts would have been the same as those for the More Urban cohorts, without the Cultural Revolution. In addition, the assumption of a relative qualitative impact of the Cultural Revolution on the More Rural kids is untestable without more officially documented evidence[41]. Hence, this analysis also performs a series of robustness checks to further cross-validate the main results (Section 7). For example, the feasibility of assuming the comparability of the More Rural and More Urban cohorts is verified by making use of a regression discontinuity sample created by the shortening of school length during the Cultural Revolution. The overall finding seems to suggest that the difference-in-differences identification approach may be valid and that the estimated policy impact associated with it may be viewed as credible evidence on the long-term impact of the Cultural Revolution education policies. The next section briefly describes the sample data, before showing the baseline results.

4. Data: China Health and Nutrition Survey

The study sample is constructed from China Health and Nutrition Survey (CHNS). CHNS is an unbalanced panel which was designed to examine the effects of health, nutrition and family planning programs implemented by central and local governments in China. It contains rich health and nutrition information for the Chinese population during a period of rapid economic transition (1989-2011)[42]. This study uses waves from 2000-2009, because the

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[38]Basic education: 6 years of primary schooling and 3 years of junior secondary schooling.

[39]Age is calculated using the formula: Age = Year – Cohort + 1. So the age eligibility of 7-8 years old does not contradict the 6-7 age threshold specified by other studies (e.g. Zhang and Zhao 2006).

[40]The new school year typically began in August to September.

[41]A coarse guess is that results for primary education may be more reliable, because the standard of secondary education generally declined and the rustication programs were more relevant for teacher compositions at primary schools (i.e. middle school graduates).

[42]The first round of the survey was conducted in 1989; eight subsequent rounds were carried out in 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. From 2000 onward, a multistage random cluster process was used to

latest round does not contain the key health information of interest here (weight and height). Second, the study sample is composed of individuals born in 1949-1970, which is based on the classification of the treated and control cohorts (Section 3). Third, missing values in education, Hukou (below), gender and date-of-birth are replaced by their corresponding values in the most adjacent wave in which an individual is observed[43]. This can be done because gender and date-of-birth do not change over time, the study sample had already passed normal school age by 2000 (31-52 years old) and Hukou status is very difficult to be changed[44] in China (below). Rectangularising the data matrix enables one to improve the efficiency of the regression estimates by pooling all the waves together while abstracting from potential problems caused by panel attrition. The final study sample has a total of 25,132 observations (around 6,283 per wave). Table 2 presents some summary statistics of the key variables of relevance in this analysis.

4.1 Education

The educational variables can be either years of completed schooling or degree ever obtained. They are constructed from answers to the question "how many years of formal schooling have you completed in a regular school" (all the primary schools are regular[45]). The answers include no education, some primary education (1-6 years), some secondary education (junior: 1-3 years; senior[46]: 1-3 years) and some college education (1-6 years or more). As this analysis is interested in individual attainment of primary education, years of schooling are years of completed primary schooling (0-6 years[47]) and degree ever obtained pertains to a binary indicator for whether an individual had a primary school degree (equal to

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draw sampling units from nine provinces (Liao Ning, HeiLongjiang, Jiang Su, Shan Dong, He Nan, Hu Bei, Hu Nan, Guang Xi and Gui Zhou), which vary substantially in geography, economic development and public resources.

[43] For example, for individuals with missing education in 2006, if they can be observed in one or more waves before 2006, missing education is replaced by non-missing education in wave 2004 for those appearing in 2004 and missing education is replaced by non-missing education in wave 2000 for those appearing in 2000; if instead they can be observed only after wave 2006 (i.e. in 2009), missing education is replaced by non-missing education in wave 2009 for those appearing in 2009.

[44] Around 9 percent of the individuals changed Hukou status from 2000-2009, so they were dropped out of the study sample.

[45] Because statistics provided by the Ministry of Education do not distinguish between types of primary schools, unlike secondary schools which can be either academic or vocational, it is assumed here that the regular primary schools in the CHNS questionnaire correspond to all the primary schools available to school-aged kids over the Cultural Revolution decade.

[46] Years spent in technical middle schools are regarded as being equivalent to time spent in senior middle schools, since students also go to technical middle schools after graduating from low middle schools.

[47] Years of primary schooling for those with secondary and/or college education (and above) were coded as 6 years (maximum).

1 if 5[48]-6 years of primary schooling). The rural sample spent on average around 5 years in primary schools and the majority of them had a primary school degree (78 percent). The urban sample were more educated (as expected), with an average of around 6 years of primary schooling and 95 percent having a primary school degree.

4.2 Health

Three types of health variables are used and compared: They are underweight and overweight status, self-reported health and diagnosed illness symptoms. Underweight and overweight are defined using individual Body Mass Index (BMI)[49], which is equal to weight in kilograms (kg) divided by height in meters squared (m^2). Weight and height were measured by professional health workers during the CHNS survey. BMI has been widely used as a population fitness indicator (Wildman et al. 2005; Caulfield et al. 2004; Chavas 2013). This analysis classifies an individual as underweight if his/her BMI was below 18.5 kg/m^2 and him/her overweight[50] if his/her BMI was above 25 kg/m^2 (inclusive). Around 4 percent of the rural sample were underweight, which was roughly 1 percentage point higher than in the urban sample. Overweight was more prevalent in urban than in rural areas, i.e. 34 percent versus 26 percent.

Self-reported health is a categorical variable and can be excellent, good, fair or poor. This analysis uses self-reported poor or fair health as an indicator for individual subjective perception of current health (Currie 2009): It is equal to 1 for fair or poor responses and 0 otherwise. Rural and urban individuals were equally likely to report a poor or fair health, around 34 percent of each subsample.

Individual objective health is measured by two binary indicators for diagnosed high blood pressure and diabetes (Kenkel, Lillard and Mathios 2006). They are constructed from answers to the question “has a doctor ever told you that you suffer from high blood pressure/diabetes” and equal to 1 if an affirmative answer was given and 0 otherwise. Around 9 percent of the urban sample and 5 percent of the rural sample had hypertension. Prevalence of diabetes was less common, 2 percent for those with an urban Hukou and 1 percent for those with a rural Hukou.

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[48] Because the Cultural Revolution condensed total years of basic education from 12 years (6 primary; 6 secondary) in the old system to 10 years (5 primary; 5 secondary).

[49] BMI of pregnant women was recoded as missing.

[50] This definition of overweight includes the case of obesity, that is, $BMI \geq 30$. Since only around 3 percent of the study sample is obese.

4.3 Health Behaviours

The health behaviour variables cover aspects such as medical care utilisation (Currie and Thomas 1997), current smoking status (Currie and Moretti 2003), dietary pattern (Chavas 2013) and physical activity (Adams 2002). Medical care utilisation refers to either medical insurance ownership or preventive care utilisation. Both are dummy variables: The former is equal to 1 if the respondent was medically insured at the time of the survey, and the latter switches on if the interviewee made use of some preventive services during the four weeks before the interview. The urbanites were around 18 percentage points more likely to have a medical insurance (around 60 percent of the total); they were also more likely to use preventive care, i.e. 4 percent versus 2 percent.

Current smoking status is a binary variable equal to 1 if the respondent was smoking at the time of the survey and 0 otherwise. Rural people were marginally more likely to smoke than urban people, as suggested by their respective sample means of around 31 percent and 29 percent.

For ease of interpretation, individual diet habit is measured by a dummy variable indicating whether his/her daily percentage fat intake exceeded the officially recommended guideline, which is 25 percent according to the published 2004 Chinese Food Composition Table. Percentage fat intake is computed from three nutritional intake variables available from CHNS, i.e. daily fat, protein and carbohydrate intakes (in gram). In particular, each nutritional intake variable in gram is first converted to its corresponding caloric units. The conversion factors are 9 kcal/g for fat intake and 4 kcal/g for protein and carbohydrate intakes. Daily percentage fat intake is then daily fat intake (in kcal) divided by daily total calorie intake (in kcal) (which is the sum of all the three nutritional intakes). Around 79 percent of the urban sample and 53 percent of the rural sample consumed a fatty diet.

The last consumption variable is physical activity. All the adults were asked if they participated in some active physical activities at least once per month, with the activities including martial arts, gymnastics (dancing or acrobatics), jogging (swimming), ball games (e.g. badminton and basketball) and any other exercises not named. Physical activity is then defined as a dummy variable equal to 1 if the respondent was an activity participator and 0 otherwise. Only 2 percent of the rural sample took additional exercises after work while this number was 19 percent for the urban sample.

4.4 Labour Supply

Labour supply is measured by current working status, occupation and income (Oreopoulos and Salvanes 2011). Labour force participation is denoted by a dummy variable equal to 1 if an individual reported as being presently working and 0 otherwise. Around 82 percent of the rural individuals and 66 percent of the urban individuals were working at the time of the interview.

To devise a more objective classification of occupations, this analysis uses the intensity of on-the-job activity as a criterion. Presumably, the more educated an individual, the more likely he/she will have a less physically demanding job. An occupation can be either light (light activity), moderate (moderate activity) or heavy (heavy activity). Each is determined by tabulating the respondents' primary occupations (e.g. doctor, officer and farmer) against their work intensities. Individual work intensity was assigned by CHNS field workers (who made the assignment after hearing about the interviewee's occupation) and can be either light[51], moderate or heavy. An occupation is classified as light if the majority of the study sample with that position fell into the light work intensity category. For example, 91 percent of the senior professionals belonged to the light work intensity category, so the occupation of senior professionals is defined as light. Over half of the rural sample had a heavy occupation, on the contrary, the majority of the urban sample worked in light/moderate positions.

Three income variables are examined: They are log yearly earnings (multiplied by 100), log non-wage income (multiplied by 100) and log total individual income (multiplied by 100). Log earnings is the logarithm of salaries one earned in the previous year including all the on-the-job bonuses and subsidies. Incomes from other non-agricultural (self-run business and pension) and agricultural (farming, fishing, gardening and raising livestock) sources in the previous year are called non-wage income. Log total individual income is the logarithm of the sum of individual earnings and non-wage income. Average income (in 2009 Yuan) was around 9,788.7 Yuan (12.763 log points) in the rural sample and around 17,246.04 Yuan (13.961 log points) in the urban sample. As expected, earnings accounted for a larger share of total income for the urbanites; the opposite was true for people in the countryside.

4.5 Other IndividualCovariates

[51]The classification in the questionnaire is in fact more elaborate: Work intensity falls into one of the five categories, i.e. very light, light, moderate, heavy or very heavy. Without loss of information, this study does not distinguish between very light (very heavy) and light (heavy) occupations.

The other individual covariates are Hukou, gender and age. Among them, the most important is individual urban-rural Hukou status (household registration type). Because of the Forced Rustication Program (FRP), it is necessary to divide the estimating sample by urban-rural place-of-birth (Section 3). Place-of-birth is highly correlated with place-of-education and is arguably more exogenous. The problem is that CHNS did not ask the respondents about their place-of-birth. This study therefore uses individual current urban-rural Hukou status as a proxy for his/her urban-rural place-of-birth. The institutional feature of the Chinese household registration system (hence Hukou status) ensures that this can be done. The reason is as follows.

The Hukou system was introduced in China in the late 1950s in order to restrict rural to urban migration, still in place today (Ito 2008; Wang and Moffatt 2008). Hukou status can be viewed primarily as an ascribed attribute and is very difficult to be changed. At its inception, everyone was registered in the administrative district where he/she resided and was attached either an urban or rural Hukou (i.e. urban residents with urban Hukou and rural residents with rural Hukou). Later, children's Hukou status is determined at birth by their mothers' Hukou (Chan 2010). This system has had its intended effects. In the pre-economic reform era (i.e. before 1979), almost everyone lived where he/she was registered. This can be explained by the ration system that was closely associated with Hukou status. Rural adults must participate in agricultural production in order to receive food rations for their households. Urban adults were officially allocated to specific work units which provided housing, food and other social services to their employees. These services were hardly available from the market. Because employment quotas in all the urban work units were tightly controlled by the government, rural migrants had little chance of finding a job in the cities, meaning that without work unit rations it could be very difficult for them to live in the cities (Wu and Treiman 2004). These suggest that Hukou status of the sample cohorts (the 1949-1970 cohorts) during their teens should be an accurate measure of their place-of-birth.

In addition, current Hukou status should approximate well past Hukou status. The reason is that Hukou conversion from rural to urban is extremely tightly controlled and permitted only under very limited conditions (Wu and Treiman 2004; 2007); on the other hand, there has been essentially no voluntary mobility in the opposite direction, given the huge advantages associated with an urban Hukou, i.e. higher socioeconomic status, better economic opportunities and access to more generous state provided public welfares (Ito 2008; Ngok 2012). Typical channels for obtaining an urban Hukou are higher education (i.e. vocational/college degree), communist Party membership and military experience in the

People's Liberation Army, but the odds of a final conversion is still low. Wu and Treiman (2004; 2007) reported that by 1996 only around 11 percent of the rural origin population had successfully obtained an urban Hukou. These suggest that current Hukou should also be a good proxy for past Hukou and hence individual place-of-birth.

In the sample, rural cohorts made up of around 56 percent of the total observations. Females constituted around 52 percent of the rural sample and 51 percent of the urban sample. Mean age was 46 in both groups.

4.6 More Rural and More Urban Sample

This analysis uses and compares four alternative definitions of More Rural and More Urban, three at the community level and one at the individual level (Section 3). For individuals with rural place-of-birth (rural sample), those with rural-village residence are classified as More Rural and those with rural-town residence are classified as More Urban. For individuals with urban place-of-birth (urban sample), those with suburban residence are designated as More Rural and those with city centre residence are designated as More Urban. The four definitions of More Rural and More Urban differ by how they determine rural-village, rural-town, suburban and city centre.

Specifically, a community is classified as rural-village (or suburban) if it was more likely to have farmland within its boundary[52], or if it was more likely to be officially designated[53] as rural–village (or suburban)[54] or if it was more likely to have above median fraction of agricultural labour force[55] (i.e. the median of the wave-urban/rural-specific distribution). Alternatively, a community is defined as rural-town (or city centre) if it was less likely to have farmland within its boundary, or if it was more likely to be officially designated as rural-town (or city centre) or if it was less likely to have above median fraction of agricultural workforce. For example, in terms of the presence of farmland, a community is rural-village if in most periods from 1989-2009 (waves in CHNS relevant for this study) it had farmland within its boundary; it is rural-town if in most periods from 1989-2009 it did

[52]The corresponding survey question is "Is there farmland in this village or neighbourhood".

[53]Types of designations include 1 city neighbourhood, 2 suburban neighbourhood, 3 town neighbourhood and 4 rural village.

[54]The corresponding survey question is "To which administrative district did this community belong in the previous survey". It should be noted that the survey question was in fact "which administrative district did this community belong to in 1989" in the 1997 survey. Hence viewed from this point the second More Rural definition may be less reliable.

[55]The corresponding survey question is "What percentage of the workforce in this village or neighbourhood is engaged mainly in agricultural activity".

not have farmland within its boundary. The individual-level More Rural and More Urban is based on individual reported place-of-residence. For example, if a respondent reported as living in a rural-village at the time of the survey, he/she is classified as More Rural; if the respondent instead reported as living in a rural-town at the time of the survey, he/she is classified as More Urban. The majority of the rural sample was More Rural (90.4 percent), and slightly over 14 percent of the urban sample was More Rural.

As noted in the previous section, the More Rural and More Urban can be mistakenly measured if individuals moved after the Cultural Revolution or if official designations of rural-village or suburban changed over time. Concerns over the former can be somehow mitigated by performing analysis only on non-migrants. For the latter, without data, it is not possible for this study to check if rural-villages stayed as rural-villages, or suburban areas stayed as suburban areas, from during the Cultural Revolution to the time of the survey. But if individuals who were More Rural (or More Urban) at the beginning of the survey (1989) remained More Rural (or More Urban) till the end of the sample period (2009), it is likely that More Rural (or More Urban) was largely time-invariant. Or in other words, it may be less worried about that errors in the More Rural and More Urban variables due to changing government designations can produce misleading results. This is likely to be the case, according to four More Rural-More Urban transition matrices computed for all the four More Rural (Table 3). For example, for presence of farmland 82.6 percent of the More Rural individuals in 1989 stayed More Rural until 2009; almost the same can be said for the other three More Rural classifications.

All the variables defined in this section are included in the empirical analysis. Results based on them are presented in the following sections.

5. Educational Outcomes of the Cultural Revolution

5.1. Difference-in-Difference Estimates

Table 4 first reports estimates of the policy impact of expanding primary education, for rural non-migrants (Columns 1-2) and urban non-migrants (Columns 3-4) respectively. The dependent variable is either years of completed primary schooling or a binary indicator for whether or not an individual had a primary school degree. Each column corresponds to a regression based on the specification in Equation 1, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics that are age (and its square) and a female dummy (equal to 1 if female). The panels differ by how

More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

It can be observed that the coefficients of interest differ significantly across the panels for rural non-migrants (Columns 1-2 of Table 4), but they do not do so in the urban sample (Columns 3-4). Because the More Rural's are based on place-of-residence (rather than place-of-birth), this suggests that potential endogeneity of the More Rural variable may be more problematic for the rural cohorts than for the urban cohorts. Given that presence of farmland is arguably more exogenous than e.g. agricultural workforce, More Rural is defined using community farmland (only) for the rural sample. Since the estimates are statistically and economically similar across the panels in Columns 3 and 4, the More Rural classification for the urban sample is made using all the four criteria.

Years of primary schooling are significantly and positively associated with the interaction terms for the full-treat Cultural Revolution generation (only) in the rural sample, but the coefficients of interest are significant and positive for all types of the Cultural Revolution generation in the urban sample. There was a relative increase in years of primary schooling of around 0.543 years for the More Rural F_c in the rural sample, compared to their More Urban counterparts. In the urban sample, the More Rural Cultural Revolution generation had around 0.444-1.152 more years of primary schooling than their More Urban counterparts. Based on sample means, these represent around 8-22% increases in the attainment of primary education. Since among those with a rural Hukou the difference-in-differences coefficients are significant only for the full-treat cohorts and for those with an urban Hukou the coefficients turn out to be the largest for the youngest treatment group throughout, this suggests that it is important to allow for heterogeneous treatment effect. Overall, these results imply that the expansion of primary education succeeded in raising years of primary schooling obtained by the Cultural Revolution generation.

Replacing the dependent variable by primary school degree ever obtained does not change the estimated results much. The probability of obtaining a primary school degree is significantly and positively correlated with the interaction term for the full-treat cohorts (only) in the rural sample but all types of the Cultural Revolution generation in the urban sample are estimated to have a significantly higher chance of obtaining a primary school degree. The magnitude of this relative advantage is around 9.9 percentage points for the rural cohorts and ranges from 6.9-28.1 percentage points for the urban cohorts. Based on sample means, these correspond to around 8-33% rises in primary education attainment. Similarly, because for the rural non-migrant cohorts the coefficients are significantly positive only for the full-treat group and the largest effect is observed for the youngest Cultural Revolution generation, this confirms previous findings that the impact of the primary education policies varied among the Cultural Revolution generation. Combined, these results suggest that the treated cohorts tended to obtain more primary schooling because of their exposure to the revolution system. Moreover, the expansion of primary education seems to have disproportionately benefited the rural cohorts who before the Cultural Revolution had more limited access to schooling. [Not sure]

5.2. The Regression Discontinuity Sample

The common trend assumption required for causal interpretation of the difference-in-differences coefficients (δ_1, δ_2 and δ_3) is strong, i.e. any gap between the More Rural and More Urban cohorts would have remained the same had there not been the intervening years of the Cultural Revolution. The challenge is that there is no way to verify whether the More Rural and More Urban cohorts are indeed comparable. But intuition suggests that if one can have a more comparable subsample of More Rural and More Urban cohorts in hand (or cohorts more reliably claimed to be so), and if similar results can be obtained by applying difference-in-differences to this ideal subsample, causal interpretation of the benchmark estimates can be more likely. Guided by this, this analysis exploits one institutional feature of the Cultural Revolution education policies that created discontinuities in cohort primary educational attainment. The idea is that since the discontinuity sample is by construction composed of two neighbouring cohorts, who may be more similar along most of the other dimensions except for their differential exposure to the Cultural Revolution system, it is the subsample of more comparable cohorts one is aiming for in the current context. It then follows that it can be used for the purpose of internal validity checks.

To be more specific, the discontinuity in cohort educational attainment comes from the shortening of primary school length at the onset of the Cultural Revolution. This reduction in school length is an intrinsic part of the revolution education agenda, i.e. it would be much easier to universalise basic education if term length can be made shorter (Andreas 2004; Deng and Treiman 1997; Wu 2008). In particular, the primary cycle was reduced from 6 to 5 years. This implicates that time spent in primary schools by the cohort who was in the 5th grade (the 1956 cohort[56]) when the Cultural Revolution broke out should be necessarily

[56] This is obtained by assuming that kids started schooling when reaching 7 years old.

shorter than time spent by the cohort who had already passed onto the 6th grade (the 1955 cohort). Indeed, Figure 5 (local linear nonparametric estimates) makes clear that in the CHNS sample the 1955 cohort (6th graders) had around 2 more months of primary schooling than the 1956 cohort (5th graders).

Then the first set of robustness checks is based on the discontinuity sample formed by the 1955 and 1956 cohorts. The empirical specification used in particular for this purpose is given in Equation 2[57] below:

$$Y_{iqcp} = \alpha + \delta(T_c * R) + \varphi T_c + \gamma R + f(\tau_{qc}; \theta) + X'_{iqcp}\beta + \varepsilon_{iqcp} \quad (2)$$

whereY_{iqcp} is the outcome of individual i born in quarter q of year c in province p. Treatment status is denoted by T_c, which is equal to 1 if i was born in 1955 and equal to 0 if i was born in 1956. $R$is the More Rural indicator equal to 1 if i was More Rural and 0 otherwise. The coefficient of interest is δ, the one that is in front of the interaction term $T_c * R$. $f(\tau_{qc}; \theta)$is a polynomial function in quarter-year-of-birth. $X_{iqcp}$is a vector of other observable controls, including a set of province fixed effects, an indicator for sample wave 2000 and two individual level characteristics (i.e. gender, age and its square). $\alpha$is a constant. $\varepsilon_{iqcp}$is an error term which is allowed to be arbitrarily correlated within and across cohorts. Equation 2 is estimated on urban and rural samples (divided by Hukou). If δ does not differ significantly from its corresponding counterpart in Equation 1 (i.e. δ_2), it is more likely that the difference-in-differences estimates can be interpreted as causal.

Table 5[58] first establishes the existence of discontinuities in cohort educational attainment. Results for the rural sample are in Columns 1-2 and those for the urban sample are in Columns 3-4. The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column corresponds to a regression similar to Equation 2, without the interaction term and the More Rural variable[59]. As might be expected, years of primary education are significantly and

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[57]Identification of Equation 7 requires that the underlying distribution of Y_{iqcp} be continuous in τ_{qc} at each discontinuity point (Hahn et al. 2001; Imbens and Lemieux 2008; Lee 2008; Angrist and Lavy 1999). Or equivalently, any smooth quarter-year-of-birth effects have been adequately controlled for by the flexible cohort trends $f(\tau_{qc}; \theta)$ after conditioning on all the observed covariates (X_{iqcp}), and δ measures the magnitude of the relative discontinuity in Y_{iqcp} that can be solely attributed to the Cultural Revolution education policies and the More Rural stats. Since this requirement is much weaker than the common trend assumption, it is more likely to be valid within current context.

[58]The other right-hand-side controls include a set of province fixed effects, an indicator for sample wave 2000 and two individual covariates (gender and age and its square). Robust standard errors are reported in parentheses.

[59]The empirical specification is:

$$Y_{iqcp} = \alpha + \varphi T_c + f(q_{qc}; \theta) + X'_{iqcp}\beta + \varepsilon_{iqcp}$$

The notations are defined in the same way as those in Equation 7 in the main text.

positively associated with the treatment indicator. The cohort who is expected to have stayed in school longer had around 0.492-0.557 more years of primary schooling (9-11%). Replacing the dependent variable by primary school degree does not change the estimated results. The cohort with longer term length was significantly more likely to have a primary school degree, by around 9.9-18.3 percentage points (12-21%). Hence, Table 5 confirms the existence of a discontinuity in cohort educational attainment.

Turn to the placebo test. Since the More Rural and More Urban cohorts that comprise the regression discontinuity sample are likely more comparable, the common trend assumption underlying difference-in-differences is more likely to be met. Then if results obtained from the discontinuity sample are similar to the baseline, more credibility can also be given to the latter. Results are presented in Table 6[60], for the rural (Columns 1-2) and urban (Columns 3-4) samples, respectively. The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column corresponds to an OLS regression using Equation 2. To figure out which More Rural is more valid for this present exercise, as usual results based on all the four More Rural definitions are presented. It turns out that while the coefficients of interest in Columns 1-2 when More Rural is defined by farmland (Panel A), agricultural workforce (Panel C) and individual residence (Panel D) cannot be statistically distinguished from each other, those in Columns 3-4 differ significantly across the panels. Therefore, potential endogeneity of More Rural (based on place-of-residence) for now may be more problematic for the urban cohorts than for the rural cohorts. Then for the same reason as explained before, this analysis uses community farmland to determine the treatment group for the urban sample, and uses and compares all the four More Rural for the rural sample.

Satisfactorily, the coefficients of interest in Table 6 when the dependent variable is years of primary schooling do not differ significantly from their baseline counterparts in Table 4 (the interaction between the indicator for the oldest Cultural Revolution generation and More Rural). For example, in Panel C of Column 1 (agricultural workforce) the difference-in-differences coefficient similarly suggests that there was a relative decrease in years of primary schooling obtained by the More Rural cohorts in the rural sample by around 0.484 years (9%). Likewise in the urban sample (Column 3), the More Rural cohorts

[60] Each column controls for a flexible polynomial trend in quarter-year-of-birth, a set of province fixed effects, a binary indicator for sample wave 2000 and two individual covariates (gender and age and its square). The panels differ by how More Rural is decided, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

(farmland) are estimated to have experienced a relative increase in their attainment of primary education by around 0.685 years (13%), which is comparable (statistically and economically) to the corresponding baseline in Panel A (farmland) and Panel C (agricultural workforce) of Table 4. The other estimates in front of the More Rural interactions do differ statistically from their benchmark, but not economically. In terms of magnitude, they imply a disproportionate decline in years of primary schooling completed by the rural cohorts of around 0.788-0.8 years (15%).

Almost the same can be said when the dependent variable is replaced by primary school degree. For example, in Panel C of Table 6 the treated rural cohorts (agricultural workforce) appear to be around 13.2 percentage points (15%) less likely to have a primary school degree. Also, similar to what is suggested by their counterparts in Panel A (farmland), Panel B (administrative district) and Panel C (agricultural workforce) of Table 4, estimates in Column 4 of Table 6 suggest that the treated urban cohorts (farmland) had a higher chance of completing primary schooling, by around 12.9 percentage points (15%). The other difference-in-differences coefficients in Table 6 are also similar to their relevant baseline in Table 4, but only economically. Combined, they imply that the More Rural cohorts with a rural Hukou were around 16.8-23.1 percentage points (20-27%) less likely to have a primary school degree.

To sum up, since the More Rural and More Urban cohorts that comprise the regression discontinuity sample are more comparable than those in the larger (baseline) sample, they are more likely to meet the common trend assumption as required by difference-in-differences. Then the similarity between the results in Table 6 and those in Table 4 as revealed in this section suggests that potential outcomes of the More Rural cohorts in the larger sample may also have evolved in a parallel way to those of their More Urban counterparts, implying that the baseline difference-in-differences estimates can be regarded as credible.

5.3. Correcting for Non-random Migration

The Difference-in-Differences (DID) analysis is applied to subsamples of non-migrants, i.e. those with rural place-of-birth (Hukou) and rural place-of-residence or those with urban place-of-birth (Hukou) and urban place-of-residence. While the majority of the initial urban and rural cohorts can be regarded as non-migrants by this definition, some individuals in the study sample indeed moved over the sample period (rural: 15%; urban: 40%). This makes one remain worried about the possibility of endogenous migration contaminating the estimated policy parameters of interest. This subsection then looks more carefully about the feasibility of restricting the estimating sample to those who had not migrated by the time of the survey. In particular, it provides more convincing evidence that non-random selection of migration (and hence the illegitimacy of the non-migrant restriction) may be less of a problem for the current study. The implication is that the long-term impact of the Cultural Revolution education policies is less likely to be misinterpreted based on results obtained from the baseline empirical framework.

To examine to what extent the previous policy estimates may be biased by non-random selection of rural-to-urban migration, a Heckman two-step procedure is used: Equation 1 is estimated jointly with a selection equation that explicitly models individual decision to migrate, which can be better explained by Equation 3 below:

$$S_{icp} = \alpha + Z'\varphi + \delta_1^s(F_c * R) + \delta_2^s(PB_c * R) + \delta_3^s(PA_c * R) + \theta_1^s F_c + \theta_2^s PB_c + \theta_3^s PA_c + \gamma^s R + X'_{icp}\beta^s + \varepsilon_{icp} \quad (3)$$

where S_{icp} is a selection indicator: It is equal to 1 if individual i born in cohort c living in province p was a non-migrant; it is equal to 0 otherwise. For example, for those with a rural Hukou S_{icp} switches on if i lived in rural areas but switches off if i lived in urban areas (Section 3). The exclusion restriction is imposed by the vector of instruments Z (details below). The other right-hand-side variables are the same as those in Equation 1. α is a constant. ε_{icp} is an error term that is allowed to be arbitrary correlated within and across cohorts. Equations 1 and 3 are jointly estimated on samples of rural and urban cohorts respectively (divided by Hukou). The idea is that if the policy impact (δ_1, δ_2 and δ_3 in Equation 1) inferred from this procedure does not differ significantly from that suggested by estimating Equation 1 on non-migrants alone, then concerns over migration biasing δ_1, δ_2 and δ_3 can be somehow mitigated. In other words, the impact results obtained so far are likely to be reliable.

Admittedly, this line of argument is applicable only if one has good instruments for S_{icp}, i.e. the Z vector. It has been found that the observed surge in the rural-to-urban migration[61] in China can be explained by among other factors[62] improved efficiency in

[61] According to the National Bureau of Statistics of China, rural out-migrant workers are defined as individuals who have a rural Hukou but have worked outside their place-of-birth for at least 6 months.

[62] Other factors also can explain the massive rural-to-urban migration since 1978, such as the development of a market-oriented economy, the establishment of special economic zones, the expansion of the non-state sector and the loosening of urban employment policies that created strong demand for migrant labour in the urban sector. In addition, decades of rural-urban segregation and uneven economic growth led to a large income gap

agricultural production that has generated surplus labour in the rural sector (Lu et al. 2013). This means that variables that can affect agricultural efficiency or labour supply are potentially good instruments for S_{icp}: They should be correlated with individual decisions to migrate while being uncorrelated with the error term in the outcome equation (i.e. predetermined). Examples of these variables can be those reflective of the institutional changes in the ownership of farmland (i.e. the Household Responsibility System[63]), changes in the government procurement prices of agricultural products or those able to gauge the impact of a series of market reforms (initiated since 1979) on agricultural production (e.g. market prices of outputs and inputs). Built upon Lin (1992), this analysis uses and compares three sets of instruments linked to the supply-side of the agricultural labour market. The first set includes five policy variables: They are the prevalence of the Household Responsibility System (i.e. the prevalence of private or contracted farmland ownership), an index for the government procurement prices of agricultural products (GP)[64], an index for the market prices of agricultural products (MP)[65], percentage of sown areas used for grain crops[66] and Multiple Cropping Index. The last two measures (i.e. percentage of sown areas used for grain crops and Multiple Cropping Index) reflect the degree of central planning in agricultural production. The second set of instruments contains, in addition to those in the first one, several other summary indexes for agricultural inputs, including labour (total and for the cropping sector in particular), land (cultivated land), capital (horsepower of tractors and draft animals) and chemical fertiliser (gross volume of fertiliser used). The gross value of crop output is the last instrumental variable used (details in Lin 1992). Data on these various

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between urban and rural areas, which provided a stimulus for people to migrate to coastal and eastern China (Lu et al. 2013).

63The Household Responsibility System is about the ownership of farmland. In particular, it contracts farmland to individual households, as opposed to its predecessor, the commune system, that contracted farmland to rural collective units (i.e. the agricultural production team). Each collective unit consisted of around 20-30 neighbouring households. The Household Responsibility System was officially approved in 1981, but as early as 1978, it was already implemented in some rural areas in China (this led to the fact that in 1981 around 45 percent of agricultural production teams, the production unit in the old system, had already been converted to the Household Responsibility System).

64Literally, in Lin (1992), the GP should be the index of above-quota prices relative to manufactured input prices. But since it is not clear what the exact definitions of manufactured input prices are and since this variable is intended to capture the impact of changes in government procurement prices of agricultural products on agricultural growth in the original paper, it is simply called the index for government procurement prices of agricultural products in this study.

65Literally, in Lin (1992), the MP should be the index of market prices relative to manufactured input prices. But since it is not clear what the exact definitions of manufactured input prices are and since this variable is intended to capture the impact of changes in the market prices of agricultural products on agricultural growth in the original paper, it is simply called the index for the market prices of agricultural products in this study.

66Lin (1992) in fact used percentage of sown areas used for non-grain crops. But since data on sown areas used for grain crops are directly available and there is little difference in using this measure instead, this analysis chooses the grain crop measure.

instruments are available in Lin (1992) for the period of 1970-1987, and their values in the year when a particular cohort reached 18 years old (i.e. should have graduated from middle schools and able to migrate; but primarily due to data availability) are assigned to the sampling cohorts[67].

The policy and input variables are significantly correlated with the decision to migrate among the study sample, while the rank condition is less likely to be satisfied by the output instrument. The first-stage results are presented in Table 7, for rural (Columns 1-3) and urban cohorts (Columns 4-6) respectively[68]. In Columns 1 and 4, the five policy instruments (i.e. prevalence of private farmland ownership, government procurement and market prices of agricultural product, percentage of sown areas used for grain crops and the Multiple Cropping Index) are jointly significant at the 1 percent level. Adding the various input indexes to this policy set (i.e. labour, land, capital and chemical fertiliser) further enhances the significance level of the instruments (Columns 2 and 5). On the contrary, the output index (i.e. gross value of crop output) cannot be distinguished from zero at conventional levels for the rural sample (Column 3) and it is statistically significant only at the 10 percent level for the urban sample (Column 6). These imply that results obtained from the first two sets of exclusion restrictions may be more reliable, while for completeness those estimated from the output instrument (i.e. the last set) are also presented.

The second-stage estimates are next shown, first for the rural sample in Table 8[69]. While the inverse Mill's ratio does appear to be statistically significant at conventional levels, the coefficients of interest in Table 8 cannot be distinguished from their less-refined counterparts in Table 4, regardless of the set of the instrumental variables used. This suggests that while rural-to-urban migration may indeed be non-random, this does not appear to bias the estimated policy impact significantly for the current study. Then as before, years of primary education are significantly and positively associated with the interaction for the full-

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[67]Because data on the instrumental variables in years from 1966-1969 (corresponding to the 1949-1952 cohorts) are missing, hence, their values are assumed to the respective 1970 values.

[68]The dependent variable is a binary indicator for non-migrant status: It is equal to 1 for those who had not moved by the time of the survey and equal to 0 otherwise. Each column is obtained from a probit regression using Equation 8. The other right-hand-side variables are a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). Robust standard errors are reported in parentheses.

[69]The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. The columns differ by the set of instrumental variables used, with the policy set in Columns 1-2, the policy and input set in Columns 3-4 and the output set in Columns 5-6. Each column is obtained from jointly estimating Equations 6 and 8. The other observable controls include a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual-level covariates (gender and age and its square). Robust standard errors are reported in parentheses.

treat Cultural Revolution generation (only). The implied relative increase in the attainment of primary education by the full-treat More Rural is estimated to be around 0.42-0.452 years (8-9%). The full-treat More Rural also tended to have a significantly higher chance of graduating from primary schools, by around 7.1 percentage points (8%).

Almost the same can be said for the urban cohorts. In Table 9[70], the estimates in front of the various interaction terms do not differ significantly from those in Table 4, no matter which set of instrumental variables is used. And the inverse Mill's ratio is not statistically significant at conventional levels. These suggest that restricting the estimating sample to non-migrants may not produce misleading estimates for the long-term impact of the Cultural Revolution. In Table 9, years of completed primary schooling are significantly and positively associated with the difference-in-differences variables for all types of the treated cohorts. For example, the full-treat More Rural had around 0.602-1.221 (11-23%) more years of primary schooling than the full-treat More Urban. The relative increase in the attainment of primary education seems to be around 0.394-0.946 years (7-18%) for the partial-before More Rural. The youngest Cultural Revolution generation is the most benefited group: The estimates are between 0.749 and 1.266 years (14-24%). When the dependent variable is primary school degree, all the coefficients of interest are once more invariably significant and positive. The full-treat More Rural was around 9.3-25.9 percentage points (11-30%) more likely to have a primary school degree. The corresponding relative increase for the partial-before More Rural is estimated to be on the order of 6.9 to 22.7 percentage points (8-27%). The largest estimates of interest are similarly found for the youngest Cultural Revolution generation, ranging from 14 to 29.6 percentage points (16-35%).

5.4. Controlling for Pre-existing Difference in Education Attainment

A closer look at the time-series pattern in primary educational attainment shown in Figure 1 leads one to find that, even before the Cultural Revolution, there was an upward trend in both primary graduation and enrolment: From 1949-1966, the two indicators of the prevalence of primary education rose by around 324% and 1294%, respectively. This can be

[70] The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. The columns differ by the set of instrumental variables used, with the policy set in Columns 1-2, the policy and input set in Columns 3-4 and the output set in Columns 5-6. Each column is obtained from jointly estimating Equations 6 and 8. The other observable controls include a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual-level covariates (gender and age and its square). The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

problematic, because it may be suggesting that cohorts differ systematically in their demand for education, which is correlated with education supply, then all the estimates presented so far are almost certainly biased. One relatively straightforward way to gauge the severity of this problem is to control for cohort pre-trend in educational attainment in the empirical specification. If the resulting estimates do not change substantially, then it may be inferred that the difference-in-differences coefficients are not wrongly attributing the effect of unobserved cohort tastes for education to the impact of the Cultural Revolution education policies. This exercise is carried out in the present subsection.

The results for rural non-migrants are first presented in Table 10A[71]. The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column corresponds to an OLS regression using Equation 1, and controls for (in addition to the original set) cohort pre-treatment difference in educational attainment, which is measured by average enrolment in primary schools in Columns 1 and 3 and average enrolment in all the academic institutions (i.e. from primary to college) in Columns 2 and 4. Average enrolment is defined as the arithmetic mean of enrolment rates in the six years before a particular cohort reached age 7 (i.e. started schooling)[72]. More Rural is defined using community farmland. In Table 10A, the coefficients in front of the various interactions with More Rural do not differ significantly from their counterparts in Table 4 (i.e. baseline results), implying that the baseline estimates may not have been contaminated by any pre-existing cohort difference in demand for education. As a result, in Column 1 the rural-village cohorts are estimated to obtain around 0.524 more years (10%) of primary schooling, compared to the rural-town cohorts. Further adding controls for secondary and college enrolment (in addition to primary) in Column 2 leaves the obtained estimates virtually unchanged: The relative increase in educational attainment is around 0.521 years (10%). Likewise, in both Columns 3 and 4 the More Rural cohorts were around 9.5 percentage points (11%) more likely to have a primary school degree.

The results for urban non-migrants are next shown in Table 10B. The table is structured in the same way as that for the rural sample; the only difference is that the panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Once more, the

[71]All the other right-hand-side controls are the same as those in Table 5. Robust standard errors are reported in parentheses.
[72]It is assumed that cohorts started schooling at age 7.

coefficients in front of the interaction terms cannot be distinguished from their corresponding counterparts in Table 4. This confirms previous finding that the sampling cohorts do not differ systematically in their demand for education, and hence the benchmark results are not biased in this respect. For example, in Column 1, when the dependent variable is years of completed primary schooling, the coefficients of interest are between 0.444 and 1.153 years (8-22%), implying that the treated cohorts tended to have more primary education. The coefficients of interest remain almost the same in Column 2, which controls additionally for high school and college enrolment: The relative increase in academic performance ranges from 0.446 to 1.157 years (8-22%). Similarly for school completion, the More Rural cohorts were around 7-28.3 (8-33%) and around 7-28.4 (8-33%) percentage points more likely to graduate from primary schools, according to estimates reported in Columns 3 and 4, respectively.

5.5. Excluding the Disrupted Cohorts

Since the treatment group includes those who were in school at the beginning (i.e. the 1955-1960 cohorts) and the end (i.e. the 1966-1970 cohorts) of the Cultural Revolution, it is therefore possible that the benchmark estimates are picking up the influences of some events other than the education policies that occurred during the especially turbulent years of the Cultural Revolution (i.e. at the beginning and at the end). For this reason, this analysis next restricts the treatment group to those who started and completed primary education within the revolution decade (the 1961-1965 cohorts); this effectively retains the full-treat cohorts in the initial estimating sample (the 1959-1965 cohorts). The idea is that, for this group of individuals, disruptions that occurred either before or after they were at primary school age may have less impact on their primary education, implying that any changes in their primary education may more likely entirely come from the primary education policies. Alternatively, if the policy impact inferred from this smaller treatment group does not stand in contrast with that obtained from the larger sample, one can be less sceptical about the main results along the lines described above.

Corresponding results are presented in Table 11[73], for rural non-migrants (Columns 1-2) and urban non-migrants (Columns 3-4), respectively. The treatment group is now the

[73] The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel

1961-1965 cohorts and the control group remains unchanged (the 1949-1954 cohorts). As might be expected, the coefficients of interest cannot be statistically distinguished from those in Table 4, either in terms of years of schooling or in terms of school completion. This suggests that the increased attainment of primary education found for the treated cohorts may not be caused by events other than the Cultural Revolution education policies. Regarding the magnitude of this new set of estimates, the More Rural cohorts spent around 0.459 more years (9%) in primary schools than the More Urban cohorts, for those with a rural Hukou; the corresponding number for those with an urban Hukou is around 0.581-0.94 years (11-18%). Come to primary school degree. The treatment group was more likely to graduate from primary schools: The coefficients in front of the interaction terms are around 0.076 (9%) in Column 2 and 0.119-0.228 (14-27%) in Column 4.

5.6. Omitted Cohort Attributes

Since the sampling cohorts were born and grew up during the early years of the communist regime, it is likely that one cohort may be systematically different from another due to e.g. a particular economic policy that was trialled out first but later shortly abolished. This means that the policy estimates of interest can still be biased (downward or upward) by the presence of omitted cohort-specific characteristics even when cohort-group fixed effects have already been controlled for. The various historical events tabulated in Tables A1-A3 seems make this line of thinking more legitimate. There is one way to further detect the relevance of this problem to the current context. That is, one can apply a similar difference-in-differences analysis to the control group and check if a significant education-policy relationship can be found where it is not expected, in order to say something about the possibility of unobserved cohort differences biasing the baseline results discussed so far: If a significant relationship comes out, then one needs to be more worried about confounding due to other cohort-specific characteristics that have not yet been taken into account; on the other hand, if no significant estimates show up, then it means that the cohort-group fixed effects are likely doing a good job.

The results are presented in Table 12[74], for rural non-migrants (Columns 1-2) and urban non-migrants (Columns 3-4), respectively. Now the estimating sample is restricted to

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B, agricultural workforce in Panel C and individual residence in Panel B. Robust standard errors are reported in parentheses.

[74] In the two tables, the dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size,

those born between 1949 and 1954, i.e. those whose primary education should not have been affected by the Cultural Revolution (or the control group in the original study sample). To carry out a difference-in-differences analysis similar to the benchmark framework, a superfluous treatment status is duly defined: It switches on for the younger cohorts (born in 1952-1954) and switches off for the older ones (born in 1949-1951).

Beginning with the rural cohorts. Among those for whom no significant estimates for the attainment of primary education are expected (i.e. the 1949-1954 cohorts), neither years of completed primary schooling nor the probability of having a primary school degree is significantly correlated with the interaction between More Rural and treatment. Similarly for the urban cohorts, years of primary schooling are not estimated to be significantly correlated with the interaction between treatment and More Rural in Panel B (administrative district), Panel C (agricultural workforce) and Panel D (individual residence), and the coefficients of interest when the dependent variable is replaced by primary school degree cannot be statistically distinguished from zero in Panel B (administrative district) and Panel D (individual residence). While a significant correlation between primary education attainment and treatment (for the control) would certainly lead one to worry about unobserved cohort-level confounding, these insignificant relationships may be viewed as suggestive evidence for the reliability of the baseline difference-in-differences.

Yet, in the urban sample, those who were treated do appear to have spent more time in primary schools and have had a higher probability of having a primary school degree, when More Rural is defined by either farmland (Panel A of Column 3) or agricultural workforce (Panel C of Column 4). This may be explained by the fact that before the Cultural Revolution education policies disproportionately favoured urban students (Deng and Treiman 1997; Hannum 1999; Lu and Treiman 2008) and that primary education had already went through three phases of expansion (Table A1); the younger urban cohorts (the treated) may be the more benefited group in terms of educational attainment in the pre-revolution system. In this regard, the baseline results obtained from the rural sample may be more credible than those estimated from those with an urban Hukou.

6. The Long-term Impact of the Cultural Revolution

6.1 Health and the Cultural Revolution

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a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual covariates (gender and age and its square). More Rural is defined using community farmland in Table 12A, and it is determined using all the four classifications in Table 12B. Robust standard errors are reported in parentheses.

The results for the health impact of the Cultural Revolution are first shown, in Table 13 for rural non-migrants and in Table 14 for urban non-migrants[75]. The dependent variables are a set of binary indicators for underweight and overweight (defined using BMI), self-reported poor health as well as diagnosed high blood pressure and diabetes. Each column corresponds to a regression based on Equation 1. More Rural is defined using community farmland in Table 13 and Table 14 uses and compares all the four More Rural.

Beginning with rural non-migrants (Table 13). The probability of being underweight is significantly and negatively associated with all the interactions between treatment and More Rural, implying that both the full-treat and partial-treat More Rural were around 4.5-5.6 percentage points (123-153%[76]) less likely to be underweight, compared to their More Urban counterparts. In addition, the full-treat More Rural also turns out to be significantly less likely to be overweight, by around 14.5 percentage points (50%). By contrast, when health is measured by diagnosed high blood pressure, the treated cohorts seem to have worse health than their not-treated counterparts. The probability of high blood pressure was significantly higher among the full-treat and partial-after More Rural, by around 6.9 (107%) and 7.6 (117%) percentage points, respectively. Therefore, the expansion of primary education may have produced a mixed health impact within the Cultural Revolution generation with rural place-of-birth. And the full-treat More Rural, while appearing to be the most benefited group in terms of education, appears to have had little health advantage compared to the other More Rural.

Results remain broadly unchanged for those born in urban areas, as shown in Table 14. On the one hand, the expansion of primary education over the Cultural Revolution seems to have induced all the More Rural cohorts to be significantly less likely to report poor health. In Column 3, the probability of reporting poor health was around 19 percentage points lower (55%) among the full-treat, 12 percentage points lower (35%) among the partial-before and 11.3-23.5 percentage points lower (33-68%) among the partial-after. Meanwhile, underweight appears to be less common among the partial-before More Rural: There was a relative decline in the incidence of underweight among this group of the Cultural Revolution generation by around 1.7-2.4 percentage points (46-66%). On the other, the coefficients of

[75]The two tables control for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual-level controls (gender and age and its square). Robust standard errors are reported in parentheses.

[76]The large percent increase in the probability of underweight is caused by near zero prevalence of underweight in the study sample. This suggests that it may be problematic to use OLS to infer the health impact of the Cultural Revolution. But more careful thinking has to be left for future work.

interest when health is measured by overweight are constantly significant and positive, implying that all the More Rural cohorts had a higher probability of being overweight. The magnitude of this relative health disadvantage ranges from 8 to 15.5 percentage points (27-53%). And unlike the partial-before More Rural, the partial-after More Rural was also around 5.6 percentage points (153%) more likely to be underweight. Hence, the urban cohorts seem not have benefited from easier access to primary education made possible by the Cultural Revolution in terms of health either. Also similar to the rural sample, the most benefited group in terms of education in the urban sample (the partial-after More Rural) is not estimated to have more positive health results than the other two less benefited groups.

6.2 Health Behaviours and the Cultural Revolution

The policy impact on health behaviours is next examined. Results for rural non-migrants are in Table 13 and those for urban non-migrants are in Table 15[77]. The dependent variables include measures for medical care utilisation (medical insurance and preventive care), smoking status, dietary pattern and physical activity. Each column corresponds to a regression based on Equation 1. More Rural is defined using community farmland in Table 13, while Table 15 uses and contrasts all the More Rural classifications.

In Table 13, the partial-before More Rural with rural place-of-birth is estimated to be around 10.3 percentage points (21%) more likely to be medically insured. This group of individuals along with the full-treat More Rural also seem less likely to smoke, by around 13.3 (43%) and 12.2 (40%) percentage points, respectively. Based on these, it may be inferred that the expansion of primary education during the Cultural Revolution has induced the rural cohorts to adopt healthier consumption behaviours. Though unexpectedly, this positive policy impact seems to be concentrated on the partial-before cohorts (rather than the full-treat who had the largest increase in primary education).

The coefficients of interest are more significant for the urban sample and the interpretation of the consumption-policy relationship remains qualitatively unchanged (Table 15). For example, medical insurance ownership is estimated to be significantly more common among all the More Rural. The corresponding relative increase in the probability of being medically insured was around 12.1-25 percentage points (25-51%) among the full-treat, 7.3-28.9 percentage points (15-59%) for the partial-before and 12.8-19.1 percentage points (26-

[77]The two tables control for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual covariates (gender and age and its square). Robust standard errors are reported in parentheses.

39%) for the partial-after. The probability of smoking was lower within the partial-after More Rural, by around 9.6 percentage points (31%). While the full-treat More Rural turns out to have a higher tendency to consume a fatty diet, by 7.7 percentage points (12%), this treatment group at the same participated more actively in physical activities, by 11.9 percentage points (137%). The partial-after More Rural was also more likely to take physical activities, with the corresponding coefficient estimated to be on the same order as that for the full-treat More Rural. Hence, for the urban cohorts as well, the more treated, the healthier the health behaviours. Since the coefficients of interest are more significant for the partial-after More Rural, it also seems that the most treated (in terms of education outcome), the healthiest the health behaviours.

6.3 Labour Supply and the Cultural Revolution

The last set of outcomes examined is individual labour supply. Estimates are shown for rural non-migrants in Table 13 and those for urban non-migrants are in Table 16[78]. The dependent variables include measures for current working status, income (log wage, log non-wage and log total income) and types of occupation (light and moderate). Each column corresponds to a regression based on Equation 1. As usual, More Rural means presence of farmland in Table 13 and the panels differ by how More Rural is defined in Table 16.

The probability of working and the income variables do not turn out to be significantly associated with the More Rural interactions for those with rural place-of-birth, implying that the expansion of primary education may not have altered the rural cohorts' decisions to participate in the labour market or their labour market productivity (Table 13). Also within the rural sample, the partial-before cohorts with More Rural residence seem 12 percentage points (48%) less likely to work in a light (on-the-job activity) occupation, but they were around 2.8 percentage points (40%) more likely to work in a moderate (on-the-job activity) occupation. Overall, since the difference-in-differences coefficients for working status and income cannot be said statistically significant at conventional levels, the revolution education policies appear to have had little impact on the labour market performance of the rural Cultural Revolution generation.

What is told by Table 16 for the urban sample is slightly different and more significant. The coefficients of interest corresponding to the partial-after More Rural are

[78] The two tables control for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). Robust standard errors are reported in parentheses.

estimated to be statistically significant at conventional levels for all the measures of labour market performance. For example, the probability of working for this group of individuals was significantly higher, by around 14.8 percentage points (19%). Total income is estimated to be significantly and positively correlated with the treatment interactions in all the panels of Column 4, implying that incomes earned by the partial-after More Rural may be around 34.2-120.5% higher than those earned by their More Urban counterparts. Results are significant and negative in Column 5 but are significant and positive in Column 6, suggesting that the partial-after More Rural may be around 11.6-22.4 percentage points (47-90%) less likely to have a light (on-the-job activity) occupation while being around 9.4-24 percentage points (134-341%) more likely to have a moderate (on-the-job activity) occupation. For the other types of the More Rural, the full-treat seems to have a higher probability of working, by 7.5 percentage points (10%), (albeit) with relatively lower wages (34.7%), compared to the full-treat More Urban. The partial-before More Rural appears more likely than the partial-before More Urban to work in a moderate (on-the-job activity) occupation, by 11.6 percentage points (165%), though similarly with lower wages (25.8%). These results then suggest that while the expansion of primary education may have produced a mixed impact on the labour market performance of the full-treat and partial-before More Rural, it may have induced the partial-after More Rural born in urban areas to work more actively and have a higher income.

7. Exploring the Mechanisms

7.1 The Preference Mechanism

The life-cycle model suggests that the expansion of primary education may affect health outcomes by shaping individual health-related preferences (Section 2). There are several preference variables from China Health and Nutrition Survey (CHNS) that capture respondents' tastes for food and physical activities and their perceptions of lifetime priorities. Because individuals' tastes for food and physical activities are predictive of their health behaviours (e.g. diet and exercising) and health, if they turn out to be significantly affected by the Cultural Revolution, then preferences may be one potential health mediator through which the Cultural Revolution affected cohort health and health behaviours. Likewise, perceptions of lifetime priorities may shape health-related preferences (e.g. time-discounting and attachment to the labour market) and hence health outcomes. For example, an individual who views having a healthy diet as one lifetime priority may be more patient and hence more likely to consume a healthy diet and less likely to be overweight. A respondent who views having a good income as important may have a higher attachment to the labour market and work more actively. Then if the Cultural Revolution turns out to have a significant impact on lifetime priorities, which may in turn influence health-related preferences and then health, it may be similarly assumed that there exists a preference channel that links the Cultural Revolution to health. This section estimates the impact of the Cultural Revolution on the preference variables from CHNS, as an attempt to shed some light on this preference mechanism.

To be more specific, based on CHNS questionnaires, five binary indicators are used to denote individual preferences[79] for food, including fast foods, salty snacks, fruits, vegetables and soft drinks. For example, the binary indicator for fast foods is equal to 1 if a respondent reported as liking fast foods and equal to 0 otherwise. Likewise, individual tastes for physical activities[80] are approximated by a set of dummy variables indicating whether or not he/she was fond of a particular kind of leisure activity, including walking, sports, body-shaping, watching TV, playing computer and reading. The dummy variables switch on if an affirmative answer was given and switch off otherwise. The priorities[81] asked by CHNS are having a good income, being physically active, eating a healthy diet, having kids being physically active and having kids eating a healthy diet. Individual perceptions of these priorities are then measured by five binary variables equal to 1 if he/she perceived a certain priority as important and equal to 0 otherwise.

Estimates are first presented for rural non-migrants (Table 17[82]). To account for the possibility that the More Rural and More Urban cohorts may differ systematically in their subjective preferences and lifetime priorities (even without the Cultural Revolution), each column controls for (in addition to the original control set) a More Rural-specific quadratic

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[79] The survey question is "How much do you like this food, dislike very much, dislike somewhat, neutral, like somewhat, like very much or does not eat this food at all". The neutral category was not included in the 2004 round of the China Health and Nutrition Survey.

[80] The survey question is "How much do you like to participate in this activity, dislike very much, dislike somewhat, neutral, like somewhat, like very much or does not participate at all". The neutral category was not included in the 2004 round of the China Health and Nutrition Survey.

[81] The survey question is "How important is this priority in your life, not important at all, not very important, important, very important, the most important or don't know".

[82] The dependent variables include individual preferences for foods (fast food, salty snacks, fruits, vegetables and soft drinks) and physical activities (walking, sports, body-shaping, watching TV, playing computer and reading) as well as lifetime priorities (having a good income, being physically active, eating a healthy diet, having kids being physically active and having kids eating a healthy diet). Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

trend in individual age (thus allowing any age-specific preference differences between More Rural and More Urban)[83].

The probabilities of liking fast foods, salty snacks and soft drinks are significantly and positively associated with the More Rural interactions for the treatment groups. Across all the More Rural, the likelihood of preferring less healthy foods was around 11-26 percentage points (96-228%) higher by fast foods, 8.5-23 percentage points (45-123%) higher by salty snacks and 34.1-74.9 percentage points (101-223%) higher by soft drinks. By contrast, the full-treat and partial-after More Rural also tended to be more fond of vegetables and fruits: The corresponding coefficients are on the order of 5.8-10.5 percentage points (6-11%) for vegetables and 12.6-17 percentage points (14-18%) for fruits.

In terms of preferences for physical activities. The treated cohorts appear more inclined to like both active and sedentary activities: The coefficients of interest for all activity preference variables are significant and positive at conventional levels. For example, all the More Rural cohorts were around 12.4-52.7 percentage points (65-276%) more likely to be fond of sports; the full-treat and partial-after More Rural were also more likely to prefer walking and body-shaping, by 55.6-69 percentage points (150-187%) and 46.6-65.3 percentage points (202-284%), respectively. On the other hand, all the treated More Rural had a higher chance of (liking) playing computer: The corresponding coefficients are significant and positive and are between 0.083 and 0.379 (59-267%). The full-treat and partial-after More Rural in addition had a significantly higher probability of preferring watching TV and reading: The magnitude of the estimates is about 0.142-0.257 (16-29%) for watching TV and around 0.165-0.332 (42-85%) for reading.

Then for lifetime priorities. The coefficients for being physically active, eating a healthy diet and having kids eating a healthy diet are significantly positive, implying that the full-treat More Rural was around 11.9 percentage points (14%) and 6.8 percentage points (7%) more likely to view being physically active and having kids eating healthily as important. Similarly, the partial-after More Rural turns out to place a higher value on all the three priorities: The estimated coefficients are around 0.222 (26%) for physical activity, 0.148 (16%) for diet and 0.085 (9%) for kids eating a healthy diet.

To interpret these results. In the previous section, all the treated cohorts are estimated to have a significantly lower probability of being underweight while being significantly more likely to have high blood pressure. This seems able to be explained by their induced

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[83] As a result, the quadratic trend in individual age (i.e. not interacted with the More Rural indicator) is omitted from the empirical specification.

preferences (by the Cultural Revolution) for less healthful foods (i.e. fast foods, salty snacks and soft drinks) and sedentary activities (i.e. watching TV, playing computer and reading). The relative decline in underweight among the partial-after More Rural (in particular) may also be viewed as coming from the possibility that the Cultural Revolution has led them to perceive eating a healthy diet as important. Likewise, the lower prevalence of overweight among the full-treat More Rural is consistent with the higher tendency for this treatment group to eat more healthful foods (i.e. fruits and vegetables), engage in more active activities (i.e. walking, sports and body-shaping) and rank being physically active as a lifetime priority. Lastly, the insignificant relationship between the income priority and treatment mirrors the insignificant relationships between labour supply and treatment as found for the rural sample in the previous section. Hence, the theoretical postulation of the existence of a preference mechanism running from the Cultural Revolution to preferences and then to health outcomes seems to be supported by the rural sample.

The results for urban non-migrants are next shown (Tables 18-20[84]). As in Table 17, to deal with potential confounding due to the presence of unobserved and systematic differences in preferences (e.g. for food intake) between the More Rural and More Urban cohorts, a More Rural-specific quadratic trend in age is included in each column[85].

Beginning with food preferences. The More Rural cohorts had a higher probability of liking fruits, but they also tended to be more likely to be fond of soft drinks: The coefficients of interest for the two food preference indicators are significantly positive. In particular, the relative increase in the preference for fruits was around 8.2-24.2 percentage points (9-26%), and that for soft drinks (for full-treat and partial-after More Rural) was around 22.6-34.4 percentage points (67-102%). The partial-after More Rural may have a healthier eating habit than the full-treat and partial-before More Rural. While the partial-after More Rural had a lower probability of liking fast foods and higher probability of liking vegetables, by 22.5-36.9 percentage points (197-323%) and 9-13.7 percentage points (9-14%), respectively, the full-treat More Rural was around 12.8 percentage points (112%) more likely to prefer fast foods

[84]The dependent variables include individual preferences for foods (fast food, salty snacks, fruits, vegetables and soft drinks) and physical activities (walking, sports, body-shaping, watching TV, playing computer and reading) as well as lifetime priorities (having a good income, being physically active, eating a healthy diet, having kids being physically active and having kids eating a healthy diet). Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

[85]Similarly, as a result, a quadratic trend in individual age (i.e. that not interacted with the More Rural indicator) is dropped out of the control set.

and the partial-before More Rural was around 3 percentage points (3%) less likely to be fond of vegetables.

The results for preferences for physical activities in Tables 18-20 are similar to those in Table 17, implying that the More Rural cohorts with urban place-of-birth as well had a significantly higher probability of liking both active and sedentary activities, compared to their More Urban counterparts. For example, on the one hand, all the More Rural was significantly more likely to like walking, doing sports and body-shaping, by 26.7-98 percentage points (72-265%), 19.1-87.1 percentage points (100-456%) and 18.3-104.1 percentage points (79-452%), respectively. On the other hand, the More Rural cohorts (either full-treat or partial-treat) were significantly more likely to play computer, by 9.9-80.9 percentage points (70-570%). The partial-after More Rural had a higher probability of (liking) watching TV, by 35.2 percentage points (39%). And the full-treat More Rural had a higher probability of (liking) reading, by 14.6 percentage points (37%).

Lastly for lifetime priorities. The coefficients in front of the various interactions are broadly insignificant at conventional levels, implying that the Cultural Revolution may have had little impact on the urban cohorts' lifetime priorities. Though the partial-after More Rural appears to have a significantly higher probability of viewing being physically active as important, by 28.4 percentage points (34%). And this group of individuals and the full-treat More Rural may also attach significantly more weight to eating a healthy diet (themselves) and having their kids being physically active, by 5.6-8.3 percentage points (6-9%) for the former and by 6-6.3 percentage points (6-7%) for the latter.

Similar to the rural sample, these various reduced-form relationships between preferences and the Cultural Revolution found for the urban sample can be used to explain the long-term impact of the Cultural Revolution on the urban cohorts' health outcomes. For example, the significantly lower prevalence of self-reported poor health within the partial-after More Rural may be explained by their induced (by the Cultural Revolution) lower tendency to be fond of fast foods and higher tendency to be fond of fruits and vegetables. The uncovered preferences for fast foods and soft drinks among the full-treat More Rural seem able to account for the higher prevalence of overweight and fatty diets among this group of individuals. A distaste for vegetables among the partial-before More Rural may be used to justify their higher likelihood of being of abnormal weight (underweight and overweight). The estimated higher tendency for full-treat and partial-after More Rural to take exercises in spare time likely comes from their higher probability of liking active physical activities (i.e. walking, sports and body-shaping). Then for the partial-after cohorts with More Rural residence, their revealed higher prevalence of underweight, lower incidence of self-reported poor health and higher probability of taking exercises may be due to the possibility that the Cultural Revolution made them put more weight on being physically active and eating a healthy diet. Overall, one interpretation of these results is that the preference channel as assumed by the life-cycle model may exist for those with urban place-of-birth as well and work in the expected direction.

7.2 The Investment Mechanism: Returns to Education

In addition to the preference mechanism, it is also possible that the Cultural Revolution affected health outcomes by altering investment in education (Section 2). More specifically, two questions are of interest regarding this investment mechanism: One is that whether the Cultural Revolution encouraged the affected cohorts to spend more on education and the other is that whether more education led to improved health outcomes. Without data on education expenditure, the first link cannot be investigated. Yet the various measures of health outcomes in China Health and Nutrition Survey (CHNS) allow this analysis to obtain some estimates on the returns to education – the education impact on health, health behaviours and labour supply. Which is what this section plans to do.

In practice, education can be (linearly) linked to individual outcomes using Equation 4:

$$Y_{icp} = \alpha^o + \delta^o E_{icp} + \theta_1^o F_c + \theta_2^o PB_c + \theta_3^o PA_c + \gamma^o R + X'_{icp}\beta^o + \varepsilon_{icp}^o (4)$$

where E_{icp} is the attainment of primary education by individual i born in year c living in province p. Y_{icp} is an outcome measure (e.g. health). The parameter of interest is thus δ^o, which can be interpreted as returns to education. The other right-hand-side variables are the same as those in Equation 1. α^o is a constant. ε_{icp}^o is an error term. But it has been long established that E_{icp} is almost certainly correlated with ε_{icp}^o, meaning that OLS estimates of δ^o is unlikely to correctly inform the education-outcome relationship (Card 2001). Therefore, the interaction terms between More Rural and treatment (full-treat, partial-before and partial-after) are used to instrument for E_{icp}, with the first-stage being in the form of Equation 5:

$$E_{icp} = \alpha^f + \delta_1^f (F_c * R) + \delta_2^f (PB_c * R) + \delta_3^f (PA_c * R) + \theta_1^f F_c + \theta_2^f PB_c + \theta_3^f PA_c + \gamma^f R + X'_{icp}\beta^f + \varepsilon_{icp}^f (5)$$

where F_c is a binary indicator that is equal to 1 for the full-treat Cultural Revolution generation and equal to 0 otherwise. The other two dummy variables PB_c and PA_c correspond to the partial-before and partial-after cohorts, respectively. R is equal to 1 if i was More Rural and 0 otherwise. α^f is a constant. ε_{icp}^f is an error term. Equations 4 and 5 are jointly estimated on urban or rural non-migrants. Instrumental Variables (IV) results are shown in the following sections, for health, health behaviours and labour supply, respectively. Robust standard errors are reported in parentheses.

7.2.1 Health Returns to Education

The results for the health returns to education are first presented, in Table 21[86] for rural non-migrants and in Table 22[87] for urban non-migrants. Years of primary education are significantly and positively associated with the probability of being underweight, implying that those with one more year of primary schooling (more educated) had a higher likelihood of being underweight, by 4.4 percentage points (120%). The coefficients for overweight are significant and mixed, suggesting that the probability of being overweight was lower for the more educated rural cohorts, by 16.3 percentage points (56%), but higher for the more educated urban cohorts, by 8.9 percentage points (31%). The results for self-reported health point to significant health returns to education, while those for diagnosed high blood pressure point to the opposite. For example, the more educated was around 30.7 percentage points (89%) less likely to report poor health, but they had a higher incidence of high blood pressure, by 6.7 percentage points (103%). These suggest that, like the reduced-form relationships (Tables 13-14), more education seems not necessarily lead to improved health in the study sample. Results are the same when the education variable is replaced by primary school degree (instead of years of completed primary schooling). (Due to space limit they are not presented in detail but are available on request.)

8.2.2 Lifestyle Returns to Education

[86] The education variable is years of completed primary schooling. Each column is obtained by jointly estimating Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

[87] The education variable is years of completed primary schooling. Each column is obtained by jointly estimating Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Focusing next on the estimates for the returns to education in terms of individual health behaviours. The results for rural non-migrants are in Table 21[88] and those for urban non-migrants are in Table 23[89].

The probability of being medically insured is significantly and positively associated with years of primary education, implying that the cohorts with one more year of primary schooling (more educated) were around 9.6-23.6 percentage points (20-49%) more likely to have medical insurance. The coefficient of interest is significant and negative for smoking, suggesting that the more educated was around 10.1 percentage points (33%) less likely to smoke. The probability of taking physical activities is also estimated to be higher for the more educated, by 8.9-14.4 percentage points (103-166%). Therefore, similar to their reduced-form counterparts (Tables 13 and 15), results in Tables 21 and 23 tend to suggest that the cohorts who were induced by the Cultural Revolution to obtain more years of primary schooling were also more likely to adopt healthier consumption behaviours. Results remain unchanged when education is measured by primary school degree (Due to space limit they are not shown).

7.2.3 Labour Market Returns to Education

The last set of results that exploits the investment mechanism is about labour market returns to education, shown in Table 21[90] for rural non-migrants and in Table 24[91] for urban non-migrants.

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[88] The education variable is years of completed primary schooling. Each column is obtained by jointly estimating Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

[89] The education variable is years of completed primary schooling. Each column is obtained by jointly estimating Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

[90] The education variable is years of completed primary schooling. Each column is obtained by jointly estimating Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

[91] The education variable is years of completed primary schooling. Each column is obtained by jointly estimating Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 together with two individual characteristics (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

The probability of working is significantly and positively associated with the education variable. Hence, the cohorts with one more year of primary schooling (more educated) were around 16.6 percentage points (22%) more likely to be working at the time of the survey. While the education coefficients for wages are mixed, those for total income are significant and positive, suggesting that one more year of primary schooling was associated with an around 38.1-116.8% increase in total income of the study sample. The more educated is also estimated to have a higher probability of working in a moderate (on-the-job activity) occupation, by 5.9-19.4 percentage points (84-276%). These results then suggest that there may be significant labour market returns to primary education, though the direct impact of education policies (i.e. the Cultural Revolution) on labour supply is less clear (Tables 13 and 16). Once more, the same can be said when the education variable is replaced by primary school degree (due to space limit results are not shown).

8. Conclusion

Health is one of the most important human capitals for economic development. While education interventions have long been perceived as a cost-effective way to improve health, findings so far in the existing literature on education's causal effect on health effectiveness have been mixed. This study provides more estimates of the health impact of education policies by exploiting a nationwide education campaign in China – the Cultural Revolution.

One major feature of the Cultural Revolution was the nationwide expansion of primary education. Indeed, the results on the education impact of the Cultural Revolution show that it significantly increased primary education obtained among the treated More Rural cohorts. In particular, the full-treat and partial-after More Rural seem have benefited more from the expansion of primary education than the partial-before More Rural, in terms of education attainment.

Yet the long-term impact of the Cultural Revolution on cohort health is more mixed. While the Cultural Revolution seems to have significantly reduced underweight and self-reported poor health among the treated More Rural, it seems have significantly increased the incidence of high blood pressure. Results for overweight are also inconclusive with flipping signs in front of the coefficients of interest. Further exploring how the Cultural Revolution may have affected two health correlates – health behaviours and labour supply – leads to estimates suggesting that the treated More Rural was more likely to have medical insurance, less likely to smoke and more likely to take physical activities. The partial-after More Rural also turns out to work more actively and have a higher income. Hence, though with little health impact, the Cultural Revolution seems to have induced the treated cohorts to behave more healthfully and work more actively.

A (maybe) more interesting aspect of this study is that it exploits the pathways through which the long-term impact of the Cultural Revolution may operate. And it finds that the Cultural Revolution significantly affected cohort health-related preferences, and the preference results seem able to explain those obtained for its long-term health impact. Furthermore, more primary schooling (induced by the Cultural Revolution) seems to have increased medical insurance ownership, reduced smoking, increased exercising, led to higher probability of working and increased income, within the study sample. It therefore seems that the long-term impact of the Cultural Revolution may come from its influence on cohort preferences and the positive correlation between education and health outcomes.

It is not clear why the Cultural Revolution produced a mixed impact on health, while appearing to have increased education attainment and generated more healthful behaviours within the treatment group. One contemplation is that increases in education at a relatively elementary level (i.e. primary and not education at higher levels) may not be sufficient to lead to substantial health improvement, or that the well discussed decline in education quality during the Cultural Revolution may have more profound implications for health than for the other (more) behavioural outcomes. Another is that the impact estimates obtained by this study are only correlational and not causal, given that the Cultural Revolution is also featured by numerous other radical events which may also have affected the health of the Cultural Revolution generation. To provide more definitive evidence on the health impact of the Cultural Revolution and for policy implications (i.e. whether health interventions[92] other than education policies may be more productive), a more careful examination is warranted, which will be left for future research.

[92]For example, those targeted at labour supply (Mukhopadhyay, Song and Zhou 2011) or health behaviours (Shi 2012).

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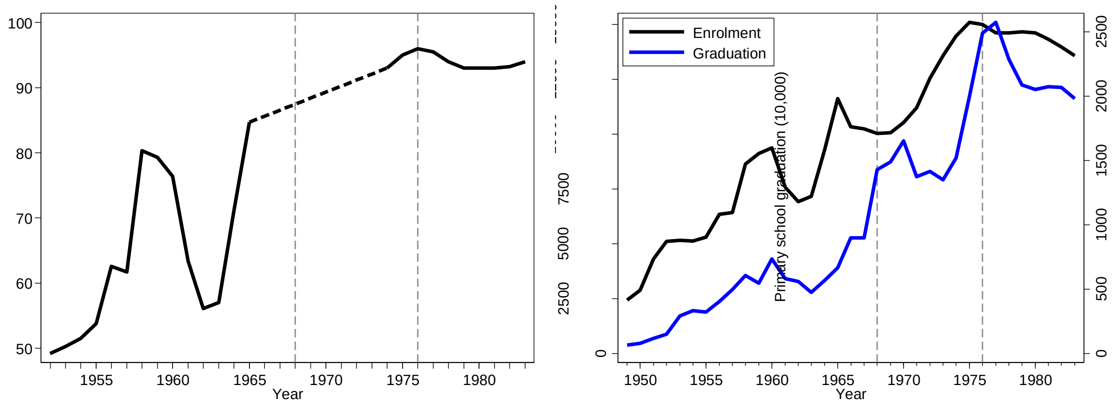
Figures and Tables

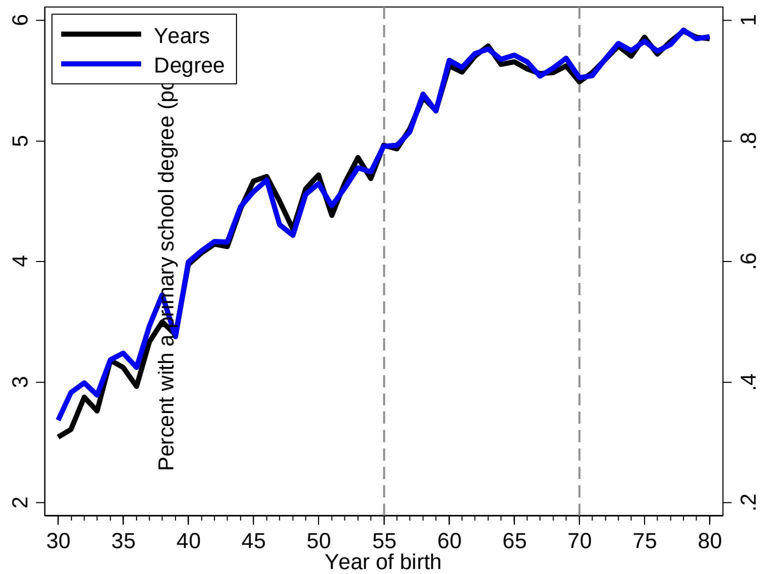
Figure 1: Quantity of primary education, official statistics

Figure 1A: Enrolment rate of school-aged kids Figure 1B: Enrolment and graduation



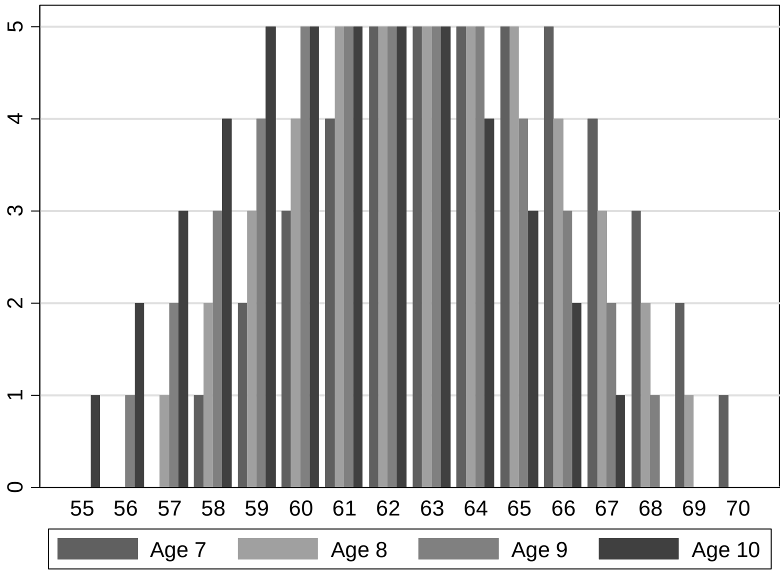
Notes: Data are obtained from National Education Commission, "Achievement of Education in China: Statistics, 1949-1983" (Beijing: People's Education Press, 1984). The two dashed lines mark the period in which the Cultural Revolution education system was in existence, i.e. from 1968-1976.

Figure 2: Attainment of primary education, CHNS



Notes: The figures are produced from the study sample, which is constructed from the China Health and Nutrition Survey (CHNS). The two dashed vertical lines are used to highlight the treatment group, which consists of cohorts born between 1955 and 1970.

Figure 3: Treatment intensity, primary education



Notes: The figure computes for each treated cohort for how long they may have been exposed to the expansion of primary education. Treatment intensity is calculated based on enrolment age (i.e. 7-10 years old) and school length (5 years). In practice, the potentially fully exposed cohorts are those born in 1959-1965 (the 1966 cohort is excluded because this group of individuals can still be in school when the Cultural Revolution was ended); the cohorts who were born before (the 1955-1958 cohorts) or after (1966-1970 cohorts) were potentially partially exposed.

Figure 4: Rural versus Urban, primary education, official statistics

Figure 4A: Enrolment

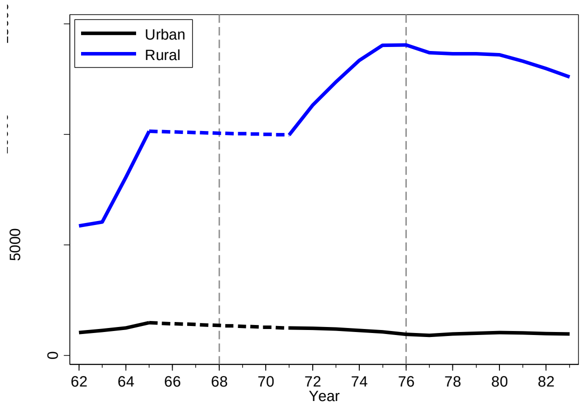


Figure 4B: Graduation

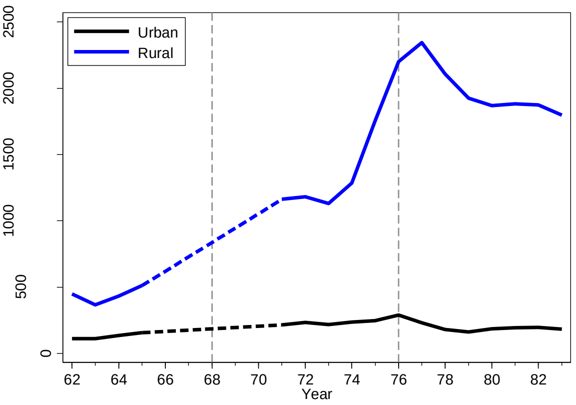
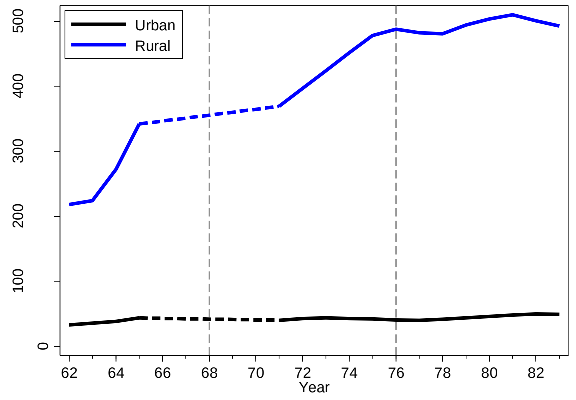


Figure 4C: Full-time teachers



Notes: Data are obtained from National Education Commission, "Achievement of Education in China: Statistics, 1949-1983" (Beijing: People's Education Press, 1984). The two dashed vertical lines mark the period in which the Cultural Revolution education system was in existence, i.e. from 1968-1976.

Figure 5: More Rural versus More Urban, primary education, official statistics

Figure 5A: Enrolment

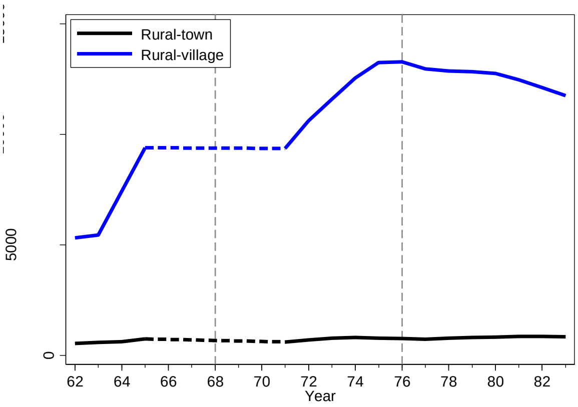


Figure 5B: Graduation

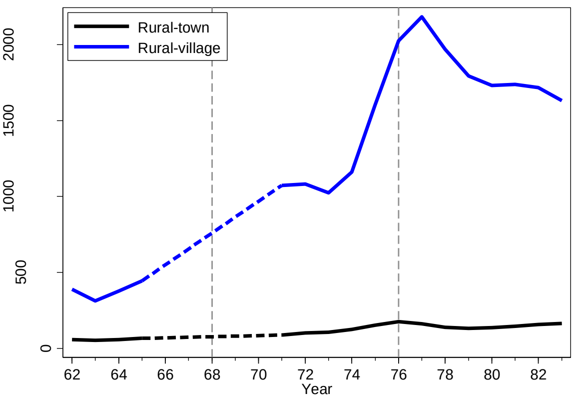
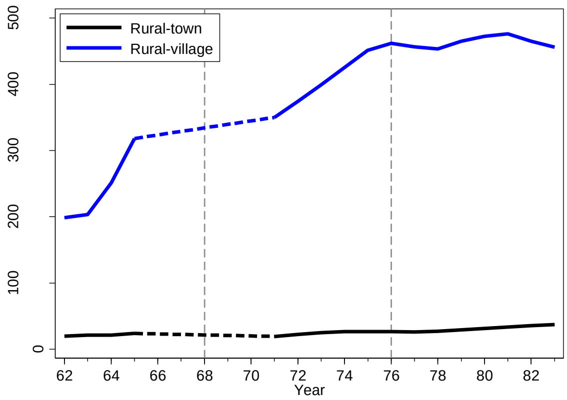


Figure 5C: Full-time teachers



Notes: Data are obtained from National Education Commission, "Achievement of Education in China: Statistics, 1949-1983" (Beijing: People's Education Press, 1984). The two dashed vertical lines mark the period in which the Cultural Revolution education system was in existence, i.e. from 1968-1976.

Figure 6: Discontinuities in attainment of primary education, CHNS

Figure 6A: The rural sample (Hukou)

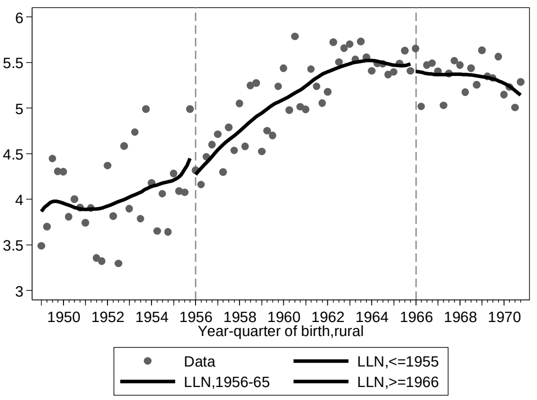
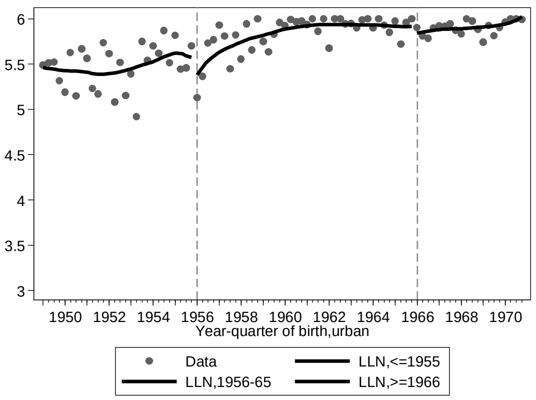


Figure 6B: The urban sample (Hukou)



Notes: The two figures are produced from the China Health and Nutrition Survey (CHNS). Local linear non-parametric regression is used to fit the data (bin width equal to 1). The discontinuity sample is comprised of two neighbouring cohorts: The 1955-1956 cohorts for the policy of reduced school length and the 1965-1966 cohorts for the policy of retrenched school provision. The 1955 and 1965 cohorts (for each policy) are expected to have more primary education because of the institutional features of the Cultural Revolution education policies.

Table 1: Quality of primary education from 1965-1976, official statistics

Variable/year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
(1) Number of full-time teachers (10,000)												
Total	385.7	322.1	319.6	325.5	348.7	361.2	409.5	439.8	467.9	494.4	520.4	528.9
Hired by education department	198	198	198	198	198	198	198	175.8	178.9	179.5	175	162.6
Hired by non-education department	12.6	12.6	12.6	12.6	12.6	12.6	12.6	19	21.2	23.1	24.6	24.7
Hired by local communities	175.1	175.1	175.1	175.1	175.1	175.1	175.1	245	267.8	291.8	320.8	341.6
(2) Type of teachers (10,000)												
Graduates from teacher-training middle school	1.8	3.86	5.22	6.22	2.1	1.13	5.1	5.87	8.4	8.8	12.44	14.84
Graduates from academic senior middle school	36	28	26.8	79.4	38	67.6	100.4	215.9	349.4	417.9	447	517.2
Graduates from academic junior middle school	173.8	162	186.4	519	361.4	618.9	835	1036	1129	1061	1048	1206
(3) Class-size (person)	34	34	34	34	34	34	34	34.7	34.7	35	34.9	34.2
(4) Student-to-teacher ratio	30.1	30.1	30.1	30.1	30.1	30.1	30.1	28.9	28.9	29.3	29	28.4

Notes: Data are obtained from National Education Commission, "Achievement of Education in China: Statistics, 1949-1983" (Beijing: People's Education Press, 1984). It should be noted that direct official statistics on types of primary school teachers in terms of their academic credentials are not available. Because graduates from teacher-training, academic senior and academic junior middle schools formed the most part of primary school teachers over the revolution decade, this analysis uses trends in the number of these three types of graduates to reflect changes in primary school quality.

Table 2: Summary statistics, CHNS

	Rural Hukou			Urban Hukou		
Variable	Obs.	Mean	S.D.	Obs.	Mean	S.D.
Panel A: Human capital						
(1) Education						
Years of primary schooling (year)	14024	4.88	1.967	11108	5.74	1.034
Primary school degree (=1 if yes;0 no)	14024	0.78	0.414	11108	0.948	0.222
(2) Health						
Body Mass Index (BMI) (kg/m2)	9758	23.212	3.157	6213	23.844	3.173
Underweight (BMI<18.5) (=1 if yes;0 no)	9758	0.042	0.2	6213	0.029	0.167
Overweight (BMI>=25) (=1 if yes;0 no)	9758	0.263	0.44	6213	0.337	0.473
Self-reported health: poor or fair (=1 if yes; 0 no)	7676	0.348	0.476	4991	0.337	0.473
Diagnosed high blood pressure (=1 if yes;0 no)	10341	0.05	0.218	6804	0.087	0.282
Diagnosed diabetes (=1 if yes; 0 no)	10287	0.006	0.077	6762	0.024	0.154
Panel B: Health behaviours						
(1) Medical care utilisation						
Medical insurance ownership	10681	0.414	0.493	6937	0.597	0.491
Preventive care utilisation	10662	0.015	0.122	6916	0.04	0.195
(2) Current smoking status (=1 if yes;0 no)						
Currently smoking (=1 if yes;0 no)	9737	0.315	0.464	6209	0.293	0.455
(3) Diet habit (=1 if yes;0 no)						
Daily % fat intake above Chinese guideline	10507	0.532	0.499	6858	0.793	0.405
(4) Physical activity (=1 if yes;0 no)						
Physical activity	7829	0.02	0.139	5147	0.189	0.391
Panel C: Labour supply						
(1) Labour force participation						
Currently working (=1 if yes;0 no)	10735	0.822	0.382	6974	0.663	0.473
(2) Income (in 2009 Yuan)						
Log(earnings*100)	2209	13.392	1.244	3997	14.061	0.817
Log(non-wage income*100)	8357	12.564	2.48	1781	13.317	2.052
Log(total income*100)	9104	12.763	2.653	5397	13.961	1.184
(3) Occupation (=1 if yes;0 no)						
Light occupational activity	10495	0.099	0.299	6948	0.474	0.499
Moderate occupational activity	10495	0.043	0.203	6948	0.111	0.315
Heavy occupational activity	10495	0.686	0.464	6948	0.086	0.281
Panel D: Other individual covariates						
Rural Hukou (=1 if yes;0 no)	14024	1	0	11108	0	0
Female (=1 if yes;0 no)	14024	0.518	0.5	11108	0.511	0.5
Age (year)	14024	45.774	7.163	11108	46.269	7.019
Panel E: More Rural and More Urban						
(1) Community level (=1 if yes;0 no)						
Presence of farmland	14024	0.914	0.28	11108	0.114	0.318
Suburban/Rural-village by official designation	14024	0.972	0.166	11108	0.162	0.369
Above median percent agricultural workforce	14024	0.77	0.421	11108	0.08	0.271
(2) Individual level (=1 if yes;0 no)						
Suburban/Rural-village residence	14024	0.961	0.194	11108	0.242	0.428

Notes: Summary statistics are computed from the study sample (the 1949-1970 cohorts), which is constructed from the China Health and Nutrition Survey.

Table 3: More Rural-More Urban transition matrices, CHNS

Table 3A: More Rural, community-level, presence of farmland

Comm. Farmland	1989-Rural	1991-Rural	1993-Rural	1997-Rural	2000-Rural	2004-Rural	2006-Rural	2009-Rural
1989-Rural	1							
1991-Rural	0.955	1						
1993-Rural	0.908	0.894	1					
1997-Rural	0.857	0.871	0.884	1				
2000-Rural	0.811	0.847	0.8	0.837	1			
2004-Rural	0.835	0.841	0.838	0.821	0.863	1		
2006-Rural	0.807	0.798	0.774	0.766	0.816	0.832	1	
2009-Rural	0.826	0.781	0.802	0.822	0.796	0.807	0.826	1

Table 3B: More Rural, community-level, administrative district

Comm. Admin. District	1989-Rural	1991-Rural	1993-Rural	1997-Rural	2000-Rural	2004-Rural	2006-Rural	2009-Rural
1989-Rural	***							
1991-Rural	***	1						
1993-Rural	***	***	***					
1997-Rural	***	0.759	***	1				
2000-Rural	***	0.714	***	0.919	1			
2004-Rural	***	0.737	***	0.952	0.947	1		
2006-Rural	***	0.719	***	0.902	0.955	0.914	1	
2009-Rural	***	0.732	***	0.903	0.947	0.922	0.942	1

Table 3C: More Rural, community-level, agricultural workforce

Comm. Agri. Labour	1989-Rural	1991-Rural	1993-Rural	1997-Rural	2000-Rural	2004-Rural	2006-Rural	2009-Rural
1989-Rural	1							
1991-Rural	0.671	1						
1993-Rural	0.702	0.8	1					
1997-Rural	0.597	0.686	0.686	1				
2000-Rural	0.568	0.675	0.679	0.72	1			
2004-Rural	0.654	0.701	0.725	0.73	0.747	1		
2006-Rural	0.59	0.577	0.617	0.697	0.694	0.769	1	
2009-Rural	0.651	0.667	0.634	0.711	0.663	0.736	0.69	1

Table 3D: More Rural, individual-level, individual residence

Individual residence	1989-Rural	1991-Rural	1993-Rural	1997-Rural	2000-Rural	2004-Rural	2006-Rural	2009-Rural
1989-Rural	1							
1991-Rural	1	1						
1993-Rural	1	1	1					
1997-Rural	1	1	1	1				
2000-Rural	1	1	1	1	1			
2004-Rural	1	1	1	1	1	1		
2006-Rural	1	1	1	1	1	1	1	
2009-Rural	1	1	1	1	1	1	1	1

Notes: The four More Rural-More Urban transition matrices are computed from China Health and Nutrition Survey. The period covered is from 1989-2009, which is the entire sampling span. The four matrices are intended to show whether a community (or individual) remained More Rural over time. For details please refer to the Data section.

Table 4: Baseline results, educational outcomes

	(1)	(2)	(3)	(4)
Primary	Rural non-migrants		Urban non-migrants	
education	Years	Degree	Years	Degree
Panel A: Community farmland				
Full*More Rural	0.543***	0.099**	0.910***	0.229***
	(0.184)	(0.040)	(0.204)	(0.048)
Partial before*More Rural	-0.192	-0.078*	0.758***	0.209***
	(0.210)	(0.043)	(0.222)	(0.052)
Partial after*More Rural	0.034	0.022	1.113***	0.281***
	(0.168)	(0.038)	(0.204)	(0.047)
Observations	11,964	11,964	6,668	6,668
R-squared	0.213	0.189	0.085	0.078
Panel B: Community administrative district				
Full*More Rural	-1.692***	-0.237***	0.609***	0.148***
	(0.381)	(0.071)	(0.105)	(0.024)
Partial before*More Rural	-2.711***	-0.414***	0.167	0.069**
	(0.372)	(0.070)	(0.147)	(0.031)
Partial after*More Rural	-1.720***	-0.235***	0.772***	0.188***
	(0.370)	(0.071)	(0.107)	(0.025)
Observations	11,964	11,964	6,668	6,668
R-squared	0.215	0.189	0.094	0.085
Panel C: Community percentage agricultural workforce				
Full*More Rural	-0.286**	-0.049**	0.994***	0.240***
	(0.111)	(0.023)	(0.170)	(0.038)
Partial before*More Rural	-0.496***	-0.097***	0.639***	0.183***
	(0.134)	(0.027)	(0.211)	(0.045)
Partial after*More Rural	-0.397***	-0.097***	1.152***	0.280***
	(0.112)	(0.023)	(0.172)	(0.039)
Observations	11,964	11,964	6,668	6,668
R-squared	0.214	0.189	0.098	0.090
Panel D: Individual residence				
Full*More Rural	-1.068***	-0.190***	0.669***	0.129***
	(0.297)	(0.057)	(0.081)	(0.017)
Partial before*More Rural	-1.190***	-0.131*	0.444***	0.080***
	(0.345)	(0.075)	(0.105)	(0.022)
Partial after*More Rural	-1.338***	-0.238***	0.796***	0.166***
	(0.274)	(0.055)	(0.087)	(0.019)
Observations	11,964	11,964	6,668	6,668
R-squared	0.214	0.189	0.108	0.089
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Each column is obtained from an OLS regression using Equation 6 (i.e. DID). Robust standard errors are reported in parentheses.

Table 5: Discontinuity results, educational outcomes

	(1)	(2)	(3)	(4)
	Rural Hukou		Urban Hukou	
Primary education	Years	Degree	Years	Degree
The 1955 cohort	0.557**	0.183***	0.492***	0.099***
	(0.238)	(0.049)	(0.181)	(0.035)
Observations	1,324	1,324	1,156	1,156
R-squared	0.210	0.175	0.125	0.118
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The discontinuity sample is composed of the 1955-1956 cohorts, i.e. the two neighbouring cohorts who were and were not affected by the policy of reduced school length. The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. Each column is obtained from an OLS regression using a specification similar to Equation 7, which does not have the interaction term (between treatment and More Rural) and More Rural. Robust standard errors are reported in parentheses.

Table 6: Placebo tests, educational outcomes

	(1)	(2)	(3)	(4)
Reduced school length:	Rural Hukou		Urban Hukou	
Primary education	Years	Degree	Years	Degree
Panel A: Community farmland				
Partial before*More Rural	-0.800**	-0.168**	0.685***	0.129***
	(0.344)	(0.066)	(0.204)	(0.042)
Observations	1,324	1,324	1,156	1,156
R-squared	0.221	0.195	0.131	0.124
Panel B: Community administrative district				
Partial before*More Rural	1.572***	0.301***	-0.538**	-0.081*
	(0.187)	(0.039)	(0.229)	(0.045)
Observations	1,324	1,324	1,156	1,156
R-squared	0.225	0.188	0.139	0.127
Panel C: Community percentage agricultural workforce				
Partial before*More Rural	-0.484*	-0.132**	0.213	0.069
	(0.274)	(0.057)	(0.291)	(0.054)
Observations	1,324	1,324	1,156	1,156
R-squared	0.218	0.183	0.129	0.122
Panel D: Individual residence				
Partial before*More Rural	-0.788	-0.231*	-0.209	-0.054
	(0.565)	(0.136)	(0.194)	(0.039)
Observations	1,324	1,324	1,156	1,156
R-squared	0.213	0.178	0.141	0.130
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The discontinuity sample is composed of the 1955-1956 cohorts (i.e. for reduced school length). Since the educational discontinuity in terms of the retrenching policy is not well-defined (i.e. no significant results found), it is not considered by Table 6. The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Each column is obtained from an OLS regression using Equation 7. Robust standard errors are reported in parentheses.

Table 7: First-stage results, decision to migrate

	(1)	(2)	(3)	(4)	(5)	(6)
		Rural Hukou			Urban Hukou	
First-stage:Decision to migrante	Policy	Policy-Input	Output	Policy	Policy-Input	Output
More Rural: Community farmland						
Government procurement price of output	0.006	0.009		0.008***	-0.032***	
	(0.004)	(0.013)		(0.003)	(0.012)	
Market price of output	-0.001	-0.025**		0.003	0.013	
	(0.006)	(0.013)		(0.005)	(0.011)	
Household Responsibility System	-0.303	-0.768**		-0.390*	-1.428***	
	(0.257)	(0.373)		(0.230)	(0.341)	
Percentage of sown areas for grain crops	-0.111***	-0.169		-0.227***	0.066	
	(0.036)	(0.119)		(0.032)	(0.104)	
Multiple Cropping Index	0.040	0.049		0.014	-0.091**	
	(0.032)	(0.045)		(0.028)	(0.040)	
Log labour:Farming (including cropping)		9.955*			-6.574	
		(5.238)			(4.539)	
Log labour:Cropping		-1.138			7.205***	
		(1.543)			(1.348)	
Log land		-48.530**			-31.890*	
		(21.193)			(18.318)	
Log capital		-2.175			1.138	
		(1.629)			(1.466)	
Log fertiliser		0.137			1.602***	
		(0.515)			(0.427)	
Log gross value of crop output			0.753			0.782*
			(0.469)			(0.406)
Joint significance:P-value	[0.003]	[0.001]	[0.108]	[0.000]	[0.000]	[0.054]
Observations	14,024	14,024	14,024	11,108	11,108	11,108
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variable is a binary indicator for non-migrant status: It is equal to 1 for those who had not moved by the time of the survey and equal to 0 otherwise. Each column is obtained from a probit regression using the specification in Equation 8. The other right-hand-side variables are a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). For space concern, only results obtained when More Rural is defined using community farmland are reported; those obtained when More Rural is defined using the remaining three classifications are virtually the same. Robust standard errors are reported in parentheses.

Table 8: Correcting for non-random migration, second-stage results, rural

	(1)	(2)	(3)	(4)	(5)	(6)
Rural primary:	Policy		Policy and Input		Output	
Correcting for migration bias	Years	Degree	Years	Degree	Years	Degree
More Rural: Community farmland						
Full*More Rural	0.420**	0.063	0.452**	0.071*	0.328	0.040
	(0.196)	(0.042)	(0.195)	(0.042)	(0.209)	(0.044)
Partial before*More Rural	-0.131	-0.061	-0.150	-0.065	-0.088	-0.050
	(0.213)	(0.044)	(0.211)	(0.044)	(0.214)	(0.044)
Partial after*More Rural	-0.154	-0.032	-0.105	-0.020	-0.291	-0.066
	(0.197)	(0.045)	(0.194)	(0.044)	(0.216)	(0.048)
Inverse Mill's ratio	-0.894*	-0.256**	-0.658	-0.203**	-1.546**	-0.419***
	(0.474)	(0.100)	(0.449)	(0.093)	(0.624)	(0.128)
R-squared	11,964	11,964	11,964	11,964	11,964	11,964
Observations	0.213	0.190	0.213	0.190	0.214	0.190
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. The columns differ by the set of instrumental variables used, with the policy set in Columns 1-2, the policy and input set in Columns 3-4 and the output set in Columns 5-6. Each column is obtained from jointly estimating Equations 6 and 8. The other observable controls include a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual-level covariates (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 9: Correcting for non-random migration, second-stage results, urban

	(1)	(2)	(3)	(4)	(5)	(6)
Urban primary:	Policy		Policy and Input		Output	
Correcting for migration bias	Years	Degree	Years	Degree	Years	Degree
Panel A: Community farmland						
Full*More Rural	0.913***	0.235***	0.982***	0.244***	1.221***	0.259***
	(0.222)	(0.052)	(0.211)	(0.049)	(0.365)	(0.083)
Partial before*More Rural	0.760***	0.213***	0.802***	0.218***	0.946***	0.227***
	(0.231)	(0.053)	(0.224)	(0.052)	(0.291)	(0.067)
Partial after*More Rural	1.115***	0.284***	1.144***	0.288***	1.266***	0.296***
	(0.209)	(0.049)	(0.205)	(0.048)	(0.258)	(0.059)
Inverse Mill's ratio	0.010	0.018	0.186	0.039	0.854	0.083
	(0.192)	(0.048)	(0.132)	(0.031)	(0.797)	(0.180)
R-squared	6,668	6,668	6,668	6,668	6,668	6,668
Observations	0.085	0.078	0.086	0.078	0.086	0.078
Panel B: Community administrative district						
Full*More Rural	0.604***	0.148***	0.621***	0.150***	0.710***	0.170***
	(0.106)	(0.024)	(0.106)	(0.024)	(0.138)	(0.032)
Partial before*More Rural	0.166	0.069**	0.171	0.070**	0.195	0.075**
	(0.147)	(0.031)	(0.147)	(0.031)	(0.151)	(0.032)
Partial after*More Rural	0.773***	0.188***	0.769***	0.187***	0.788***	0.191***
	(0.107)	(0.025)	(0.107)	(0.025)	(0.108)	(0.025)
Inverse Mill's ratio	-0.105	0.003	0.175	0.040	1.703	0.377
	(0.200)	(0.051)	(0.135)	(0.032)	(1.570)	(0.362)
R-squared	6,668	6,668	6,668	6,668	6,668	6,668
Observations	0.094	0.085	0.094	0.085	0.094	0.085
Panel C: Community percentage agricultural workforce						
Full*More Rural	0.946***	0.238***	1.068***	0.256***	0.707	0.155
	(0.187)	(0.043)	(0.178)	(0.040)	(0.544)	(0.127)
Partial before*More Rural	0.610***	0.182***	0.685***	0.193***	0.464	0.131
	(0.218)	(0.047)	(0.212)	(0.046)	(0.391)	(0.088)
Partial after*More Rural	1.114***	0.279***	1.208***	0.292***	0.912**	0.209*
	(0.181)	(0.042)	(0.177)	(0.040)	(0.458)	(0.108)
Inverse Mill's ratio	-0.135	-0.006	0.210	0.044	-0.801	-0.238
	(0.209)	(0.053)	(0.135)	(0.032)	(1.431)	(0.335)
R-squared	6,668	6,668	6,668	6,668	6,668	6,668
Observations	0.098	0.090	0.098	0.090	0.098	0.090
Panel D: Individual residence						
Full*More Rural	0.644***	0.124***	0.709***	0.136***	0.602***	0.093**
	(0.087)	(0.019)	(0.084)	(0.018)	(0.180)	(0.038)
Partial before*More Rural	0.425***	0.076***	0.474***	0.085***	0.394**	0.053
	(0.111)	(0.023)	(0.106)	(0.022)	(0.167)	(0.034)
Partial after*More Rural	0.780***	0.163***	0.822***	0.171***	0.749***	0.140***
	(0.088)	(0.020)	(0.087)	(0.020)	(0.144)	(0.030)
Inverse Mill's ratio	-0.149	-0.029	0.234*	0.042	-0.385	-0.209
	(0.208)	(0.053)	(0.128)	(0.031)	(1.024)	(0.218)
R-squared	6,668	6,668	6,668	6,668	6,668	6,668
Observations	0.108	0.089	0.108	0.089	0.108	0.089
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variable is either years of primary schooling or a binary indicator for whether an individual had a primary school degree. The columns differ by the set of instrumental variables used, with the policy set in Columns 1-2, the policy and input set in Columns 3-4 and the output set in Columns 5-6. Each column is obtained from jointly estimating Equations 6 and 8. The other observable controls include a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual-level covariates (gender and age and its square). The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 10A: Correcting for pre-existing difference in education, rural

	(1)	(2)	(3)	(4)
	Years		Degree	
Primary education	Primary	All	Primary	All
More Rural: Community presence of farmland				
Full*More Rural	0.524***	0.521***	0.095**	0.095**
	(0.184)	(0.183)	(0.040)	(0.040)
Partial before*More Rural	-0.224	-0.227	-0.084*	-0.085*
	(0.210)	(0.211)	(0.044)	(0.044)
Partial after*More Rural	0.001	-0.003	0.016	0.015
	(0.168)	(0.168)	(0.038)	(0.038)
Observations	11,964	11,964	11,964	11,964
R-squared	0.218	0.219	0.194	0.194
Enrolment:Primary	Y	Y	Y	Y
Enrolment:All	N	Y	N	Y
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column is obtained from an OLS regression using Equation 6. The empirical specification controls for cohort pre-trend in educational attainment, enrolment in primary schools in Columns 1 and 3 and enrolment in all the academic institutions in Columns 2 and 4, in addition to a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 10B: Correcting for pre-existing difference in education, urban

	(1)	(2)	(3)	(4)
	Years		Degree	
Primary education	Primary	All	Primary	All
Panel A: Community presence of farmland				
Full*More Rural	0.910***	0.909***	0.229***	0.229***
	(0.203)	(0.203)	(0.047)	(0.047)
Partial before*More Rural	0.760***	0.750***	0.210***	0.208***
	(0.223)	(0.223)	(0.052)	(0.051)
Partial after*More Rural	1.115***	1.121***	0.283***	0.284***
	(0.204)	(0.204)	(0.048)	(0.048)
Observations	6,668	6,668	6,668	6,668
R-squared	0.085	0.086	0.079	0.079
Panel B: Community administrative district				
Full*More Rural	0.610***	0.611***	0.148***	0.149***
	(0.105)	(0.105)	(0.024)	(0.024)
Partial before*More Rural	0.169	0.166	0.070**	0.070**
	(0.147)	(0.147)	(0.031)	(0.031)
Partial after*More Rural	0.773***	0.772***	0.189***	0.188***
	(0.107)	(0.107)	(0.025)	(0.025)
Observations	6,668	6,668	6,668	6,668
R-squared	0.094	0.095	0.085	0.086
Panel C: Community agricultural workforce				
Full*More Rural	0.995***	0.998***	0.241***	0.242***
	(0.170)	(0.170)	(0.038)	(0.038)
Partial before*More Rural	0.641***	0.635***	0.185***	0.183***
	(0.211)	(0.211)	(0.045)	(0.045)
Partial after*More Rural	1.153***	1.157***	0.282***	0.283***
	(0.172)	(0.172)	(0.039)	(0.039)
Observations	6,668	6,668	6,668	6,668
R-squared	0.098	0.098	0.090	0.091
Panel D: Individual residence				
Full*More Rural	0.669***	0.671***	0.129***	0.130***
	(0.081)	(0.081)	(0.017)	(0.017)
Partial before*More Rural	0.444***	0.446***	0.080***	0.080***
	(0.105)	(0.105)	(0.022)	(0.022)
Partial after*More Rural	0.797***	0.797***	0.166***	0.166***
	(0.087)	(0.087)	(0.019)	(0.019)
Observations	6,668	6,668	6,668	6,668
R-squared	0.108	0.108	0.089	0.090
Enrolment:Primary	Y	Y	Y	Y
Enrolment:All	N	Y	N	Y
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. Each column is obtained from an OLS regression using Equation 6. The empirical specification controls for cohort pre-trend in educational attainment, enrolment in primary schools in Columns 1 and 3 and enrolment in all the academic institutions in Columns 2 and 4, in addition to a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 11: Excluding the disrupted cohorts

	(1)	(2)	(3)	(4)
	Rural Hukou		Urban Hukou	
Primary education	Years	Degree	Years	Degree
Panel A: Community presence of farmland				
Full*More Rural	0.459**	0.076*	0.860***	0.221***
	(0.189)	(0.041)	(0.208)	(0.048)
Observations	5,944	5,944	3,612	3,612
R-squared	0.262	0.236	0.117	0.112
Panel B: Community administrative district				
Full*More Rural			0.581***	0.145***
			(0.109)	(0.025)
Observations			3,612	3,612
R-squared			0.122	0.118
Panel C: Community agricultural workforce				
Full*More Rural			0.940***	0.228***
			(0.170)	(0.038)
Observations			3,612	3,612
R-squared			0.136	0.129
Panel D: Individual residence				
Full*More Rural			0.622***	0.119***
			(0.082)	(0.018)
Observations			3,612	3,612
R-squared			0.145	0.121
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. The treatment group is now the 1961-1965 cohorts and the control group is the 1949-1954 cohorts. Each column is obtained from an OLS regression using Equation 6. The empirical specification controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 12: More on confounding by omitted cohort attributes

	(1)	(2)	(3)	(4)
	Rural Hukou		Urban Hukou	
Control:Primary education	Years	Degree	Years	Degree
Panel A: Community presence of farmland				
Treat*More Rural	-0.067	0.001	0.780**	0.300***
	(0.317)	(0.068)	(0.396)	(0.090)
Observations	3,032	3,032	1,940	1,940
R-squared	0.248	0.209	0.140	0.133
Panel B: Community administrative district				
Treat*More Rural			-0.035	0.007
			(0.200)	(0.046)
Observations			1,940	1,940
R-squared			0.151	0.137
Panel C: Community agricultural workforce				
Treat*More Rural			0.351	0.173**
			(0.334)	(0.076)
Observations			1,940	1,940
R-squared			0.163	0.150
Panel D: Individual residence				
Treat*More Rural			-0.066	-0.025
			(0.148)	(0.032)
Observations			1,940	1,940
R-squared			0.165	0.129
Province fixed effects	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y

Notes: The dependent variable is either years of completed primary schooling or a binary indicator for whether an individual had a primary school degree. The estimating sample is restricted to those born between 1949 and 1954. The treatment group is the 1952-1954 cohorts and the control group is the 1949-1951 cohorts. Each column is obtained from an OLS regression using Equation 6. The empirical specification controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 13: The long-term impact of the Cultural Revolution, rural

Table 13A: Rural, health

	(1)	(2)	(3)	(4)	(5)
Expansion of	BMI		Poor/fair	High blood	
primary education	Under	Over	health	pressure	Diabetes
More Rural: Community farmland					
Full*More Rural	-0.045***	-0.145**	-0.037	0.069**	0.014
	(0.016)	(0.058)	(0.054)	(0.032)	(0.015)
Partial before*More Rural	-0.056**	-0.070	-0.052	0.031	0.005
	(0.022)	(0.063)	(0.063)	(0.041)	(0.019)
Partial after*More Rural	-0.055***	-0.053	-0.028	0.076***	0.019
	(0.019)	(0.059)	(0.053)	(0.029)	(0.014)
Observations	8,341	8,341	6,604	8,862	8,822
R-squared	0.020	0.064	0.061	0.042	0.011
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables are a set of binary indicators for underweight and overweight status, self-reported poor health as well as diagnosed high blood pressure and diabetes. Each column corresponds to an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 13B: Rural, health behaviours

	(1)	(2)	(3)	(4)	(5)
Expansion of	Medical	Preventive		% Fat	Leisure
primary education	insurance	care	Smoke	above	activity
More Rural: Community farmland					
Full*More Rural	0.050	0.001	-0.122**	0.044	-0.009
	(0.042)	(0.008)	(0.058)	(0.059)	(0.025)
Partial before*More Rural	0.103**	-0.002	-0.133**	0.014	-0.016
	(0.046)	(0.013)	(0.063)	(0.067)	(0.029)
Partial after*More Rural	0.053	-0.013	0.061	0.030	0.003
	(0.045)	(0.014)	(0.061)	(0.063)	(0.026)
Observations	9,140	9,126	8,332	8,984	6,685
R-squared	0.593	0.012	0.401	0.056	0.012
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for medical care utilisation (medical insurance and preventive care), smoking status, dietary pattern and physical activity. Each column corresponds to an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 13C: Rural, labour supply

Expansion of primary education	(1) Work	(2) Log (wage)	(3) Log (non-wage)	(4) Log (income)	(5) Light	(6) Moderate
More Rural: Community farmland						
Full*More Rural	0.037	0.098	0.140	0.147	0.029	0.009
	(0.054)	(0.365)	(0.361)	(0.359)	(0.035)	(0.018)
Partial before*More Rural	-0.050	0.065	0.463	0.140	-0.120**	0.028**
	(0.056)	(0.383)	(0.449)	(0.387)	(0.048)	(0.014)
Partial after*More Rural	-0.051	-0.001	0.444	0.500	0.034	0.037**
	(0.054)	(0.358)	(0.433)	(0.397)	(0.036)	(0.018)
Observations	9,181	1,890	7,321	7,908	8,965	8,965
R-squared	0.095	0.166	0.046	0.063	0.039	0.048
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for current working status, income (log wage, log non-wage and log total income) and types of occupation (light and moderate). Each column corresponds to an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 14: The impact of the Cultural Revolution on health, urban

	(1)	(2)	(3)	(4)	(5)
Expansion of	BMI		Poor/fair	High blood	
primary education	Under	Over	health	pressure	Diabetes
Panel A: Community farmland					
Full*More Rural	0.014	0.136	-0.190*	-0.055	-0.020
	(0.027)	(0.096)	(0.105)	(0.067)	(0.029)
Partial before*More Rural	-0.018	0.096	-0.074	-0.059	-0.007
	(0.011)	(0.099)	(0.107)	(0.070)	(0.028)
Partial after*More Rural	-0.021	-0.051	-0.235**	0.014	0.034
	(0.027)	(0.099)	(0.119)	(0.075)	(0.036)
Observations	3,631	3,631	2,896	3,968	3,941
R-squared	0.034	0.057	0.058	0.055	0.027
Panel B: Community administrative district					
Full*More Rural	-0.007	0.085*	-0.051	-0.006	-0.007
	(0.018)	(0.051)	(0.061)	(0.032)	(0.017)
Partial before*More Rural	-0.024*	0.155**	-0.041	0.010	0.012
	(0.015)	(0.060)	(0.067)	(0.039)	(0.019)
Partial after*More Rural	0.011	0.071	-0.113*	0.010	0.026
exible cohort trends.	(0.026)	(0.057)	(0.067)	(0.032)	(0.017)
Observations	3,631	3,631	2,896	3,968	3,941
R-squared	0.033	0.057	0.057	0.054	0.027
Panel C: Community percentage agricultural workforce					
Full*More Rural	0.009	0.061	-0.077	0.036	-0.008
	(0.017)	(0.060)	(0.075)	(0.040)	(0.021)
Partial before*More Rural	-0.017*	0.151**	-0.043	0.041	0.000
	(0.010)	(0.072)	(0.083)	(0.047)	(0.020)
Partial after*More Rural	0.056*	0.000	-0.104	0.066	0.030
	(0.032)	(0.065)	(0.084)	(0.043)	(0.022)
Observations	3,631	3,631	2,896	3,968	3,941
R-squared	0.035	0.057	0.055	0.054	0.027
Panel D: Individual residence					
Full*More Rural	-0.017	0.093**	-0.065	-0.031	-0.023
	(0.013)	(0.042)	(0.047)	(0.026)	(0.015)
Partial before*More Rural	0.015	0.155***	-0.119**	0.024	0.005
	(0.014)	(0.047)	(0.052)	(0.032)	(0.016)
Partial after*More Rural	0.011	0.080*	-0.027	-0.009	0.010
	(0.020)	(0.047)	(0.054)	(0.026)	(0.013)
Observations	3,631	3,631	2,896	3,968	3,941
R-squared	0.034	0.062	0.056	0.055	0.028
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables are a set of binary indicators for underweight and overweight status, self-reported poor health as well as diagnosed high blood pressure and diabetes. Each column corresponds to an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 15: The impact of the Cultural Revolution on health behaviours, urban

	(1)	(2)	(3)	(4)	(5)
Expansion of primary education	Medical insurance	Preventive care	Smoke	% Fat above	Leisure activity
Panel A: Community farmland					
Full*More Rural	0.246***	-0.010	0.034	0.067	0.119*
	(0.084)	(0.023)	(0.062)	(0.078)	(0.065)
Partial before*More Rural	0.289***	0.031	0.024	0.037	0.073
	(0.086)	(0.032)	(0.081)	(0.080)	(0.068)
Partial after*More Rural	0.191**	0.037	-0.093	0.070	0.119*
	(0.095)	(0.031)	(0.061)	(0.086)	(0.069)
Observations	4,023	4,007	3,627	3,992	3,016
R-squared	0.153	0.020	0.431	0.046	0.029
Panel B: Community administrative district					
Full*More Rural	0.200***	-0.030	0.006	0.077**	0.032
	(0.048)	(0.021)	(0.040)	(0.039)	(0.047)
Partial before*More Rural	0.102*	-0.024	0.049	-0.075	-0.031
	(0.054)	(0.023)	(0.048)	(0.048)	(0.051)
Partial after*More Rural	0.128**	0.003	-0.030	-0.004	0.037
	(0.055)	(0.023)	(0.041)	(0.048)	(0.051)
Observations	4,023	4,007	3,627	3,992	3,016
R-squared	0.170	0.021	0.430	0.047	0.032
Panel C: Community percentage agricultural workforce					
Full*More Rural	0.250***	0.013	-0.058	0.077	0.075
	(0.059)	(0.018)	(0.049)	(0.047)	(0.050)
Partial before*More Rural	0.205***	0.032	0.033	-0.022	0.019
	(0.066)	(0.024)	(0.058)	(0.056)	(0.054)
Partial after*More Rural	0.160**	0.030	-0.096**	-0.025	0.087
	(0.068)	(0.019)	(0.048)	(0.058)	(0.056)
Observations	4,023	4,007	3,627	3,992	3,016
R-squared	0.171	0.022	0.430	0.045	0.033
Panel D: Individual residence					
Full*More Rural	0.121***	-0.001	0.020	0.016	0.043
	(0.037)	(0.019)	(0.031)	(0.030)	(0.040)
Partial before*More Rural	0.073*	-0.003	-0.008	-0.049	0.017
	(0.042)	(0.022)	(0.035)	(0.034)	(0.045)
Partial after*More Rural	0.035	-0.005	-0.006	-0.047	-0.057
	(0.044)	(0.018)	(0.034)	(0.037)	(0.043)
Observations	4,023	4,007	3,627	3,992	3,016
R-squared	0.151	0.019	0.430	0.044	0.028
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for medical care utilisation (medical insurance and preventive care), smoking status, dietary pattern and physical activity. Each column corresponds to an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 16: The impact of the Cultural Revolution on labour supply, urban

	(1)	(2)	(3)	(4)	(5)	(6)
Expansion of primary education	Work	Log (wage)	Log (non-wage)	Log (income)	Light	Moderate
Panel A: Community farmland						
Full*More Rural	0.115	-0.031	0.316	0.773	0.040	0.019
	(0.077)	(0.164)	(0.679)	(0.579)	(0.072)	(0.056)
Partial before*More Rural	0.118	0.046	-0.694	0.828	-0.047	0.116*
	(0.076)	(0.143)	(0.789)	(0.590)	(0.072)	(0.061)
Partial after*More Rural	0.148*	0.019	0.842	1.205**	-0.075	0.240***
	(0.088)	(0.161)	(0.682)	(0.553)	(0.078)	(0.079)
Observations	4,045	2,404	978	3,177	4,035	4,035
R-squared	0.211	0.201	0.142	0.135	0.104	0.089
Panel B: Community administrative district						
Full*More Rural	0.059	-0.010	-0.466	0.110	0.029	-0.020
	(0.046)	(0.116)	(0.570)	(0.219)	(0.048)	(0.032)
Partial before*More Rural	0.041	-0.025	-0.724	0.052	-0.032	0.021
	(0.052)	(0.115)	(0.495)	(0.234)	(0.053)	(0.035)
Partial after*More Rural	0.030	0.231*	0.339	0.522***	-0.075	0.094**
	(0.055)	(0.122)	(0.516)	(0.197)	(0.055)	(0.043)
Observations	4,045	2,404	978	3,177	4,035	4,035
R-squared	0.217	0.203	0.130	0.120	0.116	0.086
Panel C: Community percentage agricultural workforce						
Full*More Rural	0.075	-0.038	-0.119	0.608	0.035	0.009
	(0.058)	(0.158)	(0.709)	(0.426)	(0.055)	(0.037)
Partial before*More Rural	0.045	0.011	-0.621	0.569	-0.077	0.065
	(0.063)	(0.155)	(0.708)	(0.448)	(0.060)	(0.042)
Partial after*More Rural	0.043	0.081	0.871	0.942**	-0.116*	0.136***
	(0.070)	(0.167)	(0.640)	(0.411)	(0.061)	(0.050)
Observations	4,045	2,404	978	3,177	4,035	4,035
R-squared	0.216	0.202	0.143	0.131	0.119	0.086
Panel D: Individual residence						
Full*More Rural	0.075**	-0.347***	-0.008	0.065	0.048	-0.005
	(0.036)	(0.084)	(0.490)	(0.115)	(0.040)	(0.025)
Partial before*More Rural	-0.008	-0.258***	-0.322	-0.007	-0.053	0.000
	(0.041)	(0.096)	(0.325)	(0.140)	(0.044)	(0.026)
Partial after*More Rural	-0.030	-0.201**	0.592	0.342***	-0.224***	0.094***
	(0.043)	(0.096)	(0.514)	(0.127)	(0.046)	(0.031)
Observations	4,045	2,404	978	3,177	4,035	4,035
R-squared	0.213	0.218	0.130	0.112	0.108	0.086
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for current working status, income (log wage, log non-wage and log total income) and types of occupation (light and moderate). Each column corresponds to an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effects, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 as well as two individual-level covariates (gender and age and its square). The panels differ by More Rural, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 17: Preferences and the Cultural Revolution, rural

Table 17A: Preferences for food, rural

Rural: Preferences	(1) Fast food	(2) Salty snacks	(3) Fruits	(4) Vegetables	(5) Soft drinks
More Rural: Community farmland					
Full*More Rural	0.153***	0.198***	0.126***	0.058*	0.641***
	(0.039)	(0.049)	(0.047)	(0.033)	(0.069)
Partial before*More Rural	0.110***	0.085*	0.074	0.019	0.341***
	(0.028)	(0.044)	(0.051)	(0.034)	(0.069)
Partial after*More Rural	0.260***	0.230***	0.170***	0.105**	0.749***
	(0.052)	(0.065)	(0.051)	(0.041)	(0.084)
R-squared	6,725	6,726	6,729	6,729	6,722
Observations	0.035	0.058	0.022	0.010	0.078
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include individual preferences for fast food, salty snacks, fruits, vegetables and soft drinks. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000, a More Rural-specific quadratic trend in individual age and a female dummy. More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 17B: Preferences for physical activities, rural

Rural: Preferences	(6) Walking	(7) Sports	(8) Body shaping	(9) Watching TV	(10) Playing computer	(11) Reading
More Rural: Community farmland						
Full*More Rural	0.556***	0.366***	0.466***	0.142***	0.244***	0.165***
	(0.069)	(0.046)	(0.054)	(0.053)	(0.041)	(0.063)
Partial before*More Rural	-0.019	0.124***	0.091	0.009	0.083**	0.003
	(0.076)	(0.046)	(0.058)	(0.051)	(0.041)	(0.065)
Partial after*More Rural	0.690***	0.527***	0.653***	0.257***	0.379***	0.332***
	(0.081)	(0.058)	(0.067)	(0.061)	(0.049)	(0.072)
R-squared	6,718	6,716	6,716	6,725	6,711	6,719
Observations	0.071	0.065	0.080	0.015	0.045	0.054
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variables include individual preferences for walking, sports, body-shaping, watching TV, playing computer and reading. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000, a More Rural-specific quadratic trend in individual age and a female dummy. More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 17C: Lifetime priorities, rural

	(12)	(13)	(14)	(15)	(16)
Rural: Preferences	Good income	Physically active	Healthy diet	Kids active	Kids diet
More Rural: Community farmland					
Full*More Rural	0.006	0.119*	0.025	0.029	0.068*
	(0.033)	(0.062)	(0.051)	(0.042)	(0.037)
Partial before*More Rural	0.025	-0.063	-0.066	0.013	0.024
	(0.036)	(0.056)	(0.049)	(0.043)	(0.036)
Partial after*More Rural	0.017	0.222***	0.148**	0.042	0.085**
	(0.040)	(0.070)	(0.062)	(0.046)	(0.042)
R-squared	6,720	6,720	6,720	6,719	6,719
Observations	0.006	0.027	0.017	0.012	0.012
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include individual perceptions of the importance of having a good income, being physically active, eating a healthy diet, having kids being physically active and having kids eating a healthy diet. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000, a More Rural-specific quadratic trend in individual age and a female dummy. More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 18: Preferences for food, urban

Urban: Preferences	(1) Fast food	(2) Salty snacks	(3) Fruits	(4) Vegetables	(5) Soft drinks
Panel A: Community farmland					
Full*More Rural	-0.158	-0.197	0.056	-0.011	-0.054
	(0.099)	(0.150)	(0.122)	(0.015)	(0.162)
Partial before*More Rural	0.025	-0.096	0.067	-0.015	0.143
	(0.070)	(0.123)	(0.094)	(0.014)	(0.122)
Partial after*More Rural	-0.369***	-0.371*	0.168	0.058	0.035
	(0.139)	(0.191)	(0.164)	(0.047)	(0.224)
R-squared	3,016	3,017	3,018	3,018	3,017
Observations	0.066	0.054	0.035	0.013	0.055
Panel B: Community administrative district					
Full*More Rural	-0.035	-0.022	0.107*	0.030	0.058
	(0.067)	(0.086)	(0.065)	(0.028)	(0.101)
Partial before*More Rural	-0.020	-0.047	0.062	0.000	0.077
	(0.043)	(0.067)	(0.048)	(0.018)	(0.077)
Partial after*More Rural	-0.225**	-0.007	0.219**	0.137**	0.121
	(0.098)	(0.121)	(0.094)	(0.057)	(0.144)
R-squared	3,016	3,017	3,018	3,018	3,017
Observations	0.074	0.056	0.039	0.022	0.058
Panel C: Community percentage agricultural workforce					
Full*More Rural	0.014	0.045	0.081	0.019	0.245**
	(0.077)	(0.115)	(0.081)	(0.022)	(0.120)
Partial before*More Rural	0.033	-0.009	0.020	-0.026*	0.152
	(0.048)	(0.092)	(0.063)	(0.014)	(0.093)
Partial after*More Rural	-0.098	0.048	0.158	0.114**	0.283*
	(0.111)	(0.149)	(0.107)	(0.046)	(0.164)
R-squared	3,016	3,017	3,018	3,018	3,017
Observations	0.070	0.054	0.034	0.017	0.056
Panel D: Individual residence					
Full*More Rural	0.128**	0.085	0.142***	0.021	0.226***
	(0.054)	(0.064)	(0.044)	(0.019)	(0.074)
Partial before*More Rural	-0.001	-0.022	0.082**	-0.016	0.078
	(0.035)	(0.049)	(0.035)	(0.015)	(0.057)
Partial after*More Rural	0.061	0.178*	0.242***	0.090**	0.344***
	(0.083)	(0.093)	(0.061)	(0.036)	(0.106)
R-squared	3,016	3,017	3,018	3,018	3,017
Observations	0.073	0.059	0.039	0.018	0.060
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include individual preferences for fast food, salty snacks, fruits, vegetables and soft drinks. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000, a More Rural-specific quadratic trend in individual age and a female dummy. The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 19: Preferences for physical activities, urban

Urban: Preferences	(1) Walking	(2) Sports	(3) Body shaping	(4) Watching TV	(5) Playing computer	(6) Reading
Panel A: Community farmland						
Full*More Rural	0.663***	0.511***	0.578***	0.137	0.408***	-0.025
	(0.176)	(0.135)	(0.157)	(0.107)	(0.108)	(0.178)
Partial before*More Rural	0.267*	0.325***	0.255**	0.111	0.219***	0.077
	(0.144)	(0.109)	(0.126)	(0.092)	(0.075)	(0.139)
Partial after*More Rural	0.980***	0.871***	1.041***	0.352**	0.809***	-0.165
	(0.245)	(0.191)	(0.225)	(0.147)	(0.176)	(0.244)
R-squared	3,013	3,012	3,012	3,016	3,012	3,012
Observations	0.045	0.045	0.038	0.009	0.065	0.034
Panel B: Community administrative district						
Full*More Rural	0.395***	0.439***	0.460***	-0.050	0.263***	0.065
	(0.108)	(0.094)	(0.098)	(0.059)	(0.079)	(0.109)
Partial before*More Rural	0.020	0.191***	0.183**	-0.016	0.112*	0.049
	(0.084)	(0.071)	(0.074)	(0.044)	(0.057)	(0.083)
Partial after*More Rural	0.664***	0.760***	0.867***	-0.016	0.339***	-0.149
	(0.151)	(0.133)	(0.138)	(0.086)	(0.124)	(0.150)
R-squared	3,013	3,012	3,012	3,016	3,012	3,012
Observations	0.050	0.055	0.054	0.009	0.074	0.046
Panel C: Community percentage agricultural workforce						
Full*More Rural	0.484***	0.500***	0.481***	0.028	0.348***	0.063
	(0.137)	(0.113)	(0.125)	(0.079)	(0.094)	(0.136)
Partial before*More Rural	0.087	0.267***	0.241**	0.030	0.118*	0.054
	(0.109)	(0.091)	(0.099)	(0.063)	(0.070)	(0.107)
Partial after*More Rural	0.664***	0.806***	0.921***	0.050	0.438***	-0.212
	(0.178)	(0.151)	(0.165)	(0.104)	(0.142)	(0.175)
R-squared	3,013	3,012	3,012	3,016	3,012	3,012
Observations	0.049	0.052	0.047	0.008	0.073	0.042
Panel D: Individual residence						
Full*More Rural	0.410***	0.532***	0.476***	0.031	0.357***	0.146*
	(0.079)	(0.074)	(0.078)	(0.044)	(0.065)	(0.078)
Partial before*More Rural	0.086	0.255***	0.207***	0.036	0.099**	0.077
	(0.062)	(0.058)	(0.062)	(0.036)	(0.050)	(0.062)
Partial after*More Rural	0.708***	0.833***	0.788***	0.027	0.453***	0.054
	(0.110)	(0.105)	(0.109)	(0.060)	(0.098)	(0.109)
R-squared	3,013	3,012	3,012	3,016	3,012	3,012
Observations	0.053	0.062	0.057	0.007	0.077	0.039
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variables include individual preferences for walking, sports, body-shaping, watching TV, playing computer and reading. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000, a More Rural-specific quadratic trend in individual age and a female dummy. The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 20: Lifetime priorities, urban

	(1)	(2)	(3)	(4)	(5)
Urban: Preferences	Good income	Physically active	Healthy diet	Kids active	Kids diet
Panel A: Community farmland					
Full*More Rural	-0.079	0.051	0.079	-0.010	-0.010
	(0.092)	(0.100)	(0.073)	(0.043)	(0.043)
Partial before*More Rural	-0.043	-0.018	0.026	-0.003	-0.007
	(0.081)	(0.076)	(0.050)	(0.014)	(0.013)
Partial after*More Rural	-0.012	0.284**	0.128	0.036	0.025
	(0.099)	(0.137)	(0.089)	(0.061)	(0.062)
R-squared	3,016	3,017	3,017	3,016	3,016
Observations	0.032	0.034	0.019	0.010	0.013
Panel B: Community administrative district					
Full*More Rural	-0.044	0.053	-0.009	0.023	0.001
	(0.048)	(0.064)	(0.038)	(0.033)	(0.026)
Partial before*More Rural	-0.046	0.015	-0.046	0.000	-0.023
	(0.044)	(0.049)	(0.031)	(0.026)	(0.021)
Partial after*More Rural	0.010	0.089	0.050	0.037	0.005
	(0.059)	(0.093)	(0.053)	(0.041)	(0.036)
R-squared	3,016	3,017	3,017	3,016	3,016
Observations	0.031	0.032	0.020	0.012	0.016
Panel C: Community percentage agricultural workforce					
Full*More Rural	-0.084	0.025	-0.015	-0.014	-0.015
	(0.067)	(0.089)	(0.057)	(0.038)	(0.038)
Partial before*More Rural	-0.079	-0.019	-0.060	-0.025	-0.030
	(0.063)	(0.072)	(0.049)	(0.032)	(0.032)
Partial after*More Rural	-0.033	0.065	0.047	-0.008	-0.018
	(0.075)	(0.120)	(0.073)	(0.046)	(0.046)
R-squared	3,016	3,017	3,017	3,016	3,016
Observations	0.032	0.033	0.020	0.013	0.017
Panel D: Individual residence					
Full*More Rural	0.004	0.065	0.056*	0.063**	0.039
	(0.044)	(0.044)	(0.030)	(0.028)	(0.026)
Partial before*More Rural	-0.026	0.035	0.017	0.023	-0.003
	(0.037)	(0.036)	(0.025)	(0.023)	(0.021)
Partial after*More Rural	0.053	0.081	0.083**	0.060*	0.032
	(0.051)	(0.062)	(0.039)	(0.033)	(0.031)
R-squared	3,016	3,017	3,017	3,016	3,016
Observations	0.033	0.031	0.020	0.014	0.018
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include individual perceptions of the importance of having a good income, being physically active, eating a healthy diet, having kids being physically active and having kids eating a healthy diet. Each column is obtained from an OLS regression using Equation 6, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000, a More Rural-specific quadratic trend in individual age and a female dummy. The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 21: Returns to education, rural

Table 21A: Health returns to education, rural

	(1)	(2)	(3)	(4)	(5)
	BMI		Poor/fair	High blood	
IV: Health-Years	Under	Over	health	pressure	Diabetes
More Rural: Community farmland					
Years	-0.029	-0.163*	-0.018	0.067*	0.013
	(0.024)	(0.085)	(0.056)	(0.035)	(0.015)
R-squared	8,341	8,341	6,604	8,862	8,822
Observations			0.061		
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include a set of binary indicators for underweight and overweight status, self-reported poor health and diagnosed high blood pressure and diabetes. Each column is obtained from an IV regression using Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 21B: Behaviour returns to education, rural

	(1)	(2)	(3)	(4)	(5)
	Medical	Preventive		% Fat	Leisure
IV: Consumption-Years	insurance	care	Smoke	above	activity
More Rural: Community farmland					
Years	0.015	0.004	-0.122	0.045	-0.007
	(0.043)	(0.008)	(0.075)	(0.066)	(0.028)
R-squared	9,140	9,126	8,332	8,984	6,685
Observations	0.591	0.008	0.180	0.058	
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for individual medical care utilisation (medical insurance and preventive care), smoking, dietary pattern and physical activity. Each column is obtained from an IV regression using Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 21C: Labour market returns to education, rural

	(1)	(2)	(3)	(4)	(5)	(6)
IV: Labour supply-Years	Work	Log (wage)	Log (non-wage)	Log (income)	Light	Moderate
More Rural: Community farmland						
Years	0.076	0.021	-0.135	0.003	0.085*	-0.007
	(0.061)	(0.462)	(0.381)	(0.365)	(0.044)	(0.022)
R-squared	9,181	1,890	7,321	7,908	8,965	8,965
Observations		0.167	0.037	0.062		0.042
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for current working status, income (log wage, log non-wage and log total income) and types of occupation (light and moderate). Each column is obtained from an IV regression using Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). More Rural is defined using community farmland. Robust standard errors are reported in parentheses.

Table 22: Health returns to education, urban

	(1)	(2)	(3)	(4)	(5)
	BMI		Poor/fair	High blood	
IV: Health-Years	Under	Over	health	pressure	Diabetes
Panel A: Community farmland					
Years	-0.007	0.010	-0.307*	-0.006	0.018
	(0.026)	(0.101)	(0.161)	(0.079)	(0.038)
R-squared	3,631	3,631	2,896	3,968	3,941
Observations	0.028	0.054		0.053	0.020
Panel B: Community administrative district					
Years	0.021	0.013	-0.119	-0.004	0.008
	(0.025)	(0.062)	(0.092)	(0.038)	(0.019)
R-squared	3,631	3,631	2,896	3,968	3,941
Observations	0.024	0.052		0.053	0.026
Panel C: Community percentage agricultural workforce					
Years	0.044*	-0.015	-0.110	0.046	0.012
	(0.023)	(0.055)	(0.090)	(0.037)	(0.020)
R-squared	3,631	3,631	2,896	3,968	3,941
Observations		0.057	0.004	0.028	0.025
Panel D: Individual residence					
Years	-0.007	0.089*	-0.045	-0.028	-0.009
	(0.016)	(0.047)	(0.056)	(0.029)	(0.016)
R-squared	3,631	3,631	2,896	3,968	3,941
Observations	0.027	0.008	0.045	0.044	0.021
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include a set of binary indicators for underweight and overweight status, self-reported poor health and diagnosed high blood pressure and diabetes. Each column is obtained from an IV regression using Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 23: Behaviour returns to education, urban

IV: Consumption-Years	(1) Medical insurance	(2) Preventive care	(3) Smoke	(4) % Fat above	(5) Leisure activity
Panel A: Community farmland					
Years	0.236**	0.021	-0.053	0.088	0.144*
	(0.117)	(0.032)	(0.068)	(0.096)	(0.083)
R-squared	4,023	4,007	3,627	3,992	3,016
Observations		0.017	0.417	0.001	
Panel B: Community administrative district					
Years	0.202***	-0.005	-0.054	0.108*	0.073
	(0.067)	(0.026)	(0.047)	(0.057)	(0.055)
R-squared	4,023	4,007	3,627	3,992	3,016
Observations	0.063	0.018	0.416		0.017
Panel C: Community percentage agricultural workforce					
Years	0.186***	0.016	-0.101**	0.039	0.089*
	(0.062)	(0.017)	(0.047)	(0.050)	(0.047)
R-squared	4,023	4,007	3,627	3,992	3,016
Observations	0.084	0.020	0.381	0.038	0.004
Panel D: Individual residence					
Years	0.096**	-0.004	0.012	-0.013	-0.012
	(0.043)	(0.020)	(0.033)	(0.036)	(0.046)
R-squared	4,023	4,007	3,627	3,992	3,016
Observations	0.146	0.017	0.428	0.040	0.021
Province fixed effects	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for individual medical care utilisation (medical insurance and preventive care), smoking, dietary pattern and physical activity. Each column is obtained from an IV regression using Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Table 24: Labour market returns to education, urban

IV: Labour supply-Years	(1) Work	(2) Log (wage)	(3) Log (non-wage)	(4) Log (income)	(5) Light	(6) Moderate
Panel A: Community farmland						
Years	0.166*	-0.130	0.559	1.168*	-0.036	0.194**
	(0.098)	(0.463)	(0.433)	(0.689)	(0.082)	(0.090)
R-squared	4,045	2,404	978	3,177	4,035	4,035
Observations	0.150	0.175	0.064		0.086	
Panel B: Community administrative district						
Years	0.044	0.591*	0.546	0.752**	-0.022	0.050
	(0.062)	(0.303)	(0.426)	(0.324)	(0.065)	(0.048)
R-squared	4,045	2,404	978	3,177	4,035	4,035
Observations	0.223	0.021	0.059		0.106	0.063
Panel C: Community percentage agricultural workforce						
Years	0.055	0.389	0.478	1.025*	-0.024	0.066
	(0.058)	(0.621)	(0.391)	(0.578)	(0.055)	(0.042)
R-squared	4,045	2,404	978	3,177	4,035	4,035
Observations	0.221	0.138	0.089		0.108	0.047
Panel D: Individual residence						
Years	0.035	-0.502**	0.308	0.381**	-0.106**	0.059**
	(0.042)	(0.245)	(0.355)	(0.182)	(0.048)	(0.030)
R-squared	4,045	2,404	978	3,177	4,035	4,035
Observations	0.218		0.117	0.082	0.022	0.054
Province fixed effects	Y	Y	Y	Y	Y	Y
Sample wave fixed effects	Y	Y	Y	Y	Y	Y
Quarter-of-birth fixed effects	Y	Y	Y	Y	Y	Y
Individual/cohort covariates	Y	Y	Y	Y	Y	Y

Notes: The dependent variables include measures for current working status, income (log wage, log non-wage and log total income) and types of occupation (light and moderate). Each column is obtained from an IV regression using Equations 9 and 10, and controls for a set of province and quarter-of-birth fixed effect, polynomial terms in cohort size, a flexible cohort trend, a binary indicator for sample wave 2000 and two individual characteristics (gender and age and its square). The panels differ by how More Rural is defined, with community farmland in Panel A, administrative district in Panel B, agricultural workforce in Panel C and individual residence in Panel D. Robust standard errors are reported in parentheses.

Appendix A

Table A1: Education, 1949-1986

Phase	Time period	Type of schools
Consolidation and reconstruction	1949 -1952	A two-track system Regular schools, state-run Informal schools and various adult programs, not state-run The 1st phase of expanding primary schooling
Socialist construction and consolidation	1953 -1957	A two-track system Regular schools, state-run Informal schools and various adult programs, not state-run The 2nd phase of expanding primary schooling
The Great Leap Forward (GLF) Economic depression	1958 -1962	A two-track system Regular schools, state-run Informal schools and various adult programs, not state-run The 3rd phase of expanding primary schooling The 1st phase of expanding secondary schooling
Post the Great Leap Forward (GLF) Economic recovery	1963 -1965	A two-track system Regular schools, state-run Informal schools and various adult programs, not state-run The 4th phase of expanding primary schooling The 2nd phase of expanding secondary schooling
The Cultural Revolution Mobalisation phase	1966 -1967	Collapse of the old system Suspension of classes and admission examinations Student and teacher protests Factional conflicts between polarized student groups Classification of students into red and bourgeois family background (Red family background: Workers, peasants, soldiers, cadres and revolutionary martyrs)
The Cultural Revolution Consolidation phase	1968 -1976	The 1968-1976 education system An egalitarian education system Disbanding of the student and teacher protest groups The Rustication Program (middle school graduates) The 5th phase of expanding primary schooling The 3rd phase of expanding secondary schooling
Post the Cultural Revolution	1977 -1979	A two-track system Regular schools, state-run Informal schools and various adult programs, not state-run
Post the Cultural Revolution	1980 -1984	The 1st round of educational reform after 1976 The 6th phase of expanding primary schooling
Post the Cultural Revolution	1985 -1986	The 2nd round of educational reform after 1976 Passage of the Law of Nine-year Compulsory Schooling in 1986

Notes: The table is based on information provided by the Cambridge History of China, Volumes 14-15.

Table A2: The politics, 1949-1976

Phase	Time period	The politics
Consolidation and reconstruction	1949 -1952	Consensual model of the central leadership The Anti-counterrevolutionary Campaign The Three Antis Campaign (political leaders) The Five Antis Campaign (capitalists) The Thought Reform Campaign (intellectuals) The 1st classification of the peasantry into five classes (Landlords, rich peasants, middle peasants, poor peasants and landless labourers)
Socialist construction and consolidation	1953 -1957	Consensual model of the central leadership The Thought Reform Campaign (intellectuals) The Hu Feng Campaign (intellectuals) The Anti-rightist Campaign (intellectuals)
The Great Leap Forward (GLF) Economic depression	1958 -1962	Friction within the central leadership The Rectification Campaign (Political leaders, urban students and intellectuals)
Post the Great Leap Forward (GLF) Economic recovery	1963 -1965	Friction within the central leadership The Rectification Campaign (intellectuals) The 2nd classification of the peasantry into five classes (Landlords, rich peasants, middle peasants, poor peasants and landless labourers)
The Cultural Revolution (CR) Mobalisation phase	1966 -1967	Shattered central leadership Collapse of authority The thorough-going purge of revisionism (Intellectuals, the Party, the government, the army, former industralists and landlords) The February Adverse Current (Party leaders) The Wuhan Incident (military commanders) The Purge of the 516 Group of radicals (radical mass)
The Cultural Revolution (CR) Consolidation phase	1968 -1976	Reconstructing the political system: Completion of the organisation of revolutionary committee Rehabilitation of the Party Militarisation of the politics The Continuing Purify the Class Ranks Campaign (The ultra-leftist) Fall of Lin Biao and the Rectification Campaign (Lin Biao's supporters) The 13th September Incident (The set-up of a rival regime in Guangdong to Beijing) Rise and Fall of the Gang of Four The Return of Deng Xiaoping

Notes: The table is based on information provided by the Cambridge History of China, Volumes 14-15.

Table A3: The economy, 1949-1976

Phase	Time period	Economic policies
Consolidation and reconstruction	1949 -1952	The Soviet model: Urban-oriented developmental strategy Emphasis on heavy industry Downplay of agriculture and light industry Land reform (land redistribution) Formation of the Mutual Aid Teams (MATs) (Agricultural collectivisation) Incorporating private enterprises into the state sector (Industrial nationalisation)
Socialist construction and consolidation	1953 -1956	The Soviet model: Urban-oriented developmental strategy Emphasis on heavy industry Downplay of agriculture and light industry Formation of the Agricultural Producers' Cooperatives (APCs) (Agricultural collectivisation) Expanding state ownership to modern industry Re-organising private enterprises (Industrial nationalisation)
Adjusting socialist construction and consolidation	1956 -1957	The Soviet model: Urban-oriented developmental strategy Emphasis on heavy industry Downplay of agriculture and light industry Increasing private production within the Agricultural Producers' Cooperatives (APCs) framework Establishing a limited rural free market
The Great Leap Forward (GLF) Economic depression	1958 -1962	Collapse of the economy Formation of the People's Communes (PC) (Agricultural collectivisation) A sequence of ill-designed and unrealistic economic policies concerning agriculture, light and heavy industry
Post the Great Leap Forward (GLF) Economic recovery	1963 -1965	The transformed Soviet model Modification of the People's Communes (PC) Increasing private production within the People's Communes (PC) framework Sanctioned private service trade A sequence of policies intended for the recovery of agriculture, light and heavy industry
The Cultural Revolution (CR) Mobalisation phase	1966 -1967	Disruption in the economy (To a smaller extent than that caused by GLF) Factional conflicts between polarised peasant and worker groups
The Cultural Revolution (CR) Consolidation phase	1968 -1969	Disruption in the economy (To a smaller extent than that caused by GLF) Factional conflicts between polarised peasant and worker groups
The Cultural Revolution (CR) Consolidation phase	1970 -1976	Transformed Soviet model Pieces of the GLF formula Economic recovery, few fundamental new policies The Da Chai Model (Egalitarianism in agriculture) The emerging of a series of policies proposed by Deng Xiaoping

Notes: The table is based on information provided by the Cambridge History of China, Volumes 14-15.

Appendix B: The Cultural Revolution Education System (1968-1976)

A comprehensive description of the Chinese proletarian Cultural Revolution (1966-1976) is given in The Cambridge History of China by MacFarquhar and Fairbank (1991). This section briefly summarizes the educational influence of this nationwide movement. The targets of the Cultural Revolution were to "thoroughly criticize and repudiate the reactionary bourgeois ideas in the sphere of academic work, education, journalism, literature and art and publishing, and seize the leadership in these cultural spheres…to criticize and repudiate those representatives of the bourgeoisie who have sneaked into the Party, the government, the army and all spheres of culture, to clear them out or transfer some of them to other positions". Specifically, in order to "drag out the academic power holders and bourgeois intellectual authorities who presided over the breeding ground for intellectual aristocrats" (Pepper 1991), school system reform was one of the ultimate goals of the Cultural Revolution, which went through two phases over the revolution decade. Over the first mobilization phase in 1966-1967, school system reform was launched from schools with students and teachers mobilized as vanguards. The result was the overturn of the pre-1966 education system. But while the students and teachers were turning all their attention to this movement, no systematic education was provided in schools across the country. After the students were ordered back to schools that were reopened in 1967/1968, a new education system was institutionalized during the second consolidation phase from 1968-1976. Abruptly and comprehensively, this new education system was dismantled when the Cultural Revolution was officially terminated in 1977. Thereafter, the pre-1966 education framework was reinstalled.

The Cultural Revolution education system (1968-1976) was never officially standardized on a nationwide basis, making it a provisional system that changed almost from year to year and varied in detail from place to place throughout the consolidation phase. Nevertheless, guidelines from the centre indeed defined several basic parameters of this system. Education policy was made by the Central Cultural Revolution Group and its special education committees who however had little experience in this sphere (the Ministries of Education and Higher Education ceased to function in 1966). Education administration was decentralized down to the level of the provincial education bureaus and beyond: School length, curriculum, textbooks and teaching materials were fixed by provinces, cities and even communes at the primary and secondary school level and by each institution at the college level. Teachers were either assigned by the state through the education bureau or hired locally.

The objective of the new system was to equalize the quantity and quality of schooling across the country. At the primary and secondary level, a nationwide expansion of schools was sustained throughout the period 1968-1976. Mostly commonly, these schools were financed both by the state and by local collective funding. Unified entrance examinations at the primary and secondary levels were abolished; students attended their nearest neighbourhood school. At the end of the Cultural Revolution decade, primary school education was almost universal with 95 percent of all school-aged children (or 150 million) enrolled. Enrolment in middle schools also rose substantially from 1968-1976 (albeit less than universal), by around 319% to 44 million for junior middle school and 15 million for senior middle school. Yet this rapid expansion of schooling was accompanied by a decline in school quality. School length was reduced, i.e. from 12 years of primary and secondary schooling combined in the pre-1966 system to around 10 years. Courses and teaching materials were condensed and simplified. Increased emphasis was placed on practical learning, politics and manual labour. In practice, everyone was engaged in some form of work-study education. More time was spent on labour in the earlier years when students often participated in the building of new schools and other local work projects.Teaching and testing methods were also revised to eliminate the marks-in-command approach adopted in the pre-1966 system. Teachers were required to devise more flexible and informal teaching and testing methods. The result was that students tended to be passed on from grade to grade regardless of performance.

Most tertiary institutions did not resume operation until 1970. Middle school graduates were no longer permitted to go directly to colleges without working for a period of time first. Typically, city youth were required to go to the countryside and engage in manual labour. The national college entrance examinations were cancelled and college candidates were selected on the basis of recommendations by their places of work. Apart from these, the same principles were applied to tertiary institutions as elsewhere in the new education system. Despite the changed admission criterion and the intended objective of a more egalitarian kind of higher education, enrolment at the tertiary level was less uniform than that at the primary and secondary level: In the early 1970s college enrolment was concentrated on urban youth who were previously sent down to the countryside. Rural candidates did gain admission, but they tended to attend agricultural and junior college courses. Undergraduate coursework was cut from 4-5 years to about 3 years. Content was abbreviated and simplified, with heavy emphasis on practical application.

The Cultural Revolution education system was abruptly and comprehensively dismantled in 1977 when the end of the mass movement was officially proclaimed. The education system was restored to its pre-1966 framework. Everything that was criticized during the Cultural Revolution decade was exonerated, and everything that was promoted during that decade was discredited. Overall, the Cultural Revolution education system was criticized as "…the standards were too low…education was now concerned only with the present and not with future needs…universities were not engaged in theoretical and scientific research…intellectuals could not work properly so long as they continued to be opposed" (Pepper 1991).

Chapter 3 Health, Pollution and the Five-Year Plans

1. Introduction

It has been well established that hazardous air conditions adversely affect human health (see Graff Zivin and Neidell (2013) and references therein). As health is one of the major human capital factors for sustained economic growth, the potential health benefit associated with a cleaner air environment is substantial. Between 2001 and 2010, the Chinese State Council put forward the 10th and 11th Five-Year Plans (FYP) on environmental protection, which required a 20% decline in national SO_2 discharge over that period. Despite a burgeoning strand of studies that have been evaluating the effectiveness of the FYPs in terms of their pollution abatement, less attention has been paid to their intended health objective. Since more stringent standards for SO_2 were proposed in 2011, resolving this gap in the current literature becomes even more relevant. This study provides new insight into the health impact of the FYPs.

The 10th and 11th FYPs on environmental protection (2001-2010) marked an unprecedented effort by Chinese State Council and Ministry of Environmental Protection (CMEP) to reduce ambient air pollutant concentrations. To achieve the national SO_2 reduction target, a series of environmental protection regulations was promulgated. As a part of these regulations, MEP established Total Emission Control (TEC) that stated the total quantity of regulated pollutants that can be discharged by an industrial sector. Typically, the central government distributed emission targets to provincial and local governments who then allocated these targets to polluters under their jurisdiction. More polluted areas were mandated with a stricter target at the first stage.

This study combines two sources of rich data to empirically assess the effects of the FYPs on individual health in the 2000-2009 period. It determines province High/Low regulation status for each FYP using pollution data provided by CMEP and then relates detailed individual health information contained in the China Health and Nutrition Survey (CHNS) panel to it. This study's approach overcomes some of the difficulties with identifying the health impact of the FYPs. First, the biggest obstacle to estimating the FYP-health association is the lack of direct measures of regulation. This analysis proposes a novel approach based on target strictness. I construct an indicator for provinces with high and low pollutant concentrations (i.e. PM_{10}, SO_2 and NO_2)

before the implementation of the FYPs. The idea is that more polluted areas in the base years (High) should be subject to stricter regulatory oversight than their less polluted counterparts (Low). Therefore, variation in the High/Lows across provinces should capture the regional variation that the State Council and CMEP imposed with the FYPs. In fact, "High" provinces enjoyed relative pollution reductions in post-FYP periods compared to "Low" provinces, meaning that the High/Lows are legitimate proxies for FYP toughness.

Second, the detailed health questionnaires of CHNS allows for an examination of regulation's impact across a number of health outcomes. Previous medical studies have predominantly focused on Respiratory Allergic Cardiovascular (RAC) symptoms, this may provide an incomplete picture of the consequences of environmental regulations because recent reports have also revealed systemic effects of pollutant aerosols on neuropathology and central nervous system dysfunction. In contrast, this analysis examines a more aggregate health measure (i.e. being sick or not) in addition to the RAC indicator. Furthermore, because these two variables are self-reported and reflect short-term health disorders, this analysis also ascertains their validity as health indicators by their doctor-diagnosed (i.e. for concerns over reporting bias) and long-term (i.e. episodic impact of air pollution differs from its cumulative effect) measures.

Lastly, the empirical specification that links individual health to the High/Lows includes individual fixed effects. It further controls for non-random panel attrition (i.e. CHNS is an unbalanced panel) by explicitly modeling individual decision to attrite or not. Consequently, the estimated regulation effects are purged of all permanent individual characteristics that determine health and time-varying individual tastes for clean air that are associated with migration decisions. This is important because the study sample covers a period of dramatic changes in China, including demographic transformations (e.g. an aging population and declining fertility rate), economic restructuring (e.g. privatization of State-Owned Enterprises and large-scale labour mobilization) as well as an overhaul of the social security network (e.g. newly introduced pension, health and unemployment insurance programs).

This analysis finds that 2000 High (i.e. more regulated by the 10^{th}) is significantly and positively associated with a 6-point increase in both self-reported sickness and RAC. 2005 High (i.e. more regulated by the 11^{th}) does not turn out to have a significant impact on the probability of being sick but it is estimated to have induced a relative shift-up in RAC of around 5 points among treated individuals. These effects are large based on the sample means: The corresponding percentage increase is around 49% for sickness and around 46-56% for RAC. They also suggest that neither the 10th nor the 11th FYP fulfilled its health objectives. More definitive comparisons of the two plans are provided by the absolute High (i.e. more regulated by both), which suggests that individuals in absolute High provinces were around 6-11 points (49-89%) and 9 points (83%) more likely to report sickness and RAC from 2000-2004. They were also more likely to report the same two symptoms from 2006-2009, i.e. around 11-13 points (89-106%) for sickness and around 6-7 points (56-65%) for RAC. These reassure that the 11th FYP did no better than its predecessor in improving public health. Replacing self-reported sickness and RAC by their doctor-diagnosed or long-term alternatives does not change the estimated results qualitatively or quantitatively, implying that they are valid health indicators and that the perverse health impact of the FYPs inferred from them is reliable. Wald tests of no sample attrition bias mostly reject the null hypothesis for the 2000-2004 period, and Ordinary Least Squares (OLS) estimates without controlling for non-random attrition tend to be larger in magnitude than the Maximum Likelihood (ML) estimates. This suggests that health of treated non-attriters tends to be negatively selected and that OLS estimates are likely to be biased upward.

The perverse health impact of the FYPs may be interpreted as causal. First of all, the High/Lows can be shown to be largely uncorrelated with a comprehensive set of observable individual and community level covariates present in CHNS, implying that they are unlikely to be correlated with unobserved health confounders as well. Second, restricting the estimating sample to matched treated and control subjects (i.e. propensity score matching using all the observables) does not make much difference to the estimated FYP impact, either statistically or economically. Since the matched samples are more comparable in terms of their observables and probably unobservables as well, this result reinforces the contention that selection into treatment is less of a problem and that the assumption of conditional unconfoundedness of the High/Lows is likely to be tenable within current context. Lastly, the perverse FYP health impact is insensitive to replacing the High/Lows by various alternative definitions of FYP regulatory status. An additional insight provided by this exercise is that the High/Lows are not disqualified for their neglecting non-linearity in the health-concentration relationship and the non-uniformity of the spatial distribution of pollutant concentrations.

The coexistence of a relative air quality improvement and health deterioration in more regulated provinces can be explained by the re-location of pollution-intensive industries from High to Low provinces to avoid stricter regulation and by the fact that little adaptation was made by polluting industries of High provinces in terms of their pollution abatement activities. This implies that the substantial investment in pollution abatement technologies and related operating and maintenance expenses offer little incentive for pollution-intensive industries to effectively control their emission discharges. Future environmental regulations that more effectively lower the costs associated with pollution reductions, e.g. Cap-and-Trade (Carlson et al. 2000; Montero 1999) and Self-policing (Innes 1999a and 1999b) regulation designs, may bear more fruit in safeguarding public health.

This study is structured as follows: Section 2 provides an overview of the FYPs and outlines the quasi-experimental design used by this study to identify their health impact. Section 3 next introduces the CHNS and pollution data. Baseline model and identification issues are then detailed in Section 4. Section 5 further establishes the propriety of the quasi-experimental design. Main results and several more robustness checks are then presented in Sections 6 and 7. Section 8 discussed the estimated empirical results and concludes.

2. Background and Research Design

2.1 The 10th and 11th Five-Year Plans (2001-2010) on Environmental Protection

Concerned with the detrimental health effect of persistently high levels of atmospheric pollutants[93], the State Council put forward the 10th Five-Year Plan on environmental protection (henceforth Five-Year Plan or FYP) on December 26th 2001[94] and the 11th FYP on August 5th 2006[95][96]. The two plans required that, by the end of 2010, national total SO_2 discharge[97] be reduced by 20% (i.e. 10% in each five years). To achieve this national target, a series of environmental protection regulations were promulgated from 2001-2010[98][99][100], including (1)

[93] Sulphur dioxide, nitrogen oxide, greenhouse gases, and Total Suspended Particulates (TSPs).

[94] http://zfs.mep.gov.cn/fg/gwyw/200112/t20011226_81977.htm

[95] http://zfs.mep.gov.cn/fg/gwyw/200611/t20061117_96183.htm

[96] The Five-Year Plan, or the National Economic and Social Development Plan, is promulgated every five years by the Communist Party and approved by the People's Congress. It is the most important strategic planning document in China and outlines the governments' priorities in the period concerned.

[97] To be more precise, the 10th FYP also required a 10% reduction in TSPs discharge. The 10% is in terms of base year SO_2 and TSPs discharges. The SO_2 base volumes were 1,995 (10,000 tons) in 2000 and 2,549 (10,000 tons) in 2005, and the TSPs base volume was 2,257 (10,000 tons) in 2005, according to China Ministry of Environmental Protection.

[98] Related policies and regulations in the period 2001-2005 were Promotion of Clean Production Act (People's Congress, 2002), Environmental Impact Assessment Act (People's Congress, 2002), the Tenth Five-Year Plan on Control of Acid Rain and Sulfur Dioxide Pollution (State Council, 2002), A Notice on Expanding Clean Production

Emission Standards for Maximum SO_2 Concentration, which set emission limit for coal-fired power plants and forced them to install Flue Gas Desulfurization (FGD) technology; (2) Total Emission Control, which established the total quantity of regulated pollutants that can be discharged by an industrial sector. Typically, the central government distributed emission targets to provincial and local governments who then allocated these targets to polluters under their jurisdiction. More polluted areas were mandated with a stricter target at the first stage; and (3) closing of inefficient and polluting power plants (Zhang et al. 2012; Schreifels et al. 2012; Gao et al. 2009).

To achieve compliance, noncompliance penalties were levied on violators of emission standards/targets while price premiums were offered to plants installed with FGD technology (van Rooij and Lo 2010; Xu 2011; Tang et al. 2010). Provincial authorities were assessed on their process of implementing emission mitigating and control measures, as well as on their fulfillment of prescribed SO_2 reduction quotas. Outcome of this assessment was directly linked to their performance evaluation and hence prospect of further promotion (Zhang et al. 2012; Schreifels et al. 2012; Gao et al. 2009). Lastly, the elevated role of public supervision (e.g. greater transparency, public participation and interest litigation) and a better organized formal administrative system (e.g. the establishment of regional supervision centers) had the potential to enhance both plant and government accountability (Chen et al. 2013).

(State Council, 2003), Pollutant Discharge Fee Collection Standards (State Development Planning Commission, Ministry of Finance, Ministry of Environmental Protection, and State Economic and Trade Commission, 2003), and Administration of Pollutant Discharge Fee Collection (Ministry of Environmental Protection, 2003).

99Related policies and regulations in the period 2006-2010 were A Notice on Encouraging the Production of Low-emission Vehicles (State Council, 2005), A Notice on City Development (State Council, 2006), the 2006 Work Plan (State Council, 2006), Closing Small Power Plants (State Council, 2007), A Comprehensive Plan on Energy Saving and Emission Reduction (State Council, 2007), A Notice on the Monitoring and Implementation of Energy Saving and Emission Reduction (State Council, 2007), the 2008 Work Plan (State Council, 2008), the 2008 Economic System Reform (State Council, 2008), the 2009 Economic System Reform (State Council, 2009), the 2009 Plan on Energy Saving and Emission Reduction (State Council, 2009), Enhancing the Collection of Pollutant Discharge Fee (Ministry of Environmental Protection, 2007), Implementation of the 11th Five-Year plan (State Council, 2006), the 11th Five-Year Plan on Environmental Protection (State Council, 2007), Control of the Emission of Major Pollutants between 2006 and 2010 (State Council, 2006), and Regulations on the Violation of Environmental Protection Statutes (Ministry of Supervision, Ministry of Environmental Protection, 2006).

100 These plant-specific legislations and/or regulations were Promotion of Clean Production Act (People's Congress, 2002), Environmental Impact Assessment Act (People's Congress, 2002), A Notice on Expanding Clean Production (State Council, 2003), Pollutant Discharge Fee Collection Standards (State Development Planning Commission, Ministry of Finance, Ministry of Environmental Protection, and State Economic and Trade Commission, 2003), Administration of Pollutant Discharge Fee Collection (Ministry of Environmental Protection, 2003), Enhancing the Collection of Pollutant Discharge Fee (Ministry of Environmental Protection, 2007), and Regulations on the Violation of Environmental Protection Statutes (Ministry of Supervision, Ministry of Environmental Protection, 2006).

Results were mixed. By the end of 2005, reported SO_2 emissions increased by 28% from the 2000 level. Conversely, the 11th FYP outperformed its 10% national target by an additional 4%. It therefore seems that the 11th FYP was more effective than its predecessor in terms of pollution control. Yet, still, little is known about the health impact of the FYPs, either respectively or relatively, this analysis attempts this exercise using a quasi-experimental design that is outlined in the subsection that follows.

2.2 Geographical Variation in reduction quotas

Time-series and cohort medical studies have linked exposure to ambient air pollution to inflammation and destruction of peripheral airways as well as increased sensitization to common allergens that cause lung dysfunction (e.g. respiratory tract infections, chronic obstructive pulmonary diseases and lung cancer), cardiovascular disorders (e.g. myocardial infarction, congestive and ischemic heart failure) and allergies (Ezzati and Kammen 2001; Boezen et al. 1999; Shah et al. 2013; Peters et al 1997). Indeed, the potential health benefit associated with a cleaner air environment was one of the motives behind the promulgation of the Five-Year Plans (FYP), yet until recently very few studies have identified the extent to which this target had been fulfilled, leaving open the question as to whether the health benefits of the FYPs outweighed their costs and therefore offering little insights for further policy remedies. This gap in the literature is partly due to the difficulty in obtaining an appropriate measure for FYP regulatory impact that pertains to air quality only and that is less likely to be confounded by other institutional features concurrent with the interventions. This study adds to the first set of evidences on the health impact of the FYPs by exploiting the substantial geographic variation in ambient air quality across provinces before the implementation of the FYPs. Specifically, it proposes measuring FYP regulatory impact by base year province High/Low pollution status and then compares changes in individual health in more affected provinces to the changes in less affected areas, using a panel of individuals taken from China Health and Nutrition Survey (CHNS) in 2000, 2004, 2006 and 2009. This section outlines this quasi-experimental design of this study and it begins by demonstrating that pre-regulation province High/Low pollution status is a reasonable proxy for province High/Low FYP regulatory status over the respective treatment period of the two FYPs.

Ideally, FYP toughness can be measured by province-specific[101] SO_2 reduction quotas prescribed by each FYP, this possibility is precluded however because it is not clear what these quotas were for the 10th FYP. Yet a closer look at the SO_2 quotas of the 11th FYP and total SO_2 discharge by each province in 2005 reveals that a higher reference year total SO_2 volume is associated with a stricter pollution reduction task (Columns 1-2 of Table 1). This suggests that base year ambient air quality can be tantamount to FYP regulatory pressure and if this is true then more polluted provinces in 2000 (2005) should experience relative pollution reductions from 2000-2004 (2006-2009). To test this contention, Table 1 first shows that there was spatial variation in province atmospheric air quality in pre-FYP periods. Province atmospheric air quality is measured by Province Air Pollution Index (PAPI) which is provided by China Ministry of Environmental Protection (CMEP) on a daily basis from 2000 onwards. A higher value of PAPI (ranges from 0-500) denotes a higher level of air pollution and China Ambient Air Quality Standards have designated PAPI equal to 300 as the threshold of heavy pollution (Data section). In 2000 (Panel A), the 95% range of the yearly average PAPIs across the nine provinces included in the study sample was around 73 units (mean: 330 units), and the standard deviation of the distribution of yearly PAPI bites (fraction of PAPI>300) was around 12% (mean: 74%). A similar pattern emerged in the year 2005 as well (Panel B).

Given these inter-province variations, Panels C-E of Table 1 next divides provinces into High/Low pollution status by their base year PAPIs. The 2000 High/Low provinces in Panel C are those with above/below median average PAPIs (or PAPI bite) in 2000. The 2005 High/Low provinces in Panel D are defined similarly with 2005 in place of 2000. Panel E flags a province as absolute High/Low if its yearly average PAPI (or PAPI bite) was above/below the median in the reference period of both FYPs. It is noteworthy that the 2005 High/Low classified by PAPIs in Columns 3-4 broadly mirror that in Column 2 grouped by absolute SO_2 reduction mandates, suggesting that pre-FYP pollution levels are likely to correspond well with FYP relevance for each province. More definitive evidences are provided by Table 2 which compares changes in yearly average PAPI and PAPI bite in High provinces to the changes in Low provinces over the regulation period of each FYP. It is clear from Table 2 that pollutant concentrations in High provinces remained significantly higher cross-sectionally but they enjoyed a relative shift-down

[101] It should be noted that the 10% SO_2 reduction quota described in the previous subsection is on a national basis, and hence for each province its pollution reduction quota during each FYP can well differ from the 10% national target.

from 2000-2004 (Column 3) and from 2006-2009 (Column 6). For example among 2000 High/Low provinces, the magnitude of this relative improvement was around 49 units (p-value: 0.000) by PAPI and around 9 points (p-value: 0.000) by high PAPI from 2000-2004 (Panel A). The same is true for 2005 High/Low provinces over 2006-2009 (Panel B): Yearly PAPI went disproportionately down by 7 units (p-value: 0.142) in initially more polluted areas. Notably, absolute High provinces accomplished more in pollution management between both 2000-2004 and 2006-2009, compared to absolute Low provinces (Panel C). These suggest that the impact of the FYPs is indeed mainly concentrated on provinces that started worse, and hence FYP toughness can be properly approximated by High/Low province status derived from pre-FYP pollution levels.

This study takes advantage of this geographic variation in FYP toughness across provinces as a consequence of base year ambient air quality variation and evaluates the effectiveness of the FYPs in promoting public health. Specifically, it compares the pre-post treatment changes in individual health in High provinces to the changes in Low provinces, exploiting the panel nature of CHNS that gives detailed health information in both pre- and post-FYP periods alongside a comprehensive set of other individual and community covariates. In Table 1, there are three possible ways to define High/Low provinces, i.e. 2000 High/Low, 2005 High/Low and absolute High/Low. As measures for FYP toughness, the former two are well suited for each FYP separately and the latter one is the most legitimate for both. Identification also requires random assignment of the regulative pressure indicator across provinces, or in other words, changes in health of residents in High provinces should have been the same as those in Low provinces absent the introduction of the FYPs. It will become clearer later that this requirement is likely to be met by all the three High/Lows, at least after netting out any time-invariant individual heterogeneity and controlling for all the changes in observable determinants of health. Hence one advantage of this research design is its ability to estimate and compare the FYP-health association using various High/Low classifications. More importantly, investigation of this inter-province pattern of pre-post FYP health variation for individuals provides a convincing test for the causal pathway from the FYPs by affecting air pollution to human health, rather than from other factors that were concomitant with the FYPs.

Before proceeding to the empirical analysis, Table 3 first provides some preliminary evidence on the health impact of the FYPs. The health outcome variables are individual self-reported sickness and individual self-reported Respiratory Allergic Cardiovascular (RAC) symptoms. Self-reported sickness is an aggregate measure of personal physical well-being whereas RAC disorders have been overwhelmingly associated with ambient pollutant particles by the medical literature and hence they may more likely detect any adverse impact of hazardous air conditions (Data section). Yearly changes in the incidence of self-reported sickness between High and Low provinces are compared in Columns 1-6, and a similar analysis is performed for RAC symptoms in Columns 7-12. High/Low provinces are defined as 2000 High/Low in Panel A, 2005 High/Low in Panel B and absolute High/Low in Panel C. If the FYPs succeeded in reducing environmental health risks, one would expect a relative shift-down in the frequency of adverse health episodes in High provinces.

Yet on the contrary this exercise suggests little health accomplishment that was made by the FYPs: Health of residents in provinces where the FYP had more relevance deteriorated more than those in less regulated provinces, no matter how High/Low is defined and which FYP is under consideration. For example, this relative shift-down in health was around 4 points (p-value:0.007) by sickness and 5 points (p-value:0.001) by RAC in 2000 High provinces from 2000-2004, it was around 1 point (p-value:0.536) by sickness and 4 points (p-value:0.016) by RAC in 2005 High provinces from 2006-2009, and it was as large as 10 points (p-value:0.000) by sickness and 8 points (p-value:0.000) by RAC in absolute High provinces throughout the sample period. It should also be noted that the prevalence of disease episodes in High provinces was not necessarily significantly higher than in Low provinces, which could be partly explained by a still health-threatening ambient air quality by either Chinese or international standards even in Low provinces (Data section). Admittedly, these contrasts are almost certainly confounded by e.g. individual initial health conditions and regional economic development, a more careful analysis that more rigorously accounts for any selection bias is detailed in the following sections.

3. Data

The study sample is constructed from China Health and Nutrition Survey (CHNS) which is an unbalanced panel designed to examine the effects of health, nutrition, and family planning programs implemented by central and local governments in China. It contains rich health and nutrition information for the Chinese population during a period of rapid economic transition in nine provinces[102], which vary in geography, economic development, public resources, and health indicators. The first round of the survey was carried out in 1989, and seven subsequent rounds were conducted in 1991, 1993, 1997, 2000, 2004, 2006, and 2009. From 2000 onwards, sampling units were interviewed in August-December. Two cities and four counties were sampled from each province in every wave, resulting in a total of 54 cities/counties. This study uses waves 2000-2009 because pollution data are not available for years before 2000, which leads to a final panel of around 28,643 individuals in total (aged 1-102y) with an average of around 7,161 observations per wave. This section presents some descriptive statistics for the outcome and explanatory variables included in the following analysis.

3.1 Health Outcome Variables

Two binary indicators for self-reported[103] sickness and self-reported Respiratory Allergic Cardiovascular (RAC) disorders[104] are examined in order to see whether and to what extent the FYPs succeeded in protecting public health. They are equal to 1 if an individual self-reported as being unwell in the 4 weeks prior to his/her interview and 0 otherwise. Self-reported RAC is designed to more closely capture any adverse impact of hazardous air conditions because medical studies in the past decades have predominantly linked exposure to ambient air pollution to lung dysfunction (e.g. respiratory tract infections, chronic obstructive pulmonary diseases and lung cancer), cardiovascular disorders (e.g. myocardial infarction, congestive and ischemic heart failure) and allergies (Ezzati and Kammen 2001; Boezen et al. 1999; Shah et al. 2013; Peters et al 1997). In addition recent reports have also revealed systemic effects of pollutant aerosols on neuropathology and central nervous system dysfunction (Block et al. 2009), therefore, the more aggregate sickness indicator is intended to incorporate any not yet revealed pathways through which pollutants impair health. There was significantly more self-reported sickness in 2004 (8 points; p-value: 0.000) and in 2009 (3 points; p-value: 0.000), and the prevalence of RAC disorders was around 10 points higher (p-value: 0.000) in 2004 and around 1 point higher (p-value: 0.248) in 2009 (Table 4). Hence consistent with findings in Table 3, these patterns also imply that little health benefit was generated by the two FYPs, at least within the study sample.

[102]They are Liao Ning, HeiLongjiang, Jiang Su, Shan Dong, He Nan, Hu Bei, Hu Nan, Guang Xi, and Gui Zhou.

[103]It is not clear from the questionnaires whether kids self-reported their illness or not, but presumably for those who were too young to be surveyed, their health status should be reported by their parents.

[104]The Respiratory Allergic Cardiovascular (RAC) disorders include fever, sore throat, cough, headache, rash, eye/ear disease, infectious illness and heart failure.

3.2 PAPI and FYP Toughness Indicator

Daily city-level ambient air quality data are obtained from China Ministry of Environmental Protection[105] (CMEP) for years 2000-2009. This database reports daily Air Pollution Index (API) for most median- and large-size cities in China, including all the province-level municipalities and provincial capitals[106]. The API is constructed using pollutant concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and fine particles (PM_{10})[107] collected by CMEP's nationwide network of pollution monitors[108], i.e. CMEP translates each pollutant's daily average concentration into a pollutant-specific API, with the reported API for each city being the maximum of all the pollutant-specific APIs on a given day (Chen et al. 2013). Each API ranges from 0-500 units and is capped at 500 if the maximum pollutant API is above the upper bound. This top-coding of API may raise concerns over misclassification of pollution exposures within the study sample, an issue that can be circumvented by making use of China Ambient Air Quality Standards which will be described in more detail below. Another drawback of the API dataset along the same line is its absence of data on exact geographic locations of its monitoring stations, but this lack of information does not invalidate API as being a representative indicator of city air conditions because it is known that all the pollution monitors are sparsely distributed within each city, e.g. one monitor is required for every 25-30 km^2 in Beijing.

Using this API database, this study constructs daily Province Air Pollution Index (PAPI) as the atmospheric air quality measure for the sampling provinces in CHNS: PAPI is the city annual population weighted average of APIs of each province on a given day. The aggregation from city to province is necessary for accurate assignment of pollution exposure because CHNS does not release city identifiers for its sampling cities (Liu and Zhao, 2012). Nevertheless, an attempt is made to identify the sampling cities and APIs (not PAPIs) are matched to each city directly. As mentioned above, the censoring of PAPI at 500 leads one to doubt the accurateness of pollution exposure determined by this atmospheric air quality measure. To ameliorate this kind of concern,

105 The website is http://datacenter.mep.gov.cn/.

106 The number of monitored cities was 42 in 2000, 47 in 2001, 72 in 2002-2003, 84 in 2004, and 86 in 2005-2009.

107 Fine particles (PM_{10}) are within the category of Total Suspended Particulates (TSPs), while TSPs are particulates with an aerodynamic diameter less than 100 micrometers (μm) and PM_{10} are particles with an aerodynamic diameter of at most 10 μm.

108 Carbon monoxide (CO) intensity is also monitored but is not reported by this database.

another air quality variable is also used and compared, i.e. high PAPI[109] which is a binary indicator equal to 1 if PAPI exceeds 300 and 0 otherwise. 300 is the threshold of heavy pollution designated by China Ambient Air Quality Standard and it is in conformity with (if anything looser than) other existing international air quality guidelines (Table A1). Together, PAPI more amply captures prolonged pollution exposure whereas high PAPI emphasizes high spikes of pollutant concentrations that can pose health hazards for those with an already impaired health system (Koop and Tole 2004; Evans and Smith 2005; Henderson 1996;Auffhammer and Kellogg 2011). Table 4 shows that yearly average PAPIs did not change significantly from 2000-2004 (6 units; p-value: 0.128) or from 2006-2009 (4 units; p-value: 0.128). There were no significant changes in yearly PAPI bite (fraction of high PAPIs) over the same period either.

The idea of this analysis is to see whether and to what extent FYP toughness enhanced health of the study sample, hence how it is measured is crucial for implementing this quasi-experimental design. This study adopts and compares three different definitions of FYP toughness, i.e. 2000 High/Low, 2005 High/Low and absolute High/Low. 2000 High/Low provinces are those with 2000 yearly average PAPI or PAPI bite above/below the median of the province yearly average PAPI or PAPI bite distribution. 2005 High/Low is defined similarly with 2005 in place of 2000. Absolute High/Low provinces are those with yearly average PAPI or PAPI bite above/below the median of the province distribution in both 2000 and 2005. Section 2 has verified that a dichotomous indicator for High/Low province derived from pre-FYP pollution levels is a legitimate proxy for FYP regulatory pressure, hence as a FYP toughness indicator 2000 and 2005 High/Low fit well for each FYP separately whilst absolute High/Low is the most appropriate for both. Identification also requires that the assignment of provinces into different regulatory status be random, a condition that can also be shown to be met by all the three High/Lows in the section that follows. Combined this richness in High/Low classifications offers one the possibility to cross-validate the estimated FYP health impact by varying the composition of more and less affected provinces. Detailed division of provinces into High and Low is shown in Table 1. Around a half of the study sample were living in High provinces in each period, and there were no significant changes in this fraction from 2000-2004 and from 2006-2009 (Table 4).

[109] One additional merit of high PAPI is its ability to mitigate doubts over the credibility of the API data due to evidences suggesting that local authorities manipulate their reported APIs around the clean air threshold of 100 (Chen et al. 2012; 2013).

Shorten 3.1 ad 3.2 and it would be good to have one table with the pollution measure and what it measures and one table for the health emasures and how they are defined

3.3 Weather Variables

Monthly capital city-level[110] weather conditions, i.e. temperature, relative humidity, amount of rainfall and hours of sunshine, are collected from China Statistics Yearbooks for years 2000-2009. Deschênes and Greenstone (2011) find a negative health impact of extreme weather conditions. This study controls for this possibility by including these weather variables in the control set. In particular, weather information is matched to each individual based on his/her interview date[111] and the health question structure (health in the month prior to the interview) so that it reflects the meteorological conditions that are pre-determined for individual health. Precipitation level was significantly higher in 2004 (47 millimeters; p-value: 0.000) and in 2009 (18 mm; p-value: 0.000). Sunlight declined by 16 hours (p-value: 0.000) from 2004-2004 but increased by 10 hours (p-value: 0.000) from 2006-2009.

This is great because it gives you some exogenous variation in pollution exposure. Please mention this in the introduction, generally emphasize it more and use also measures that interact pollution with these measures.

3.4 Other Individual and Community Variables

Other individual and community covariates are obtained from CHNS for years 2000-2009. Since target tightness(High/Low) is essentially an indicator for where people lived and the period of 2000-2009 was a timeframe of rapid economic restructuring (e.g. large-scale labour migration and privatisation of State-Owned Enterprises etc.), remarkable socio-demographic transformation (e.g. an aging population and declining fertility rate) and nation-wide amplification of social security networks (e.g. health insurance and pension programs etc.), one might be worried about any systematic differences between High and Low provinces in changes in individual behaviour and other authoritative interventions that are also predictive of health, e.g. changes in occupational characteristics (Cropper 1977), highest educational degree obtained (Ross et al. 2012), marital status (Dehejia and Lleras-Muney 2004), age, smoking behaviour

[110] There were 3 exceptions in 2000 and 2004. Liao Ning, Shan Dong and Guang Xi provinces each have 2 cities on which weather data are available in the 2000 and 2004 China Statistics Yearbooks, but otherwise only weather conditions for capital cities of each province are reported by the yearbooks.

[111] The interview date ranged from 8/30-12/27 in 2000, 8/21-12/23 in 2004, 8/4-12/24 in 2006, and 8/16-12/26 in 2009.

(Pampel and Denney 2011), rural Hukou (an indicator for permanent rural-urban migration), household size and income (Hayward and Gorman 2004), or regional health infrastructure generosity (Davis and Reynolds 1975). This analysis controls for a rich set of individual and community covariates to ameliorate this kind of concern. Summary statistics of these variables are displayed in the rest part of Table 4.

There were significant changes in almost all the individual characteristics from 2000-2004 and from 2006-2009. For example, equivalised real household income (in 2009 Yuan) was around 26% higher (p-value: 0.000) in 2004 and around 47% higher (p-value: 0.000) in 2009, coinciding with the 2-digit GDP growth rate in China over the same period. It is also noteworthy that fraction of individuals with a rural Hukou declined by 3 points (p-value: 0.000) over 2000-2004 but rose by the same magnitude (p-value: 0.002) in 2006-2009. This implies that compositional change of residents in High and Low provinces due to inter-regional migration is a cause of concern for consistent estimation of the FYP-health association. One advantage of CHNS is its 12 indexes of community qualities reflecting various regional aspects such as population density and diversity, economic condition and public service quality. Each community variable ranges from 0-10 and a higher value of, e.g. economic condition, indicates a better economic environment. Over the sample period individuals were more likely to live in communities that were more densely and diversely populated, performed economically better and provided higher quality public health infrastructures (i.e. sanitation, housing, health and social service). This suggests that caution should be also be taken in controlling for any possible regional confounding.

Alternatively given the panel nature of the study sample, another reason that is able to account for these significant changes in observable individual and community covariates over time and that also warrants concern is endogenous sample selection, i.e. there exist systematic differences between sample attriters and non-attriters in terms of observables and probably unobservables as well. This possibility is carefully dealt with by the empirical model described below.

4. Baseline Model and Identification

The idea of this analysis is to see how the inter-province variation in the power of the 10th and 11th Five-Year Plans (FYP) is correlated with pre-post regulation changes in individual health, as well as comparing their health effectiveness. This suggests an econometric specification that is akin to a Difference-in-Differences (DID) regression framework. Equation 1 outlines the baseline model for identifying the health impact of the FYPs:

$$\Delta H_{icp} = \alpha + \delta AQ_p + \Delta x'_{icp}\theta_1 + \Delta z'_{cp}\theta_2 + \Delta w'_p\theta_3 + \Delta\varepsilon_{icp} (1)$$

where $\Delta H_{icp} = H_{icp,post} - H_{icp,pre}$ is pre-post intervention changes in individual i's health (i.e. sickness or RAC) who lived in community c of province p. AQ_p is the FYP toughness measure (i.e. High/Low indicator) which is equal to 1 if province p was High and 0 otherwise. $\Delta x_{icp} = x_{icp,post} - x_{icp,pre}$ is a vector of first-differenced individual characteristics, $\Delta z_{cp} = z_{cp,post} - z_{cp,pre}$ controls for changes in community covariates and $\Delta w_p = w_{p,post} - w_{p,pre}$ is a set of first-differenced meteorological conditions (Table 4). First-differencing the health equation removes any unobserved time-constant individual heterogeneity that may be correlated with one or more of the right-hand-side variables while the inclusion of the other explanatory variables controls for available confounders the exclusion of which may contaminate the estimated FYP impact. It should be noted that changes in individual i's pre-determined health[112] (i.e. it is changes in health in the two years before 2000) is also included in Δx_{icp} to control for any systematic differences between High and Low residents in their pre-existing health conditions and hence in their susceptibility to environmental health risks (Seaton et al. 1995).

The coefficient of interest δ is identified through variation in provincial FYP toughness and variation in changes in health before and after each FYP, among the subsample of non-attriters in China Health and Nutrition Survey (CHNS) under the assumption that changes in individual health in High provinces should have been the same as the changes in Low provinces absent the interventions. This poses two identification issues. The first one is the possibility of non-random panel attrition, i.e. CHNS is an unbalanced panel and individuals can well drop out of the survey for reasons that were systematically related to their health or refuse to answer survey questions pertaining to their health. Indeed, around 49.6% of the respondents who were present in the sample in 2000 dropped out till 2009 and the item non-response rate was around 0.4%. Meanwhile, results in Table 5[113] suggest that the probability of being present in the sample with non-missing health information was significantly and negatively correlated with all the health

[112] Missing values are recoded as 0 (over 91% of those with non-missing information did not experience differential health conditions between 1993 and 1997) and an indicator for imputation is also included on the right-hand-side of Equation 1.

[113] Each column in Table 5 is a probit regression of a non-attriter dummy on all the explanatory variables in Table 4 and province-specific time trends.

disorders, implying that a weaker individual was more likely to disappear from CHNS or choose not to reply to health questions. It also implies that consistent estimation of the health impact of the FYPs hinges on whether or not sample selection bias has been sufficiently corrected for.

Therefore, this study further models an individual's decision to attrite following Heckman (1979) selection model in addition to the underlying health equation given in Equation 1 using a specification like:

$$s_{icp} = 1\left[X_1'\beta_1 + X_2'\beta_2 + v_{icp} > 0\right](2)$$

where s_{icp} is a selection indicator for individual i in community c of province p which is equal to 1 ($s_{icp} = 1$) if i is observed throughout the sample panel and 0 otherwise. The vector X_1 includes all the right-hand-side variables in Equation 1, i.e. $X_1 = \left(\alpha, AQ_p, \Delta x_{icp}', \Delta z_{cp}', \Delta w_p'\right)'$. X_2 is a vector of attrition identifiers. Specifically, they should be wave 2000 values of some individual covariates that are observed for all people at the start of the panel and affect an individual i's health trajectory exclusively through determining his/her s_{icp}. Candidates for X_2 that have been explored in the survey and economic literature comprise number of item imputations (Zabel 1998), survey loyalty variables corresponding to the enumerator and the interview process (Maitra and Vahid, 2006), affinity measures indicating whether or not a potential respondent is a member of the group conducting the survey (Hamermesh and Donald, 2008) and original sample membership (Cappellari and Jenkins, 2004) among others. Number of item imputations has been found to be predictive of item non-response with respondents first failing to answer some questions and subsequently refusing to answer any question whereas the rest loyalty or affinity variables have been proved to be reflective of an interviewee's desire to reciprocate previous favors and thus cooperate in the interview. Based on these ideas this study makes use of two individual-level retention identifiers including a binary indicator for whether or not some elements of a respondent's income were imputed in 2000 and a binary indicator for an individual's sample membership status in 1989 (i.e. the first wave of CHNS). The validity of these identifiers is confirmed by the data which will become clearer in the subsequent section.

Equations 1 and 2 are estimated by maximum likelihood on waves 2000-2004 for the 10th FYP and on waves 2006-2009 for the 11th FYP. Consistent estimation of the health impact δ requires that (a) $\left(s_{icp}, X_1', X_2'\right)'$ be always observed for individual i in any post-regulation period; (b) $(X_1', X_2')'$ be exogenous across Equations 1 and 2; and (c) $Corr\left(\Delta\varepsilon_{icp}, v_{icp}\right) = \rho$. Assumption (c) holds by construction while Assumption (b) is untestable but somewhat standard in the sample selection literature (Wooldridge 2002). The remaining problem is that the explanatory variables X_1 are not observed for drop-outs, and for estimation their missing values are replaced by non-missing observations in periods before attrition. This imputation method can be justified by the short period covered by each FYP (i.e. 2000-2004 for the 10th and 2006-2009 for the 11th). Robust standard errors are computed to allow for arbitrary cross-sectional correlation and heteroskedasticity.

One might still be worried about the tenability of assuming random assignment of provinces into High/Low. It is possible that changes in health in High and Low provinces would not have followed the same pathway anyway due to their systematic differences in e.g. demographic and industrial composition, economic condition, healthcare and environmental amenities. For example, if individuals living in initially more polluted provinces invested more in healthcare, or if provinces under higher regulative pressure from the FYPs also experienced stronger economic growth and hence improved health, the impact of the FYPs will be overestimated (Chay and Greenstone, 2003 and 2005; Currie and Neidell 2005; Knittel, Miller and Sanders 2011; Moretti and Neidell 2011). Alternatively, if individuals who cared more about health and hence healthier moved to provinces endowed with a cleaner air environment, the health benefit of the FYPs will be understated. Insofar as variation in these factors is province-specific and time-constant, biases in the FYP estimate of this sort are purged out with a first-differenced health equation. The section that follows will also argue that endogeneity of AQ_p resulted from time-varying confounders like individual health behaviour and other institutional interventions (e.g. economic and health system reforms) is less of a problem with the inclusion of time-varying individual and especially the twelve community covariates.

5. Validity of Attrition Identifiers and Random Assignment of High/Low

Successful application of the empirical model explained in the previous section relies on the feasibility of using original sample membership and income imputation indicator as attrition identifiers and conditional independence of the Five-Year Plan (FYP) variable in the estimating health equation. This section explores these two identifying assumptions in more detail and shows that they are likely to hold within current context. It begins by providing empirical rationale for using the two attrition identifiers and then assures conditional unconfoundedness of the FYP toughness indicator.

5.1 Validity of Attrition Identifiers

To establish that original sample membership and income imputation indicator are valid candidates for identifying sample attrition, this subsection first shows that they are closely correlated with individual retention status. This correlation cannot be explained by all the other individual and community covariates. Next, it shows that these two instruments are not statistically significant at conventional levels in the estimating health equation after controlling for the retention correction term, implying that they do not have a direct effect on individual health except through determining his/her sample observability. One additional insight provided by this exercise is the necessity of using first-differenced health regression (instead of non-differenced) in obtaining consistent estimates of the FYP impact.

The first requirement for any valid attrition identifier is its strong correlation with a unit's participating decision. Table 6 compares the fraction with imputed income and original sample membership among non-attriters (Column 1) to the fraction among attriters (Column 2). The non-attriters (35%; 3,698 obs.) are a panel of individuals who stayed in the sample with non-missing health information throughout 2000-2009. The remaining individuals are defined as attriters (65%; 6,797 obs.). As expected, non-attriters are around 23 points (p-value: 0.000) less likely to have some elements of their incomes imputed and 8 points (p-value: 0.000) more likely to be an original sample member. More definitive evidences are detailed in Table 7 which presents first-stage estimates of Equation 2. Each column in Table 7 corresponds to a probit regression of a non-attriter dummy on original sample membership and income imputation indicator controlling for all the other explanatory variables in the health equation. The non-attriter dummy switches on for non-attriters and switches off otherwise. The columns vary by which health outcome is under consideration (i.e. changes in pre-determined sickness or RAC) and how FYP toughness is measured. Robust standard errors are reported in parentheses.

The probability of being a non-attriter is significantly and inversely correlated with income imputation over the regulation period of both FYPs (10^{th} Panel A; 11^{th} Panel B). This implies that respondents who were less cooperative at the beginning of the panel were indeed more likely to drop out in later periods. Also intuitively, being an original sample member significantly raises the odds of staying in the panel, confirming the contention that re-interviewed agents had a tendency to reciprocate previous favors. Tests of joint significance of these two instruments suggest that they are always statistically significant at 1 percent level. These significant associations, either separately or jointly, are invariant to further including all the other individual controls, suggesting that they are not an artifact of statistical correlation between attrition status and alternative individual aspects. Overall results in Table 7 provide empirical rationale for using original sample membership and income imputation indicator as attrition identifiers in terms of the rank condition.

The second empirical rationale for using original sample membership and income imputation indicator is that they are also likely to be uncorrelated with the error term in the health equation. Evidences are presented in Table 8, each column of which is an Ordinary Least Squares (OLS) regression of Equation 1 that additionally controls for original sample membership, income imputation indicator and a retention correction term (i.e. inverse Mill's ratio calculated from Equation 2). The columns vary by the dependent variable (i.e. changes in sickness or RAC) and the FYP toughness measure. Robust standard errors are reported in parentheses. The idea is to test the statistical significance of these two identifiers: If they are not statistically significant at conventional levels, it means that they are unlikely to impose a distinct impact on individual health except through determining his/her sample observability. It is evident that original sample membership and income imputation indicator do not differ significantly from zero at conventional levels across all the columns in Table 8, indicating that the possibility for them to be separate determinants of individual health between 2000-2004 (Panel A) and 2006-2009 (Panel B) is minimal. Tests of joint significance of these two variables reinforce this conclusion: They are never distinguishable from zero at 1 percent level. Notably, this is not true for non-differenced health equations. By contrast, the inverse Mill's ratio tends to be significantly and negatively correlated with changes in sickness/RAC, purporting to the chance of positive health-selection bias and highlighting the necessity of modelling endogenous panel attrition.

Therefore this subsection suggests that original sample membership and income imputation indicator satisfy both the rank and excludability prerequisites for them to be valid instruments. The following subsection proceeds to establish the conditional independence of the FYP variable.

5.2 Random Assignment of High/Low

Throughout the sample period, there was ongoing transformation in the structure of China's economy (e.g. large-scale labour mobility) and social security (e.g. pension, unemployment and health insurance) networks (Giles and Wang, 2013). This, reinforced by the highly decentralized administrative system, has produced remarkable imbalances between provinces in their rate of economic growth and population migration as well as in their desire for different forms of social protection and financing capabilities (Blanchard and Giavazzi 2006). As the quasi-experimental design of this study relies on the assumption that changes in health of residents in more regulated provinces should have been the same as those in less regulated areas absent the Five-Year Plans (FYP), these regional diversities raise doubts over the propriety of this presumption. To ameliorate this kind of concern, this subsection demonstrates that treatment status, measured either by 2000 High/Low (more polluted in 2000), 2005 High/Low (more polluted in 2005) or absolute High/Low (more polluted in both 2000 and 2005), is largely uncorrelated with changes in observable individual and community characteristics over the regulation period of each FYP. This implies that changes in unobserved health determinants are unlikely to be correlated with it as well and hence the underlying health trend in High and Low provinces can be assumed to be comparable.

Table 9 begins by presenting the associations of the High/Lows with changes in various individual covariates. Results for the 10th FYP are in Columns 1-4 and those for the 11th FYP are in Columns 5-8. The columns under each FYP differ by how regulatory pressure is approximated. Entries in each column are the differences in the means of changes in included variables between the two sets of provinces. Standard errors are reported in parentheses. If the assignment of High/Low is random, one would see very few significant differences. This is likely to be true within current context. For example, the majority of the comparisons in Columns 1-4 are not statistically distinguishable from zero by 2000 High/Low or by absolute High/Low. This pattern persists for Columns 5-8: Most of the changes in characteristics of more affected individuals do not differ significantly from those of their less affected counterparts, for both 2005 and absolute High/Lows. Therefore it is reasonable to postulate that residents of High and Low provinces are likely to be similar along their unobserved dimensions as well. Besides, absolute High/Low only reveals two more significant contrasts than 2000 High/Low in Columns 1-4, indicating that endogeneity of absolute High/Low due to its reliance on pollution levels post the implementation of the 10th FYP is less of a problem. Nevertheless, High and Low individuals do tend to differ on their pre-existing health conditions and some of their other observed covariates (e.g. household income), consequently, all the following analyses will control for these aspects.

Apart from individual health determinants, there is also a potential for provincial imbalances in e.g. population composition, economic performance and public welfare amenities to confound the FYP estimates. To gauge the severity of this possibility, Table 10 next performs a similar analysis for the twelve community quality indicators. It can also be inferred that High and Low communities are broadly balanced in terms of these covariates, indicating that the scope for omitted regional confounders to bias the estimated FYP-health association is limited as well. For example at most two of the community level contrasts can be distinguished from zero by 2000 High/Low (Columns 1-2). The same can be said for absolute High/Low in Columns 3-4, reflecting that this FYP toughness measure is no more likely to be correlated with changes in observed and unobserved community covariates over the period of 2000-2004. Yet some of the community variables of treated and control localities do differ significantly, e.g. health care and social service amenities, especially for the 11th FYP (Columns 5-8). Therefore, these variables will be controlled for in the estimating health regression.

Descriptive evidences provided by this subsection do not stand against the perception of conditional independent designation of provinces as High/Low. Furthermore, they suggest that absolute High/Low is no more endogenous than 2000 High/Low in estimating the health impact of the 10th FYP. These combined with the finding in the previous subsection (i.e. validity of attrition identifiers) imply that inferences on the FYP-health association derived by this analysis are likely to be reliable. Main results are presented in the following sections.

6. Main Results

This section presents the main results on the health impact of the 10th and 11th Five-Year Plans (FYP) (Table 11). The adverse impact of hazardous air conditions may be more closely related to Respiratory Allergic Cardiovascular (RAC) symptoms (Columns 5-8) than to self-reported sickness (Columns 1-4). Aggregate sickness, however, can capture any unintended damage caused by inhalation of pollutant particles. The FYP variables are 2000 High/Low (air quality in 2000), 2005 High/Low (air quality in 2005) and absolute High/Low (air quality in both 2000 and 2005). The former two are used to infer the respective impact of the two plans while absolute

High/Low is used to pin down their relative effectiveness. As mentioned earlier, the High/Lows are defined alternatively by base year average PAPI and PAPI bite because the top-coding of PAPI may lead to misclassification of High/Low provinces based on their average PAPIs only (Data section). Each column of Table 11 corresponds to a Maximum Likelihood (ML) estimation of Equations 1 and 2 and controls for changes in all the individual, community and weather covariates. Robust standard errors are reported in parentheses and p-values of tests of no sample selection bias are in brackets. If the FYPs succeeded in enhancing the public health, one would expect a relative shift-down in the incidence of self-reported sickness and RAC among residents of High provinces.

Yet results in Table 11 point to the opposite direction. Stricter emission targets in the first year plan are significantly and positively associated with a 6-point increase in both self-reported sickness and RAC. (Panel A). We do not find a significant impact of this for the second year plan on the probability of being sick but a relative shift-up in RAC of around 5 points among more regulated individuals (Panel B). These effects are large: The corresponding percentage increase is around 49% for sickness and around 46-56% for RAC. They also suggest that neither the 10th nor the 11th FYP fulfilled its health objectives. More definitive comparisons of the two plans are provided by coefficients in front of the absolute High/Lows. It can be observed that individuals in absolute High provinces were around 6-11 points (49-89%) and 9 points (83%) more likely to report sickness and RAC over the period of 2000-2004, compared to their absolute Low counterparts. Similarly, growth in the prevalence of sickness and RAC was around 11-13 points (89-106%) and 6-7 points (56-65%) faster in absolute High than in absolute Low provinces from 2006-2009. These larger magnitudes of health deterioration can be explained by the more apparent gap in ambient air quality between absolute High and Low areas and they reassure that the 11th FYP did no better than its predecessor in improving public health.

Several additional insights are also provided by Table 11. The first one is that the adverse impact of ambient air pollution is not necessarily larger on RAC than on sickness. This may be caused by the particular health question structure in China Health and Nutrition Survey (CHNS), i.e. it is only related to physical disorders that appeared in the month before the interview. Hence a respondent may report as being sick exactly because he/she experienced a short-term RAC episode. Second, the FYP coefficients when High/Low is defined by average PAPI do not differ significantly from those when High/Low is reclassified by PAPI bite, meaning that top-coding of

PAPI is unlikely to cause incorrect assignment of provincial treatment status and hence biased FYP estimates. Lastly, Ordinary Least Squares (OLS) estimates of the FYP impact tend to be larger in magnitude than their ML counterparts and Wald tests of no sample attrition bias mostly reject the null hypothesis for the period of 2000-2004. This implies the possibility of negative health selection among treated non-attriters and upwardly biased FYP estimates if non-random panel attrition is not controlled for.

Results above rely on the assumption of random assignment of provinces into High and Low, yet a direct test of this assumption is not available. Therefore one may well argue that there still exist unobserved health confounders that are systematically related to treatment status and that have not been sufficiently captured by all the controls, leading to misinterpreted FYP health impact. To check the severity of this possibility, this section re-estimates the baseline model on various subsamples of matched treated and control subjects (i.e. propensity score matching[114] using all the observables). Since the matched samples are more comparable in terms of their observables and probably unobservables as well, the refined FYP estimates should be less subjected to selection into treatment. Results are presented in Table 12. If the High/Lows (i.e. 2000 High/Low, 2005 High/Low and absolute High/Low) balance treated and control provinces well, one would expect estimates in this table not to be significantly different from those in Table 11.

As expected, the FYP coefficients in Table 12 do not differ significantly from the main results in Table 11, implying that selection bias is less of a problem in this study and providing reassuring evidence on the failure of the two plans in reducing environmental health risks. These coefficients are also similar in magnitude to those estimated above, but due to a smaller sample size, they are less likely to be distinguishable from zero. In terms of those that are significant, 2000 High/Low is associated with a 5-point (49%) disproportionate increase in the probability of being sick among residents who enjoyed a relative air quality improvement from 2000-2004 (Panel A). The occurrence of RAC disruptions is around 6 points (56%) more likely among 2005 High individuals (Panel B). The perverse health impact of the FYPs is still made more apparent by absolute High/Low comparisons: Incidence of sickness and RAC was around 15 points

[114]Specifically, each non-attriter in High provinces is matched to its nearest single counterpart in Low provinces based on the propensity score, which is the predicted probability of being treated from a probit regression of a High/Low indicator on changes in all the individual and community characteristics. It should be noted that matching is performed for non-attriters only, hence the probit regression is estimated on the subsample of non-attriters and the set of attriters is the same as that in Table 11.

(122%) and 14-31 points (130-287%) higher in absolute High provinces than in absolute Low provinces (Panel B).

Overall results in this section point to the conclusion that the FYPs bore little fruit in protecting the public health and that the 11th FYP, albeit being more successful in meeting the nationally prescribed SO_2 reduction quota, did no better than its predecessor. This finding is robust to refining the estimating sample to more comparable High and Low provinces, suggesting that it is not an artefact of diverse health trends between treated and control areas that would have prevailed even without the FYPs. Furthermore, results not shown here suggest that replacing the dichotomous FYP toughness indicator by a continuous measure does not change the estimated FYP coefficients qualitatively either. The following section proceeds to provide several more robustness checks on the estimated FYP-health association.

7. Further Robustness Checks

7.1 Other Health Outcome Measures

There are at least two shortcomings of self-reported sickness and RAC. First of all, it is possible for two equally healthy individuals to report distinct levels of health because of their different conceptions and expectations of good health (d'Uva et al. 2011). It means that if residents in High and Low provinces differed systematically on their inclination to report a weak health for reasons that have not been captured by the observed controls (e.g. health of their peers), results in Table 11 are misleading. Second, long-term cumulative effects of air pollution are not the same as its short-term episodic damages (Peters and Pope III, 2002), implying that benefits of any substantial and sustained air quality improvement induced by the FYPs may be overshadowed by temporary sickness and RAC disruptions as revealed by the data.

To determine how these drive the conclusion reached in the previous section, this subsection links three alternative health outcome measures to the High/Lows. They are diagnosed sickness and RAC for detecting reporting bias in their self-reported counterparts and an indicator for chronic cardiovascular disorders (i.e. hypertension, diabetes, myocardial infarction and apoplexy) for revealing any incremental influence of pollution exposure (WHO 2006). Results are presented in Table 13. If a similar pattern of the FYP-health association emerges, one could be certain that self-reported sickness and RAC are adequate indicators for individual health and the counter-intuitive FYP impact is not a result of incorrectly chosen health outcome measures.

Replacing self-reported sickness and RAC by their more objective counterparts does not make much difference to the FYP estimates, either statistically or economically. For example, the probability of being diagnosed sick is around 5-21 points (60-251%) higher in provinces where the 10^{th} FYP had more relevance. Effects are larger for diagnosed RAC: The magnitude of health deterioration is around 4-13 points (105-342%). The 11^{th} FYP was no more superior: It is associated with a 7-point (84%) relative shift-up in diagnosed sickness and 3-4-point (79-105%) higher incidences of diagnosed RAC among treated residents. These imply that reporting bias in self-reported health measures is unlikely to hinder an accurate assessment of the interventions and that the two plans accomplished little in terms of the more objective health indicators as well. Long-term FYP estimates also broadly mirror the short-term coefficients, suggesting that more regulated areas had a disproportionately higher prevalence of chronic cardiovascular disorders of around 3-4 points (32-42%). This indicates that the episodic perverse health effects attached to the FYPs do not mask their potential cumulative merits.

7.2 Other FYP Toughness Measures

Results obtained so far can also be invalidated by errors in the High/Lows, i.e. 2000 High/Low (air quality in 2000), 2005 High/Low (air quality in 2005) and absolute High/Low (air quality in both 2000 and 2005). At first glance, the choice of province median as the criterion for determining treatment status seems a bit arbitrary, and it is not clear whether re-classifying provinces by other cutoff points would lead to an opposite interpretation. Besides, PAPI data are not available for months before June in 2000 but ambient air quality follows a strong monthly pattern (Figures A-C). This raises doubts over the comparability between the various High/Lows and hence comparison of the FYP estimates based on them. In addition, Section 2 suggests that efforts on environmental protection were primarily targeted at SO_2 emissions, meaning that regulation status may be better approximated by SO_2 concentrations than by PAPIs (which are constructed from concentrations of all the major air pollutants). Lastly, the High/Lows are derived from provincial pollutant concentrations per se (i.e. above/below the median of the concentration distribution). For the purpose of this analysis, it is also worthwhile to elaborate on these measures by their potential environmental health risks and see if results change substantially. Therefore, this subsection focuses on examining whether the perverse FYP impact is invariant to the use of alternative FYP toughness measures. If a similar finding shows up, one can safely rule out the possibility of misclassification of provinces into High and Low causing biased estimates of the FYP impact (Table 14).

In Columns 1-4, redefining treated and control provinces by the mean of their base year pollution levels does not change the FYP estimates statistically and economically. The 10th FYP is associated with a respective 4-8-point (33-65%) and 5-8-point (46-74%) relative shift-up in self-reported sickness and RAC. Similarly, areas where the 11th FYP had more bite suffered from an additional 8-11-point (65-89%) and 5-8-point (46-74%) increase in the same two symptoms. This implies that ranking provinces by their typical atmospheric air quality and not by their average conditions is not the reason behind the counter-intuitive FYP impact (henceforth all the demarcations are based on province median). Columns 5-8 next restrict the time window for calculating pre-FYP pollution exposure to July[115]-December (the sampling months of CHNS), but this does not make much difference to the FYP coefficients either. Prevalence of sickness and RAC rose by 6-10 points (49-81%) and by 6-9 points (56-83%) among more affected individuals from 2000-2004, compared to their less affected counterparts. There was also a disproportionate increase in sickness (6 points; 49%) and RAC (5 points; 46%) among treated individuals between 2006 and 2009. These suggest that the various High/Lows (i.e. 2000 High/Low, 2005 High/Low and absolute High/Low) are still comparable to each other despite data inadequacy in 2000. They also further support the observation of negligible FYP health impact inferred from the High/Lows.

To more closely capture FYP influence, the next two columns (Columns 9-10) retrieve[116] SO_2 concentrations from the API data and then determine provincial regulation status by reference year SO_2 levels. Estimates in these two columns broadly mirror those in the previous columns: The 10th FYP seems to have induced a deeper health deterioration of around 3 points (24%) and relevance of the 11th FYP is not significantly related to any health outcome measure. This suggests that there is little difference in using PAPI or SO_2 to indicate ambient air quality. Furthermore, because data on SO_2 are more likely to be missing (i.e. they are observed only

[115]Precisely speaking, the sample months should be from August to December. But as the health question purports to health conditions one month before the CHNS interview, therefore July is also included in the computation of average PAPI and PAPI bite.

[116]The reported APIs are the maximum of all the pollutant-specific APIs (i.e. SO_2, PM_{10} and NO_2). This means that SO_2 concentration can be converted from APIs on days when SO_2 is the primary pollutant, as long as one knows how pollutant concentration is translated to pollutant-specific API. Based on this idea, this study obtains SO_2 densities using the formula in Chen et al. (2013) that links API to pollutant concentration.

when SO_2 is the primary pollutant), this study prefers to use the High/Lows as FYP toughness proxies. Notably, coefficients in Column 11 where FYP toughness is measured directly by absolute pollution reduction quotas of the 11th FYP (Table 1) also point to 4-5-point (37-41%) higher incidences of weak reports in more affected locations, providing re-assuring evidence that the High/Lows are doing a good job and that little health benefits can be attributed to the FYPs.

These alternative FYP variables considered so far still depend on pollutant concentrations per se, for the purpose of this analysis, FYP regulatory status can also be defined on environmental health risks associated with provincial pollution levels. This means that the High/Lows cannot be fully justified without comparing them to this remaining set of relevance indicators. Therefore, the last four columns of Table 14 divide provinces by their Province Health Hazard (PHH). PHH is the ratio of province base year SO_2 concentration to the SO_2 concentration threshold (24-hour or annual) recommended by China or international air quality guidelines (WHO 2006, Table A1). The higher the ratio, the higher the environmental health risks within each province. Because all the air quality standards are pollutant specific, SO_2 (rather than PAPI) is used to construct PHH. Furthermore, although this analysis attempted to distinguish between SO_2 standards common in developed countries (i.e. WHO, EU, US and Japan) and those in developing countries (i.e. Brazil, Mexico, South Africa, India and China), SO_2 levels in this study sample far exceed all the thresholds, leading to no variation in province treatment status determined by PHHs that are constructed from various guidelines. Refining the FYP toughness measure by PHHs does not lead to significantly different FYP coefficients: The 10th FYP seems to have induced a relative shift-up in the probability of being sick of around 3 points (24%) in more affected areas, and estimates for the 11th FYP are never statistically significant for either sickness or RAC. Hence despite that the High/Lows ignore any nonlinearity in the health-concentration relationship, they are still doing reasonably well in approximating FYP relevance and the perverse interpretation of the FYPs persists.

7.3 API and Health of City Residents

As mentioned in the Data section, CHNS does not release its city identifiers so that the city level pollution data cannot be directly merged with the study sample. Rather, this analysis aggregates city level APIs to the province level and uses PAPI as the atmospheric air quality measure. This leads one to worry about how accurate this assignment of pollution concentration is, that is, rural residents (69%) must have exposed to distinct pollution levels from their city counterparts (31%)

despite being in the same province because the distribution of pollution exposure is highly non-uniform (Hoek et al. 2002). This also leaves open the question that the counter-intuitive FYP impact obtained so far is misguided by incorrectly determined base year pollution levels and hence the High/Lows. This subsection exploits this question and compares changes in individual health between more and less affected cities (not provinces) to further estimate the FYP impact. Sampling cities are identified by matching their population and land area records to those published by China statistical office (in China Statistics Yearbooks) using, sequentially, Mahalanobis- and Euclidean-distance matching and principal component analysis. The final set of matched cities is given in Tables B1-2. APIs are then linked to these cities and city treatment status (i.e. 2000 and 2005 CHigh/CLow[117]) is determined in the same way as that for the provinces (i.e. 2000 and 2005 High/Low). Results are in Table 15. If this new set of estimates once more tells a similar story, inaccurateness in the High/Lows for neglecting differences in pollution concentration between urban and rural areas is less of a problem and it is safe to use them to interpret the regulation outcome.

The FYP estimates in front of the CHigh/CLows in Columns 1-2 cannot be distinguished from those in front of the corresponding High/Lows, either statistically or economically. The 10th FYP is associated with an 8-point (53%) and 6-point (44%) relative shift-up in sickness and RAC in more affected cities. Similarly, more regulated city residents by the 11th FYP also experienced an additional increase in the occurrence of these same two symptoms: It was around 2 points (13%) for sickness and around 7 points (51%) for RAC. Albeit due to a much smaller sample size, these effects are never statistically significant at conventional levels. These suggest that the health impact of the FYPs found in the previous sections is not biased by incorrect assignment of pollutant concentrations or the High/Lows and that the FYPs indeed accomplished little in promoting public health.

Re-assigning city treatment status by APIs within the sampling months changes the estimated coefficients little, suggesting that the above finding is unlikely to merely reflect any incomparability between the CHigh/CLows (due to data limitation in 2000) and not the FYP impact per se (Columns 3-4). More directly measuring FYP regulatory pressure by reference year SO_2 levels does not make the estimates significantly different from those in Columns 1-2 either, implying that the CHigh/CLows are proper indicators for city regulation status and that

[117] Absolute High/Low is not allowed by a much smaller sample size.

inferences based on them are reliable. The last two columns of Table 15 refine the definition of treated and control cities by their environmental health risks using City Health Hazard (CHH). CHH is the ratio of city base year SO_2 levels to the SO_2 concentration thresholds recommended by China or international air quality guidelines and hence it elaborates on pollutant concentrations by their associated health risks (Section 7.2). This too does not alter what has been found, implying that the CHigh/CLows are not disqualified by their ignorance of any non-linearity in the health-concentration association and that the persistent counter-intuitive FYP health impact inferred from them allows one to be confident in the quasi-experimental design of this analysis.

8. Discussion and concluding remarks: FYP Toughness and Polluting Activities

It is perplexing at first glance that the Five-Year Plans (FYP) generated no more health benefit in areas that enjoyed larger air quality improvement, especially for the 11^{th} FYP. This lack of health impact is not caused by selection into treatment, incomprehensive health outcome measures or inappropriate High/Lows. This leads one to further think about why relative pollution reduction and health deterioration occurred simultaneously in High provinces. Air quality regulations are associated with substantial investment in pollution abatement technologies and related operating and maintenance expenses. It has been observed that, when the specification and application of environmental regulations vary intentionally across space, polluting activities tend to re-locate from more to less polluted areas to avoid stricter regulation in more polluted areas (Henderson 1996; Greenstone 2002). Therefore, if polluting activities relocated from more to less affected provinces over the FYP period and consequently more affected provinces did not alter their pollution abatement measures substantially (due to less burden imposed by these polluting industries), pollutant discharges by treated localities would still be higher in each period but experience a slower growth over time. This can serve to explain the coexistence of relative air quality improvement and health degradation in High provinces. This subsection exploits this explanation in more detail. If data show that ambient air quality was persistently worse in High provinces statically and that polluting activities tended to be more intensive in Low provinces temporally, the perverse health impact of the FYPs estimated by this analysis can be justified.

Figures 1-3 begin by presenting cross-sectional comparisons of atmospheric air quality between High and Low provinces. Distributions of monthly average PAPIs before and after each FYP are plotted for more and less affected areas, respectively. As expected, monthly PAPIs in High provinces lie mostly above those in Low provinces in pre-treatment periods (Figures 1A, 2A, 3A and 3C). The largest discrepancies suggested by these figures are around 61% (p-value: 0.000) by 2000 High/Low[118], 12% (p-value: 0.000) by 2005 High/Low and 16-101% (p-value: 0.000-0.001) by absolute High/Low. This suggests that base year ambient air quality was indeed worse in High than in Low locations. More importantly, a similar contrast can be observed in post-treatment periods as well (Figures 1B, 2B, 3B and 3D). For example, monthly PAPI could be around 38% (p-value: 0.000) and 8% (p-value: 0.013) higher in 2000 and 2005 High areas towards the end of the FYPs. This discrepancy is more transparent between absolute High and Low provinces, i.e. 105% (p-value: 0.000) in 2004 and 18% (p-value: 0.001) in 2009. Hence, these findings confirm the conjecture that pollutant concentrations remained higher in more regulated areas despite the presence of the FYPs. Furthermore, these comparisons reflect a narrowing gap in ambient air quality between the two sets of provinces, providing suggestive evidence that air quality deteriorated more in less regulated areas over the sample period.

To figure out how polluting activities changed in more and less regulated provinces, it would be nice to have detailed data on firm locations and outcomes (e.g. growth of employment, investment and shipments of manufacturers) so that specific questions, e.g. how FYP toughness was associated with output and employment of pollution-intensive industries, can be examined. Absent these data it is still possible to obtain some indirect inferences however using a specification like (Henderson 1996):

$$PAPI_{pdmt} = \alpha + \delta_1 AQ_p + \delta_2 Post_t + \gamma \overline{PAPI}_{pt,m-1} + \sum_{j=2}^{12} \theta_j^1 d_{mj} + \sum_{j=2}^{12} \theta_j^2 \left(Post_t * d_{mj}\right) + \sum_{j=2}^{12} \gamma_j^1 \left(AQ_p * d_{mj}\right) + \sum_{j=2}^{12} \gamma_j^2 \left(Post_t * AQ_p * d_{mj}\right) + w'_{pmt}\beta + \varepsilon_{pdmt} \qquad (3)$$

[118]Because PAPI data are not available for months before June in 2000, wave 2001 instead of wave 2000 is used to depict the year around distribution of ambient air quality for each province.

where $PAPI_{pdmt}$ is PAPI of province p on day d in month m of year t. AQ_p is a High/Low indicator equal to 1 for High provinces and 0 otherwise. $Post_t$ is a year indicator equal to 1 for post-FYP period and 0 otherwise. $\overline{PAPI}_{pt,m-1}$ is average PAPI of province p in month $m-1$ of year t which is included to reflect the fact that air pollution persists and dissipates non-instantaneously[119]. d_{mj} is a month indicator equal to 1 if $m = j$ and 0 otherwise. w_{pmt} is a vector of weather covariates, α is a constant and ε_{pdmt} is an error term. The idea is that, after controlling for undissipated lagged PAPI levels ($\overline{PAPI}_{pt,m-1}$) and weather effect (w_{pmt}), the coefficient θ_j^2 ($j = 2, \dots, 12$) captures changes in polluting activities of Low provinces in response to the FYPs and the coefficients $\theta_j^2 + \gamma_j^2$ ($j = 2, \dots, 12$) reflect the equivalent changes in High provinces. This specification is estimated by OLS on waves 2001-2004 and on waves 2006-2009 of the pollution data (i.e. for each FYP). Results are plotted in Figures 4-5. If pollution-intensive industries moved from High to Low provinces, one would expect plots for Low provinces to lie above those for their High counterparts.

This is indeed the case. For example, except for February and June, the monthly cycle of 2000 Low provinces always lies above that of 2000 High provinces (Figure 4A). The gap between the plots for 2005 High and Low provinces is less transparent, nevertheless, it still points to a more positive shift-up in pollutant discharges from socioeconomic activities in less regulated areas over 2006-2009 (Figure 5A). As might be expected, these two patterns are confirmed by corresponding contrasts between absolute High and Low provinces (Figures 4C and 5C). Furthermore, changes in predicted PAPIs of High and Low provinces tract well with their changes in polluting activities (Figures 4B, 4D, 5B and 5D), and the monthly coefficients used to produce these figures are jointly significant at 1 percent level (Table A2). This provides re-assuring evidence that these plots are capturing aspects of socioeconomic activities that are related to ambient air quality, over and above the effects of undissipated past pollution discharges and current weather conditions. Therefore, it seems that investment in pollution abatement technologies and related operating and maintenance costs incentivized pollution-intensive industries to re-locate from more to less regulated areas. This, combined with the

[119] It is not clear at the outset how many lags should be included in order to sufficiently control for the lasting effect of previous pollutant concentrations. Results in Table A3 show that coefficients in front of the monthly dummies obtained when two lags are included do not differ significantly from those when only one lag is controlled for, hence, Equation 3 includes just one lag of monthly average PAPI.

finding of a persistent worse air quality in High than in Low provinces, explains the coexistence of a relative shift-down in both pollution exposure and health among treated individuals over the FYP period and hence justifies the perverse health impact of the FYPs estimated by this analysis.

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Tables and Figures

Table 1: Pre-FYP PAPIs and High/Low classification

Province	(1) Quota (%)	(2) Amt.SO2 (10,000 tons)	(3) PAPI,1-12 (unit)	(4) High PAPI,1-12 (%)
Panel A: Mean in 2000				
Liao Ning	***	***	346.8	71.9
Hei Longjiang	***	***	338.7	77.4
Jiang Su	***	***	360.9	81
Shan Dong	***	***	378.3	88.6
He Nan	***	***	362.1	84.8
Hu Bei	***	***	309	70.5
Hu Nan	***	***	221.5	46.7
Guang Xi	***	***	347.4	73.3
Gui Zhou	***	***	301.7	69.5
Observations	***	***	1,888	1,888
Panel B: Mean in 2005				
Liao Ning	12	119.7	356.4	76.7
Hei Longjiang	2	50.8	350.4	77.3
Jiang Su	18	137.3	348.8	78.1
Shan Dong	20	200.3	371.9	92.6
He Nan	14	162.5	320.7	67.1
Hu Bei	7.8	71.7	339	70.4
Hu Nan	9	91.9	340.9	63.8
Guang Xi	9.9	102.3	328.8	71.2
Gui Zhou	15	135.8	371.9	85.8
Observations	9	9	3,285	3,285
Panel C: 2000 High/Low				
Liao Ning	***	***	**High**	Low
Hei Longjiang	***	***	Low	**High**
Jiang Su	***	***	**High**	**High**
Shan Dong	***	***	**High**	**High**
He Nan	***	***	**High**	**High**
Hu Bei	***	***	Low	Low
Hu Nan	***	***	Low	Low
Guang Xi	***	***	**High**	**High**
Gui Zhou	***	***	Low	Low

Table 1 continued

Panel D: 2005 High/Low				
Liao Ning	***	**High**	**High**	**High**
Hei Longjiang	***	Low	**High**	**High**
Jiang Su	***	**High**	**High**	**High**
Shan Dong	***	**High**	**High**	**High**
He Nan	***	**High**	Low	Low
Hu Bei	***	Low	Low	Low
Hu Nan	***	Low	Low	Low
Guang Xi	***	Low	Low	Low
Gui Zhou	***	**High**	**High**	**High**
Panel E: Absolute High/Low				
Liao Ning	***	***	**High**	***
Hei Longjiang	***	***	***	**High**
Jiang Su	***	***	**High**	**High**
Shan Dong	***	***	**High**	**High**
He Nan	***	***	***	***
Hu Bei	***	***	Low	Low
Hu Nan	***	***	Low	Low
Guang Xi	***	***	***	***
Gui Zhou	***	***	***	***

Notes: Data are from China Ministry of Environmental Protection and China Health and Nutrition Survey. Province Air Pollution Index (PAPI) and high PAPI (PAPI>300) are two atmospheric quality measures. A higher value of PAPI denotes a higher level of air pollution. Provinces are divided into High and Low by their pre-FYP average PAPIs or PAPI bites (fraction of high PAPIs). 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 2: Trends in PAPIs of High/Low provinces

	(1)	(2)	(3)	(4)	(5)	(6)
	10th FYP			11th FYP		
	2000	2004	DID	2006	2009	DID
Panel A: 2000 High/Low						
(1) High-Low, PAPI	66.495***	17.539***	-48.957***	-1.118	3.722	4.840
	(6.709)	(4.292)	(7.612)	(3.394)	(3.173)	(4.646)
(2) High-Low, High PAPI	0.164***	0.070***	-0.094***	0.020	-0.004	-0.024
	(0.020)	(0.015)	(0.025)	(0.014)	(0.014)	(0.020)
Observations	1,888	3,294	5,182	3,285	3,276	6,561
Panel B: 2005 High/Low						
(1) High-Low, PAPI	35.255***	31.529***	-3.726	17.285***	10.474***	-6.811
	(6.832)	(4.268)	(7.650)	(3.380)	(3.168)	(4.633)
(2) High-Low, High PAPI	0.089***	0.098***	0.009	0.089***	0.090***	0.001
	(0.020)	(0.015)	(0.026)	(0.014)	(0.014)	(0.020)
Observations	1,888	3,294	5,182	3,285	3,276	6,561
Panel C: Absolute High/Low						
(1) High-Low, PAPI	96.722***	46.798***	-49.923***	14.024***	12.039***	-1.985
	(8.634)	(5.801)	(10.071)	(4.365)	(4.233)	(6.081)
Observations	1,050	1,830	2,880	1,825	1,820	3,645
(2) High-Low, High PAPI	0.238***	0.165***	-0.072**	0.106***	0.080***	-0.026
	(0.027)	(0.021)	(0.035)	(0.020)	(0.019)	(0.028)
Observations	1,048	1,830	2,878	1,825	1,820	3,645

Notes: Data are from China Ministry of Environmental Protection and China Health and Nutrition Survey. Province Air Pollution Index (PAPI) and high PAPI (PAPI>300) are two atmospheric quality measures. A higher value of PAPI denotes a higher level of air pollution. Provinces are divided into High and Low by their pre-FYP average PAPIs or PAPI bites (fraction of high PAPIs). 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 3: Trends in self-reported sickness in High/Low provinces

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Sick						RAC					
	10th FYP			11th FYP			10th FYP			11th FYP		
	2000	2004	DID	2006	2009	DID	2000	2004	DID	2006	2009	DID
Panel A: 2000 High/Low												
(1) High-Low, PAPI	0.012	0.053***	0.040***	0.004	0.084***	0.080***	0.003	0.049***	0.046***	-0.001	0.046***	0.047***
	(0.009)	(0.012)	(0.015)	(0.011)	(0.012)	(0.016)	(0.007)	(0.012)	(0.014)	(0.011)	(0.012)	(0.016)
(2) High-Low, High PAPI	0.011	0.003	-0.008	-0.017	0.064***	0.082***	0.005	0.010	0.004	-0.017	0.014	0.031*
	(0.009)	(0.012)	(0.015)	(0.011)	(0.012)	(0.016)	(0.007)	(0.012)	(0.014)	(0.011)	(0.012)	(0.016)
Observations	3,698	3,698	7,396	3,698	3,698	7,396	3,698	3,698	7,396	3,698	3,698	7,396
Panel B: 2005 High/Low												
(1) High-Low, PAPI	-0.027***	0.009	0.037**	-0.048***	-0.038***	0.010	-0.023***	0.019	0.042***	-0.050***	-0.011	0.039**
	(0.009)	(0.012)	(0.015)	(0.011)	(0.013)	(0.017)	(0.007)	(0.012)	(0.014)	(0.011)	(0.012)	(0.016)
(2) High-Low, High PAPI	-0.027***	0.009	0.037**	-0.048***	-0.038***	0.010	-0.023***	0.019	0.042***	-0.050***	-0.011	0.039**
	(0.009)	(0.012)	(0.015)	(0.011)	(0.013)	(0.017)	(0.007)	(0.012)	(0.014)	(0.011)	(0.012)	(0.016)
Observations	3,698	3,698	7,396	3,698	3,698	7,396	3,698	3,698	7,396	3,698	3,698	7,396
Panel C: Absolute High/Low												
(1) High-Low, PAPI	-0.012	0.043**	0.054**	-0.046***	0.051***	0.097***	-0.014	0.052***	0.066***	-0.051***	0.033**	0.083***
	(0.012)	(0.018)	(0.022)	(0.016)	(0.017)	(0.023)	(0.010)	(0.018)	(0.020)	(0.015)	(0.017)	(0.023)
Observations	2,016	2,016	4,032	2,016	2,016	4,032	2,016	2,016	4,032	2,016	2,016	4,032
(2) High-Low, High PAPI	-0.013	0.007	0.020	-0.062***	0.038**	0.099***	-0.013	0.024	0.037*	-0.062***	0.010	0.072***
	(0.012)	(0.017)	(0.021)	(0.015)	(0.017)	(0.023)	(0.010)	(0.017)	(0.020)	(0.015)	(0.016)	(0.022)
Observations	1,996	1,996	3,992	1,996	1,996	3,992	1,996	1,996	3,992	1,996	1,996	3,992

Notes: Data are from China Health and Nutrition Survey. Self-reported sickness and Respiratory Allergic Cardiovascular (RAC) are two binary indicators equal to 1 if an interviewee self-reported as the corresponding symptom in the 4 weeks prior to his/her interview and 0 otherwise. Province Air Pollution Index (PAPI) and high PAPI (PAPI>300) are two atmospheric quality measures. A higher value of PAPI denotes a higher level of air pollution. Provinces are divided into High and Low by their pre-FYP average PAPIs or PAPI bites (fraction of high PAPIs). 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 4: Summary statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	10th FYP				11th FYP			
Variable	2000	2004	(2)-(1)	P-value	2006	2009	(6)-(5)	P-value
Health outcomes (=1 if yes; 0 otherwise)								
Self-reported sickness	0.079	0.160	0.081	0.000	0.129	0.156	0.027	0.000
RAC (Respiratory,Allergic,Cardiovascular)	0.051	0.155	0.104	0.000	0.129	0.136	0.007	0.248
Pollution measure								
PAPI (unit)	329.6	335.4	5.8	0.128	352.6	356.2	3.5	0.128
High PAPI (=1 if PAPI>300)	0.737	0.732	-0.005	0.675	0.786	0.790	0.004	0.715
Fraction in High provinces								
By PAPI (=1 if yes; 0 otherwise)								
2000 High	0.555	0.557	0.002	0.754	0.542	0.545	0.003	0.771
2005 High	0.572	0.571	-0.002	0.840	0.586	0.586	0.000	0.991
Absolute High	0.620	0.618	-0.001	0.894	0.620	0.624	0.004	0.763
By high PAPI (=1 if yes; 0 otherwise)								
2000 High	0.551	0.541	-0.010	0.215	0.558	0.565	0.007	0.430
2005 High	0.572	0.571	-0.002	0.840	0.586	0.586	0.000	0.991
Absolute High	0.617	0.607	-0.010	0.332	0.631	0.638	0.007	0.574
Weather								
Prov. Monthly temperature (degree)	25.0	25.1	0.081	0.132	25.9	25.7	-0.222	0.000
Prov. Monthly humidity (%)	75.5	75.1	-0.472	0.000	74.2	74.2	-0.033	0.679
Prov. Monthly amount of rainfall (mm)	112.6	159.3	46.676	0.000	135.9	153.9	18.014	0.000
Prov. Monthly hours of sunshine (hour)	189.8	173.4	-16.339	0.000	179.8	189.7	9.932	0.000
Occupation (=1 if yes; 0 otherwise)								
Currently working	0.558	0.493	-0.065	0.000	0.529	0.557	0.028	0.002
Employment position								
Permanent	0.141	0.110	-0.031	0.000	0.112	0.101	-0.011	0.061
Temporary	0.044	0.067	0.023	0.000	0.077	0.087	0.010	0.075
Self-employed	0.384	0.313	-0.071	0.000	0.332	0.360	0.028	0.002
Family worker	0.004	0.004	0.000	0.673	0.005	0.005	0.000	0.757
Work unit								
State-owned enterprises	0.106	0.090	-0.016	0.001	0.087	0.083	-0.004	0.436
Collective-owned enterprises	0.049	0.025	-0.024	0.000	0.024	0.018	-0.006	0.017
Private enterprises	0.082	0.125	0.043	0.000	0.142	0.163	0.021	0.002
Family contract farming	0.324	0.243	-0.081	0.000	0.260	0.277	0.017	0.035
Education (=1 if yes; 0 otherwise)								
Currently in school	0.171	0.161	-0.010	0.108	0.125	0.090	-0.035	0.000
Educational attainment								
Primary school degree	0.243	0.240	-0.003	0.658	0.197	0.220	0.023	0.002
Low-middle school degree	0.284	0.308	0.024	0.001	0.290	0.317	0.027	0.001
High-middle school degree	0.145	0.174	0.029	0.000	0.185	0.159	-0.026	0.000
College degree or higher	0.033	0.033	0.000	0.830	0.043	0.043	0.000	0.929
Other individual and household								
Household size (unit)	4.017	3.746	-0.271	0.000	3.755	3.759	0.004	0.919
Equivalised real household income (2009 Yuan)	9506.2	11962.9	2456.7	0.000	14051.0	20725.1	6674.1	0.000
Married (=1 if yes; 0 otherwise)	0.616	0.697	0.081	0.000	0.753	0.780	0.027	0.001
Widowed (=1 if yes; 0 otherwise)	0.045	0.062	0.017	0.000	0.067	0.078	0.011	0.017
Divorced (=1 if yes; 0 otherwise)	0.008	0.010	0.002	0.073	0.011	0.014	0.003	0.161
Female (=1 if yes; 0 otherwise)	0.503	0.516	0.013	0.113	0.517	0.508	-0.009	0.307
Age (year)	37.5	44.2	6.673	0.000	47.4	50.7	3.220	0.000
Minority (=1 if yes; 0 otherwise)	0.140	0.148	0.008	0.185	0.140	0.144	0.004	0.600
Rural Hukou (=1 if rural; 0 otherwise)	0.617	0.591	-0.026	0.000	0.610	0.639	0.029	0.002
Currently smoking (=1 if yes; 0 otherwise)	0.236	0.243	0.007	0.290	0.245	0.269	0.024	0.003
Urban residence (=1 if urban; 0 otherwise)	0.317	0.321	0.004	0.592	0.315	0.300	-0.015	0.074

Table 4 continued

Community (unit; 0-10)								
Population density	5.672	5.785	0.113	0.000	5.663	5.824	0.161	0.000
Population diversity	4.518	4.667	0.149	0.000	5.118	5.346	0.228	0.000
Economic condition	4.500	5.761	1.261	0.000	6.346	6.187	-0.159	0.007
Education	3.264	3.306	0.042	0.052	3.354	3.313	-0.041	0.127
Sanitation	5.780	6.368	0.588	0.000	6.525	6.576	0.051	0.352
Health service quality	5.587	5.162	-0.425	0.000	4.899	5.798	0.899	0.000
Social service quality	1.735	2.828	1.093	0.000	3.102	3.305	0.203	0.000
Housing quality	5.895	6.515	0.620	0.000	6.918	7.442	0.524	0.000
Transportation quality	5.659	5.919	0.260	0.000	5.740	5.801	0.061	0.170
Communication quality	4.782	5.682	0.900	0.000	6.085	6.649	0.564	0.000
Traditional market quality	5.896	5.121	-0.775	0.000	4.770	4.664	-0.106	0.129
Modern market quality	4.702	4.727	0.025	0.606	4.551	4.057	-0.494	0.000
Observations	10,495	6,707	17,202	17,202	6,149	5,292	11,441	11,441

Notes: Data are from China Health and Nutrition Survey in 2000, 2004, 2006 and 2009. The study sample consists of a panel of the 2000 cross-section aged between 1-102y over the sample period. Due to sample attrition, sample sizes vary across waves.

Table 5: Correlation between health and attrition status

	(1)	(2)	(3)	(4)
	Self-reported		Doctor-diagnosed	
Variable	Sick	RAC	Sick	RAC
Health status	-0.093***	-0.074**	-0.017	-0.049
	(0.030)	(0.031)	(0.034)	(0.047)
Individual covariates	Y	Y	Y	Y
Community covariates	Y	Y	Y	Y
Weather covariates	Y	Y	Y	Y
Province-specific time trends	Y	Y	Y	Y
Observations	28,603	28,578	28,536	28,536

Notes: Each column corresponds to a probit regression of a non-attriter dummy on the variables listed in the table. The non-attriter dummy is equal to 1 for non-attriters and 0 otherwise. Standard errors are clustered by individual. Sample sizes differ across columns due to missing values in health outcome variables.

Table 6: Tabulation of attrition identifiers by attrition status

	(1)	(2)	(3)	(4)
Variable	Non-attriter	Attriter	Diff. (2)-(1)	P-value
Income imputed in 2000	0.279	0.512	-0.233	0.000
Original sample member in 1989	0.629	0.551	0.078	0.000
Observations	3,698	6,797	10,495	10,495
Fraction of the panel	35%	65%	100%	100%

Notes: It is based on observations in the first sample period.

Table 7: Estimates of the sample selection equation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sick				RAC			
	2000/2005 High/Low		Absolute High/Low		2000/2005 High/Low		Absolute High/Low	
Variable	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI
Panel A: 10th FYP, 2000-2004								
Income imputed in 2000	-0.554***	-0.538***	-0.570***	-0.495***	-0.554***	-0.538***	-0.570***	-0.495***
	(0.030)	(0.030)	(0.041)	(0.042)	(0.030)	(0.030)	(0.041)	(0.042)
Original sampling unit in 1989	0.201***	0.329***	0.280***	0.355***	0.200***	0.326***	0.279***	0.342***
	(0.042)	(0.044)	(0.052)	(0.077)	(0.041)	(0.043)	(0.051)	(0.074)
P-value of test of joint significance	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	10,495	10,495	5,575	5,536	10,495	10,495	5,575	5,536
Panel B: 11th FYP, 2006-2009								
Income imputed in 2000	-0.482***	-0.482***	-0.562***	-0.413***	-0.482***	-0.482***	-0.561***	-0.412***
	(0.029)	(0.029)	(0.040)	(0.041)	(0.029)	(0.029)	(0.040)	(0.041)
Original sampling unit in 1989	-0.015	-0.015	-0.154***	0.218***	-0.003	-0.003	-0.145***	0.221***
	(0.040)	(0.040)	(0.052)	(0.072)	(0.040)	(0.040)	(0.051)	(0.070)
P-value of test of joint significance	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	10,495	10,495	5,575	5,536	10,495	10,495	5,575	5,536
FYP variable	Y	Y	Y	Y	Y	Y	Y	Y
Changes in pre-determined health	Y	Y	Y	Y	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Each column corresponds to a probit regression of a non-attriter dummy on the listed variables in the table. The non-attriter dummy is equal to 1 for sample non-attriters and 0 otherwise. Robust standard errors are reported in parentheses. P-values of test of joint significance of the income imputation and original sample membership indicators are reported in brackets. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 8: Significance of attrition identifiers in the health equation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sick				RAC			
	2000/2005 High/Low		Absolute High/Low		2000/2005 High/Low		Absolute High/Low	
Variable	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI
Panel A: 10th FYP, 2000-2004								
Inverse Mill's ratio	-0.296**	-0.304**	-0.258	-0.179	-0.067	-0.108	-0.031	-0.023
	(0.139)	(0.136)	(0.196)	(0.211)	(0.138)	(0.135)	(0.176)	(0.197)
Income imputed in 2000	0.100*	0.100**	0.097	0.055	0.009	0.024	0.007	0.005
	(0.053)	(0.051)	(0.076)	(0.071)	(0.053)	(0.050)	(0.066)	(0.066)
Original sampling unit in 1989	-0.002	-0.008	-0.010	-0.035	0.044	0.052	0.052	-0.027
	(0.029)	(0.037)	(0.048)	(0.069)	(0.030)	(0.037)	(0.045)	(0.064)
P-value of test of joint significance-change	[0.077]	[0.031]	[0.224]	[0.738]	[0.147]	[0.034]	[0.207]	[0.879]
P-value of test of joint significance-level	{0.985}	{0.953}	{0.411}	{0.915}	{0.683}	{0.567}	{0.609}	{0.582}
Observations	3,698	3,698	2,016	1,996	3,698	3,698	2,016	1,996
Panel B: 11th FYP, 2006-2009								
Inverse Mill's ratio	-0.103	-0.103	-0.049	0.068	-0.099	-0.099	0.020	0.038
	(0.086)	(0.086)	(0.104)	(0.098)	(0.087)	(0.087)	(0.103)	(0.088)
Income imputed in 2000	0.016	0.016	-0.011	-0.056*	0.042	0.042	0.005	-0.035
	(0.032)	(0.032)	(0.043)	(0.033)	(0.032)	(0.032)	(0.044)	(0.031)
Original sampling unit in 1989	0.017	0.017	0.003	0.095*	0.037	0.037	0.028	0.074
	(0.027)	(0.027)	(0.035)	(0.052)	(0.026)	(0.026)	(0.032)	(0.051)
P-value of test of joint significance-change	[0.740]	[0.740]	[0.947]	[0.058]	[0.182]	[0.182]	[0.683]	[0.208]
P-value of test of joint significance-level	{0.000}	{0.000}	{0.004}	{0.000}	{0.000}	{0.000}	{0.012}	{0.009}
Observations	3,698	3,698	2,016	1,996	3,698	3,698	2,016	1,996
FYP variable	Y	Y	Y	Y	Y	Y	Y	Y
Changes in pre-determined health	Y	Y	Y	Y	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Each column corresponds to an Ordinary Least Squares regression of a first-differenced health indicator on the listed variables in the table. Robust standard errors are reported in parentheses. P-values of test of joint significance of income imputation and original sample membership indicators in the first-differenced health equations are reported in brackets. The corresponding p-values in non-differenced health equations are reported in braces. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 9: Balancing test of High/Lows, changes in individual covariates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	10th FYP, 2000-2004				11th FYP, 2006-2009			
	2000 High/Low		Absolute High/Low		2005 High/Low		Absolute High/Low	
Variable	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI
Changes in pre-determined health								
Self-reported sickness	-0.004	-0.004	-0.025**	-0.026**	-0.020**	-0.020**	-0.025**	-0.026**
	(0.008)	(0.008)	(0.011)	(0.011)	(0.008)	(0.008)	(0.011)	(0.011)
Self-reported RAC (Respiratory,Allergic	-0.003	-0.003	-0.020**	-0.020**	-0.015**	-0.015**	-0.020**	-0.020**
and Cardiovascular)	(0.006)	(0.006)	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.008)
Changes in occupation								
Currently working	0.033**	0.010	0.071***	0.056***	0.030*	0.030*	-0.009	-0.009
	(0.015)	(0.015)	(0.021)	(0.021)	(0.016)	(0.016)	(0.022)	(0.022)
Employment position								
Permanent	-0.000	0.008	-0.008	-0.002	0.001	0.001	0.007	0.013
	(0.010)	(0.010)	(0.016)	(0.016)	(0.009)	(0.009)	(0.013)	(0.013)
Temporary	0.013	0.006	0.019	0.015	0.007	0.007	-0.002	-0.004
	(0.009)	(0.009)	(0.014)	(0.013)	(0.010)	(0.010)	(0.016)	(0.015)
Self-employed	0.030**	-0.001	0.081***	0.059***	0.023	0.023	-0.011	-0.015
	(0.014)	(0.014)	(0.020)	(0.020)	(0.016)	(0.016)	(0.022)	(0.021)
Family worker	-0.001	-0.003	-0.002	-0.004	-0.002	-0.002	-0.005	-0.005
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.005)	(0.005)
Work unit								
State-owned enterprises	0.008	0.019**	0.001	0.008	0.001	0.001	0.013	0.013
	(0.009)	(0.009)	(0.013)	(0.013)	(0.007)	(0.007)	(0.010)	(0.010)
Collective-owned enterprises	-0.004	0.003	0.005	0.010	-0.009*	-0.009*	-0.021**	-0.022**
	(0.008)	(0.008)	(0.014)	(0.014)	(0.006)	(0.006)	(0.009)	(0.009)
Private enterprises	0.011	-0.020*	0.007	-0.015	0.001	0.001	-0.010	-0.023
	(0.012)	(0.011)	(0.017)	(0.016)	(0.012)	(0.012)	(0.018)	(0.017)
Family contract farming	0.017	0.011	0.063***	0.060***	0.032**	0.032**	0.004	0.018
	(0.014)	(0.014)	(0.019)	(0.019)	(0.015)	(0.015)	(0.020)	(0.019)
Changes in education								
Currently in school	-0.013	0.005	-0.020*	-0.008	-0.002	-0.002	-0.009	-0.012
	(0.008)	(0.008)	(0.010)	(0.011)	(0.007)	(0.007)	(0.010)	(0.010)
Educational attainment								
Primary school degree	-0.011	0.001	0.000	0.009	-0.010	-0.010	0.028	0.011
	(0.008)	(0.008)	(0.012)	(0.012)	(0.015)	(0.015)	(0.019)	(0.020)
Low-middle school degree	-0.014*	-0.014*	-0.006	-0.007	-0.021	-0.021	-0.043**	-0.031
	(0.007)	(0.007)	(0.011)	(0.011)	(0.014)	(0.014)	(0.019)	(0.019)
High-middle school degree	0.011**	0.006	0.012	0.008	0.022**	0.022**	0.009	0.006
	(0.005)	(0.005)	(0.008)	(0.008)	(0.009)	(0.009)	(0.013)	(0.014)
College degree or higher	-0.004	0.007**	-0.009	-0.001	0.001	0.001	0.002	0.008
	(0.003)	(0.003)	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)	(0.007)
Changes in other individual covariates								
Household size	0.081**	0.079**	-0.024	-0.025	0.002	0.002	0.044	0.027
	(0.034)	(0.034)	(0.043)	(0.043)	(0.044)	(0.044)	(0.054)	(0.053)
Equivalised real household income	382	1,003***	2,603***	3,073***	1,557**	1,557**	2,029**	2,737***
	(375)	(374)	(566)	(569)	(705)	(705)	(918)	(991)
Married	0.003	0.008	-0.024*	-0.020	0.002	0.002	0.007	0.004
	(0.008)	(0.008)	(0.012)	(0.012)	(0.006)	(0.006)	(0.009)	(0.009)
Widowed	0.002	-0.005	0.005	-0.000	-0.002	-0.002	-0.004	-0.000
	(0.004)	(0.004)	(0.007)	(0.006)	(0.005)	(0.005)	(0.008)	(0.008)
Divorced	-0.000	-0.002	-0.004	-0.006	-0.005	-0.005	-0.002	-0.002
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
Rural Hukou	-0.013	-0.002	-0.023	-0.015	-0.019**	-0.019**	-0.035***	-0.024**
	(0.010)	(0.010)	(0.015)	(0.014)	(0.009)	(0.009)	(0.013)	(0.012)
Currently smoking	0.017*	0.011	0.013	0.009	0.004	0.004	0.022	0.017
	(0.010)	(0.010)	(0.014)	(0.015)	(0.011)	(0.011)	(0.014)	(0.015)
Observations	3,698	3,698	2,016	1,996	3,698	3,698	2,016	1,996

Notes: It is based on the subsample of non-attriters. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 10: Balancing test of High/Lows, changes in community covariates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	10th FYP, 2000-2004				11th FYP, 2006-2009			
	2000 High/Low		Absolute High/Low		2005 High/Low		Absolute High/Low	
Variable	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI
Changes in community characteristics								
Population density	-0.121	-0.027	-0.040	0.031	0.240	0.240	0.234	0.434*
	(0.112)	(0.113)	(0.171)	(0.126)	(0.180)	(0.180)	(0.182)	(0.245)
Population diversity	-0.013	-0.087	0.023	-0.034	-0.109	-0.109	-0.195	-0.242
	(0.148)	(0.148)	(0.232)	(0.213)	(0.156)	(0.156)	(0.227)	(0.219)
Economic condition	-0.722	-0.457	-0.359	-0.158	-0.548	-0.548	-0.871	-0.617
	(0.504)	(0.507)	(0.718)	(0.733)	(0.494)	(0.494)	(0.667)	(0.670)
Education	-0.059	0.046	-0.213*	-0.130	0.094	0.094	0.067	-0.004
	(0.083)	(0.084)	(0.125)	(0.121)	(0.096)	(0.096)	(0.136)	(0.146)
Sanitation	-0.071	0.290	-0.370	-0.087	-0.119	-0.119	0.560	0.392
	(0.281)	(0.280)	(0.379)	(0.415)	(0.269)	(0.269)	(0.393)	(0.377)
Health service quality	0.374	0.659	0.371	0.585	0.999**	0.999**	0.773	1.045*
	(0.444)	(0.441)	(0.553)	(0.509)	(0.477)	(0.477)	(0.553)	(0.585)
Social service quality	0.172	-0.922*	0.451	-0.393	-1.168*	-1.168*	-0.524	-0.611
	(0.498)	(0.490)	(0.707)	(0.654)	(0.630)	(0.630)	(0.997)	(0.931)
Housing quality	-0.002	0.002	-0.414	-0.407	-0.294	-0.294	-0.546	-0.617*
	(0.189)	(0.189)	(0.277)	(0.267)	(0.223)	(0.223)	(0.345)	(0.330)
Transportation quality	0.463	-0.764	0.619	-0.339	0.153	0.153	-0.968	-0.509
	(0.525)	(0.523)	(0.673)	(0.754)	(0.534)	(0.534)	(0.758)	(0.797)
Communication quality	-0.433*	-0.705***	-0.634*	-0.835**	-0.221	-0.221	0.114	0.410
	(0.244)	(0.238)	(0.342)	(0.337)	(0.239)	(0.239)	(0.345)	(0.348)
Traditional market quality	0.085	0.369	1.333	1.555	-2.253***	-2.253***	-3.492***	-3.486***
	(0.721)	(0.721)	(1.063)	(1.077)	(0.601)	(0.601)	(0.804)	(0.786)
Modern market quality	0.058	-0.203	0.098	-0.105	-1.364***	-1.364***	-1.545**	-1.794***
	(0.603)	(0.604)	(0.860)	(0.874)	(0.430)	(0.430)	(0.589)	(0.575)
Observations	105	105	56	57	105	105	56	57

Notes: It is based on the subsample of non-attriters. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 11: Health impact of the 10^{th} and 11^{th} FYPs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sick				RAC			
	2000/2005		Absolute		2000/2005		Absolute	
Variable	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI
Panel A: 10th FYP, 2000-2004								
High	0.058***	-0.013	0.109***	0.062*	0.061***	-0.005	0.085***	0.087**
	(0.016)	(0.017)	(0.034)	(0.035)	(0.015)	(0.016)	(0.031)	(0.036)
High - OLS	0.063***	-0.005	0.120***	0.073**	0.065***	0.002	0.097***	0.086***
	(0.015)	(0.016)	(0.031)	(0.028)	(0.015)	(0.016)	(0.030)	(0.027)
Wald test of indep. eqns.	[0.059]	[0.017]	[0.416]	[0.586]	[0.050]	[0.007]	[0.281]	[0.968]
Observations	10,495	10,495	5,575	5,536	10,495	10,495	5,575	5,536
Panel B: 11th FYP, 2006-2009								
High	0.025	0.025	0.106***	0.127***	0.046**	0.046**	0.058*	0.069**
	(0.021)	(0.021)	(0.032)	(0.031)	(0.020)	(0.020)	(0.034)	(0.030)
High - OLS	0.030	0.030	0.097***	0.117***	0.047**	0.047**	0.067**	0.055*
	(0.021)	(0.021)	(0.031)	(0.030)	(0.020)	(0.020)	(0.031)	(0.029)
Wald test of indep. eqns.	[0.138]	[0.138]	[0.210]	[0.317]	[0.838]	[0.838]	[0.582]	[0.281]
Observations	10,495	10,495	5,575	5,536	10,495	10,495	5,575	5,536
Changes in pre-determined health	Y	Y	Y	Y	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Results are obtained by estimating the sample selection model described in the text by maximum likelihood. Robust standard errors are reported in parentheses. P-values of test of no sample selection bias are reported in brackets. Sample sizes differ by the composition of High and Low provinces. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 12: Health impact of the 10th and 11th FYPs – matched sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sick				RAC			
	2000/2005		Absolute		2000/2005		Absolute	
Variable	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI	PAPI	High PAPI
Panel A: 10th FYP, 2000-2004								
(1) High - Matched, 0.01	0.053***	-0.040*	0.137	-0.013	0.030	-0.006	0.100	0.065
	(0.020)	(0.021)	(0.088)	(0.068)	(0.019)	(0.021)	(0.066)	(0.089)
Wald test of indep. eqns.	[0.044]	[0.009]	[0.910]	[0.477]	[0.005]	[0.018]	[0.277]	[0.891]
Observations	9,716	9,554	4,687	4,747	9,750	9,569	4,782	4,730
(2) High - Matched, 0.005	0.052***	-0.040*	0.102	-0.054	0.029	-0.007	0.109	0.063
	(0.020)	(0.021)	(0.090)	(0.066)	(0.019)	(0.021)	(0.071)	(0.078)
Wald test of indep. eqns.	[0.049]	[0.008]	[0.739]	[0.049]	[0.004]	[0.014]	[0.540]	[0.818]
Observations	9,703	9,541	4,548	4,521	9,738	9,555	4,598	4,500
(3) High - Matched, 0.001	0.048**	-0.039*	0.100	0.062	0.028	-0.005	0.076	0.083
	(0.020)	(0.022)	(0.119)	(0.086)	(0.019)	(0.021)	(0.092)	(0.122)
Wald test of indep. eqns.	[0.030]	[0.021]	[0.405]	[0.346]	[0.003]	[0.019]	[0.479]	[0.913]
Observations	9,600	9,338	3,935	3,919	9,626	9,340	3,919	3,894
Panel B: 11th FYP, 2006-2009								
(1) High - Matched, 0.01	0.013	0.013	0.015	0.030	0.060*	0.060*	0.222*	0.019
	(0.030)	(0.030)	(0.089)	(0.089)	(0.032)	(0.032)	(0.130)	(0.131)
Wald test of indep. eqns.	[0.361]	[0.361]	[0.375]	[0.478]	[0.732]	[0.732]	[0.543]	[0.562]
Observations	9,633	9,633	4,687	4,747	9,656	9,656	4,782	4,730
(2) High - Matched, 0.005	0.013	0.013	0.020	-0.038	0.062*	0.062*	0.140*	0.006
	(0.030)	(0.030)	(0.113)	(0.070)	(0.033)	(0.033)	(0.077)	(0.100)
Wald test of indep. eqns.	[0.343]	[0.343]	[0.603]	[0.011]	[0.769]	[0.769]	[0.693]	[0.338]
Observations	9,584	9,584	4,548	4,521	9,608	9,608	4,598	4,500
(3) High - Matched, 0.001	-0.008	-0.008	0.152*	0.096	0.064	0.064	0.314***	0.011
	(0.039)	(0.039)	(0.082)	(0.066)	(0.045)	(0.045)	(0.079)	(0.083)
Wald test of indep. eqns.	[0.153]	[0.153]	[0.951]	[0.951]	[0.857]	[0.857]	[0.415]	[0.006]
Observations	9,123	9,123	3,935	3,919	9,123	9,123	3,919	3,894
Changes in pre-determined health	Y	Y	Y	Y	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Results are obtained by estimating the sample selection model described in the text by maximum likelihood. Robust standard errors are reported in parentheses. P-values of test of no sample selection bias are reported in brackets. Sample sizes differ by the composition of High and Low provinces. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005. Each non-attriter in High provinces is matched to his/her nearest single counterpart in Low provinces based on a propensity score, which is the predicted probability of being treated from a probit regression of a High/Low indicator on changes in individual and community covariates. In each panel, three sets of results are displayed, varying by how the nearest single control is defined (i.e. within 0.01, 0.005 or 0.001 points of the estimated propensity score of the treated subject).

Table 13: Health impact of the 10th and 11th FYP – other health outcome variables

	(1)	(2)	(3)	(4)
	2000/2005		Absolute	
Variable	PAPI	High PAPI	PAPI	High PAPI
Panel A: 10th FYP, 2000-2004				
(1) High - Sick, diagnosed	0.046***	0.014	0.208***	0.192***
	(0.013)	(0.014)	(0.028)	(0.026)
Wald test of indep. eqns.	[0.935]	[0.653]	[0.000]	[0.000]
(2) High - RAC, diagnosed	0.036***	0.042***	0.118***	0.131***
	(0.009)	(0.010)	(0.019)	(0.018)
Wald test of indep. eqns.	[0.001]	[0.000]	[0.000]	[0.000]
(3) High - Long-term cardiovascular illness	-0.004	-0.014	-0.000	0.004
	(0.011)	(0.012)	(0.024)	(0.023)
Wald test of indep. eqns.	[0.000]	[0.001]	[0.000]	[0.000]
Observations	10,495	10,495	5,575	5,536
Panel B: 11th FYP, 2006-2009				
(1) High - Sick, diagnosed	0.011	0.011	0.044	0.065**
	(0.019)	(0.019)	(0.029)	(0.028)
Wald test of indep. eqns.	[0.056]	[0.056]	[0.218]	[0.346]
(2) High - RAC, diagnosed	0.025*	0.025*	0.016	0.039**
	(0.013)	(0.013)	(0.022)	(0.020)
Wald test of indep. eqns.	[0.729]	[0.729]	[0.748]	[0.885]
(3) High - Long-term cardiovascular illness	0.026*	0.026*	0.038	0.042*
	(0.014)	(0.014)	(0.023)	(0.022)
Wald test of indep. eqns.	[0.041]	[0.041]	[0.012]	[0.013]
Observations	10,495	10,495	5,575	5,536
Changes in pre-determined health	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y

Notes: Results are obtained by estimating the sample selection model described in the text by maximum likelihood. Robust standard errors are reported in parentheses. P-values of test of no sample selection bias are reported in brackets. Sample sizes differ by the composition of High and Low provinces. 2000 High/Low provinces are those with above/below median average PAPIs or PAPI bites in 2000. 2005 High/Low provinces are defined similarly. Absolute High/Low provinces are those with above/below median average PAPIs or PAPI bites in both 2000 and 2005.

Table 14: Health impact of the 10th and 11th FYPs – other FYP toughness measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	PAPI-Avg.		High PAPI-Avg.		PAPI,7-12		High PAPI,7-12		SO2 (µg/m³)		Quota	PHH-Daily		PHH-Annual	
	0/5	Abs.	0/5	Abs.	0/5	Abs.	0/5	Abs.	0/5	Abs.	5	0/5	Abs.	0/5	Abs.
Panel A: 10th FYP, 2000-2004															
(1) High - Sick	0.035*	0.075**	0.020	0.081***	0.058***	-0.032	0.065***	0.098***	0.026*	-0.029		0.026*	-0.029	0.026*	-0.029
	(0.020)	(0.030)	(0.016)	(0.026)	(0.016)	(0.049)	(0.017)	(0.023)	(0.015)	(0.029)		(0.015)	(0.029)	(0.015)	(0.029)
Wald test of indep. eqns.	[0.024]	[0.165]	[0.017]	[0.669]	[0.059]	[0.126]	[0.049]	[0.443]	[0.034]	[0.761]		[0.034]	[0.761]	[0.034]	[0.761]
Observations	10,495	6,729	10,495	6,799	10,495	3,317	10,495	7,992	10,495	5,865		10,495	5,865	10,495	5,865
(2) High - RAC	0.048***	0.075***	0.022	0.084***	0.061***	-0.035	0.069***	0.088***	0.022	-0.016		0.022	-0.016	0.022	-0.016
	(0.019)	(0.027)	(0.015)	(0.025)	(0.015)	(0.048)	(0.016)	(0.022)	(0.015)	(0.026)		(0.015)	(0.026)	(0.015)	(0.026)
Wald test of indep. eqns.	[0.017]	[0.096]	[0.008]	[0.746]	[0.050]	[0.035]	[0.033]	[0.146]	0.026	0.479		[0.026]	[0.479]	[0.026]	[0.479]
Observations	10,495	6,729	10,495	6,799	10,495	3,317	10,495	7,992	10,495	5,865		10,495	5,865	10,495	5,865
Panel B: 11th FYP, 2006-2009															
(1) High - Sick	0.025	0.113***	0.025	0.075***	-0.068***	0.029	0.025	0.055**	-0.018	0.001	0.046**	-0.018	0.001	-0.018	0.001
	(0.021)	(0.029)	(0.021)	(0.027)	(0.020)	(0.051)	(0.021)	(0.026)	(0.021)	(0.035)	(0.021)	(0.021)	(0.035)	(0.021)	(0.035)
Wald test of indep. eqns.	[0.138]	[0.150]	[0.138]	[0.193]	[0.107]	[0.184]	[0.138]	[0.168]	[0.107]	[0.863]	[0.154]	[0.107]	[0.863]	[0.107]	[0.863]
Observations	10,495	6,729	10,495	6,799	10,495	3,317	10,495	7,992	10,495	5,865	10,495	10,495	5,865	10,495	5,865
(2) High - RAC	0.046**	0.075***	0.046**	0.049*	-0.029	0.048	0.046**	0.053**	-0.033	-0.022	0.038*	-0.033	-0.022	-0.033	-0.022
	(0.020)	(0.028)	(0.020)	(0.026)	(0.019)	(0.046)	(0.020)	(0.024)	(0.023)	(0.049)	(0.021)	(0.023)	(0.049)	(0.023)	(0.049)
Wald test of indep. eqns.	[0.838]	[0.522]	[0.838]	[0.130]	[0.666]	[0.833]	[0.838]	[0.386]	0.700	0.865	[0.768]	[0.700]	[0.865]	[0.700]	[0.865]
Observations	10,495	6,729	10,495	6,799	10,495	3,317	10,495	7,992	10,495	5,865	10,495	10,495	5,865	10,495	5,865
Changes in pre-determined health	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Results are obtained by estimating the sample selection model described in the text by maximum likelihood. Robust standard errors are reported in parentheses. P-values of test of no sample selection bias are reported in brackets. Sample sizes differ by the composition of High and Low provinces.Provinces are first divided into High/Low by the mean of their base year PAPIs in Columns 1-2 and PAPI bites in Columns 3-4. Columns 5-8 next restrict the time window for calculating average PAPI and PAPI bite to the sampling months, i.e. July to December. The next two columns then replace average PAPI and PAPI bite by annual SO_2concentration extracted from the API data. The next column directly use absolute pollution reduction quotas prescribed by the 11th FYP to indicate FYP regulatory status. The last 4 columns define FYP toughness measures by environmental health risks associated with base year pollution levels. Province Health Hazard (PHH) is the ratio of province base year SO_2 concentrations to the SO_2 concentration thresholds recommended by China or international air quality guidelines. The higher the PHH the higher the environmental health risks and hence FYP regulatory pressure. Although this analysis attempted to distinguish between SO_2 standards common in developed countries (i.e. WHO, EU, US and Japan) and those in developing countries (i.e. Brazil, Mexico, South Africa, India and China), SO_2 levels in this study sample far exceed all the thresholds, leading to no variation in province treatment status determined by PHHs that are constructed from various guidelines.

Table 15: Health impact of the 10th and 11th FYPs – city residents

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Months 1-12		Months 7-12		SO2	CHH	
	API	High API	API	High API	(µg/m³)	Daily	Annual
Panel A: 10th FYP, 2000-2004							
(1) CHigh - Sick	0.005	0.082	0.005	0.152***	0.024	0.024	0.024
	(0.055)	(0.055)	(0.055)	(0.055)	(0.050)	(0.050)	(0.050)
Wald test of indep. eqns.	[0.095]	[0.107]	[0.095]	[0.195]	[0.476]	[0.476]	[0.476]
(2) CHigh - RAC	-0.012	0.061	-0.012	0.101*	0.072	0.072	0.072
	(0.055)	(0.055)	(0.055)	(0.054)	(0.051)	(0.051)	(0.051)
Wald test of indep. eqns.	[0.134]	[0.161]	[0.134]	[0.145]	[0.485]	[0.485]	[0.485]
Observations	1,803	1,803	1,803	1,803	1,803	1,803	1,803
Panel B: 11th FYP, 2006-2009							
(1) CHigh - Sick	0.000	0.021	-0.077	-0.009	-0.005	-0.005	-0.005
	(0.075)	(0.067)	(0.080)	(0.074)	(0.089)	(0.089)	(0.089)
Wald test of indep. eqns.	[0.296]	[0.158]	[0.125]	[0.215]	[0.146]	[0.146]	[0.146]
(2) CHigh - RAC	0.065	0.073	0.027	0.065	0.035	0.035	0.035
	(0.075)	(0.075)	(0.081)	(0.082)	(0.082)	(0.082)	(0.082)
Wald test of indep. eqns.	[0.846]	[0.769]	[0.569]	[0.839]	[0.636]	[0.636]	[0.636]
Observations	1,803	1,803	1,803	1,803	1,803	1,803	1,803
Changes in pre-determined health	Y	Y	Y	Y	Y	Y	Y
Changes in individual covariates	Y	Y	Y	Y	Y	Y	Y
Changes in community covariates	Y	Y	Y	Y	Y	Y	Y
Changes in weather covariates	Y	Y	Y	Y	Y	Y	Y

Notes: Results are obtained by estimating the sample selection model described in the text by maximum likelihood. Robust standard errors are reported in parentheses. P-values of test of no sample selection bias are reported in brackets. Cities are first divided into High/Low by the median of their base year APIs in Columns 1-2 and API bites in Columns 3-4. Columns 5-8 next restrict the time window for calculating average API and API bite to the sampling months, i.e. July to December. The next column then replaces average API and API bite by annual SO_2 concentration extracted from the API data. The last 2 columns define FYP toughness measures by environmental health risks associated with base year pollution levels. City Health Hazard (CHH) is the ratio of city base year SO_2 concentrations to the SO_2 concentration thresholds recommended by China or international air quality guidelines. The higher the CHH the higher the environmental health risks and hence FYP regulatory pressure. Although this analysis attempted to distinguish between SO_2 standards common in developed countries (i.e. WHO, EU, US and Japan) and those in developing countries (i.e. Brazil, Mexico, South Africa, India and China), SO_2 levels in this study sample far exceed all the thresholds, leading to no variation in province treatment status determined by CHHs that are constructed from various guidelines.

Figures 1-3: Distribution of monthly average PAPIs

Figure 1A: 2000 High/Low, 2001

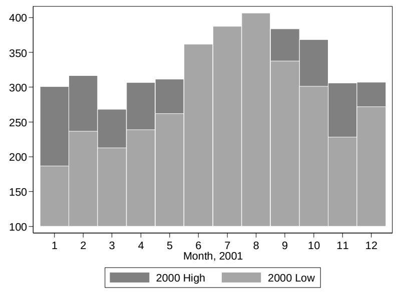


Figure 1B: 2000 High/Low, 2004

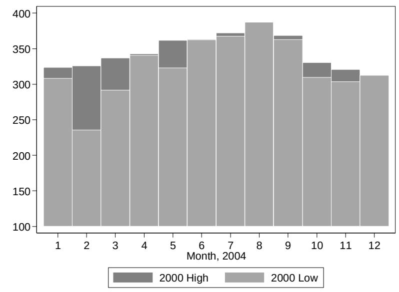


Figure 2A: 2005 High/Low, 2006

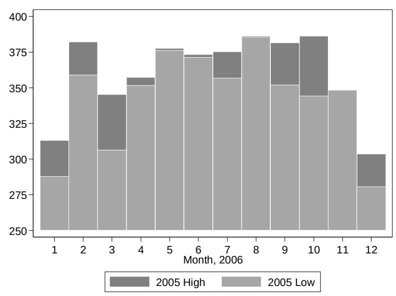


Figure 2B: 2005 High/Low, 2009

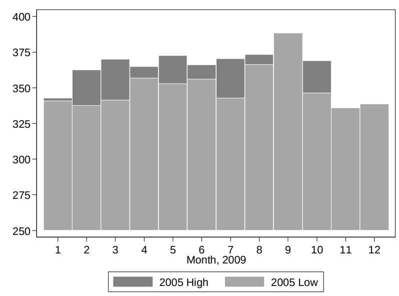


Figure 3A: Absolute High/Low, 2001

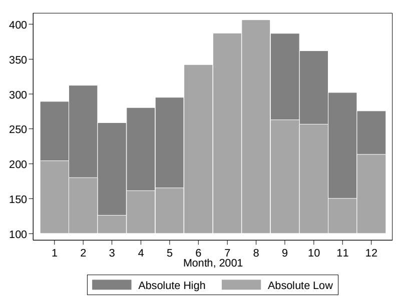


Figure 3B: Absolute High/Low, 2004

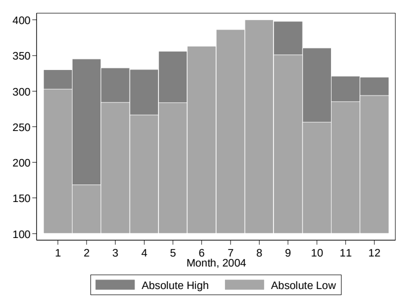


Figure 3C: Absolute High/Low, 2006

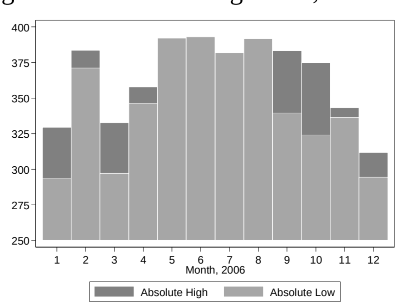
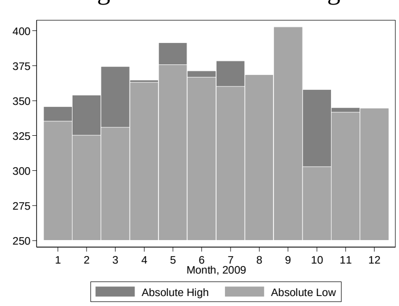


Figure 3D: Absolute High/Low, 2009



Notes: Data are from China Ministry of Environmental protection. Because PAPI data are not available before June in 2000, wave 2001 instead of wave 2000 is used as the control period for the 10th FYP (i.e. 2001 V.S. 2004).

Figures 4-5: Changes in polluting activities and predicted PAPIs

Figure 4A: 2000 High/Low, activity

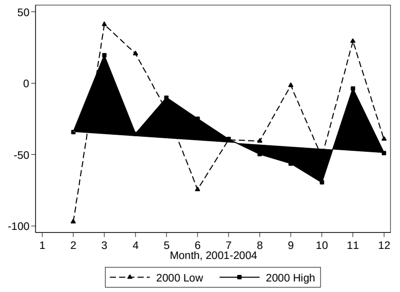


Figure 4B: 2000 High/Low, predicted PAPI

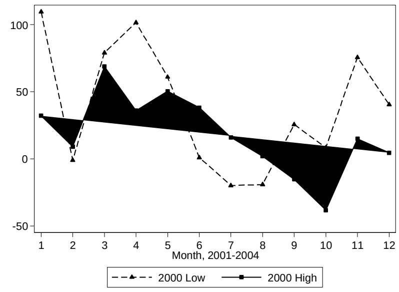


Figure 4C: Absolute High/Low-10th, activity

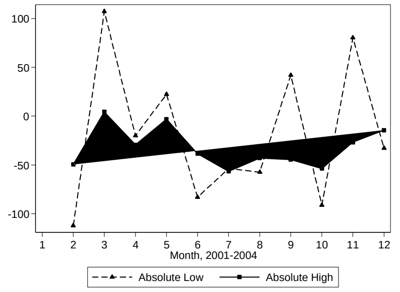


Figure 4D: Absolute High/Low-11th, predicted PAPI

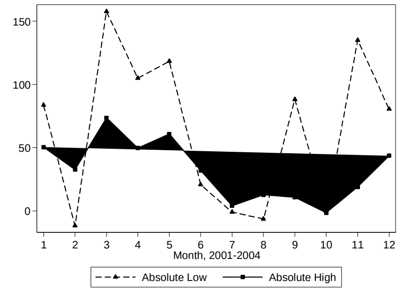


Figure 5A: 2005 High/Low, activity

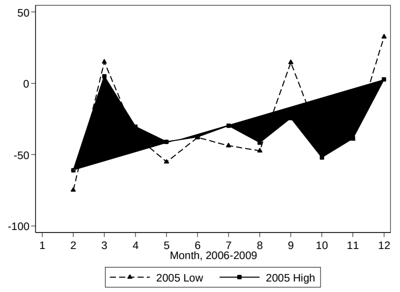


Figure 5B: 2005 High/Low, predicted PAPI

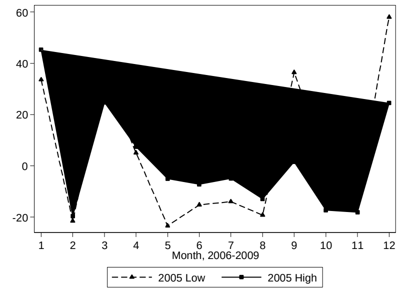


Figure 5C: Absolute High/Low-11th, activity

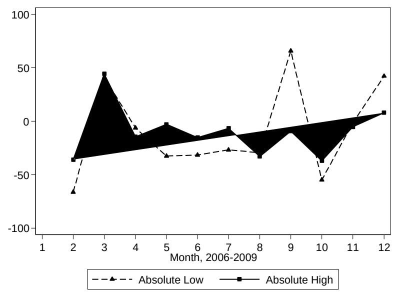
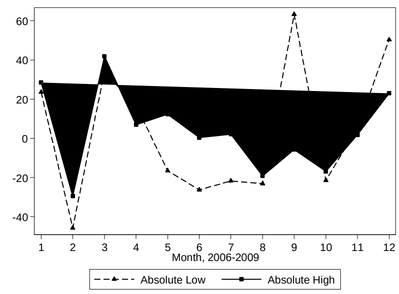


Figure 5D: Absolute High/Low-11th, predicted PAPI



Notes: These plots are based on monthly coefficients and predicted values from Columns 1 and 3 in Table A2. Because PAPI data are not available before June in 2000, wave 2001 instead of wave 2000 is used as the control period for the 10th FYP.

Appendix A: Supplementary Tables

Table A1: Air quality guidelines

Source	SO2 (µg/m³)		PM10 (µg/m³)	
	Annual	24-hour	Annual	24-hour
WHO		20	20	50
European Union		125	40	50
United States	78	366	50	150
California		105	20	50
Japan		105		100
Brazil	80	365	50	150
Mexico	78	341	50	120
South Africa	50	125	60	180
India (Sensitive populations/Residential/Industrial)	15/60/80	30/80/120	50/60/120	
China (Class I/II/III)	20/60/100	50/150/250	40/100/150	50/150/250

Table A2: Estimates for monthly cycles of polluting activities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	10th FYP, 2001-2004				11th FYP, 2006-2009			
Variable	2000		Absolute		2005		Absolute	
Monthly PAPI, lag 1	0.542***	0.480***	0.423***	0.286***	0.355***	0.340***	0.291***	0.273***
	(0.035)	(0.043)	(0.084)	(0.097)	(0.042)	(0.046)	(0.089)	(0.093)
Monthly PAPI, lag 2		0.118***		0.325***		0.063		0.093
		(0.042)		(0.096)		(0.043)		(0.095)
Month 2	5.748	23.069	-78.146**	-35.513	66.605***	67.869***	67.598***	72.709***
	(22.984)	(23.917)	(31.609)	(33.836)	(12.676)	(12.714)	(18.452)	(19.669)
Month 3	-37.647*	-27.348	-126.586***	-111.965***	-22.412*	-18.946	-33.022	-29.689
	(22.136)	(22.726)	(28.824)	(28.834)	(13.216)	(13.358)	(21.440)	(22.031)
Month 4	17.832	19.651	-69.249**	-54.097	39.974***	37.920***	47.247**	41.049*
	(23.618)	(23.575)	(33.721)	(33.654)	(13.494)	(13.436)	(23.488)	(23.817)
Month 5	24.532	29.340	-90.877***	-49.196	45.744***	47.706***	80.518***	81.160***
	(23.908)	(23.837)	(34.993)	(35.986)	(12.692)	(12.843)	(23.709)	(23.759)
Month 6	119.865***	122.378***	81.369**	112.203***	29.135**	28.661**	73.855***	69.667***
	(23.433)	(23.575)	(34.114)	(34.545)	(12.897)	(12.870)	(26.359)	(26.328)
Month 7	88.584***	92.982***	47.238	105.307***	23.190*	20.669	66.647**	57.886**
	(22.698)	(22.777)	(38.533)	(39.812)	(13.534)	(13.480)	(27.715)	(28.393)
Month 8	82.725***	78.456***	46.522	51.292	55.451***	52.919***	80.762***	71.061**
	(20.659)	(20.599)	(34.759)	(34.747)	(12.978)	(12.981)	(28.766)	(29.657)
Month 9	-4.474	-10.160	-109.066**	-115.157***	6.934	6.458	10.872	4.165
	(24.498)	(24.476)	(42.597)	(42.530)	(13.824)	(13.803)	(26.740)	(27.168)
Month 10	0.394	-9.690	-42.782	-79.645**	12.746	9.992	13.660	5.507
	(23.634)	(23.600)	(35.155)	(37.214)	(13.693)	(13.682)	(22.925)	(23.620)
Month 11	-56.024**	-59.735***	-134.223***	-127.894***	24.485*	23.726*	18.390	16.725
	(22.830)	(22.658)	(31.811)	(31.999)	(12.828)	(12.790)	(20.643)	(20.551)
Month 12	20.072	18.510	-14.562	-25.476	-40.185**	-40.522**	-33.326	-32.467
	(21.150)	(21.141)	(31.593)	(31.878)	(16.252)	(16.220)	(24.654)	(24.762)
Post*Month 2	-97.090***	-105.757***	-112.247***	-118.382***	-74.919***	-72.352***	-66.432***	-63.704***
	(29.468)	(29.381)	(39.980)	(39.911)	(16.612)	(16.695)	(24.220)	(24.298)
Post*Month 3	41.158	26.231	107.141***	69.206*	14.978	11.784	41.068*	38.115
	(26.936)	(27.325)	(35.795)	(36.795)	(16.306)	(16.391)	(23.962)	(24.464)
Post*Month 4	20.769	24.288	-20.083	3.001	-36.584**	-33.996**	-6.234	1.023
	(25.585)	(25.379)	(41.737)	(42.680)	(15.499)	(15.486)	(22.926)	(23.432)
Post*Month 5	-19.100	-22.686	22.392	-20.125	-55.138***	-56.568***	-32.616*	-33.413*
	(25.108)	(24.876)	(39.637)	(40.755)	(13.938)	(14.011)	(19.430)	(19.524)
Post*Month 6	-74.510***	-82.959***	-82.965**	-105.881***	-38.043***	-38.091***	-31.690*	-31.196*
	(20.627)	(20.938)	(32.421)	(32.553)	(12.883)	(12.872)	(17.485)	(17.450)
Post*Month 7	-39.620**	-46.854***	-53.768**	-97.497***	-43.741***	-41.840***	-26.867*	-24.323
	(17.703)	(17.693)	(26.796)	(27.719)	(12.619)	(12.486)	(15.554)	(15.335)

Table A2 continued

Post*Month 8	-40.561**	-42.403***	-57.427**	-70.405***	-47.312***	-45.852***	-29.509*	-25.747
	(15.874)	(15.882)	(23.167)	(23.214)	(12.153)	(12.083)	(17.028)	(16.717)
Post*Month 9	-1.523	-0.428	41.866	34.637	14.569	15.535	65.859***	68.563***
	(22.623)	(22.620)	(35.441)	(35.056)	(14.207)	(14.162)	(20.682)	(20.597)
Post*Month 10	-51.916**	-48.904**	-91.092***	-80.668**	-42.072**	-39.694**	-54.986**	-49.823*
	(23.299)	(23.350)	(34.768)	(35.053)	(16.922)	(16.931)	(25.554)	(25.590)
Post*Month 11	29.470	27.008	80.219**	46.962	-39.086**	-41.107**	-1.398	-5.447
	(23.990)	(23.919)	(32.547)	(34.030)	(16.355)	(16.413)	(23.271)	(24.072)
Post*Month 12	-39.170	-36.584	-32.777	-17.149	32.658*	33.016*	42.163	46.119*
	(23.903)	(23.932)	(36.635)	(37.270)	(19.403)	(19.387)	(28.319)	(28.015)
High*Month 2	13.631	2.792	106.187***	79.975**	-1.369	-0.194	-13.546	-19.868
	(25.123)	(25.589)	(33.037)	(34.054)	(14.695)	(14.669)	(19.801)	(21.146)
High*Month 3	12.150	6.452	74.534**	90.539***	14.132	13.700	18.669	14.587
	(23.761)	(24.088)	(30.248)	(30.844)	(17.339)	(17.320)	(23.022)	(23.462)
High*Month 4	21.596	18.948	42.786	47.608	-28.059*	-27.747*	-10.470	-12.162
	(23.919)	(23.893)	(34.156)	(34.039)	(16.098)	(16.054)	(22.536)	(22.687)
High*Month 5	9.327	9.926	62.948*	64.422**	-20.497	-21.887	-19.598	-24.422
	(23.155)	(22.984)	(32.818)	(32.828)	(13.659)	(13.733)	(18.043)	(19.074)
High*Month 6	-64.332***	-65.664***	-86.707***	-80.305***	-11.599	-11.296	-16.194	-19.329
	(20.707)	(20.814)	(31.101)	(31.080)	(12.796)	(12.762)	(18.036)	(18.567)
High*Month 7	-9.646	-13.384	-3.579	-25.068	0.016	0.705	13.330	11.520
	(17.879)	(17.969)	(30.191)	(30.173)	(12.655)	(12.588)	(17.515)	(17.740)
High*Month 8	-30.361*	-24.457	-37.279	-9.468	-21.959*	-21.151*	9.662	9.174
	(16.733)	(16.695)	(27.354)	(28.176)	(12.054)	(12.000)	(16.641)	(16.672)
High*Month 9	70.741***	75.507***	147.419***	166.083***	17.824	16.918	60.100***	57.723***
	(22.181)	(22.139)	(37.171)	(37.326)	(14.425)	(14.508)	(21.516)	(21.723)
High*Month 10	30.651	42.415*	49.804	106.355***	21.252	21.949	41.613**	40.604*
	(22.876)	(22.888)	(33.757)	(37.465)	(14.512)	(14.490)	(20.924)	(21.014)
High*Month 11	33.827	36.083	106.295***	104.591***	-28.558*	-29.380*	-5.595	-10.554
	(24.515)	(24.417)	(32.487)	(32.651)	(15.543)	(15.555)	(20.950)	(21.659)
High*Month 12	-8.895	-8.677	-1.524	9.403	16.220	13.780	17.119	10.950
	(23.274)	(23.222)	(33.414)	(33.630)	(19.660)	(19.744)	(26.482)	(27.657)
High*Post*Month 2	62.907**	71.159**	62.686	80.780**	13.818	10.712	30.503	28.228
	(30.209)	(30.158)	(38.838)	(39.038)	(16.265)	(16.397)	(23.080)	(23.309)
High*Post*Month 3	-21.567	-8.803	-102.822***	-78.071**	-10.069	-8.811	3.254	5.755
	(27.583)	(27.847)	(35.578)	(36.329)	(17.902)	(17.872)	(24.510)	(24.616)
High*Post*Month 4	-56.274**	-57.944**	-9.333	-38.062	6.153	5.572	-8.333	-10.706
	(26.057)	(25.837)	(39.727)	(40.512)	(16.106)	(16.086)	(22.911)	(23.016)
High*Post*Month 5	8.955	6.425	-25.525	-7.467	14.122	14.862	29.712*	28.411*
	(25.003)	(24.896)	(37.728)	(37.938)	(12.904)	(12.896)	(16.199)	(16.281)
High*Post*Month 6	49.629***	56.122***	44.485	53.503*	0.382	0.500	16.471	17.082
	(18.718)	(19.016)	(28.441)	(28.318)	(10.978)	(10.985)	(15.867)	(15.923)
High*Post*Month 7	0.470	4.510	-2.898	18.371	14.007	12.697	20.163*	18.569
	(13.126)	(13.125)	(18.350)	(18.464)	(9.617)	(9.538)	(11.228)	(11.326)
High*Post*Month 8	-9.202	-10.863	14.500	12.617	5.759	5.328	-3.512	-5.321
	(10.843)	(10.857)	(15.530)	(15.456)	(8.821)	(8.788)	(12.674)	(12.712)
High*Post*Month 9	-54.775***	-58.208***	-86.368***	-84.267***	-38.885***	-39.100***	-75.197***	-76.679***
	(19.150)	(19.198)	(30.571)	(30.236)	(11.338)	(11.363)	(17.197)	(17.310)
High*Post*Month 10	-17.605	-23.009	37.342	19.441	-9.873	-10.526	17.950	17.337
	(21.880)	(21.936)	(32.392)	(32.768)	(15.612)	(15.628)	(25.056)	(25.066)
High*Post*Month 11	-33.177	-31.765	-106.991***	-83.410**	0.459	2.475	-3.965	2.626
	(24.556)	(24.495)	(32.744)	(33.913)	(17.841)	(17.863)	(22.937)	(23.949)
High*Post*Month 12	-9.796	-7.741	18.302	0.633	-29.873	-28.821	-34.194	-34.064
	(24.029)	(23.897)	(35.155)	(35.661)	(21.663)	(21.679)	(29.398)	(29.391)
Constant	109.451***	88.371***	239.209***	175.575***	234.787***	213.989***	323.844***	288.712***
	(31.518)	(32.112)	(46.004)	(48.944)	(23.618)	(26.438)	(39.250)	(52.886)
Observations	6,579	6,579	3,655	3,655	6,561	6,561	3,645	3,645
R-squared	0.165	0.166	0.242	0.245	0.093	0.093	0.100	0.100

Appendix B: City Identification

Each province in China Health and Nutrition Survey (CHNS) has two sampling cities in every wave. The two sampling cities are called City 1 and City 2.

Two variables are used to identify the cities – city total population and land area. Within the sample (or CHNS), the population variable is available from 2000-2009, but the land area variable is missing in 2000. Also, population information is missing for City 1 in one province in 2000, and land area information is not observed for City 1 in one province in 2004. Official records on city total population (region- or city-level) and land area (region- or city-level) are collected from China City Statistics Yearbooks.

Minimum distance matching and Principal Component Analysis on the two variables are performed wave by wave, for City 1 and City 2, respectively. Final results are in Table A1 for City 1 and Table A2 for City 2. Details are in Tables A3-A14.

Table B1: City 1 – matching results

Province	Dist.-Mahalanobis	Dist.-Euclidean	Principal Component	Final choice
Panel A: First best match				
Liao Ning	Shen Yang	Shen Yang	Shen Yang	Shen Yang
Hei Longjiang	Ha Er Bing	Ha Er Bing	Ha Er Bing	Ha Er Bing
Jiang Su	Su Zhou	Su Zhou	Chang Zhou	Su Zhou
Shan Dong	Ji Nan	Ji Nan	Lai Wu	Ji Nan
He Nan	Zheng Zhou	Zheng Zhou	Nan Yang	Zheng Zhou
Hu Bei	Jin Zhou	Jin Zhou	E Zhou	Jin Zhou
Hu Nan	Lou Di	Lou Di	Xiang Tan	Lou Di
Guang Xi	Bei Hai	Bei Hai	He Zhou	Bei Hai
Gui Zhou	Liu Pan Shui	Liu Pan Shui	Gui Yang	Liu Pan Shui
Panel B: Second best match				
Liao Ning	Da Lian	Da Lian	Da Lian	Da Lian
Hei Longjiang	Jia Mu Si	Jia Mu Si	Qi Qi Ha Er	Jia Mu Si
Jiang Su	Su Zhou	Su Zhou	Wu Xi	Su Zhou
Shan Dong	Liao Cheng	Liao Cheng	Zao Zhuang	Liao Cheng
He Nan	Luo Yang	Luo Yang	Xin Yang	Luo Yang
Hu Bei	E Zhou	E Zhou	Huang Shi	E Zhou
Hu Nan	Huai Hua	Huai Hua	Lou Di	Huai Hua
Guang Xi	Wu Zhou	Wu Zhou	Gui Gang	Wu Zhou
Gui Zhou	An Shun	Zun Yi	An Shun	An Shun

Notes: The first two columns refer to distance matching, based on Mahalanobis and Euclidean distance measures, respectively.

Table B2: City 2 – matching results

Province	Dist.-Mahalanobis	Dist.-Euclidean	Principal Component	Final choice
Panel A: First best match				
Liao Ning	Ying Kou	Ying Kou	Da Lian	Ying Kou
Hei Longjiang	Shuang Ya Shan	Shuang Ya Shan	Jia Mu Si	Shuang Ya Shan
Jiang Su	Yang Zhou	Yang Zhou	Zhen Jiang	Yang Zhou
Shan Dong	Tai An	Tai An	Lai Wu	Tai An
He Nan	He Bi	He Bi	An Yang	He Bi
Hu Bei	Shi Yan	Shi Yan	E Zhou	Shi Yan
Hu Nan	Yue Yang	Yue Yang	Chang De	Yue Yang
Guang Xi	Wu Zhou	Wu Zhou	Fang Cheng Gang	Wu Zhou
Gui Zhou	Liu Pan Shui	Liu Pan Shui	Liu Pan Shui	Liu Pan Shui
Panel B: Second best match				
Liao Ning	Liao Yang	Liao Yang	Hu Lu Dao	Liao Yang
Hei Longjiang	Ji Xi	Ji Xi	He Gang	Ji Xi
Jiang Su	Zhen Jiang	Zhen Jiang	Tai Zhou	Zhen Jiang
Shan Dong	Liao Cheng	Liao Cheng	Zao Zhuang	Liao Cheng
He Nan	**Shang Qiu**	**Nan Yang**	**Zhou Kou**	**Shang Qiu**
Hu Bei	Xian Ning	Xian Ning	Huang Shi	Xian Ning
Hu Nan	Huai Hua	Huai Hua	Chang Sha	Huai Hua
Guang Xi	Bei Hai	Bei Hai	Bei Hai	Bei Hai
Gui Zhou	An Shun	An Shun	An Shun	An Shun

Notes: The first two columns refer to distance matching, based on Mahalanobis and Euclidean distance measures, respectively. In terms of the second best match for He Nan province in Panel B, outcome based on Mahalanobis distance matching is chosen.

Conclusion

This thesis explores issues related to health in China by looking at three different issues.

The first chapter investigates the role of nutrition as one of the major determinants of bodyweight and estimates the income effects on individual nutritional intakes using China Health and Nutrition Survey. Understanding the socio-economic gradient in health outcomes and behaviours is crucial for the design of policies to reduce health inequalities. Recent years have witnessed a sharp increase in obesity levels throughout the world, turning it into one of the largest and most costly public health risks. While Chinese obesity rates are still comparatively low, the country is facing large increases in obesity and bodyweight.We investigate the role of nutrition as one of the major determinants of bodyweight and estimate income effects on individual nutritional intakes using the Chinese health and Nutrition Survey from 1998 to 2006. We propose an innovative identification strategy using changes in marginal tax rates for non-agricultural individuals and supply shocks affecting agricultural production for agricultural individuals as instruments for income. In addition, we use a refined set of instruments using (tax) bracket creep resulting from inflation and nominal denomination of tax schedules. We find that simple OLS and FE estimates commonly used in the demand literature yield biased results compared to our IV estimates. We find hump-shaped Engel curves in calories for both non-agricultural and agricultural households with similar income elasticitiesbetween 0.08 and 0.09 at median income.We also find significant gender differences: Females are more income elastic towards calorie and other macronutrients than males. Poor males from non-agricultural background are more income elastic towards fat. Couples are the least income elastic towards calories and other nutrient intakes in the non-agricultural sector, but they are the most income elastic in the agricultural sector. Our results suggest that strong income growth in China has resulted in a shift in females' diet patterns away from the traditional one—mainly rice (and carbohydrates) —and no change in diets of males.

The second chapter explores the impact of the Chinese Cultural Revolution (1968-1976) on health, consumption and labour supply in later life (between 1989-2011) using the Chinese Health and Nutrition Survey. The Chinese Cultural Revolution led to a nationwide expansion of schools during the period 1968-1976 with the aim of equalising access to education (and educational attainment) across individuals and across geographical areas. We exploit regional differences in the extent of the expansion, especially between rural and urban districts, as well as cohort differences in exposure to the treatment to identify its impact[120]. We further distinguish between the impact of exposure in primary and secondary schooling and find that it has induced the treated cohorts to obtain significantly more years of primary education, adopt healthier consumption habits and engage more actively in the labour market, though with a mixed health impact.

[120]Fully treated cohorts pertain to those born between 1959 and 1965, and the partially treated cohorts are those born in 1955-1958 (before) or in 1966-1970 (after).

The third chapter aims to evaluate and compare the health impact of two air quality regulations in China. It finds that being more regulated by the FYP was inversely associated with significantly higher incidences of pollution-related illnesses. To explain this perverse health-policy relationship, this chapter suggests that the FYP did not succeed in inducing pollution-heavy industries to substantially alter their pollution control technologies and may have caused heavy polluters to relocate from more to less regulated areas, leading to persistently worse ambient air quality in High provinces and larger pollution increases in Low provinces over the regulation period.