I Z A Institute
of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11754

Non-Labor Income and the Age of Marriage: Evidence from China's Heating Policy

Junhong Chu
Haoming Liu
I.P.L. Png

AUGUST 2018

I Z A Institute
of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11754

Non-Labor Income and the Age of Marriage: Evidence from China's Heating Policy

Junhong Chu
National University of Singapore

Haoming Liu
National University of Singapore and IZA

I.P.L. Png
National University of Singapore

AUGUST 2018

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Non-Labor Income and the Age of Marriage: Evidence from China's Heating Policy*

We exploit China's heating policy to investigate how non-labor income affects marriage. From the mid-1950s, the policy gave substantial subsidies to urban residents north of the Huai River. Applying geographic regression discontinuity, we find that, with the policy, urban men in the north married 15 months earlier than southerners. The difference is substantial compared with the average age of first marriage of 24.9 years for urban men in the south. The effect is larger for later birth cohorts, which is consistent with the progressive implementation of the policy. The effect is smaller among women, consistent with women having less power in the household than men. There is no effect among rural people, who did not benefit from the heating policy.

JEL Classification: J12

Keywords: age at marriage, regression discontinuity, non-labor income, China

Corresponding author:
Haoming Liu
Department of Economics
National University of Singapore
1 Arts Link
Singapore 117570
E-mail: ecsliuhm@nus.edu.sg

* We thank Aloysius Siow, James Kung, Xie Huihua, Yi Junjian, other NUS colleagues and audiences at HKUST and the NUS Centre for Family and Population Research, and especially the Deputy Editor and reviewers for thoughtful advice, NUS colleagues for help with the survey, and Xiong Xi and Duan Yige for outstanding research assistance. This research was funded by Academic Research Fund grant MOE 2013-T2-2-045 (R-313-000-109-112).

1 Introduction

Between 1982 and 2010, the worldwide age at first marriage rose from 22.4 to 24.7 among women and from 25.1 to 26.5 among men, narrowing the spousal age gap by 0.9 years.[1] The age of marriage has important economic and social implications. Foremost is the effect on fertility. Most children are born after marriage, and so, the age at marriage, particularly the woman's, affects fertility (Cecos et al., 1982; Oppenheimer et al., 1997; Baizán et al., 2003). Second, the age at marriage might affect the stability of marriage, which in turn affects the welfare of children (Bongaarts, 1978; Bloom and Reddy, 1986; Thornton and Rodgers, 1987; Oppenheimer, 1988; Lehrer, 2008; Rotz, 2016). Third, the age at marriage might affect investment in education, especially among women (Field and Ambrus, 2008; Iyigun and Lafortune, 2016), with consequent effects on productivity, fertility, and child development (Isen and Stevenson, 2011; Bhrolcháin and Éva, 2012). Fourth, the spousal age gap might affect wages. To the extent that younger women marry older men, specialization within a family affects women's wages relatively more (Loughran and Zissimopoulos, 2009). Fifth, since women tend to marry older men but live longer, a smaller spousal age gap would benefit women by reducing the widowhood length.

Owing to the economic and social importance of marriage, policy-makers and scholars are keen to understand the effect of income and wealth on marriage (Nakosteen and Zimmer, 1987; Schneider, 2011; Yu and Xie, 2015; Weiss et al., 2017). However, empirical studies are challenging due to possible endogeneity. For instance, while earnings affect the timing of marriage, marriage also affects the growth of earnings. The most robust empirical tests exploit exogenous shocks that raised the earnings of the mainly male workers in the oil and gas industry, but find mixed results. The 1979 oil shock raised the marriage rate of young men in U.S. oil producing areas (Jelnov, 2016). By contrast, in the late 1990's and 2000's, increases in U.S. oil and gas production due to new fracking technology did not cause more men to marry (Kearney and Wilson, 2017).

[1]Source: World Bank, World DataBank, Health Nutrition and Population Statistics, http://databank.worldbank.org/data/reports.aspx?source=health-nutrition-and-population-statistics.

Jelnov (2016) and Kearney and Wilson (2017) study the effect of earnings on marriage. Theoretically, higher wages might either increase or reduce the gains from marriage, and so, would affect the age of marriage in conflicting ways. In the Becker (1973, 1974) model of the gains from marriage due to specialization in outside vis-à-vis domestic work, an increase in wages raises income (increasing the gains from marriage) and the time cost of domestic work (reducing the gains from marriage). Moreover, higher earnings may be associated with more inequality in earnings. Then, higher-earning men defer marriage to prove their earnings potential. With greater inequality of earnings among men, the gains from searching for potential partners would be higher, and so, women would search longer, thus, delaying marriage (Bergstrom and Bagnoli, 1993; Loughran, 2002; Gould and Paserman, 2003; Cherlin et al., 2016).

By contrast, an increase in *non-labor income* raises income but does not affect the time cost of domestic work, and so, unambiguously raises the gains from marriage. Here, we extend the Becker (1973, 1974) model and show that higher non-labor income directly increases the gains from marriage by raising men's earnings and women's home production. Normally, men's wages are higher than women's. After marriage, men work more in the labor market while women work more at home. Men substitute their hours of home work with their wife's time, and so, benefit more from marriage. Nevertheless, women might share some of the gains from higher non-labor income through bargaining with their husbands.

We then test the theoretical predictions by exploiting an exogenous increase in non-labor income due to Chinese government policy.[2] In the mid-1950s, the government of China decided to subsidize heating during winter. The subsidy took the form of cash allowances, amounting to 6-12% of winter monthly salary, coupled with the distribution of free or subsidized coal. To limit the cost of the heating policy, the government restricted the subsidy to urban residents north of a boundary, demarcated by the Huai River in the east and the Qin Mountains in the west. The government did not provide allowances to or subsidize heating for rural residents or those who lived south of the Huai-Qin boundary.

[2]The gains from marriage also manifest in the rate of marriage (Choo and Siow, 2006). However, in China, during our study period, marriage was almost universal. Accordingly, we represent the gains from marriage by the age at marriage.

The arbitrary division of urban China into areas with and without subsidized heating provides a unique quasi-natural experiment to investigate the causal effect of non-labor income on the age of marriage. among urban residents north of the boundary, and so, would not have affected search for marital partners. Importantly, since the heating subsidies were the same for all urban residents of a county, it would not have affected search for marital partners. We apply geographical regression discontinuity (GRD) analysis (a method cited by Duncan (2008) for demography research and applied by Legewie (2013)) to identify the effect of the heating policy on the age of first marriage among urban residents in the three provinces spanned by the Huai River – Henan, Anhui, and Jiangsu.

The concept (and assumption) of GRD is that people living just north of the Huai River are essentially comparable to those living just south of the river, except for the heating policy. Then, any north-south difference in the age of marriage at the Huai River is attributable to the heating policy.[3] Applying a sharp GRD design, we find that, among urban men, the age at first marriage was 1.25 years or 15 months lower in the north than the south. This difference is meaningful compared with the average age at first marriage of 24.9 years in the south. Among female urban residents, the age at first marriage was lower in the north than south (by 7.8 months) only in the 1956-65 birth cohort. These results are robust to the GRD method and bandwidth, and inclusion of control variables.

Our interpretation of the north-south difference as being due to the heating policy is buttressed by three falsification exercises. First, applying GRD analysis to urban men by birth cohort, we find no significant north-south difference among the 1926-35 birth cohort (most of whom married before the heating policy) or the 1936-45 cohort (some of whom married before the heating policy), but a significant difference only in the 1946-55 and 1956-65 cohorts. Second, we do not find any significant north-south difference among rural men, which is consistent with the heating policy benefiting only urban residents. Third, we also find no significant north-south difference in the age at first marriage with counterfactual boundaries (latitude 32.5 degrees north, or the Huai River plus/minus 50 kilometers).

[3]As Section 4 explains, the GRD accounts for differences between people in other factors that affect the age of marriage by functions (which may differ between north and south) of the distance from the river.

The weaker north-south difference in the age at first marriage among women suggests that they benefited less than men from the gains from marriage due to the heating policy. This disparity is consistent with men enjoying more power in the household than women, social norms that men bear more of the financial responsibilities of marriage than women, or norms that associate men's status with their earnings.

Our findings have implications for government subsidies for health, housing, heating, poverty alleviation, and other purposes that increase non-labor income. Besides their intended objectives, these subsidies, by increasing non-labor income, encourage earlier marriage. Further, to the extent that the effect on the age at marriage is stronger for men than women, it reduces the spousal age gap and shortens the widowhood period for women and increases their wellbeing. In the specific context of China's heating policy, our findings suggest that the policy possibly yields countervailing benefits that should be weighed against the costs such as the harmful effects of emissions on health and mortality (Almond et al., 2009; Chen et al., 2013; Xiao et al., 2015).

2 Model

Following Becker (1973), we assume individuals consume only a domestic good, Z, which is produced at home using inputs purchased from the market, x, and time, t. For simplicity, specify the production function of the domestic good as Cobb-Douglas,

$$Z = x^{\alpha} t^{1-\alpha},$$

where α is the share of market inputs with their price normalized to one. Since the marginal utility of the domestic good is always positive, the individual seeks to

$$\max_{x,t} Z \text{ subject to } x = v + wl, \tag{1}$$

where v is non-labor income, w is the wage rate, and l is the quantity of labor supplied in the labor market, with $t + l = 1$. For a single person, the optimal solution is

$$Z_i^* = \alpha^\alpha [1-\alpha]^{1-\alpha} S_i w_i^{\alpha-1} \tag{2}$$

where $S_i = v_i + w_i$, represents the individual's total income and subscripts $i = f, m$ denote the spouse respectively with lower and higher wage rate, $w_m > w_f$. (Please refer to Appendix I for the proofs of the optima for a single person and married couple.)

For a married couple, any reduction in the domestic good would render someone worse off without making anyone better off. Hence, they will maximize the joint production of the domestic good. Assume that the time of husband and wife is perfectly substitutable in home production, and that, after marriage, the wife continues to work in the labor market. Then the husband should allocate all of his time to market work, $l_m = 1$. (If $l_m < 1$, he should work more in the labor market and she should work less, which would raise their earnings and production of the domestic good.) Accordingly, for a married couple with the wife working in the labor market, the household production is

$$Z = x^\alpha t_f^{1-\alpha}, \tag{3}$$

where $x = v_m + v_f + w_m + w_f[1 - t_f]$. The optimal solution is

$$Z^* = \alpha^\alpha [1-\alpha]^{1-\alpha} [S_m + S_f] {w_f}^{\alpha-1}, \tag{4}$$

where S_m and S_f are as defined above. The difference in the production of the domestic good between marriage and singlehood is

$$G = Z^* - Z_m^* - Z_f^* = \alpha^\alpha [1-\alpha]^{1-\alpha} S_m w_m^{\alpha-1} [1 - r^{\alpha-1}], \tag{5}$$

where $r = w_m/w_f$ is the ratio of the husband's to wife's wages.

The assumption $w_m > w_f$ implies that $r > 1$. Further, $\alpha < 1$, and hence, $G > 0$, i.e., marriage increases the production of the domestic good. Accordingly, people will prefer to

marry rather than remain single. The gains from marriage do not vary with the woman's non-labor income, but increase with the man's non-labor income. Formally, with respect to the woman's non-labor income,

$$\frac{\partial G}{\partial v_f} = 0, \text{ and } \frac{\partial^2 G}{\partial v_f^2} = 0, \tag{6}$$

while with respect to the man's non-labor income,

$$\frac{\partial G}{\partial v_m} = \alpha^{\alpha}[1-\alpha]^{1-\alpha} w_m^{\alpha-1}[r-1] > 0, \text{ and } \frac{\partial^2 G}{\partial v_m^2} = 0. \tag{7}$$

Intuitively, with constant returns to scale in home production, the gains from marriage are purely driven by specialization, which equals the number of hours that the man spent on home production when single multiplied by the husband-wife wage differential. Given the wage rates, a higher non-labor income implies longer working hours at home as a single and hence, benefit more from marriage.

Referring to (7), the second derivative suggests that the marginal gain from marriage for men does not depend on their non-labor income. However, if a household's utility is concave in Z, then the gains from marriage would be lower for men with higher earnings. In our empirical analysis, we proxy earnings by education and test its moderating effect on the effect of non-labor income on timing of marriage.

By contrast, as long as women's wages are lower than men's, married women always spend time on home production. The increase in the woman's hours in home production after marriage depends only on her husband's pre-marriage hours in home production, and does not vary with the woman's non-labor income. Hence, the gains from marriage do not vary with women's non-labor income.

Our theory implies that an increase in non-labor income would raise the gains from marriage by raising men's earnings and women's home production. However, our theory is silent on the division of the gains from marriage. To the extent that men have more power in the household than women, men bear more of the financial responsibilities of marriage than

women, or men and women share the gains from marriage according to their earnings, the gains would be larger for men than women. Intuitively, a large gain encourages people to marry early. Hence, our model implies that an increase in non-labor income reduces the age at first marriage. The impact is likely to be larger for men if they enjoy a larger share of the gains from the rise in non-labor income. We test these model predictions in Section 6.

3 Institutional Context

China's heating policy originated in the first five-year plan (1953-57). The long-term intent was to provide and subsidize central heating. In the interim, pending the construction of central heating systems, the government decided to pay cash allowances and subsidize coal purchase (State Council of China, 1956). To economize on resources, the government limited the heating policy to urban residents in the coldest parts of China. Specifically, it demarcated a boundary marked by the Huai River in the east and the Qin Mountains in the west (State Council of China, 1956). The Huai-Qin boundary runs through the provinces of Jiangsu, Anhui, Henan, Shaanxi, and Gansu. The heating policy did not apply to rural residents or those living south of the Huai-Qin boundary.

The Chinese government built the first central heating system only in 1958 in Beijing and subsequently expanded it to other urban areas. However, even in the year 2000, only 27% of Beijing had central heating. The coverage elsewhere was very likely lower. Consequently, for most people, the heating policy took the form of cash allowances and free or subsidized coal for home use.

The heating policy was a major welfare benefit for urban residents living north of the Huai-Qin boundary. Table 1 lists the cash allowances during winter months stipulated by the central government in Anhui, Henan, and Jiangsu (State Council of China, 1978). During the sample period, most urban residents were employed directly or indirectly by the government (Xie et al., 2009). Work units typically gave allowances in excess of the amounts stipulated by the central government. Based on interviews with residents of the three provinces, the cash allowance ranged between 6.7-11.5% of monthly winter income. Besides the cash allowance,

the heating policy also provided free or subsidized heating coal (please refer to Appendix II, Table A-II-1, Panel B).

Although the government promulgated the heating policy in 1957, there is some evidence that it was implemented progressively. For instance, an Anhui provincial government document states that the heating cash allowance was implemented only in 1979. However, the Central government specified the cash allowance in Anhui as 9 Yuan per year in 1978 (State Council of China, 1978), and local residents report receiving the allowance in the 1970s. Importantly, the cash allowances and free or subsidized coal were lump sum payments, and not related to work income.

Another important feature of the Chinese institutional context is the hukou (household registration) system established in 1958, which allows individuals to have legal status only in their registered hukou place of residence. This affects birth, marriage, divorce, housing, food and other rationed items, education, and employment. In particular, only people with the local hukou qualify for the heating subsidy. If two people with different hukou registrations marry, it may take years to re-register the spouse's hukou. Therefore, it is reasonable to assume that people could not migrate to take advantage of heating subsidies, and that, indeed, any person who left their registered residence would lose their heating subsidy for some years. By our calculation using the 2000 Census, over 90% of urban residents lived in their birth provinces.

The third relevant feature of the Chinese institutional context is labor markets. Until the economic reforms beginning in 1978, almost all urban Chinese were government employees, either directly or indirectly (Xie et al., 2009). Surprisingly, even under Communism, wages varied considerably. In Appendix II, Table A-II-1, Panel A, presents monthly wage rates for workers in various industries in Henan, Anhui, and Jiangsu provinces. Wages varied by responsibility, skill, and occupational hazard. For instance, in the mining industry, underground workers were paid more than above-ground workers. Presumably, workers who put in longer hours and more effort could increase their prospects for promotion to better-paid positions. Moreover, workers could earn additional wages for over-time work and rewards for producing beyond their quota. Some workers were paid by piece rate or on hourly basis, and

so, would earn more by working longer.

To check whether labor markets and marriage conditions during the study period conformed with the assumptions of our theory, we surveyed 51 female and 44 male urban residents of Henan, Anhui, and Jiangsu who married before 1980. As Table 2 reports, about 40% of women and half of the men reported that, before marriage, men earned more than their wife. Both women and men considered the spouse's income and job to be important in marriage. About 20% of women and over 40% of men reported that they had delayed marriage because of low income. Over 10% of women and over 40% of men reported that, if they had received a windfall gain, they would have married earlier.

After marriage, over 90% of women reported doing more housework. By contrast, over 50% and over 40% of men reported working harder and more overtime after marriage. Broadly, the survey findings fit the assumptions of our theory that, before marriage, men earned more than women, income was a factor in marriage, and non-labor income enlarged the gains from marriage by enabling men to increase paid work in the labor market while women increased domestic work.

4 Empirical Strategy

To investigate the effect of non-labor income on marriage, consider the linear reduced form model:

$$a_{ji} = X'_{ji}\beta + \gamma y_{ji} + \nu_{ji}, \tag{8}$$

where a_{ji} represents the age at first marriage of individual j with urban hukou living in county i, X_{ji} is a vector of personal and community characteristics that affect the decision to marry and β is their coefficients, y_{ji} is non-labor income and γ is the coefficient, and ν_{ji} is a random error term.

The ordinary least squares (OLS) estimate of γ might be biased if ν is correlated with y. One obvious source for such a correlation is earnings, which affect both age of marriage and

non-labor income. Moreover, people with higher non-labor income might also share other characteristics, such as social status, that affect their attractiveness in marriage.

The limitation of the heating policy to urban residents living north of the Huai-Qin boundary provides a natural quasi-experiment. Given the sharp change in policy along the boundary, it is intuitive to apply GRD analysis. Duncan (2008) cited RD as a method for causal inference in demography research, and Legewie (2013) used RD to study U.S. immigration.

Assuming that subjects are continuously distributed around the boundary and all factors besides the heating policy that affect the age at first marriage vary smoothly around the boundary, the GRD method produces a consistent estimate of the coefficient of non-labor income. Almond et al. (2009), Chen et al. (2013), Wang (2015), and Wang and Hong (2015) applied GRD around the Huai-Qin boundary to investigate the effect of emissions on respiratory illnesses and the effect of rice culture on economic liberalization and income. To apply GRD, let non-labor income be

$$y_{ji} = Z'_{ji}\phi + \delta N_i + \epsilon_{ji}, \tag{9}$$

where Z_{ji} is a vector of observed personal and community characteristics and ϕ is their coefficients, N_i is an indicator of county i being situated north of the boundary, and ϵ_{ji} is random error. The north indicator, N_i, represents the heating policy. Since the heating policy provides cash allowances and subsidized or free coal only to urban residents living north of the boundary, the coefficient of the heating policy, $\delta > 0$. Substituting (9) in (8), the reduced-form model resolves to

$$a_{ji} = X'_{ji}\beta + Z'_{ji}\phi\gamma + \delta\gamma N_i + \eta_{ji}, \tag{10}$$

where $\eta_{ji} = \nu_{ji} + \epsilon_{ji}$.

Further, define d_i to be the distance of county i from the boundary, with $d_i > 0$ and $d_i < 0$ for counties north and south of the boundary respectively. Let $f(\cdot)$ and $g(\cdot)$, with $g(d_i) = 0$ for $d_i < 0$, be smooth functions that represent other factors (besides the heating policy) that affect non-labor income and are correlated with distance. Then, we replace (10) with the

GRD model of the age at first marriage as a function of the heating policy

$$a_{ji} = \mu N_i + f(d_i) + g(d_i) + \eta_{ji}. \tag{11}$$

In (11), the coefficient of the heating policy, $\mu \equiv \delta\gamma$. The heating policy raises non-labor income, and so, $\delta > 0$. Accordingly, the sign of μ, is the same as that of γ. A negative μ implies that non-labor income reduces the age at first marriage. The functions, $f(\cdot)$ and $g(\cdot)$ may differ, and so, the GRD approach allows the effect of the other factors to differ between north and south.

The key identifying assumption of the GRD analysis is that all factors other than the heating policy vary continuously at the boundary. Under this assumption, η_{ji} is a random error, and Model (11) provides a consistent estimate of μ. In particular, we do not need to control for personal and community characteristics, X_{ji} and Z_{ji}. Obviously, if the sample is limited to people who live very close to the boundary, then the estimate would not be sensitive to whether we control for these characteristics. With a larger sample that extends further from the boundary, the north-south differences in these characteristics would be larger. However, assuming that X_{ji} and Z_{ji} change continuously with distance from the boundary, then functions $f(\cdot)$ and $g(\cdot)$ should account for their impact on the dependent variable. By the same reasoning, not controlling for unobserved characteristics that are correlated with both y_{ji} and a_{ji} in equation (11) will also not bias the estimate of μ. Nevertheless, including personal and community characteristics reduces the residual variation in the age at first marriage, and thereby improves the precision of the estimates. In robustness checks, we compare the estimates of μ with different sets of control variables.

There are two ways to apply regression discontinuity (Lee and Lemieux, 2010). The parametric approach specifies $f(\cdot)$ and $g(\cdot)$ as polynomial functions and estimates (11) by OLS using all observations. The non-parametric approach estimates (11) over an optimally selected subset of the data. Intuitively, as the sample is narrowed to counties closer to the boundary, the assumptions on the functional form become less restrictive. In the non-parametric approach, the selection of the bandwidth (which counties to include in the analysis) is important. Here we focus on the MSE-optimal method (Calonico et al., 2016) with symmetric

bandwidth, and stipulate locally quadratic distance functions. In robustness checks, we use the parametric and the non-parametric approach with asymmetric bandwidth.[4]

In applying GRD around the Huai-Qin boundary, one concern is that the Qin Mountains are thinly populated, which challenges the GRD assumption that subjects are continuously distributed around the discontinuity. By contrast, the Huai River basin in Henan, Anhui and Jiangsu is an unobstructed geographical area, with easy movement throughout. Importantly, areas immediately north and south of the river are well populated. Accordingly, to meaningfully apply GRD analysis, we limit our study to these three provinces (Figure 1).

5 Data

Administratively, China is divided into provinces, which are further divided into prefectures, and which are further divided into counties. We carry out our analyses by county as the heating policy is administered as such (State Council of China, 1978). Henan, Anhui and Jiangsu provinces comprise 47 prefectures, made up of 166 counties located south of the Huai River and 206 counties north of the River.

China's 2000 Population Census is the first census to report age at first marriage. From the one percent sample of the Census, we collect data on age at first marriage, current marital status, family, ethnicity, education, and employment for individuals born between 1925-65. The marriages of those born before 1925 might have been affected by the Sino-Japanese War, Second World War, or Chinese Civil War, and relatively few survived until 2000. Accordingly, we exclude people born before 1925 from the study. Obviously, information on age at marriage is only available for those who marry. Among those with urban hukou and born before 1965, 98.8% of men and 99.6% of women had married by the year 2000. By comparison, among urban residents born between 1966 and 1975, the marriage rate is only 79 percent for men and 91 percent for women. Accordingly, we limit our study to people born before 1965.

[4] Calonico et al. (2016) generalize the non-parametric methods developed by Ludwig and Miller (2007), Imbens and Kalyanaraman (2011), and Calonico et al. (2014).

Our main analyses focus on individuals with urban hukou, while, in falsification analyses, we also consider individuals with rural hukou. To minimize the impact of possible migration (notwithstanding the hukou policy), we limit our analysis to individuals who resided in the same neighborhood since birth. Our final sample comprises 72,264 individuals in 372 counties, of which 46% resided north of the River (Table 3).

We divide the sample into four ten-year birth cohorts: 1926-35, 1936-45, 1946-55, and 1956-65. The marriages of people in these cohorts might have been disrupted by three upheavals – the Chinese Civil War (1946-49), Great Famine (1959-61), and Cultural Revolution (1966-76).

In the 1926-35 cohort, 82% had married by 1958, and so, their decisions to marry were largely unaffected by the heating policy but might have been affected by the Civil War. In the 1936-45 cohort, 10% married before 1958, and another 18% married during the Great Famine (1959-1961). Their decisions to marry might have been affected by the heating policy and the famine. In the 1946-55 cohort, all married after 1961, and over half married during the Cultural Revolution and about one third married afterward. Their decisions to marry might have been affected by the heating policy and the Cultural Revolution. In the 1956-65 cohort, 96% were married in 1978 or after. The marriage decisions in the north should have been fully affected by the heating policy and not much affected by the Cultural Revolution.

Table 3, Panel A, summarizes the marriage data. Marriage is almost universal at 99.6% among women and 98.8% among men. We calculate the age at first marriage as the year of first marriage minus birth year. Among urban residents, the average age at first marriage is 22.6 among women in the north versus 22.9 in the south, and 23.6 among men in the north versus 24.9 in the south. Apparently, urban northerners married earlier than urban southerners, and the difference is more pronounced among men than women.

Table 3, Panel B, summarizes other individual and county characteristics that might possibly affect marriage. Almost all the people were Han Chinese (98 percent), the average person was born in 1951 and had 8.7 years of schooling, and 18% were employed by the government or in professional occupations.

Marriage might be affected by social norms and culture, which might differ between the north and south of the Huai River. We account for norms and culture in several ways. First is an indicator (multi-generation household) of individuals living with either their parents or married adult children. People in multi-generation households are likely to be more family-oriented or less affluent. Second, we consider Confucianism, a system of philosophical, ethical, and socio-political thinking that emphasizes family and obedience to authority. Confucianism might be stronger in the north as it originated in Shandong Province, which abuts Henan, Anhui, and Jiangsu to the north (Kung and Ma, 2014). Third, Talhelm et al. (2014) theorize that growing of rice requires collective action, and so, societies that historically grew rice are more collectivist. Single people in collectivist cultures might marry earlier. Rice growing requires a temperate climate, and so, rice culture would vary from north to south.

Two other factors that affect marriage that might differ across the Huai River are gender balance and economic development. For each county, we construct gender ratio as the number of males per female among people born between 1926-65. We represent economic development by the proportion of employment in state-owned enterprises (SOEs) and gross domestic product (GDP) per capita.

Finally, using Google Maps, we plot the geo-coordinates and calculate the shortest distance from each county seat to the Huai River. From the China Meteorological Administration, we collect daily instrumental observations of minimum and maximum temperatures at 64 stations over the years 1956-87. We match each county seat to the nearest weather station. The average daily winter temperature (December to February) is 1.27°C and 3.44°C in the north and south respectively.

For data available only at the prefecture level (density of Confucian temples, rice culture, SOE employment, and GDP for some prefectures), we assume that the data applies to all counties within the prefecture. This might result in classical measurement error, and to that extent, the estimated coefficients would be biased downward.[5]

[5] Please refer to Appendix II, Table A-II-2, for the detailed sources of data and construction of the variables.

6 Estimates

The Chinese government promulgated the heating policy with effect from 1957. Our model predicts that the heating policy raised the gains from marriage, particularly for men. Accordingly, we analyze men and women separately. Further, since the heating policy might have been implemented progressively and thus have had more effect on the marriage of people born later, we analyze the effect of the policy by birth cohort.

Figures 2(a)-(d) plot the county average age at first marriage among men and women with urban and rural hukou by distance from the Huai River. The Figures also depict the fitted values from local polynomial regressions of the individual age at first marriage on the distance from the Huai River, and the corresponding 95% confidence intervals. The graphs evince a discrete north-south difference in the age at first marriage among urban men as well as urban women,[6] but not among rural men and rural women.

Next, to explore differences according to the age of the individuals when the heating policy came into effect, Figures 3(a)-(h) plot graphs of the fitted local polynomial regressions and corresponding 95% confidence intervals. For comparison, these figures also plot the average age at first marriage within 50 kilometer bins. The graphs for men show no north-south difference in the oldest and next to oldest cohorts, but do show discrete north-south differences in the later cohorts. The graphs for women evince a north-south difference only in the youngest cohort.

Following up on the graphical analysis, Table 4 presents GRD analyses of the age at first marriage among urban men and women. Panel A shows that among all urban men, there is a significant north-south difference in the age at first marriage of -1.25 (s.e. 0.43) years, which is large relative to the average age at first marriage of 24.9 years in the south. The north-south difference is not significant in the two older cohorts, but is significant in the two younger cohorts. In the youngest cohort, northerners married about 1.5 years or 18 months earlier than southerners. Panel B reports the estimates for urban women. There is no significant north-south difference in the age at first marriage except in the youngest

[6]These are regressions by individual, and so, the confidence intervals are very tight.

cohort. The estimate suggests that, in the youngest cohort, northerners married 0.65 years or 7.8 months earlier than southerners, which is large relative to the average age at first marriage of 23.5 years in that cohort in the south.

Table 4 shows that the mean age of marriage is lower among individuals who benefited from the heating policy than other people. Was this effect due to more people marrying early or fewer people marrying late? To investigate, we carry out a GRD analysis on the probability of marriage before the government-encouraged age of later marriage, which is 25 for men and 23 for women.[7] Table 4, column (f), reports the estimates for the youngest cohort.Both northern men and northern women were more likely to marry before the age of later marriage. Apparently, the heating policy did encourage people to marry in their early 20s.

We find an economically and statistically significant north-south difference in the age at first marriage and interpret it as being due to the heating policy. This interpretation is buttressed by three sets of falsification exercises. First, referring to Table 4, Panel A, the north-south difference is not significant in the two older cohorts, which were not affected by the heating policy. Second, referring to Appendix II, Table A-II-3, column (b), there is no significant north-south difference in the age at first marriage among men with rural hukou, which is consistent with the heating policy benefiting only urban residents.

Third, we experiment with counterfactual boundaries for the heating policy. Previous GRD studies of China's heating policy defined the boundary by latitude 32 or 32.5 degrees north (Almond et al., 2009; Chen et al., 2013; Wang, 2015) rather than the actual geo-coordinates of the river. Referring to Figure 1, the Huai River follows latitude 32.5 degrees north quite closely in Henan but not in Anhui and Jiangsu. This discrepancy means that people on both sides of the latitude would be eligible for heating allowances and subsidies, challenging the GRD method. Referring to Table A-II-3, columns (c)-(e), in GRD estimates with the boundary stipulated as latitude 32.5 degrees north, or 50 kilometers north or south

[7]From 1982, the government promoted later marriage by giving 7 to 12 days of additional paid leave to women and men who married after ages 23 and 25 (Ministry of Labor Circular [80]29, and Ministry of Finance, Circular [80]41).

of the Huai River, the coefficient of north is positive and not statistically significant.[8]

6.1 Robustness

A potential threat to our identification strategy is discontinuities at the Huai River in other factors that affect marriage. Focusing on urban men born in 1956-65, we first check graphically whether other factors that possibly affect marriage are discontinuous at the Huai River. These factors are ethnicity, age, education, occupation, social norms and culture, the availability of marriage partners (gender ratio), employment in state-owned enterprises, and overall economic development.

Referring to Appendix II, Figure A-II-1, there are geographical discontinuities at the Huai River in government/professional occupation and Confucianism, and, less precisely, age and rice culture. The figure suggests that those who live north of the Huai are more likely to be employed in government or professional occupations. Subject to the proviso that the information on occupation is from the 2000 Census, and not at marriage, the difference in occupation might challenge our identification strategy. The discontinuity in Confucianism may be an artifact of the data being at the prefectural level, and the coarseness giving the appearance of a discontinuity. Nevertheless, this does threaten our identification strategy to the extent that people living north of the Huai were more Confucianist, and Confucianists tend to marry earlier.

Figure A-II-1 suggests that people living north of the Huai tend to be older. Older cohorts would have married earlier, and so, the apparent discontinuity does challenge our identification strategy. The difference in rice culture would confound our identification strategy to the extent that rice-growing societies are more collectivist (Talhelm et al., 2014) and encourage earlier marriage. However, rice culture is weaker in the north, which suggests that our estimates are conservative.

To check whether our results are sensitive to the exclusion of other factors that possibly affect marriage, Table 5, columns (b)-(i), report non-parametric GRD estimates including

[8]See Appendix II for more falsification tests.

each of these factors individually and all of them together as additional controls. Some of these other factors do significantly affect the age of marriage. Yet, in each robustness check, the coefficient of north is quite similar to the preferred estimate without additional controls and precisely estimated. These results suggest that the smooth functions of distance to the Huai River effectively controls for the impact of other factors.

The coefficients of these control variables should be interpreted with caution as the variables might be correlated with unobserved factors. For instance, Confucianism emphasizes obedience to authority as well as family. Government policy urged people to marry later, while family-oriented people might marry earlier. The positive coefficient of Confucianism suggests that the former effect dominates. Similarly, while people who voluntarily live in multi-generation households might be more family-oriented, hence marry earlier, those forced to live in multi-generation households due to lack of housing might have difficulty finding a spouse, hence might marry late.

To further check the robustness of the empirical findings, Appendix II reports additional GRD estimates. One set (Table A-II-3, columns (f)-(i)) checks sensitivity to method and applies the nonparametric approach with linear distance functions, alternative kernel functions, and multi-level model (Stata routine *meglm*). Another set checks sensitivity to sample. Table A-II-3, columns (j)-(k) report estimates that apply the nonparametric approach with the sample limited to urban couples, and estimates that include seven adjacent provinces – Shanxi, Hebei, and Shandong to the north, and Hubei, Jiangxi, Zhejiang, and Shanghai to the south. Table A-II-3, column (l), reports estimates that apply the parametric approach and include all counties in ten provinces. Another set of robustness checks (Table A-II-5, Panels A and B) applies the parametric GRD approach to the entire sample. Yet, another set of estimates (Table A-II-5, Panels C and D) applies the non-parametric approach with asymmetric bandwidths (Calonico et al., 2016). Our finding that the age at first marriage among urban residents is significantly lower in the north, and particularly among men in later cohorts, is robust to these alternative methods and sample.[9]

[9] Appendix III reports similar results from a difference-in-differences (DID) analysis.

6.2 Mechanism

Our interpretation of the north-south difference in the age at first marriage as being due to the effect of the heating policy on non-labor income is supported by the differential and much stronger effect on men vis-à-vis women. This difference is consistent with men enjoying more power in the household than women (Mangyo, 2008; Shu et al., 2013), or social norms that men bear more of the financial responsibilities of marriage than women, or norms that men's status is positively correlated with their earnings.

Next, we investigate the moderating effect of income on the effect of the heating policy. To the extent that the heating policy affects the gains from marriage through non-labor income and the marginal utility of the home-produced good diminishes with quantity, the heating policy should have less effect on higher-earning people. Lacking direct information on individual income, we use two proxies – years of education and employment by the government or in a professional occupation.

Better-educated people would qualify for more responsible positions and earn higher wages (Appendix II, Table A-II-1) and education would not change much between the time of marriage and the 2000 Census. As Table 6, column (b), reports, the coefficient of the interaction between north and education is positive, which is consistent with diminishing marginal utility of the home-produced good. However, the estimate is imprecise, perhaps owing to insufficient variation in the education within the sample. In Appendix II, Table A-II-6 reports estimates on the entire sample of counties, not limited to the optimal bandwidth. The coefficient of north is negative, significant and smaller among more educated individuals (with above high school education) than the less educated. In an estimate including the interaction between north and education, the coefficient of the interaction is positive and significant and similar to the estimate in Table 6, column (b).

In pre-reform China, government employees and professionals earned more in wages and benefits than others. As Table 6, column (c), reports, the coefficient of the interaction between north and government/professional occupation is positive, which is consistent with diminishing marginal utility of the home-produced good. However, the estimate is imprecise,

perhaps because of measurement error. The estimate uses the occupation at the Census, and so, depends on the occupation remaining unchanged since marriage. In Appendix II, Table A-II-6 reports estimates on the entire sample of counties. The coefficient of north is negative, significant, and smaller among those in government/professional occupations relative to others.

Subject to the imprecision of the estimates, we infer that there is some evidence that the heating policy had less effect on people with higher incomes. This is consistent with diminishing marginal utility of the home-produced good in our model of the effect of non-labor income on the gains from marriage.

6.3 Alternative Explanations

We show that the heating policy was associated with earlier marriage, and interpret this as the effect of an increase in non-labor income on the gains from marriage. Yet, our study is not a controlled experiment, and so, the effect of the heating policy is open to alternative explanations.

One alternative explanation relates to income inequality. If people care about absolute income inequality, the policy should not have affected search behavior since it did not affect the dispersion of income. Nevertheless, the policy did reduce proportionate inequality, which might have affected search. To the extent that men bear greater financial responsibility, it should have a larger impact on search by women. However, we find a relatively larger effect on men, suggesting that changes in inequality do not explain the relation between the heating policy and age of marriage.

Another set of explanations is that wealth defines eligibility for marriage, savings buffer against future uncertainty and stress (Schneider, 2011), or more prosaically, higher non-labor income helps to pay for the costs of marriage such as home, furnishings, and ceremonies. These alternative explanations do not account for the differential effect of the heating policy on men vis-à-vis women. However, we cannot definitely rule out these explanations if

combined with a social norm that the husband bears more of the financial responsibilities of marriage.

The heating policy could affect marriage directly through thermal comfort. The policy makes being together more comfortable, hence encourages people to marry earlier. By this theory, the heating policy should have more of an effect in areas where the climate is more severe. Table 6, columns (d)-(f), report estimates contingent on measures of winter climate. The coefficient of north interacted with winter temperature is negative, implying that, where the winter is milder, the effect of the heating policy was larger. This result is inconsistent with the thermal comfort theory. The coefficient of north interacted with precipitation is negative and significant, which is consistent with the thermal comfort theory. The coefficient of north interacted with sunshine hours is positive but imprecise. Nevertheless, even if thermal comfort does explain the interaction between the heating policy and winter climate, the estimated north-south differences in Table 6, columns (d)-(f), are close to the baseline estimate. This suggests that the heating policy did affect marriage beyond thermal comfort.

Another possible set of explanations relates to the Great Famine (1959-61) and Cultural Revolution (1966-76), which overlapped in time with the progressive implementation of the heating policy. While both shocks certainly disrupted marriage, the issue is whether they differentially affected marriage north and south of the Huai River. Table 6, column (g), reports an estimate contingent on the severity of the Great Famine, as represented by the dip in county level population during the famine period (Chu et al., 2016). Table 6, columns (h)-(i), report estimates contingent on the severity of the Cultural Revolution, as represented by the county-level average loss of education due to urban youths being "sent down" to the countryside, and two historical measures of the strength of Communist Party in the county (Xu et al., 2018). The estimated coefficient of north is robust to all of these contingencies.

7 Discussion

Through geographical regression discontinuity analyses, we find a significant north-south difference around the Huai River in the age of first marriage among men with urban hukou

born between 1946-65 and women with urban hukou born between 1956-65. We interpret these differences as being due to the Chinese government's heating policy, which provided cash allowances and subsidized coal to urban residents north of the Huai River. The results are consistent with the implications of our extended Becker (1973, 1974) model, which shows that an increase in non-labor income raises the gains from marriage by raising men's labor supply while reducing women's.

Lacking information on the individual cash allowance or coal subsidy, we can only roughly calculate the elasticity of the age at first marriage with respect to non-labor income. This calculation is biased upward as it ignores the coal subsidy. According to our survey, the heating allowance amounted to 6.7-11.5% of monthly salary, while we estimate that the age of first marriage among urban men in the north was 1.25 years lower, which is 5.4% lower than the average of 23.3 years. Hence, roughly, a 1% increase in non-labor income is associated with 0.47-0.81% reduction in marriage age.

Our findings bear implications for government policies that raise non-labor income. Such policies increase the gains from marriage, and so, encourage and accelerate marriage. With regard to China's heating policy, our findings point to additional benefits (besides thermal comfort) to balance against the deleterious effects on health. The age at marriage affects fertility, stability of marriage, and education, which effects are particularly consequential for countries trying to encourage marriage and fertility. Further, the spousal age gap possibly affects wages and widowhood. Given the difficulty of identifying the causal effect of the age at marriage on these outcomes, China's heating policy might provide a useful identification strategy.

A clear limitation of our empirical design is that the heating policy raised the non-labor income of both men and women. Hence, for women, we cannot distinguish the direct effect of the increase in non-labor income (which, according to our theory, is zero) from the indirect effect through men sharing their gains from marriage. An obvious direction for future work is to investigate the effect of an increase in women's non-labor income separately from increase in men's non-labor income.

References

Almond, Douglas, Yuyu Chen, Michael Greenstone, and Li Hongbin, "Winter Heating or Clean Air? Unintended Impacts of China's Huai River Policy," *American Economic Review*, 2009, *99* (2), 184–190.

Baizán, Pau, Arnstein Aassve, and Francesco C. Billari, "Cohabitation, marriage, and first birth: The interrelationship of family formation events in Spain," *European Journal of Population*, 2003, *19* (2), 147–169.

Becker, Gary S., "A Theory of Marriage: Part I," *Journal of Political Economy*, 1973, *81* (4), 813–846.

_ , "A Theory of Marriage: Part II," *Journal of Political Economy*, 1974, *82* (2), S11–S26.

Bergstrom, Theodore C. and Mark Bagnoli, "Courtship as a Waiting Game," *Journal of Political Economy*, 1993, *101* (1), 185–202.

Bhrolcháin, Máire Ní and Beaujouan Éva, "Fertility Postponement is Largely Due to Rising Educational Enrolment," *Population Studies*, 2012, *66* (3), 311–327.

Bloom, David E. and P. H. Reddy, "Age Patterns of Women at Marriage, Cohabitation, and First Birth in India," *Demography*, 1986, *23* (4), 509–523.

Bongaarts, John, "A Framework for Analyzing the Proximate Determinants of Fertility," *Population and Development Review*, 1978, *4* (1), 105–132.

Calonico, Sebastian, Matias D. Cattaneo, and Rocio Titiunik, "Robust Nonparametric Confidence Intervals for Regression-Discontinuity Designs," *Econometrica*, 2014, *82* (6), 2295–2326.

_ , _ , **Max H. Farrell, and Rocio Titiunik**, "Regression Discontinuity Designs Using Covariates," University of Michigan Working Paper 2016.

Cecos, Federation, D. Schwartz, and M. J. Mayaux, "Female Fecundity as a Function of Age," *New England Journal of Medicine*, 1982, *306*, 404–406.

Chen, Yuyu, Avraham Ebenstein, Michael Greenstone, and Hongbin Li, "Evidence on the Impact of Sustained Exposure to Air Pollution on Life Expectancy from China's Huai River Policy," *Proceedings of the National Academy of Sciences*, 2013, *110* (32), 12936–12941.

Cherlin, Andrew J., David C. Ribar, and Suzumi Yasutake, "Nonmarital First Births, Marriage, and Income Inequality," *American Sociological Review*, 2016, *81* (4), 749–770.

Choo, Eugene and Aloysius Siow, "Who Marries Whom and Why," *Journal of Political Economy*, 2006, *114* (1), 175–201.

Chu, Junhong, Ivan PL Png, and Junjian Yi, "Entrepreneurship and the School of Hard Knocks: Evidence from China's Great Famine," SSRN Working Paper 2789174 June 2016.

Duncan, Greg J, "When to promote, and when to avoid, a population perspective," *Demography*, 2008, *45* (4), 763–784.

Field, Erica and Attila Ambrus, "Early Marriage, Age of Menarche, and Female Schooling Attainment in Bangladesh," *Journal of Political Economy*, 2008, *116* (5), 881–930.

Gould, Eric D. and M. Daniele Paserman, "Waiting for Mr. Right: Rising Inequality and Declining Marriage Rates," *Journal of Urban Economics*, 2003, *53* (2), 257–281.

Imbens, Guido and Karthik Kalyanaraman, "Optimal Bandwidth Choice for the Regression Discontinuity Estimator," *Review of Economic Studies*, 2011, *52* (6), 890–922.

Isen, Adam and Betsey Stevenson, "Women's Education and Family Behavior: Trends in Marriage, Divorce and Fertility," in John B. Shoven, ed., *Demography and the Economy*, Chicago: University of Chicago Press, 2011, pp. 107–140.

Iyigun, Murat and Jeanne Lafortune, "Why Wait? A Century of Education, Marriage Timing and Gender Roles," IZA Discussion Paper 2016.

Jelnov, Pavel, "The Marriage Age U-shape: What Can We Learn from Energy Crises?," Leibniz University Hannover Working Paper 2016.

Kearney, Melissa S and Riley Wilson, "Male Earnings, Marriageable Men, and Nonmarital Fertility: Evidence from the Fracking Boom," National Bureau of Economic Research Working Paper 23408 2017.

Kung, James K. and Chicheng Ma, "Can Cultural Norms Reduce Conflicts? Confucianism and Peasant Rebellions in Qing China," *Journal of Development Economics*, 2014, *111*, 132–149.

Lee, David S. and Thomas Lemieux, "Regression Discontinuity Designs in Economics," *Journal of Economic Literature*, 2010, *48* (2), 281–355.

Legewie, Joscha, "Terrorist events and attitudes toward immigrants: A natural experiment," *American Journal of Sociology*, 2013, *118* (5), 1199–1245.

Lehrer, Evelyn L., "Age at Marriage and Marital Instability: Revisiting the Becker-Landes-Michael Hypothesis," *Journal of Population Economics*, 2008, *21* (2), 463–484.

Loughran, David S., "The Effect of Male Wage Inequality on Female Age at First Marriage," *Review of Economics and Statistics*, 2002, *84* (2), 237–250.

_ **and Julie Zissimopoulos**, "Why Wait? The Effect of Marriage and Childbearing on the Wages of Men and Women," *Journal of Human Resources*, 2009, *44* (2), 326–349.

Ludwig, Jens and Douglas L. Miller, "Does Head Start Improve Children's Life Chances? Evidence from a Regression Discontinuity Design," *Quarterly Journal of Economics*, 2007, *122* (1), 159–208.

Mangyo, Eiji, "Who Benefits More from Higher Household Consumption? The Intrahousehold Allocation of Nutrients in China," *Journal of Development Economics*, 2008, *86* (2), 296–312.

Nakosteen, Robert A and Michael A Zimmer, "Marital Status and Earnings of Young Men: A Model with Endogenous Selection," *Journal of Human Resources*, 1987, *22* (2), 248–268.

Oppenheimer, Valerie K., Matthijs Kalmijn, and Nelson Lim, "Men's Career Development and Marriage Timing During A Period of Rising Inequality," *Demography*, 1997, *34* (3), 311–330.

Oppenheimer, Valerie Kincade, "A Theory of Marriage Timing," *American Journal of Sociology*, 1988, *94* (3), 563–591.

Rotz, Dana, "Why have divorce rates fallen? The role of women's age at marriage," *Journal of Human Resources*, 2016, *51* (4), 961–1002.

Schneider, Daniel, "Wealth and the Marital Divide," *American Journal of Sociology*, 2011, *117* (2), 627–667.

Shu, Xiaoling, Yifei Zhu, and Zhanxin Zhang, "Patriarchy, Resources, and Specialization: Marital Decision-Making Power in Urban China," *Journal of Family Issues*, 2013, *34* (7), 885–917.

State Council of China, "Circular on Payment of Winter Heating Allowances by National Governmental Agencies, Institutions, and Enterprises in 1956," The State Council of China 1956.

_ , "Circular on Heating Allowance for Urban Employees Living in Dormitories," State Administration of Labor and Ministry of Finance 1978.

Talhelm, T, X Zhang, S Oishi, C Shimin, D Duan, X Lan, and S Kitayama, "Large-scale Psychological Differences Within China Explained by Rice versus Wheat Agriculture," *Science*, 2014, *344*, 603–608.

Thornton, Arland and Willard L. Rodgers, "The Influence of Individual and Historical Time on Marital Dissolution," *Demography*, 1987, *24* (1), 1–22.

Wang, Yuhua, "Rice, State Capacity, and Economic Transformation in China," Harvard University Working Paper 2015.

_ **and Ji Yeon Hong**, "Rice, State, and Income," Harvard University Working Paper 2015.

Weiss, Yoram, Junjian Yi, and Junsen Zhang, "Cross-border Marriage Costs and Marriage Behavior: Theory and Evidence," *International Economic Review*, 2017, *forthcoming.*

Xiao, Qingyang, Zongwei Ma, Shenshen Li, and Yang Liu, "The Impact of Winter Heating on Air Pollution in China," *PloS ONE*, 2015, *10* (1), e0117311.

Xie, Yu, Qing Lai, and Xiaogang Wu, "Danwei and social inequality in contemporary urban China," *Research in the Sociology of Work*, 2009, *19*, 283–306.

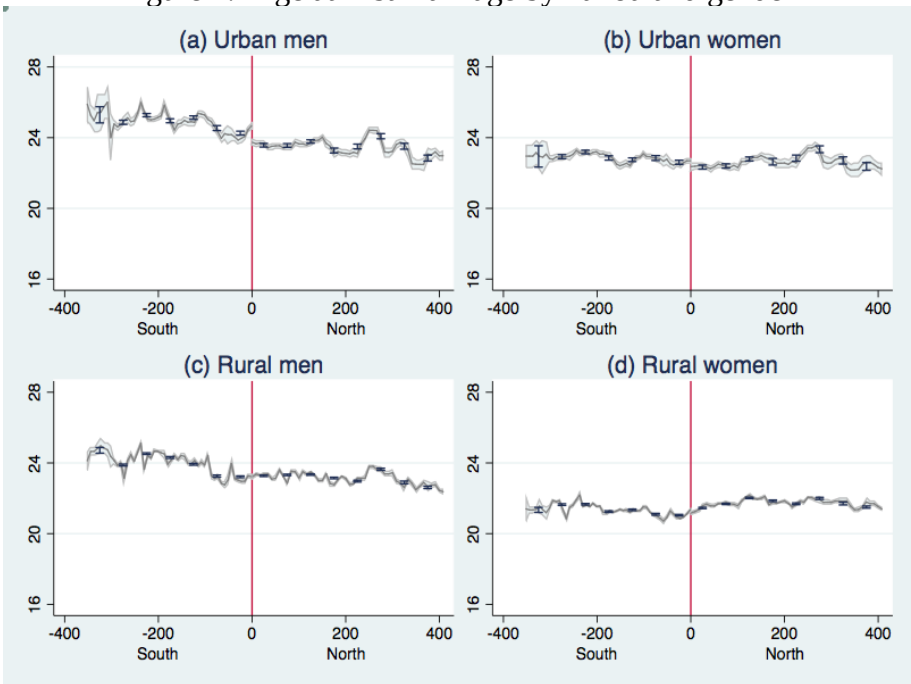
Xu, Xiaohong, IPL Png, Junhong Chu, and Yehning Chen, "Tocqueville Meets Fei Xiaotong: The Agrarian Causes of the Chinese Communist Revolution Reconsidered," NUS Working Paper 2018.

Yu, Jia and Yu Xie, "Changes in the Determinants of Marriage Entry in Post-Reform Urban China," *Demography*, 2015, *52* (6), 1869–1892.

Figure 1. Heating policy: Huai River

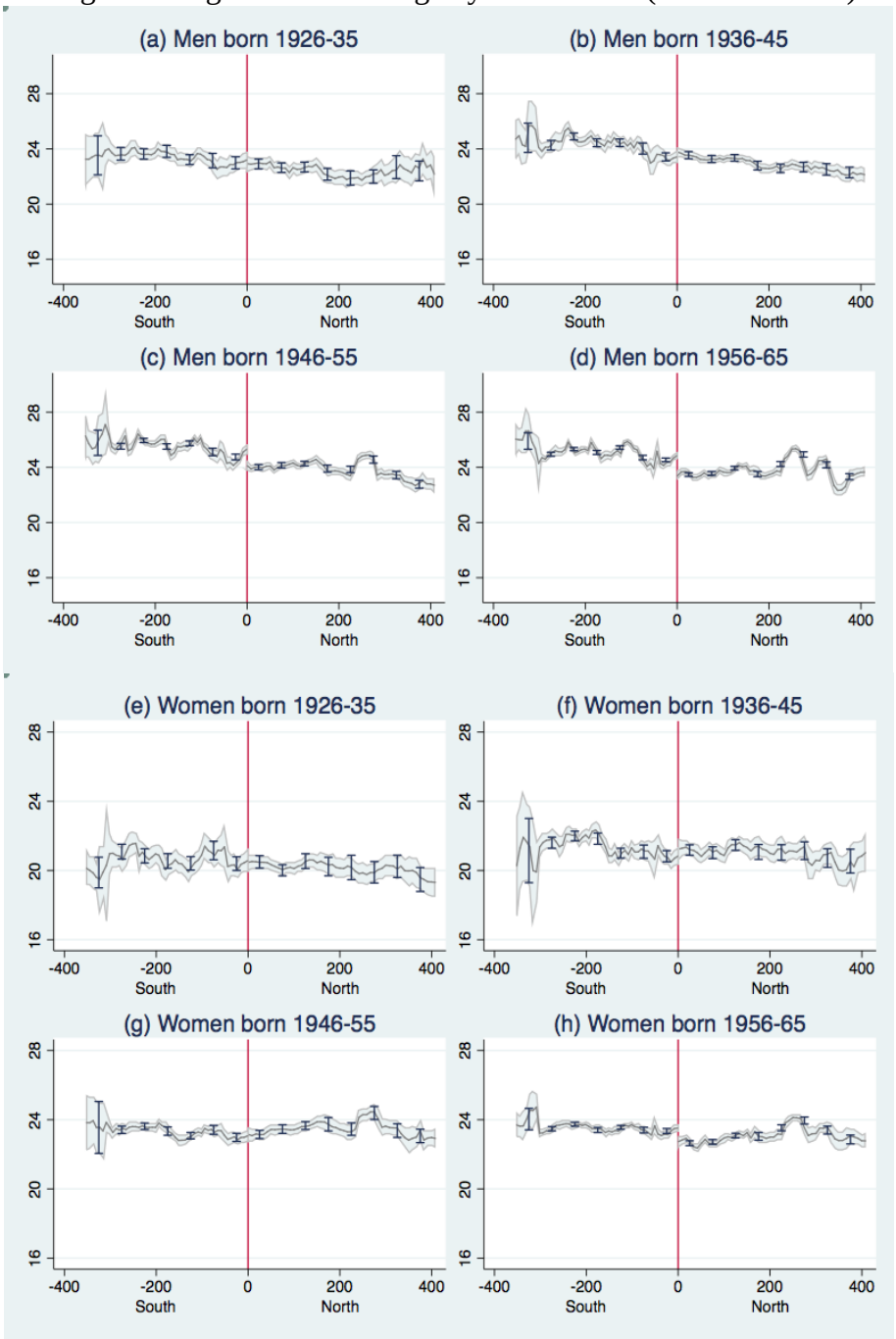
Notes: From east to west, the boundary of the heating policy follows the Huai River (in red). To the west of Huai River, the boundary follows the Qinling Mountains, which are sparsely populated. Thus, we focus on the Huai River part of the heating policy boundary, which runs through Jiangsu (very light blue), Anhui (light blue), and Henan (dark blue). The 32.5 degree north latitude is represented by the orange dashed line.

Figure 2. Age at first marriage by hukou and gender



Notes: Sample comprises all birth cohorts (born in 1926-65). Graphs depict fitted values from local polynomial estimate of the individual age at first marriage on distance from the Huai River, and corresponding 95 percent confidence intervals. Dots represent average age at first marriage within 50 kilometer bins.

Figure 3. Age at first marriage by birth cohort (urban residents)



Notes: Samples comprise all male and female residents with urban hukou in all birth cohorts (born in 1926-65). Graphs depict fitted values from local polynomial estimate of the individual age at first marriage on distance from the Huai River, and corresponding 95 percent confidence intervals. Dots represent average age at first marriage within 50 kilometer bins.

Table 1. Heating policy: Implementation

	Henan	Anhui	Jiangsu
(a) Earliest implementation	1957	1979	1957
(b) Average salary of urban worker (1978) (Yuan per month)	49.17	46.25	42.75
(c) Minimum heating allowance (1978/79) (Yuan per month)	4	3	3
(d) Minimum heating allowance relative to average salary (1978/79)	8.14%	6.49%	7.02%
(e) Heating allowance relative to monthly salary (1960-1999)	11.5%	6.73%	9.57%
	(3.16)	(3.11)	(6.66)

Sources: Row (a): China State Council (1956) and documents listed in Appendix II, Table A-II-1; Row (b): China Compendium of Statistics 1949-2008 [Xin zhongguo 60 nian tongji ziliao huibian]; Row (c): China State Administration of Labor and Ministry of Finance (1978); Row (d): (b) divided by (c); Row (e): Based on authors' survey of urban residents of Henan, Anhui, and Jiangsu, with each cell reporting mean and standard error (in parentheses).

Table 2. Marriage: Factors and behavior

	Women	Men	Difference
Age at marriage			t-test
Mean	23.9	24.8	-0.83
Std. Dev.	3.18	3.46	(p = 0.22)
Who earned more before marriage			Rank-sum test
Self	5	27	3.74***
Neither	25	3	(p < 0.001)
Spouse	21	14	
Importance to marriage			Chi2 test
Spouse's income important	34	21	3.48*
Spouse's income not important	17	23	(p = 0.06)
Spouse's job important	41	27	4.20**
Spouse's job not important	10	17	(p = 0.04)
Timing of marriage			Chi-2 test
Delayed due to low income	11	19	5.11**
Not delayed	40	25	(p = 0.02)
Would marry earlier if getting cash windfall	6	19	12.02***
Would not marry earlier	45	25	(p = 0.001)
After marriage			Chi-2 test
Spent more time on household work	47	25	16.08***
Did not spend more time on household	4	19	(p < 0.001)
Worked harder	12	23	8.39***
Did not work harder	39	21	(p = 0.004)
Worked more overtime	6	19	12.02***
Did not work more overtime	45	25	(p = 0.001)
Number of observations	51	44	

Source: Authors' survey of urban residents in Henan, Anhui, and Jiangsu provinces conducted in August 2017; Sample restricted to people with urban hukou at the time of marriage and who married before 1980. Rightmost column reports statistics and p-values of tests of differences between women and men (***p < 0.01, **p < 0.05, *p < 0.1).

Table 3. Summary statistics

Panel A

	Age at first marriage		Marriage rate	
	Women	Men	Women	Men
North	22.63	23.58	99.70	99.23
	(2.95)	(3.29)	(5.50)	(8.76)
	[11,507]	[21,423]	[11,542]	[21,590]
South	22.86	24.88	99.55	98.38
	(3.04)	(3.40)	(6.70)	(12.61)
	[16,353]	[22,338]	[16,427]	[22,705]
Total	22.77	22.92	99.61	98.79
	(3.01)	(4.20)	(6.23)	(10.91)
	[27,860]	[43,861]	[27,969]	[44,295]
North-south difference	-0.23	-1.30	0.15	0.84
t-statistic	-6.34	-40.65	1.95	8.13

Panel B

Variables	Unit	N	Mean	Std dev	Min	Max
Age at first marriage	Years	71,621	23.67	3.34	16	45
Early marriage	Indicator	72,264	0.65	0.48	0	1
Male	Indicator	72,264	0.61	0.49	0	1
Han Chinese	Indicator	72,264	0.98	0.13	0	1
Age in year 2000	Years	72,264	48.59	10.51	35	74
Years of schooling	Years	72,264	8.74	3.36	0	18
Parental years of schooling	Years	6,830	4.26	3.78	0	16
Government official/professional	Indicator	72,264	0.18	0.39	0	1
Multi-generation	Indicator	71,621	0.27	0.44	0	1
Confucian temples density	per million persons	372	1.01	0.95	0	3.22
Rice culture	Proportion	372	0.33	0.31	0	0.91
Gender ratio	Proportion	372	1.18	0.20	0.57	2
SOE employment	Proportion	372	0.95	0.03	0.88	0.999
GDP per capita	‘000 Yuan	372	9.46	8.03	1.68	37.74
North	Indicator	72,264	0.46	0.50	0	1
Jiangsu	Indicator	72,264	0.49	0.50	0	1
Henan	Indicator	72,264	0.30	0.46	0	1
Anhui	Indicator	72,264	0.21	0.41	0	1
Distance to Huai River	Kilometers	372	167.15	103.91	0.49	407.91
Average daily winter temperature	^{o}C	372	2.24	1.46	-1.81	5.03
Average winter precipitation	mm / day	372	0.78	0.49	0.18	2.64
Average winter sunshine hours	hours / day	372	5.06	0.41	3.97	6.20
Relative cohort loss rate		371	-0.44	0.20	-1.04	0.33
Education loss of sent down youth	Years	372	-0.04	0.09	-0.40	0.14
Historical agricultural population	Proportion	224	0.59	0.24	.05	0.96
Historical tenancy rate	Proportion	342	0.78	0.13	0.21	0.995

Notes: Sample comprises residents in the 2000 census in Henan, Anhui and Jiangsu born in 1926-65, with urban hukou, who did not move from neighborhood of birth. Panel A: Reports mean, standard deviation in parentheses, and frequency in brackets. The t-statistic is for the difference between north and south.

Table 4. Urban residents: Regression discontinuity

Variables	(a)	(b)	(c)	(d)	(e)	(f)
	Age at first marriage					Married early
	All cohorts	1926-35	1936-45	1946-55	1956-65	1956-65
			A. Men			
North	-1.25***	0.07	0.58	-1.20**	-1.49***	0.18***
	(0.43)	(0.48)	(0.43)	(0.49)	(0.40)	(0.05)
Observations	11,260	2,893	4,599	4,141	4,895	5,026
Counties	86	194	193	111	90	91
BIC	59,270	16,462	25,352	21,941	23,668	5,844.8
Bandwidth (km)	78.96	169.42	167.64	101.49	82.46	84.87
			B. Women			
North	-0.15	0.51	0.79*	0.18	-0.65**	0.09**
	(0.27)	(0.48)	(0.42)	(0.28)	(0.29)	(0.04)
Observations	13,820	1,274	1,893	3,952	6,124	9,433
Counties	157	148	139	159	144	174
BIC	70,003	6,619.8	9,854.6	20,318	28,502	11,646
Bandwidth (km)	136.53	131.47	119.53	137.33	125.27	145.26

Notes: Estimated by OLS with quadratic distance polynomials, rectangular kernel functions and MSE-optimal bandwidth; Sample comprises married residents in 2000 census in Henan, Anhui and Jiangsu, born in 1926-65, with urban hukou, who did not move from neighborhood of birth; Dependent variable is age at first marriage for Columns (a)-(e), and fraction of residents married early (before 25 for men, before 23 for women); Standard errors clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1).

Table 5. Urban men (born 1956-65): Confounding variables

Variables	(a) Preferred estimate	(b) Individual covariates	(c) Family orientation	(d) Confu-cianism	(e) Rice culture	(f) Gender ratio	(g) SOE employment	(h) Economic development	(i) All controls
North	-1.49***	-1.38***	-1.38***	-1.40***	-1.42***	-1.24***	-1.25***	-1.23***	-1.12***
	(0.40)	(0.36)	(0.36)	(0.36)	(0.35)	(0.35)	(0.29)	(0.31)	(0.27)
Han Chinese		-0.81***	-0.81***	-0.78**	-0.80**	-0.81***	-0.87***	-0.74***	-0.76***
		(0.31)	(0.31)	(0.31)	(0.30)	(0.30)	(0.29)	(0.28)	(0.28)
Age in year 2000		0.16***	0.16***	0.16***	0.16***	0.16***	0.16***	0.16***	0.16***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Years of schooling		0.11***	0.11***	0.11***	0.11***	0.11***	0.11***	0.11***	0.11***
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Parental years of schooling		0.08***	0.08***	0.08***	0.08***	0.08***	0.08***	0.08***	0.08***
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Missing parental years of schooling		-0.14	-0.20	-0.13	-0.14	-0.14	-0.12	-0.09	-0.12
		(0.14)	(0.25)	(0.14)	(0.14)	(0.14)	(0.15)	(0.14)	(0.25)
Govt. official or professional		-0.30***	-0.30***	-0.29***	-0.29***	-0.27***	-0.26**	-0.23**	-0.20**
		(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Multi-generation household			-0.07						-0.04
			(0.20)						(0.20)
Confucian temples				0.15**					0.07
				(0.07)					(0.07)
Rice culture					-0.71				-0.33
					(0.71)				(0.47)
Gender ratio						-1.20***			-0.83**
						(0.44)			(0.36)
SOE employment							0.10***		0.05
							(0.03)		(0.03)
GDP per capita								0.12***	0.10***
								(0.03)	(0.02)
Province F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,895	4,895	4,895	4,895	4,895	4,895	4,895	4,895	4,895
Counties	90	90	90	90	90	90	90	90	90
BIC	23,668	23,540	23,538	23,537	23,544	23,547	23,467	23,459	23,473
Bandwidth (km)	82.46	82.46	82.46	82.46	82.46	82.46	82.46	82.46	82.46

Notes: Estimated by OLS with quadratic distance polynomial and MSE-optimal bandwidth; Sample comprises married male residents in the 2000 census born in 1956-65, with urban hukou in 90 counties within bandwidth of 82.46 km (as in preferred estimate from Table 3, Panel A, column (e)), who did not move from neighborhood of birth; Dependent variable is age at first marriage; All estimates control for province fixed effects; Standard errors clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1). Column (a): Preferred estimate from Table 3, Panel A, column (e); Column (b): Controlling for indicator of Han Chinese, age, years of schooling and parental years of schooling, and indicator for government or professional occupation; Column (c): Also controlling for indicator for couples living with parents or married children, Column (d): Also controlling for ratio of number of Confucian temples in Ming and Qing dynasties in prefecture to population (Kung and Ma, 2015), Column (e): Also controlling for percentage of sown land devoted to rice paddies in the early 1990s, Column (f): Also controlling for county gender ratio (number of men to 100 women); Column (g): Also controlling for proportion of SOE employment; Column (h): Also controlling for county GDP per capita; Column (i): All controls.

Table 6. Urban men (born 1956-65): Mechanism and alternative explanations

	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Variables	Education	Govt. official / professional	Winter climate			Great Famine	Send down	Cultural Revolution	
			Temp.	Precip.	Sunshine			Agri	Tenancy
North	-1.50***	-1.53***	-1.44***	-1.40***	-1.42***	-1.47***	-1.23***	-1.21***	-1.45***
	(0.40)	(0.39)	(0.19)	(0.19)	(0.19)	(0.40)	(0.37)	(0.31)	(0.36)
Moderator	0.05***	-0.17	0.18*	-0.00	-0.47**	0.45	-4.53**	-0.01***	-2.19**
	(0.02)	(0.14)	(0.10)	(0.42)	(0.20)	(0.73)	(1.74)	(0.00)	(0.88)
North x	0.05	0.21	-0.25**	-2.65***	0.45*	-1.18	-7.14**	0.02***	5.07***
moderator	(0.03)	(0.19)	(0.12)	(0.68)	(0.24)	(0.89)	(3.12)	(0.01)	(1.35)
Observations	4,895	4,895	4,895	4,895	4,895	4,895	4,895	3,542	4,712
Counties	90	90	90	90	90	90	90	63	85
Weather stations			26	26	26				
BIC	23,654	23,683	23,680	23,660	23,680	23,681	23,628	17,226	22,817
Bandwidth (km)	82.46	82.46	82.46	82.46	82.46	82.46	82.46	82.46	82.46

Notes: Estimated by OLS with quadratic distance polynomial and MSE-optimal bandwidth; Sample comprises married male residents in the 2000 census born in 1956-65, with urban hukou in 90 counties within bandwidth of 82.46 km (as in baseline estimate from Table 3, Panel A, column (e)), who did not move from neighborhood of birth; Dependent variable is age at first marriage; Standard errors clustered by county (columns (a)-(c)) and by weather station (columns (d)-(f)) in parentheses (***p < 0.01, **p < 0.05, *p < 0.1). Column (a): Baseline estimate from Table 4, Panel A, column (e); Column (b): Effect of heating policy contingent on years of education; Column (c): Effect of heating policy contingent on indicator for government official or professional occupation; Columns (d)-(f): Effect of heating policy contingent on winter climate (daily average temperature, precipitation, and sunshine hours in December, January and February during 1956-87 specified as difference from mean), with standard errors adjusted for small number of clusters using Stata routine, clustse; Columns (g)-(j): Effect of heating policy contingent on intensity of the Great Famine (relative cohort loss rate), the Send Down movement (loss of education among sent down youth) and Cultural Revolution (historical agricultural population and tenancy rate) specified as difference from mean.

Appendix I: Proofs

Single person

The single person maximizes

$$Z = x^{\alpha}t^{1-\alpha}, \tag{A-I-1}$$

subject to $x = v + wl$ and $t + l = 1$. Substituting from the constraints in (A-I-1), the maximand simplifies to

$$Z = \Big[v + w[1-t]\Big]^{\alpha}t^{1-\alpha}. \tag{A-I-2}$$

The first-order condition with respect to t,

$$-w\alpha\Big[v + w[1-t]\Big]^{\alpha-1}t^{1-\alpha} + [1-\alpha]\Big[v + w[1-t]\Big]^{\alpha}t^{-\alpha} = 0.$$

Simplifying,

$$-w\alpha\Big[v + w[1-t]\Big]^{-1}t + [1-\alpha] = 0,$$

and so,

$$t = \frac{[1-\alpha][v+w]}{w}.$$

Substituting in (A-I-2),

$$\begin{aligned} Z &= [v + w - wt]^{\alpha}\left[\frac{[1-\alpha][v+w]}{w}\right]^{1-\alpha} \\ &= \Big[\alpha[v+w]\Big]^{\alpha}\left[\frac{[1-\alpha][v+w]}{w}\right]^{1-\alpha} \\ &= \alpha^{\alpha}[1-\alpha]^{1-\alpha}[v+w]w^{\alpha-1}. \end{aligned} \tag{A-I-3}$$

Substituting $S = v + w$ yields (1).

Married couple

The husband works full time in the labor market and let the wife work $1 - t_f$ in the labor market. Then they will purchase the quantity of inputs, $x = v_m + v_f + w_m + w_f[1 - t_f]$.

Accordingly, their joint home product will be

$$Z = [S_m + S_f - w_f t_f]^{\alpha} t_f^{1-\alpha}. \tag{A-I-4}$$

The first-order condition with respect to t_f is

$$-\alpha w_f [S_m + S_f - w_f t_f]^{\alpha-1} t_f^{1-\alpha} + [1-\alpha][S_m + S_f - w_f t_f]^{\alpha} t_f^{-\alpha} = 0,$$

which simplies to

$$-\alpha w_f [S_m + S_f - w_f t_f]^{-1} t_f + [1-\alpha] = 0,$$

or

$$\alpha w_f t_f = [1-\alpha][S_m + S_f - w_f t_f],$$

which implies that

$$t_f = \frac{[1-\alpha][S_m + S_f]}{w_f}. \tag{A-I-5}$$

Substituting in (A-I-4),

$$\begin{aligned} Z &= \Big[S_m + S_f - [1-\alpha][S_m + S_f]\Big]^{\alpha} \left[\frac{[1-\alpha][S_m + S_f]}{w_f}\right]^{1-\alpha} \\ &= \alpha^{\alpha}[1-\alpha]^{1-\alpha}[S_m + S_f]{w_f}^{\alpha-1}, \end{aligned}$$

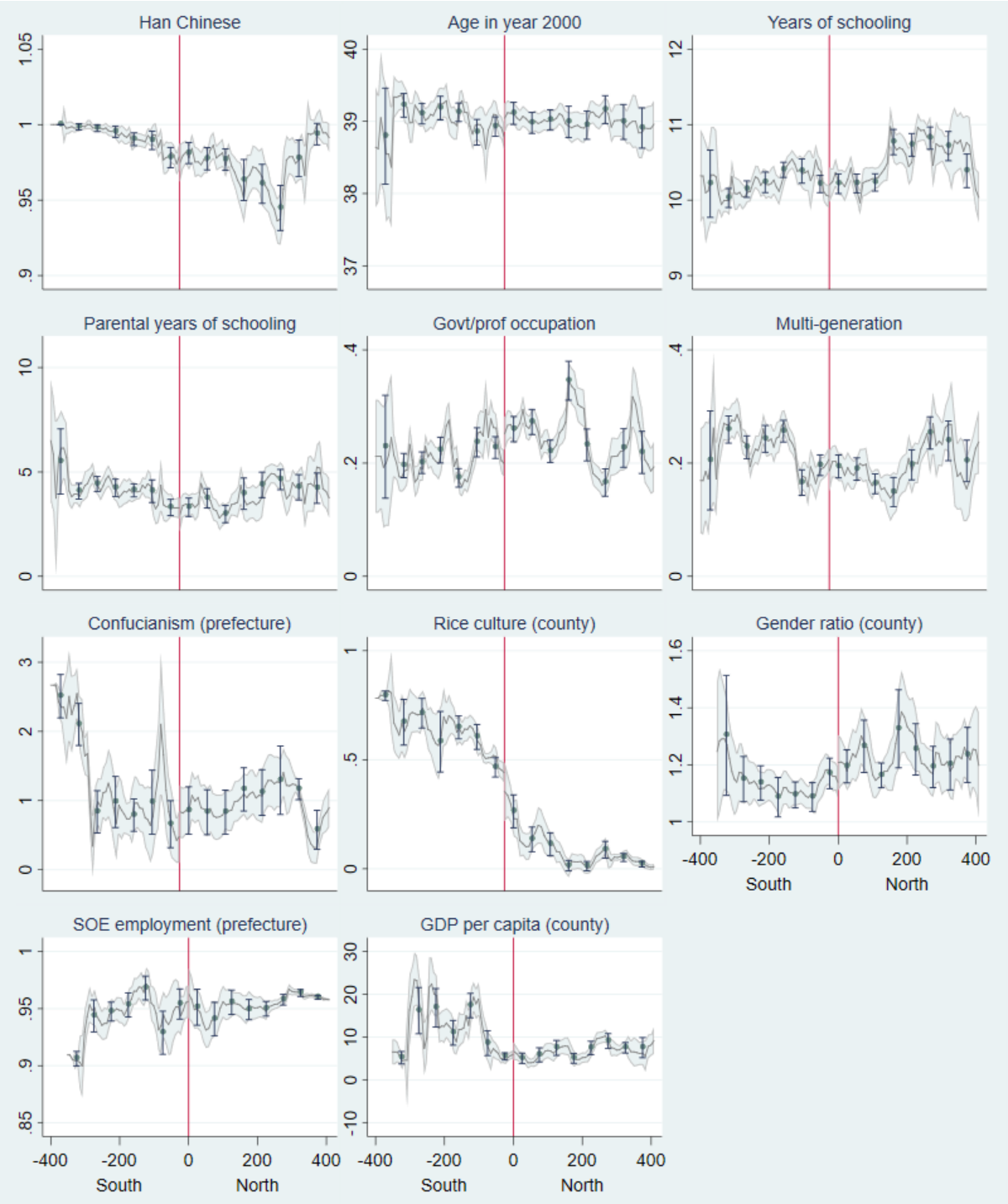
which is (3).

Appendix II. Data and Supplementary Estimates

To further check whether our estimated north/south difference in age of first marriage is driven by factors than are not related to heating policy, we run another 20 counterfactual analyses by setting hypothetical policy boundaries at 50-kilometer intervals from 500 kilometers south to 500 kilometers north of the Huai River. Figure A-II-2 plots these hypothetical boundaries. The figure shows that while the Huai River is in the middle of a flat region (the Huang-huai and Jiang-huai plains), most of the hypothetical policy boundaries cross mountains as well as plains. Obviously, mountainous areas are thinly populated, and so, the bulk of the people on the two sides of a hypothetical boundary crossing mountains could live hundreds of kilometers apart. Hence, people living on different sides of the boundary could behave quite differently, which a smooth function of distance would not properly control for. This violates a fundamental assumption of GRD, and the GRD estimate is likely to be sensitive to the choice of the boundary.

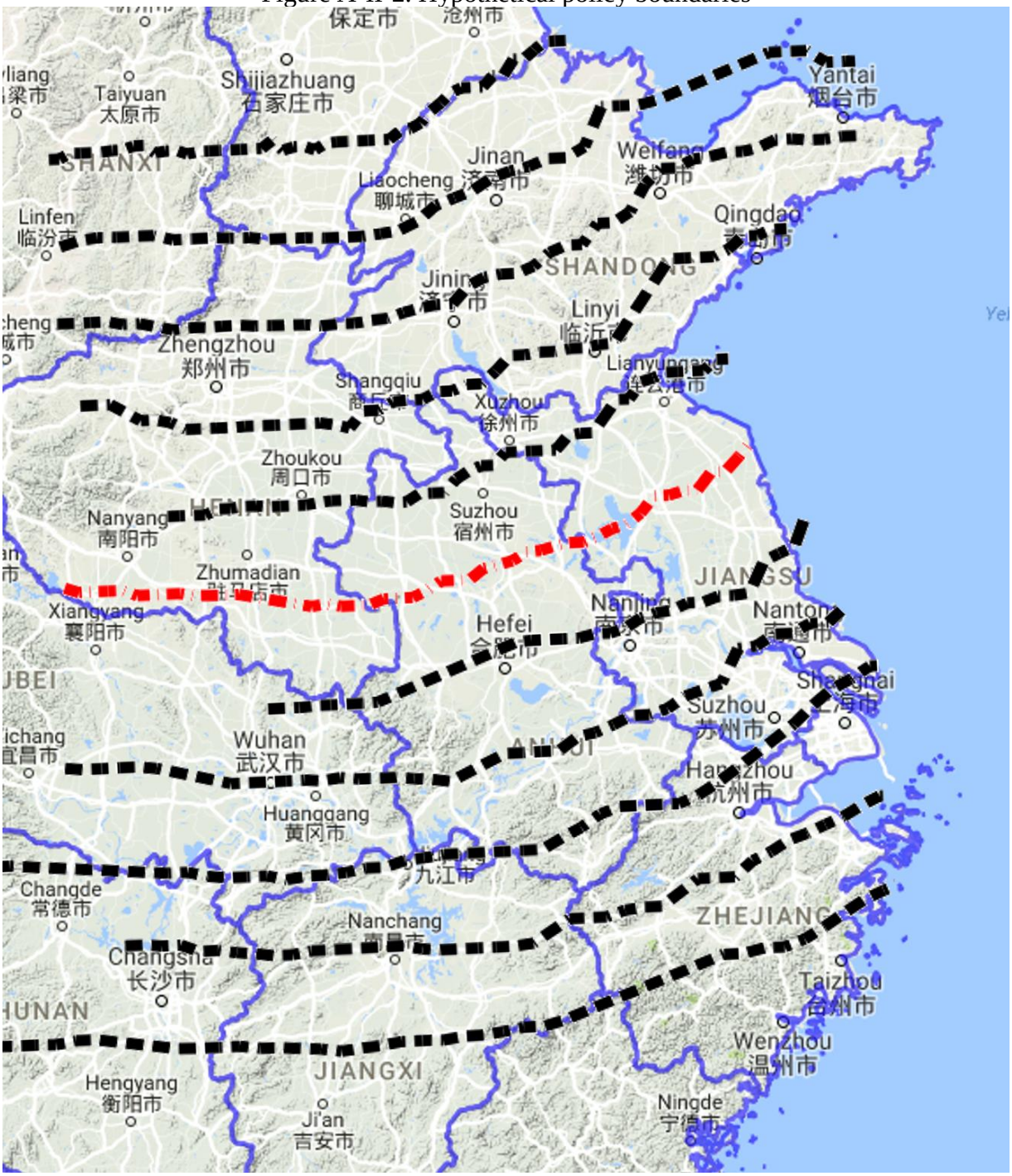
The estimates using hypothetical boundaries are reported in Table A-II-4 and plotted in Figure A-II-3. Most of the coefficients are not significantly different from zero. The coefficients that are statistically significant are unstable. For instance, among the three clusters of coefficients that are significant -- between 450 and 250 kilometers south, between 150 and 200 kilometers north, and between 350 and 450 kilometers north, the estimates oscillate between positive and negative. The instability of these estimates could be due to the hypothetical boundaries crossing mountains. The only robust estimate is that for the actual Huai River boundary. These estimates provide further support to our conclusion that the heating policy indeed affected the age of first marriage of the affected cohorts.

Figure A-II-1. Possible confounds (urban men born in 1956-65)



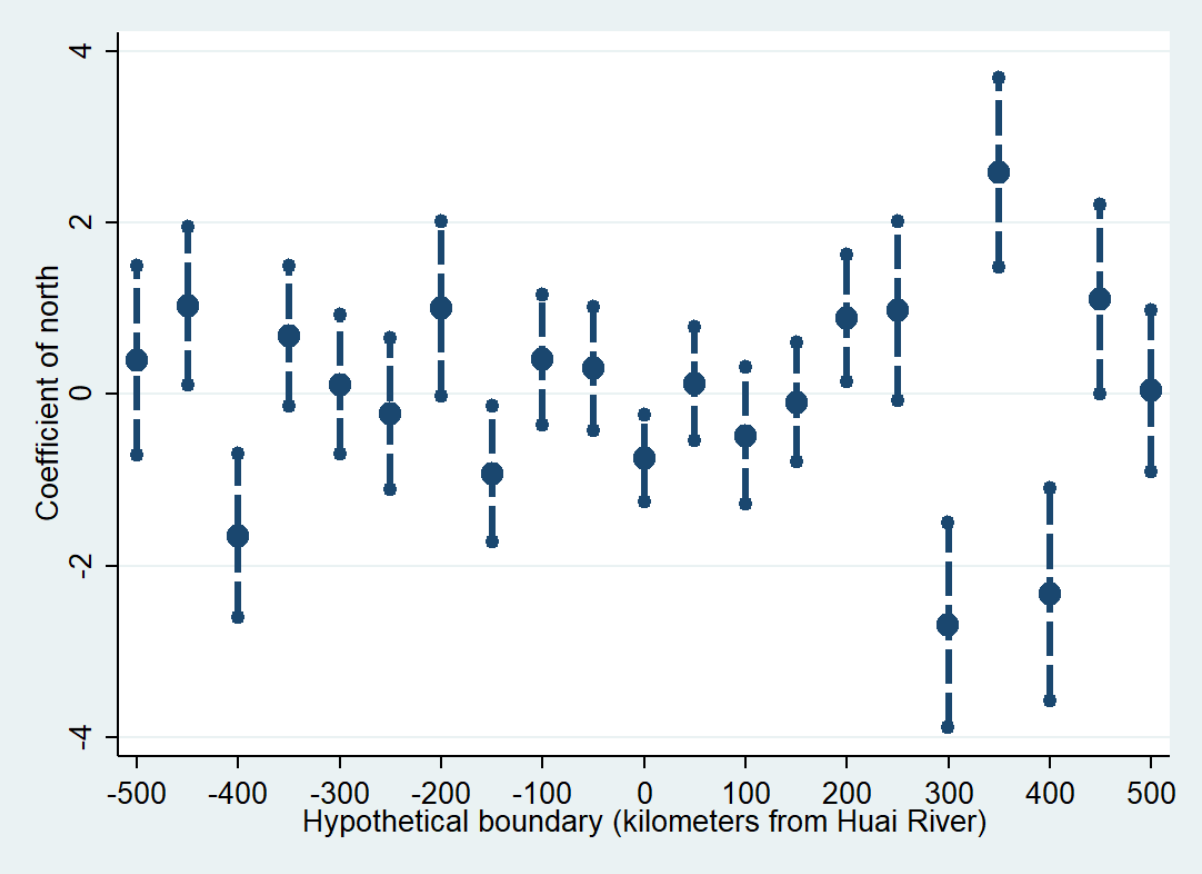
Notes: Sample comprises male residents with urban hukou born in 1956-65. Graphs depict fitted values from local polynomial estimate of the possible confounds (as labeled in each graph and explained in Table 2, Panel B) on distance from the Huai River, and corresponding 95 percent confidence intervals. Dots represent average of possible confounds within 50 kilometer bins. All estimates are at individual level, except for rice culture, gender ratio, and GDP per capita by county, and Confucianism and SOE employment by prefecture.

Figure A-II-2. Hypothetical policy boundaries



Notes: The red dotted line on the map is the Huai River and the black dotted lines are the hypothetical policy boundaries at 100-kilometer intervals from 500 kilometers south to 500 kilometers north of the Huai River.

Figure A-II-3. Regression discontinuity estimates with hypothetical policy boundaries



Notes: Coefficients of north and corresponding confidence intervals from GRD estimates with hypothetical policy boundaries at 50-kilometer intervals from 500 kilometers south to 500 kilometers north of the Huai River (Table A-II-4).

Table A-II-1. Additional institutional background statistics

A. Wages (Yuan per month)

	Henan, 1957				Anhui, 1959	Jiangsu, 1959
	Coal mining workers	Mechanical workers	Cigarette manufacturing workers	Coal staff	Coal mining	Mining
(a) Highest grade	105.60	94.50	71.25	175	105.6	105.62
(b) Lowest grade	28	29.50	26.50	36	26	33

Sources: Henan Provincial Gazetteer, Vol. 18 No. 25, Labor, Chapter 7.5, Tables 7-5-3, 7-5-4, 7-5-5, 7-5-7 (http://www.hnsqw.com.cn/sqsjk/hnsz/ldrsz/); Anhui Provincial Gazetteer, Labor, Chapter 5.1.2 (http://60.166.6.242:8080/was40/index_sz.jsp?rootid=15387&channelid=47966); Jiangsu Provincial Gazetteer, Labor Management, Chapter 6.5, (http://www.jssdfz.com/book/ldglz/DEFAULT.html.

B. Coal Subsidy

Heating coal, Harbin, 1975	20 Yuan per ton (Equivalent to US$13.30 at highly inflated official exchange rate)
Coal: International price	US$21.26 per ton
Average annual wage, 1978	615 Yuan

Sources: China Coal Association, Zhongguo Meitan Tongji Ziliao Huibian 1949-2004 (Collection of China Coal Statistics 1949-2004), Beijing: Meitan Gongye Chubanshe (Coal Industry Press), 2006; U.S. Energy Information Administration, https://www.eia.gov/totalenergy/data/annual/showtext.php?t=ptb0709; China Data Online.

Table A-II-2. Data sources and construction

Variable	Construction/remarks	Source
Age at first marriage	Year of first marriage minus year of birth	1% sample of the China Population Census 2000
Early marriage	= 1 if men marry at or before 25 or women marry at or before 23; = 0 otherwise	
Male		
Han Chinese		
Age in year 2000	2000 minus year of birth	
Years of schooling	= 0 if illiterate; = 6 if primary school; = 9 if secondary school; = 12 if high school; = 14 if professional education; = 16 if undergraduate; = 18 if graduate	
Parental years of schooling	Average of parents' years of schooling	
Government official or professional occupation	= 1 if occupation code (GB/T6565-1999) starts with 1 or 2; = 0 otherwise	
Multi-generation	= 1 if live with (1) parents, (2) parents in law, (3) son and son-in-law, or (4) daughter and daughter-in-law; = 0 otherwise	
Gender ratio	Ratio of men over women	
Confucianism	Ratio of number of temples during the Ming and Qing dynasties to population of prefecture	Kung and Ma (2014); 1% sample of the China Population Census 2000
Rice culture	Percentage of cultivated area of prefecture or county sown with rice	Anhui, Henan and Jiangsu Statistical Yearbooks 1991; 1% sample of the China Population Census 2000
SOE (State-owned enterprise) employment	Ratio of employment in state-owned and collective enterprises to total employment by prefecture	
GDP (Gross domestic product) per capita	By prefecture for urban areas and by county for rural areas	China City Statistical Yearbook 2001; China Regional Economy Statistical Yearbook 2001
North		Google Maps
Distance to Huai River		
Average daily winter temperature, precipitation and sunshine hours	Daily average in December, January and February during 1956-87	China Meteorological Administration
Relative cohort loss rate	See Meng, et al. (2015) and Chu, et al. (2018)	1% sample of the China Population Census 2000
Education loss of sent down youth	High school graduation rate of cohort affected by the movement (born in 1946-62) minus that of those unaffected (born in 1963-80).	
Historical agricultural population	Percentage of county total population as agricultural in early 1930s	Xiao (1977)
Historical tenancy rate	Percentage of county agricultural population as tenants or semi-tenants in early 1930s	

Table A-II-3. Urban men (born 1956-65): Falsification and robustness

Variables	(a) Preferred estimate	(b) Sample: Rural men	(c) Counterfactual boundaries: Latitude 32.5°N	(d) Counterfactual boundaries: North 50km	(e) Counterfactual boundaries: South 50km	(f) Linear dist. function
North	-1.49***	-0.53	0.22	1.00*	0.53	-1.24***
	(0.40)	(0.32)	(0.51)	(0.51)	(1.10)	(0.35)
Observations	4,895	42,455	7,979	4,433	3,704	3,405
Counties	90	127	144	85	62	62
BIC	23,668	212,826	38,864	21,658	18,231	16,467
Bandwidth	82.46 km	114.72 km	0.93°	66.98 km	56.40 km	59.91 km

Variables	(g) Kernel: Triangular	(h) Kernel: Epanech-nikov	(i) Multi-level model	(j) Sample: Urban couples	(k) Sample: Incl. adjacent provinces	(l) Sample: Incl. adjacent provinces
North	-1.45***	-1.39***	-1.24***	-1.14***	-0.65**	-0.49**
	(0.39)	(0.38)	(0.31)	(0.37)	(0.30)	(0.20)
Observations	5,842	6,003	4,895	3,229	12,394	45,072
Counties	109	111	90	101	241	1,111
BIC	n.a.	n.a.	23,425	15,005	60,319	222,630
Bandwidth	99.51 km	101.51 km	82.46 km	92.27 km	175.90 km	n.a.

Notes: Estimated by OLS (except columns (f)-(g) by Stata routine, rdrobust), with quadratic distance polynomials and MSE-optimal bandwidth; Sample comprises married male residents in the 2000 census with urban hukou within MSE-optimal bandwidth, born in 1956-65, who did not move from neighborhood of birth; Dependent variable is age at first marriage; Standard errors clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1). Column (a): Preferred estimate from Table 3-A, column (e); Column (b) repeats column (a) but replaces the urban sample by its rural counterpart; Column (c) specifies boundary as 32.5°N and assigns distance by latitude, with optimal bandwidth of 0.93°; Columns (d)-(e) specify boundary as 50 kilometers north or south of the Huai River; Column (f) repeats column (a) with linear distance polynomials; Columns (g)-(h) repeat column (a) with alternative density functions; Column (i) repeats column (a) using a multi-level model that includes county fixed effects, county-specific random coefficients for age, Han Chinese, education, occupation, living with parents, and province-specific coefficients for Confucianism, rice culture, gender ratio and GDP per capita; Column (j) excludes men whose wife holds rural hukou; Column (k) includes urban men in adjacent provinces (Shandong, Hebei, Shanxi, Hubei, Jiangxi, Zhejiang, and Shanghai); Column (l) repeats column (k) with parametric RD method.

Table A-II-4. Counterfactual boundaries

Shift to south

	-50 km	-100 km	-150 km	-200 km	-250 km	-300 km	-350 km	-400 km	-450 km	-500 km
North	0.12	-0.48	-0.09	0.89**	0.97*	-2.69***	2.58***	-2.33***	1.11*	0.04
	(0.34)	(0.41)	(0.35)	(0.38)	(0.53)	(0.61)	(0.56)	(0.63)	(0.56)	(0.48)
Observations	20,920	16,268	13,591	17,909	14,826	18,114	12,460	8,779	8,913	5,830
Counties	384	283	228	300	244	328	236	182	199	172
BIC	101592	79137	65979	90103	74765	91453	63714	45979	46259	29602
Bandwidth	254.37	184.08	142.59	179.05	134.74	188.57	138.39	106.54	125.25	113.35

Shift to north

	50 km	100 km	150 km	200 km	250 km	300 km	350 km	400 km	450 km	500 km
North	0.30	0.40	-0.93**	1.00*	-0.22	0.11	0.68	-1.65***	1.03**	0.39
	(0.37)	(0.39)	(0.40)	(0.52)	(0.45)	(0.41)	(0.42)	(0.48)	(0.47)	(0.56)
Observations	12,324	10,071	8,277	11,660	13,386	10,963	10,489	5,554	4,098	5,050
Counties	243	209	188	287	351	305	319	185	164	192
BIC	60180	48978	40231	55921	64344	52506	50084	25923	19298	24441
Bandwidth	176.25	149.00	121.61	174.91	208.99	167.07	183.86	103.29	101.47	121.59

Notes: Estimated by OLS with quadratic distance polynomials and MSE-optimal bandwidth; Sample comprises married male residents in the 2000 census with urban hukou within MSE-optimal bandwidth of Jiangsu, Anhui, Henan, Hebei, Shanxi, Shanghai, Zhejiang, Fujian, Jiangxi, Shandong, Hubei, Hunan provinces, born in 1956-65, who did not move from neighborhood of birth; Dependent variable is age at first marriage; Standard errors clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1).

Table A-II-5. Regression discontinuity: Alternative methods and specifications

Variables	(a)	(b)	(c)	(d)	(e)	(f)
	Age at first marriage					Marry early
	All cohorts	1926-35	1936-45	1946-55	1956-65	1956-65
	A. Men: Parametric GRD					
North	-0.72***	0.34	0.51*	-0.86***	-1.36***	0.16***
	(0.23)	(0.37)	(0.29)	(0.30)	(0.25)	(0.03)
Observations	43,761	4,988	8,213	13,155	17,405	17,668
Counties	372	367	372	371	372	372
BIC	229743	28,445	44,958	68,575	84,274	22,354
	B. Women: Parametric GRD					
North	-0.45**	-0.11	0.56*	-0.03	-0.98***	0.19***
	(0.18)	(0.33)	(0.29)	(0.20)	(0.20)	(0.04)
Observations	27,860	2,591	4,211	8,087	12,971	13,041
Counties	372	338	362	370	372	372
BIC	140331	13,451	21,695	41,432	59,187	18,652
	C. Men: Non-parametric GRD with asymmetric bandwidth					
North	-1.07***	0.08	0.79*	-1.60***	-1.31***	0.16***
	(0.40)	(0.52)	(0.47)	(0.48)	(0.39)	(0.05)
Observations	12,787	2,519	4,240	4,834	5,292	6,986
Counties	99	166	173	125	99	126
BIC	67,170	14,298	23,412	25,403	25,658	8,543.5
Bandwidth (km)	78.19/	145.30/	187.44/	91.19/	78.50/	115.78/
	99.08	139.64	122.49	136.00	100.77	101.48
	D. Women: Non-parametric GRD with asymmetric bandwidth					
North	-0.51	-0.35	0.45	-0.95**	-0.74**	0.14***
	(0.36)	(0.54)	(0.49)	(0.43)	(0.34)	(0.05)
Observations	18,836	2,014	3,625	6,499	9,025	5,882
Counties	145	135	151	169	166	140
BIC	99,576	11,431	19,934	34,352	44,165	8,311.2
Bandwidth (km)	148.00/	130.80/	116.38/	134.03/	170.15/	138.76/
	105.81	111.69	139.57	147.47	125.13	111.15

Notes: Panels A and B estimated by OLS, using parametric GRD with quadratic distance functions; Panels C and D estimated by Stata routine, rdrobust, using non-parametric GRD with quadratic distance functions and asymmetric MSE-optimal bandwidths (reported as "south/north"). Sample: men and women with urban hukou in all cohorts; Standard errors clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1).

Table A-II-6. Mechanism: Robustness

Variables	(a)	(b)	(c)	(d)	(e)	(f)
	Education		All	Govt/prof occupation		All
	Less	More	counties	No	Yes	counties
North	-1.39***	-1.27***	-1.34***	-1.45***	-1.07***	-1.38***
	(0.46)	(0.43)	(0.26)	(0.40)	(0.58)	(0.25)
Education			0.12***			
			(0.02)			
North x education			0.04**			
			(0.02)			
Govt/prof occupation						-0.26***
						(0.09)
North x govt/prof occupation						0.14
						(0.12)
Observations	9,824	7,581	17,405	13,454	3,951	17,405
Counties	371	370	372	372	363	372
BIC	47,911	36,272	84,213	65,662	5,779	18,582

Notes: Estimated by OLS with quadratic distance functions. Sample comprises married male residents in the 2000 census from all 372 counties in Jiangsu, Anhui and Henan, with urban hukou, born in 1956-65, who did not move from neighborhood of birth; Dependent variable is age at first marriage; Standard errors clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1). Columns (a)-(b): Estimates on individuals with below and above median years of education; Columns (d)-(e): Estimates on individuals in government or professional occupation or otherwise.

Table A-II-7. Marriage: Factors and behavior

	Women	Men	Difference
Age at marriage			T-test
Mean	24.21	25.09	-0.87***
Std. Dev.	2.85	3.15	(p = 0.004)
Who earned more before marriage			Rank-sum test
Self	29	76	4.30***
Neither	62	18	(p < 0.001)
Spouse	123	79	
Importance to marriage			Chi-2 test
Spouse's income important	130	83	6.31**
Spouse's income not important	84	90	(p = 0.012)
Spouse's job important	149	102	4.78**
Spouse's job not important	65	71	(p = 0.029)
Timing of marriage			Chi-2 test
Delayed due to low income	27	39	6.66**
Not delayed	187	134	(p = 0.010)
Would marry earlier if getting cash windfall	18	35	11.31***
Would not marry earlier	196	138	(p = 0.001)
After marriage			Chi-2 test
Spent more time on household work	189	122	19.20***
Did not spend more time on household	25	51	(p < 0.001)
Worked harder	52	64	7.35***
Did not work harder	162	109	(p = 0.007)
Worked more overtime	35	62	19.33***
Did not work more overtime	179	111	(p < 0.001)
Number of observations	214	173	

Source: Authors' survey of urban residents in Henan, Anhui, and Jiangsu provinces conducted in August 2017; Sample restricted to people with urban hukou at the time of marriage and who married before 1990. Rightmost column reports statistics and p-values of tests of differences between women and men (***p < 0.01, **p < 0.05, *p < 0.1).

Appendix III: Differences in Differences

The GRD analyses estimate the local average treatment effect (LATE) of the heating policy in the neighborhood of the Huai River. Besides, it is also useful to understand the average treatment effect (ATE) of the heating policy, which is the effect on the broader population.

To investigate, we apply an empirical strategy of Differences in Differences (DID) and estimate a regression of the age at first marriage among all people with urban hukou:

$$a_j = \lambda_0 + \lambda_1 N_j + \sum_{t=1926/35}^{1956/65} \lambda_{2t} C_{jt} + \sum_{t=1926/35}^{1956/65} \lambda_{3t} N_j \cdot C_{jt} + X'_{ji}\beta + \varepsilon_{ji}, \qquad \text{(A-III-1)}$$

where $C_{jt} = 1$ if individual j was born in cohort t, λ_0 is a constant, λ_1 represents the north-south difference in age at first marriage across all urban birth cohorts, λ_{2t} represents the common time trend for birth cohort t, and λ_{3t} represents the north-south difference in the time trend for cohort t, which is due to the heating policy, and ε_{ji} represents a random error term. The other variables and coefficients are as defined in (8) and (11).

Besides identifying the ATE rather than the LATE, the DID analysis is also helpful as it relies on different identification assumptions from the GRD analyses. DID analyses assume that the outcome of interest follows the same trend in both the control and treatment groups subject to a possible time invariant difference. Typically, this would be validated by showing a common pre-treatment trend. Unfortunately, our sample contains only one cohort (1926-35) which married before the heating policy, and so, we cannot test the existence of a common pre-treatment trend. Nevertheless, since counties in the north and south of the Huai River belong to the same provinces, and so, are subject to similar regulations, the common trend hypothesis is justifiable. By comparison, the GRD analyses rely on the assumption that the heating policy is the only factor that affects marriage which is discontinuous at the Huai River. Although we have checked the robustness of the GRD finding in various ways, it is useful to apply tests that rely on different assumptions.

As a preliminary, Table A-III-1 reports the age at first marriage among men and women in the various birth cohorts with urban hukou resident in areas north and south of the Huai

River. Among all cohorts of men and all cohorts of women except those born between 1946-55, the age at first marriage is significantly lower in the north than south.

Table A-III-2 reports estimates for men and women with urban hukou, and including controls, X_{ji}, comprising prefecture fixed effects and demographic, social, cultural, and other factors that affect marriage. The coefficient of north represents the north-south difference in the age at first marriage in the oldest cohort (1926-35). The coefficient of north for the later cohorts represents the difference in the north-south difference in the age at first marriage between the respective cohort and the oldest cohort.

Referring to Table A-III-2, column (a), for men, the coefficient of north is not significant, while the coefficients of north for the 1946-55 and 1956-65 cohorts are negative and significant. The estimate suggests that, in the 1956-65 cohort, northerners married $0.36 + 0.06 = 0.42$ years or 5 months earlier than southerners.[1]

The estimate of the ATE is smaller than the corresponding GRD estimate of the LATE in Table 4, column (e). Apparently, the heating policy had a smaller effect on the age at first marriage in the north vis-à-vis south as a whole as compared with the immediate north vis-à-vis south of the Huai River. Referring to Figure 3(d), the age at first marriage increased with distance from the Huai River towards the south and north. The DID estimate suggests that, controlling for province and other controls, the north-south difference becomes smaller with distance from the Huai River.

[1]For women, the coefficient of north for the 1956-65 cohort is negative but imprecise. Combined with the coefficient of north for the 1926-35 cohort, the estimated north-south difference in the 1956-65 cohort is 0.43 years and significant. A puzzle is that the coefficient of north for the 1946-55 cohort is positive.

Table A-III-1. Urban residents: Age at first marriage

Variables	(a)	(b)	(c)	(d)	(e)	(f)	(g)
	Age at first marriage					% Early marriage	Marriage rate (%)
	All	1926-35	1936-45	1946-55	1956-65		
				Men			
North	23.58	22.49	23.06	24.01	23.87	75.87	99.23
	(3.29)	(4.16)	(3.55)	(3.20)	(2.74)	(42.78)	(8.76)
	[21,423]	[2,672]	[4,178]	[6341]	[8,232]	[21,590]	[21,590]
South	24.88	23.42	24.31	25.49	25.04	60.03	98.38
	(3.40)	(4.20)	(3.94)	(3.37)	(2.73)	(48.99)	(12.61)
	[22,338]	[2,316]	[4,035]	[6,814]	[9,173]	[22,705]	[22,705]
Total	24.24	22.92	23.67	24.78	24.49	67.75	98.79
	(3.41)	(4.20)	(3.80)	(3.37)	(2.80)	(46,74)	(10.91)
	[43,761]	[4,988]	[8,213]	[13,155]	[17,405]	[44,295]	[44,295]
North-south difference	-1.30	-0.93	-1.26	-1.48	-1.17	15.85	0.84
t-statistic	-40.65	-7.87	-15.19	-25.84	-28.30	36.19	8.13
				Women			
North	22.63	20.25	21.13	23.51	23.05	63.13	99.70
	(2.95)	(2.87)	(3.03)	(3.12)	(2.36)	(48.25)	(5.50)
	[11,507]	[1,055]	[1,740]	[3,205]	[5,507]	[11,542]	[11,542]
South	22.86	20.71	21.40	23.31	23.50	58.32	99.55
	(3.04)	(3.44)	(3.28)	(3.14)	(2.38)	(49.30)	(6.70)
	[16,353]	[1,536]	[2,471]	[4,882]	[7,464]	[16,427]	[16,427]
Total	22.77	20.52	21.29	23.39	23.31	60.31	99.61
	(3.01)	(3.23)	(3.18)	(3.13)	(2.39)	(48.93)	(6.23)
	[27,860]	[2,591]	[4,211]	[8,087]	[12,971]	[27,969]	[27,969]
North-south difference	-0.23	-0.46	-0.27	0.20	-0.45	4.81	0.15
t-statistic	-6.34	-3.58	-2.68	2.85	-10.69	8.11	1.95

Notes: Sample comprises residents in the 2000 census in Henan, Anhui, and Jiangsu born in 1926-65, with urban hukou, who did not move from neighborhood of birth. Upper rows report mean values, standard deviations in parentheses and frequencies in brackets; Lower rows report difference in means between north and south with t-statistics (***p < 0.01, **p < 0.05, *p < 0.1).

Table A-III-2. Urban residents: Difference in differences

Variables	(a) Men	(b) Women
Constant	22.85***	19.97***
	(0.25)	(0.20)
Born 1936-45	0.85***	0.17
	(0.12)	(0.12)
Born 1946-55	1.86***	1.64***
	(0.10)	(0.11)
Born 1956-65	1.29***	1.39***
	(0.10)	(0.11)
North	-0.06	-0.26
	(0.20)	(0.18)
North x Born 1936-45	-0.33**	0.12
	(0.15)	(0.16)
North x Born 1946-55	-0.57***	0.48***
	(0.15)	(0.15)
North x Born 1956-65	-0.36**	-0.17
	(0.15)	(0.15)
Prefecture fixed effects	Yes	Yes
Covariates	Yes	Yes
Observations	43,572	27,860
Counties	372	372
R-squared	0.11	0.19
North-south difference		
Cohort 1936-45	-0.389**	-0.137
p-value	[0.035]	[0.419]
Cohort 1946-55	-0.624***	0.228*
p-value	[0.000]	[0.094]
Cohort 1956-65	-0.414**	-0.429***
p-value	[0.015]	[0.002]

Notes: Sample comprises residents in 2000 census with urban hukou born in 1926-65 who did not move from neighborhood of birth; Estimated by OLS with prefecture fixed effects and covariates (as listed in Table 4); Dependent variable: age at first marriage; Column (a): Men; Column (b): Women. Standard error clustered by county in parentheses (***p < 0.01, **p < 0.05, *p < 0.1). North-south difference is the sum of the coefficient of North and the coefficient of the interaction of North with the respective birth cohort.