One Child Policy and Arising of Man-Made Twins*

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Abstract

Using 1982, 1990, 2000 and 2005 census data, this paper documents that twins birth rate in China more than doubled from late 1960s through early 2000s, from 3.5 to 7.5 per thousand births. Matching the sample with one-child policy regulatory fine data in each province every year, we investigate the role of one child policy in this phenomenon. Estimates from the linear probability model suggests that one child policy accounts for at least one third of the increase in twins rate. Furthermore, using a twins sample from CHNS data, we analyze the association between policy fine and within-pair height difference. The results show that increasing by one year's income in policy fine is remarkably associated with over one centimeter increase in same-gender twins' height difference but not significantly related to that of different-gender twins', which is consistent with the hypothesis that one-child policy stimulates people's incentive to give birth to twins through taking fertility drugs.

JEL Codes: J08, J11, J13

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(First draft for comment only)

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"'One is too few,' said a woman (in China) waiting at the hospital..."

- By Elizabeth Grether, ABC News, Aug. 3rd, 2011

1 Introduction

In past several decades, twins rate in China increased rapidly and substantially.[1] As Figure 1a shows, twins birth rate in China rose by over 100 percent from late 1960s through early 2000s, from 3.5 to 7.5 per thousand births. Though China seems not alone when compared to other countries,[2] the Chinese case may be special because of one-child policy. As the policy name suggests, one couple is allowed to have one child, but twins are an exemption. Consequently, twins are favorable under such a policy, especially to those who like more kids (children preference) or those with strong boy preference, because individuals are able to own two babies without going against the law and they are more likely to have one boy in a single birth. The twins-favor has lead to many "strange" phenomena: if you Google "Twins" in Chinese, there will be plenty of advertisements for private hospitals and informal drug stores that may help you to give birth to twins. As ABC News reported, Chinese women tried to bypass the one-child policy with "multiple baby pills" for twins[3]. Some parents reported siblings as twins to escape the punishment from the policy.[4] Therefore, at least one question is left to be answered: is one-child policy relevant to the twins rate increase in China in the past few decades?

[Figure 1a about here]

Surprisingly, there is no previous research answering the question above. Instead, there is a growing literature using twins data in China to understand some interesting issues or to answer some questions in development economics and labor economics. The methodologies are well developed by a huge strand of literature (Rosenzweig and Wolpin, 1980a, 1980b; Ashenfelter and Krueger, 1994; Ashenfelter and Rouse, 1998; Rosenzweig, 2000; Ponczek and Souza, 2012). Using a set of Chinese twins data to control for the genetic and family background effects, Zhang et al. (2007) examine whether the cultural revolution (CR) cohort have smaller economic returns to schooling than the non-CR cohort. Li et al. (2008) estimate the causal effect of family size on children's education in China by exploiting exogenous variation induced by a twin birth. Most recently, Li et al. (2012) estimate returns to education using a twins sample in urban

[1] The more accurate name should be "reported" twins.

[2] Countries like Japan, India and the US, twins rate also rose over time. For example, the twins rate in the United States rose by 76 percent from 1980 through 2009, from 18.9 to 33.3 per 1,000 births (Martin et al., 2012), and that in Japan increased from 5.80 to 7.75 per 1,000 deliveries from 1980 to 1995 (see Appendix Table 1).

[3] http://abcnews.go.com/Health/chinese-women-fertility-drugs-bypass-child-policy/story?id=14219173 , accessed March 10th, 2013.

[4] An example (in Chinese): http://www.wuhan.jcy.gov.cn/yasf/200905/t20090519_221490.html , accessed March 10, 2013

China, and Rosenzweig and Zhang (2012) use twins' birth weight to estimate gender differences in schooling outcomes. Using twins as "tools" in economics is based on several facts (or maintained assumptions): twins are born randomly across the population by controlling for biological factors; twins share similar genes; parents could not expect them until mothers are pregnant. However, if twins' births are selected due to boy or children preferences, there will be some potential problems in identification and estimation.[5]

This paper tries to shed some light on the question whether one child policy contributes to twins rate increase since 1970s. Matching census data to one-child policy regulatory fine data by province and year, we find that increasing by one year's income in policy fine is associated with about 0.06 per thousand births increase in twins, indicating that about one third of the twins rate increase since 1970s can be explained by one-child policy. In addition, the association between policy fine and twins incidence only exists in Han ethnicity subsample, which is consistent with the fact that one-child policy was mainly implemented in people of Han ethnicity. Furthermore, we also find heterogeneity in urban/rural areas, by different birth orders or mother's education levels.

Using census data, we find evidence for policy-associated twins, but do know whether the policy-associated twins are monozygotic (MZ) or dizygotic (DZ) or simply purposefully reported by parents (not twins at all, "fake twins" hereafter). We do know that different-gender twins, if real, are DZ. Height difference within twins is used to shed more light on this issue.[6] Therefore, we turn to China Health and Nutrition Survey (CHNS) data and compose a twins sample from it. Estimates show that height difference within twins is positively associated with policy fine and this association only exists in same-gender twins sample. This finding is consistent with that the one-child policy stimulates people's incentive to give birth to twins through taking fertility drugs.[7]

This paper contributes to existing literature or policy making in several ways. First, as far as we know, this is the first paper documenting the rise of twins rate in China since 1970s and linking this phenomenon to the one-child policy. In addition, this study also raises a twins-selection issue in China. In previous literature, twins are usually considered as the "random gift" of the god. However, researchers have to re-consider their estimates using Chinese twins, because part of them may be man-made or fake, which may potentially bring problems to their studies. Finally, this study helps better understand people's reaction under the one-child

[5]For example, if twins' birth is correlated with children preference and they are also used as an instrument for family size to estimate its effect on mothers' labor market participation, the results would be biased when mother's labor supply is correlated with children preference or expectation of having twins, which is quite possible.

[6]Firstly, a significantly higher concordance in height is found for MZ pairs than for DZ pairs during puberty in children, and the height spurt occurs more simultaneously for MZ twins in comparison to DZ twins (Fischbein, 1977). Secondly, the height difference within fake twins should be larger than that of real ones because the fake twins are actually siblings, whose members have not only different genes but also different real ages though they are reported to be the same.

[7]The mechanism of these drugs is to induce ovulation, which are usually taken to treat infertility. When normal women take them, the possibility of multiple ovulation would be increased, and thus it is more likely to have twins. Though these drugs are classified as prescription medicine, it is still possible for individuals to purchase them in some private hospitals and get prescription from some doctors.

policy, and motivates us to rethink over the policy's social consequences. Since the fertility drugs may have negative effect on women's health and threat the quality of babies as well, the consequences of having these drugs would bring a higher cost for the whole society in addition to the cost of the one-child policy itself.

The structure of the paper is as follows. Section 2 introduces the data used in this study and provides background for the one-child policy. Section 3 provides evidence that the policy is associated with twins rate, together with some robustness checks. Section 4 links height difference within twins and the policy. Section 5 concludes with a discussion of findings and their implications for policy.

2 Data

2.1 Census data and twins in China

The data used in this study include 1% sample of the 1982, 1990 Population Census, 0.1% sample of 2000 Census, and 2005 population study sample. All the data sets contain variables including birth year, region of residence, type of residence,[8] sex, ethnicity, education, and relation to the head of the household. The data sets after 1982 also include month of birth. For the women older than 15, the data provide information about their fertility history, like how many children were born and how many of them are alive now.

For the analysis of twins birth and family background, we restrict our sample by the following steps. Firstly, we only keep those family household with at least one child. Secondly, we restrict the sample to those households where mother's information is not missing. Thirdly, we restrict the sample to those households in which number of children born equals to number of children alive, and number of children born equals to number of children observed in the census. Fourth, we drop those households with children aged more than 17 when surveyed because some of the children aged over 17 may go to colleges or university and leave their parents. Finally, we only keep the households in which mother's age when giving birth is higher than 15 and less than 50 because the households outside these boundary may be special or have some errors. [9]

We keep the sample of the children, and twins is defined as those children in the same household with the same birth year and birth month.[10] Because twins are composed of at least two children, I keep one of them

[8] 1990 Census does not provide the type of current residence. Instead, it provides the whether the respondents lived in the same place 5 years ago and what the type of residence was then. Therefore, we constructed a variable to indicator the type of current residence. First, we keep those who were in the same place. Then, we calculate the proportion of people in this sample for each residence type 5 years ago. We use the type which has highest proportion as the type of current residence in the same area.

[9] We also drop Tibet data.

[10] Because 1982 Census data do not have information on birth month, we just define twins in that year are those children born in the same household with the same birth year only. Actually, the results are almost the same if we drop the 1982 Census or define twins only using the year of birth in all data sets.

so that one observation in the sample is one birth. For each birth, I also construct several indicators whether this birth is twins, whether this birth is male twins, or female twins, or different gender twins, respectively. Figure 1a plots twins birth rate changing over year of birth between 1965 and 2005. Variation before 1970 and after 1990 is larger because of smaller sample size. Sampling weights are applied in throughout this analysis. In Figure 2a, we divide twins into same-gender twins and different-gender twins, and plot them over year of birth. Firstly, it shows that proportion of same-gender twins is higher than that of different-gender twins, which is consistent with the statistics in the U.S. and Japan. Secondly, the period between 1980 and 2000 witnesses significant increase in both types of twins rates. Figure 1c divides the same-gender twins into male twins and female twins, and we do not find significant difference between them. As a result, we do not separate the two types of twins any more in further analysis.

[Figures 1b and 1c about here]

2.2 One Child Policy

In the 1970s, after two decades of explicitly encouraging population growth, policy makers in China enacted a series of measures to curb population growth, especially to Han ethnicity. Beginning around 1972, the policy "Later [age], longer [the spacing of births], fewer [number of children]" offered economic incentives to parents who spaced the birth of their children over four year apart (Qian, 2009). One-child policy was formally conceived in 1979, but actual implementation already started in some regions in 1978, and enforcement gradually tightened until it was firmly established across the country in 1980. (Croll et. al., 1985; Banister, 1987)

The one-child policy, as the name suggests, restricted a couple to having only one child. The strictness of the one-child policy was partly reflected in enforcement. Before 1978, Family Planning Policy (FFP) was mainly driven by political and administrative forces rather than law. In 1978, FPP appeared in the Constitution for the first time, and came up with more details in the 1982 amended Constitution (Wang, 2012). Legal measures, such as monetary penalties and subsidies, also ensured the effective enforcement of the one-child policy since 1979. Due to various development levels in different regions in China, Central Party Committee "Document 7" devolved responsibility from central government to the local and provincial government so that local conditions could be better addressed. It actually allowed for regional variation in family planning policies, like the amounts of monetary penalties or subsidies (Greenlaugh, 1986). As the population was still growing rapidly in the 1980s, Chinese policymakers felt more compelled to limit fertility and emphasized the importance of this policy in several different documents. After then, local governments tightened the enforcement by reduction of land allotments, denial of public services and increasing unauthorized births, and so on.

However, it is worthwhile to note here that one child policy mainly focused on Han ethnicity. Though local governments might enact different regulations for the local minority people, these regulations were generally less restrict compared to those for Han. For example, the regulations in Gansu province[11] allows the minority parents to give a second birth, which is not allowed for Han ethnicity.

The measure of one child policy in this study is the average monetary penalties rate for one unauthorized birth in province-year panel from 1979 to 2000, which are from Ebenstein (2008).[12] The one child policy regulatory fine (policy fine) is formulated in multiples of annual income (Ebenstein, 2008; Wei, 2010). Though the monetary penalty is only one aspect of this policy and the government may take other administrative actions, it's still a good proxy for this policy because an increase in fine is usually associated with other stricter policies. Figure 2 shows the pattern of policy fine during 1980-2000 in each province.

[Figure 2 about here]

It's obvious that the fines and bonus in different provinces generally have different patterns, both in timing and magnitude. For the fine levels, Liaoning Province increased it from one year's income to five in 1992, but Guizhou Province increased the number from two to five in 1998, and Hunan increased from one to two in 1989. The average level of fine in 1990s is higher than that in 1980s, which is consistent with stricter policy enforcement in 1990s. The geographical and temporal variance helps us to identify the effects of one-child policy in empirical analysis.

Since about nine months are needed from beginning of pregnancy to giving birth to a baby, the parents' decision of having a baby, if any, should be made almost one year before. Therefore, I matched the sample from Census with the policy fine of the previous year before their birth in the corresponding province. For example, a birth happened in 1986 in Hunan province will be matched with the Hunan's fine level in 1985. Therefore, the births before 2001 are matched with the fine data,[13] and the ones not matched are dropped. Table 1 presents the summary statistics. Column 1 is full sample, which is composed of over four million observations. Then we divide the sample by parents' ethnicity.[14] Column 2 reports the results for whole Han sample, and columns 3 and 4 present the statistics in this sample for those living in urban and rural areas, respectively. The last column reports the statistics for minority. The twins birth rate in full sample is 5.7 per thousand births, and that in Han ethnicity is 5.8, which is higher than that in minority sample. Within the Han sample, twins rate in urban areas, 2.3, is higher than that in rural areas, 1.7. In addition, mother's age when giving birth or mother's education is higher in urban areas and mothers in urban areas

[11] http://www.mjrkj.gov.cn/html/gs-law/17_31_12_360.html

[12] The details about the construction of this variable can be found in Ebenstein (2008),

[13] We assume fines are zero before 1979 because there was no formal one child policy then.

[14] For simplicity, Han ethnicity mentioned below means both of parents are Han ethnicity.

give births less. Mean age of the sample is about eight.

Table 2 compares twins rate before and after one child policy. For Han ethnicity sample, twins rate increased by 0.26 percentage points, and either same-gender twins or different-gender twins contributed half to it. To the contrary, twins rate only increased 0.11 percentage points in the minority group, which is less than half of that in Han ethnicity sample. This simple comparison indicates one child policy potentially accounts for a large proportion of twins rate increase. More careful analysis is in Section 3.

2.3 CHNS data

The China Health and Nutrition Survey (CHNS) was designed to examine the effects of the health, nutrition, and family planning policies and programs implemented by national and local governments and to see how the social and economic transformation of Chinese society is affecting the health and nutritional status of its population. The survey used a multistage, random cluster process to draw a sample of about 4400 households with a total of 26,000 individuals within 218 neighborhoods in nine provinces that vary substantially in geography, economic development, public resources, and health indicators.[15] The nine provinces contain approximately 56% of the population of China mainland. The data collection began in 1989 and has been implemented every 2 to 4 years since (Jones-Smith and Popkin, 2010). We chose CHNS to conduct this study because it is currently the largest and longest household panel data of China for public use, and contains detailed information on family background, demographic variables and biological measures, including height, for both adults and children. For children under 18, height is measured in millimeters in each wave.

Twins in this study are defined as the children below 18 years old with exactly same birth year and birth month within the same household. We pick them out from CHNS data, and there are 85 pairs in total,[16] including 60 same-gender pairs and 25 different-gender pairs. Then we define height gap of one pair as the height of the taller individual less that of the shorter one. Considering that the height gap may change as the children grow up, we also introduced ratio of height gap to the mean height in the pair (Gap/Height) as another measure of height difference. Similar to above, we also match the twins sample to the fines data, and drop those born after 2001. The summary statistics and analysis will be provided in Section 3.2.

[15]The nine provinces are Liaoning, Heilongjiang, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi and Guizhou.

[16]Because CHNS data are panel, some particular twins may be interviewed for several waves. I also dropped 3 outliers.

3 Empirical Results

3.1 One Child Policy and Twins Birth Rate

3.1.1 One Child Policy Fine and Twins Incidence

To estimate the effect of one child policy on twins rate, we estimate the equation below:

$$Twins_{ijkt} = \alpha + \beta Fine_{jt} + \delta X_{ijkt} + \gamma_t YOB_t + \gamma_j Prov_j + \theta_j Prov_j \times trend + \gamma_k wave_k + \epsilon_i \quad (1)$$

in which the dependent variable, indicator $Twins_{ijkt}$ denotes whether the birth i is a pair of twins. $Fine_{jt}$ is one-child policy penalties in province j and year *t-1*. The coefficient on it, β, is main coefficient of interest and gives policy fine's association with twins incidence, and is interpreted as the impact of one-child policy. X_{ijkt} is a set of covariates, which include dummies for residence type (urban/rural), parents' ethnicity (both Han/either minority), birth order, mother's education levels and mother's age when giving birth. YOB_t is year of birth dummies and $Prov_j$ denotes a set of province dummies. In addition, we also control for province-specific linear time trend, by adding the interactions between time trend (year of birth minus 1965) and province dummies. $wave_k$ means the dummies for the survey year of the data, and ϵ_i is the error term.

The coefficient estimates from equation (1) are presented in Table 3. Only the coefficients β's and standard errors are reported. All the coefficients should be interpreted as percentage because all dependent variables in each panel have been multiplied by 100. The estimates for full sample are presented in column 1, and those for Han ethnicity sample and those for minority sample are reported in column 2 and 3, respectively. The results indicate that one year's increase in policy fine is associated with about 0.06 percentage points increase in twins rate. The according estimates for different-gender twins and same-gender twins are 0.032 and 0.027, respectively. Therefore, the policy-associated twins are distributed almost equally in the different-gender and same-gender group, which is somehow consistent with what shown in Figure 1b. All these estimates are at least significant at 10 percent significance level. Results in column 2 present strong evidence for the positive association between policy fine and twins rate in Han ethnicity sample. According to the statistics in Table 2, coefficients in the second column indicates that one child policy find explains about 35 percent of twins increase. The effect of one child policy are almost equal on different-gender and same-gender twins. However, we do not find any evidence that policy fine associated with twins rate in minority group.

However, as Li et al. (2011) argues, the spatial and temporal variations of the one-child policy may be endogenous to twins incidence. Li and Zhang (2008) found that the level of the fine increases with the community wealth level and the local government's birth-control incentives but decreases with the local government's revenue incentives. In particular, the spatial and temporal variations in the one-child policy have been documented as being affected by the fertility rate, which, in turn, may be correlated with twins incidence. To avoid this problem, we follow the methodology in Li et al. (2011) by estimate the following equation:

$$Twins_{ijkt} = \alpha + \beta(Policy_{t \geqslant 1980} \times Han) + \delta X_{ijkt} + \gamma_t YOB_t + \gamma_j Prov_j + \theta_j Prov_j \times trend + \gamma_k wave_k + e_i \quad (2)$$

in which $Policy_{t \geqslant 1980}$ denotes an indicator whether born after 1980 and Han is an indicator for han ethnicity group. The sample is the same as that used to estimate Equation (1). The estimates for coefficient β for Equation (2) are reported in Table 4, which also provide strong evidence for the positive association of one child policy with twins incidence. This Difference-in-Differences estimates indicates that one child policy explains about 44 percent of the twins increase, indicating our estimates in Table 3 may be underestimate the effect of the policy. This may be reasonable because policy fine is only one dimension for the regulations, and so it may miss many other useful variations that may increase twins rate.

Equation (2) is a standard Difference-in-Differences estimation, which requires the trends in treated group (Han ethnicity) and control group (Minority group) should be similar. To shed some light on it, I plot the twins rate by parents' ethnicity group in Figure 3. Though we do not have the counterfactual data to see how twins rate changes over time in Han group without one child policy, it is still meaningful to see how twins rates evolves before 1979. As shown in the figure, the trends in the two groups are almost the same between 1970 and 1979.[17] Though we derived similar results in this DID model, it should be noted that minority may not be a perfect control group because they are also under the control of one child policy. That's why I use temporal and geographical variations in fines to estimate the effect.

[Figure 3 about here]

In addition, we also test the endogeneity of policy fine by using twins rate to predict the fine in the future. With all the other covariates, we use twins or different types of twins as independent variables, and take the policy fine in the next year or that in the year after the next year as dependent variables. The regression results are reported in Table 5. Panel A shows the results when using all the sample. Because policy fine is assumed to be zero before 1979 and we do not want this assumption to influence the results, we then use those born after 1979 to run the same regressions and report the results in Panel B. The results in Table 5 tell us that neither twins or different types of twins can predict the one policy fine in the next two years, conditional on other covariates. These results do not find evidence for the endogeneity problem of policy fine in this study,

[17] The data before 1970 are not taken into account because of small sample size.

3.1.2 Heterogeneity

Because one child policy have different enforcement in urban or rural areas. For example, one child policy in large part of rural areas allows a household to give a second birth if the first birth is a girl. This is called one and half child policy. Those living in rural areas are generally poorer educated and most of them lead a poor life, and so it is possible that people in rural areas may have stronger children or boy preferences. In addition, the economic condition are also different in urban or rural areas. Those living in urban areas are easier to get access to hospitals or drugs. Considering the above factors, it is difficult to predict whether and how one child policy is associated with twins in urban or rural areas and whether there is any difference. We divide the sample into two by type of residence and conduct the regressions same to equation (1). Panel A in Table 6 presents the results. The estimates show that policy fine is positively associated with twins in both urban and rural areas, and the effect of one child policy in urban areas is larger.

Furthermore, we also interact policy fine with birth order dummies and report the coefficients of the interactions in Panel B. Estimates in the full sample show that twins in second birth order are mostly policy-associated, and this also holds in both urban and rural areas. What is interesting is that the coefficient on the interaction between first order and policy fine is also significant in urban area but that in rural areas is much smaller and insignificant, which is consistent with the fact that a large part of rural areas are ruled by one and half child policy.

Finally, policy may have heterogenous effect on different education level parents. For one thing, those who have higher education may have less children or boy preference. For another, illiterate ones may do not know that taking fertility drugs can increase probability of twins birth. In addition, it is also possible that higher education ones are more likely to occupy the positions in state-owned firms, where one child policy is enforced more strictly. Therefore, we also interact policy fine with mother's education level and run the same regressions as (1). The results are shown in Panel C. In the full sample, the coefficients on the interactions show an inverse-U pattern over mother's education level. The association is strongest in those mother with primary school and middle high school education. However, the patterns in urban and rural areas are different. In urban areas, the higher mother's education is, the weaker the association is. However, the pattern in rural areas is also inverse-U shape. The reasons may be multiple, and one explanation is as follows. Twins-making methods are more available in urban areas, like fertility drugs or hospitals. Therefore, the boy or children preference drive the results in urban areas because people can choose give birth to twins as they can. However, individuals in rural areas with very low education even do not know how to give birth to twins. And these low educated people in rural areas may be very difficult to administrated or to follow, so the one child policy is not binding to them. Thus, these effect with boy preference drive these results.

3.2 One Child Policy and Height Difference within Twins

Using census data, we find evidence for policy-associated twins, but do know whether the policy-associated twins are monozygotic (MZ) or dizygotic (DZ) or simply purposefully reported by parents (not twins at all, "fake twins" hereafter). We do know that different-gender twins, if real, are DZ. Appendix provides some analysis using twins height differences to identify the probability twins are MZ or DZ under some reasonable assumptions. As mentioned above, we turn to China Health and Nutrition Survey (CHNS) data and match it with policy fine data. Summary statistics are provided in Table 7. The mean of height gap is 2.1 centimeters and gap/height ratio is 1.71 percent. In addition, the fine is about 1.5 years' income on average, with the standard deviation being 0.6.

3.2.1 Graphical analysis

The association between twins' height difference and one-child policy is of interest in this paper. Prior to econometric analysis, some illustrative figures may shed some light on it. In this part, we divide full twins sample into same-gender ones and different-gender ones, and analyze them separately by using graphics.

Figure 3a and 3b plot same-gender twins' height gap and gap/height ratio against fine level respectively, and both include a linear fit relation. The shadow area shows 95% CI of the linear fit. The two figures show that height difference presents a strongly positive correlation with policy fine level.[18] Similarly, Figures 4a and 4b shows the relation between height difference and fine level among different gender twins. However, the linear fit is also flat, and thus there is no clear relation between height difference and fine level in different-gender twins sample.[19]

[Figures 4a and 4b about here]

[Figures 5a and 5b about here]

However, the results are not sufficient to conclude that one child policy has impact on height difference of twins. For one thing, the fine and height difference may be both correlated with time trend, and the time trend is correlated with some unobservables related to twins' height difference. For example, as GDP grows fast and more kinds of food became available, composition of diet Chinese people becomes richer and people get more protein, meat and milk than before. The change in diet is likely to influence twins' rate and DZ ones' proportion as well. Therefore, the positive association between fine and height difference may be

[18] Specifically, the regression function in Figure 4a is Height gap = 1.13 (.365) Fine - .46 (.613), and that in Figure 4b is Gap/Height = .92 (.254) Fine - .41(.426).

[19] The linear regression functions in 5a and 5b are Height gap = -.85 (2.70) Fine + 5.58 (3.92) and Gap/Height = -.05 (2.16) Fine + 3.80 (3.12), respectively.

driven by the time trend since both are correlated with the trend. For another thing, policy fine and twins' height difference may be also correlated to geographic factors, like gene agglomeration, climate and so on. The relation between height difference and policy penalties may be also driven by these factors. We address these issues in in the next section.

3.2.2 Regression results

Similar to the analysis in Section 3.1, we addresses the issues by estimating the following ordinary least squares (OLS) equation:

$$HD_{ijt} = \alpha + \beta Fine_{jt} + \gamma same_i + \delta X_{ijt} + \gamma_t YOB_t + \gamma_j Prov_j + \theta_j Prov_j \times trend + \epsilon_i \quad (3)$$

where the dependent variable, HD_{ijt} denotes height difference within the i's pair of twins in province j born in year t, and it might be height gap or gap/height ratio as defined above. The coefficient β, gives policy fine's association with twins' height difference. $same_i$ is an indicator whether the *i's* pair of twins is same-gender or different-gender one. We denote by the set of covariates that are potentially correlated with twins' height difference, including indicator variables such as urban residence, same-gender pair, boy being taller in different gender twins, and also mean of height within the pair i (height mean value of the pair), mother's age when giving birth, age and age square. Because of small sample, I combined the year of birth into four groups (every five years as one group), YOB_t, and controlled for the according dummies to capture the time trend effects. Finally, province dummies and province-specific time trends are also controlled for.

Table 8 reports the estimates of equation (3) and some of its extensions, with standard errors clustered at province-year levels. The first column shows that increasing fine by one year's income suggests twins' height gap increasing by 1.4 centimeters on average. This result rules out the possibility that policy-associated twins are MZ, and provides evidence that people may take methods to create twins by themselves (by taking drugs or false reporting). I then interact *fine* with same-gender twins and different-gender twins and implement the same regression to identify one-child policy's impact to different types of twins, and column 2 reports the results for it. The results show that policy fine is significantly and positively associated with same-gender twins' height difference, and the policy has no significant relation with that of different-gender pairs, given the coefficients of the two interactions are 1.6 (0.5) and 0.5 (1.3), respectively. Furthermore, the third column reports the regression result using only same-gender sample, with an additional indicator whether the pair is female controlled for.[20] Coefficient of fine becomes more significant, and one deviation increase in fine is associated with 0.44 deviation increase in height gap of the same gender twins. The results in the first three columns seem to support man-made twins hypothesis rather than fake twins hypothesis because there is no evidence showing one-child policy has positive effect on different-gender twins' height difference, which is

[20] The regression for different-gender twins is not implemented due to small sample.

predicted in A.2.

Columns 4 through 6 present the regression results with the dependent variable being Gap/Height ratio, and results are very consistent with those in first three columns. Specifically, one year's increase in fine is significantly associated with gap/height ratio increasing by 1.2 percentage points (column 4), and the effect only exist significantly in same-gender twins (columns 5 and 6).

[Table 8 about here]

3.2.3 Robustness check

Since CHNS is a panel data and one certain pair of twins may be surveyed in couple of waves, the height difference may change as the twins grow up because the individuals in one pair would have different environmental influences though their lives. To avoid potential econometric problems, I only keep one observation for each pair and run the same regressions as the first two columns in Table 8, and the results are reported in Table 9. In first four columns of Table 9, I only keep the latest wave for the duplicated twins, and keep earliest wave in last four columns. Though such a small sample, the results in the first four columns still show robust pattern. The estimates show that when the policy fine increase by one unit, the height gap of same gender twins will increase by about 2.5 centimeters, and their gap/height ratio will increase by 1.8 accordingly. The coefficients on fine or its interactions in the last four columns are not significant, and the reason may be larger measurement error when the twins are younger.

[Table 9 about here]

4 Conclusion

Using 1982, 1990, 2000 and 2005 census data, this paper documents that twins birth rate in China more than doubled from late 1960s through early 2000s, from 3.5 to 7.5 per thousand births. Though similar phenomenon also happened in other countries like the U.S. and Japan, China may be special because of one child policy. To those who like more kids (children preference) or those with strong boy preference, twins are favorable because individuals are able to own two babies without going against the regulations and they are more likely to have one boy in a single birth as well. Given such a strong incentive, individuals are likely to take measures to increase the probability of giving birth to twins, which may includes taking fertility drugs, asking for help from private hospitals or reporting fake twins and so on.

However, there is no previous research on this issue though many articles have been published using Chinese twins to estimate interesting parameters to find causal effects. This paper shed some light on the question whether and how one child policy and twins are related. Above all, through matching census data to one-child policy regulatory fine data by province and year, we find that increasing by one year's income in policy fine is associated with about 0.06 per thousand births increase in twins. The estimates in our preferred model indicates that about one third of the twins rate increase since 1970s can be explained by one child policy. By dividing twins into same-gender and different-gender groups and doing the similar analysis, we find the policy-associated twins are distributed almost equally in the two groups.

Then we divide the full sample into urban and rural groups and interact fines data with birth order and mother's education level. We find that the impact of the policy is larger in urban areas, and that the policy increase the twins rate in first and second birth orders in urban areas but second or higher birth orders in rural areas. We also find heterogenous effect of the policy on the mothers with different education levels. These results indicate that twins may not randomly distributed in population, conditional on the age of mothers' giving birth.

Using census data, we find evidence for policy-associated twins, but do know whether the policy-associated twins are MZ, DZ or fake twins. Therefore, we turn to China Health and Nutrition Survey (CHNS) data and match the twins sample with the fines data. Estimates show that height difference within twins is positively associated with policy fine and this association only exists in same-gender twins sample. This finding is consistent with that the one-child policy stimulates people's incentive to give birth to twins through taking fertility drugs. However, we do not rule out the possibility of fake twins hypothesis though we do not find the evidence for it. The reason may be that the size of sample we used for analysis is very small.

Appendix: Twins Height Difference and One-Child Policy

In this part, different consequences of man-made twins and fake twins hypothesis are derived, and empirical analysis is presented afterward. For simplicity, I only use the financial penalties (*fine*) to measure one-child policy, and assumes it equals to one when the financial penalty policy has established in the local province, and zero if otherwise.

A.1 Man-made Twins Hypothesis

Man-made twins hypothesis indicates that individuals are motivated to take technologies, like fertility drugs, to give birth to twins, under one-child policy.[21] The mechanism of these drugs is to are usually to to induce ovulation, which are usually taken to treat infertility. When normal women take them, the possibility of multiple ovulation would be increased, and thus it is more likely to have twins. Though these drugs are classified as prescription medicine, it is still possible for individuals to purchase them in some private hospitals[22] and get prescription from some doctors.[23]

Under Man-Made Twins Hypothesis, individuals are more likely to take fertility drugs ($Take = 1$) to have more children while avoid being punished under one-child policy, that is, $Pr(Take = 1|Fine = 1) > Pr(Take = 1|Fine = 0)$. According to the medical literature and realized facts, we know that taking certain fertility drugs or using some technologies really increase the probability of giving birth to twins:$Pr(Twins = 1|Take = 1) > Pr(Twins = 1|Take = 0)$. We also assume that conditional on individuals' behaviors ($Take$), giving birth to twins is independent of one-child policy: $Twins \amalg Fine|Take$. In addition, the biological results of fertility drugs or embryo technologies is to make multiple zygotes developed in the uterus at the same time, rather than to stimulate a single fertilized egg in the mother's body to divide into two or more embryos. Thus, these actions only raise probability of DZ twins rather than that of MZ twins,[24] that is, $Pr(DZ = 1|Take = 1) > Pr(DZ = 1|Take = 0)$ and $Pr(MZ = 1|Take = 1) = Pr(MZ = 1|Take = 0)$.

According to the medical literature, MZ twins are genetically nearly identical and they are always of the same sex unless there has been a mutation during development. But it is possible that same-gender twins are DZ Certain characteristics of MZ twins become more alike as twins age, such as IQ and personality (Segal, 1999). DZ twins, however, like any other siblings, have an extremely small chance of having the same chromosome profile. DZ twins may look very different from each other, and may be of different sexes or the same sex. The above also holds for brothers and sisters from the same parents, meaning that DZ twins

[21]Taking drugs should be more reasonable because embryo technologies did not appear in China until late 1990s.
[22]Some even have advertisements on Google to "ensure" twins.
[23]They may bribe the doctors or tell lies.
[24]There are only two types of twins, MZ and DZ, that is, $Pr(MZ = 1|Twins = 1) + Pr(DZ = 1|Twins = 1) = 1$.

can be viewed as siblings who happen to be of the same age. Therefore, we have$Pr(DZ = 1|DG = 1) = 1$, $Pr(SG = 1|MZ = 1) = 1$, $0 < Pr(DZ = 1|SG = 1) < 1$ and $0 < Pr(MZ|SG = 1) < 1$.

An established strand of literature has proved that, DZ twins tend to have more differences than MZ ones as they grow up because of genetic disparity, including height (Fischbein, 1977; Smith et al., 1973), weight (Stunkard et al., 1986), mental ability profiles (Segal, 1985), bone mass (Smith et al., 1973) and so on. Specifically, Fischbein (1977) found that MZ twins have a significantly higher concordance in height than for DZ pairs during puberty, for both boys and girls, and yearly height increments are also more similar for the MZ pairs, indicating that the height spurt occurs more simultaneously for MZ twins in comparison to DZ twins. Thus, we presume that the height difference (HD) within a DZ (same-gender) pair[25] should be larger than that of a MZ pair if other factors are equalized. Thus, $E(HD|SG = 1, DZ = 1) > E(HD|SG = 1, MZ = 1)$.

Additionally, we also assume that the actions people may take do not influence twins' height difference conditional on these twins' type (MZ or DZ), that is, $HD \amalg Take|MZ, DZ$. Based on the facts or assumptions above, it can be shown that

(1) $E(HD|Fine = 1, Twins = 1) > E(HD|Fine = 0, Twins = 1)$,

(2) $E(HD|Fine = 1, SG = 1) > E(HD|Fine = 0, SG = 1)$,

and (3) $E(HD|Fine = 1, DG = 1) = E(HD|Fine = 0, DG = 1)$.

Equation (1) tells us that twins' height difference would be larger under one-child policy because there will be more DZ twins due to the methods individuals take as response to one-child policy. This response will increase DZ proportion in same-gender twins, and thus the height difference in this group will enlarge (Equation 2). However, different-gender twins' height difference will not change because they themselves are DZ (Equation 3). Because we do not know whether a woman took fertility drugs or not,[26] or whether a pair of twins is MZ or DZ,[27] equations (1) through (3) are important because height difference, one-child policy fine and twins' gender composition are all observables, and thus allow for empirical tests.

A.2 Fake Twins Hypothesis

Fake twins hypothesis means that parents report real siblings as twins so as to except from the punishment of one-child policy. It is somehow feasible under some special circumstances in earlier China. Firstly, many pregnant women gave birth to babies at home in the 1980s and population administration would not be noticed until the parents report the infants though they were required to do so. Second, birth certification

[25]Because MZ twins must be of the same sex, $Pr(SG = 1|MZ = 1) = 1$.
[26]Because CHNS does not have the information and respondents may not tell the truth even they are asked.
[27]CHNS does not provide the information.

did not launch until 1997,[28] and the children's birth date was easy to revised before that. Third, children especially siblings look alike especially when the age difference is not large enough. Though parents would face more harsh punishment once they are found to report fake twins, many parents may still choose to do so because of strong children or boy preference.

Under fake twins hypothesis, one child policy stimulate people's incentive to report fake twins, that is,

$Pr(Twins^*|Fine = 1) > Pr(Twins^*|Fine = 0)$,

in which $Twins^*$ denotes the observed twins, including real ones and fake ones. For real twins ($Twins$), I assume all of them are reported, that is, $Pr(Twins^*|Twins) = 1$.

For simplicity, I do not consider the gender factor in height difference in different-gender twins here,[29] then because of age difference, the height difference within fake twins is supposed to be larger, so

$E(HD|Twins^*) > E(HD|Twins)$ if $Pr(Twins|Twins^*) < 1$.

> The condition $Pr(Twins|Twins^*) < 1$ ensures that there exist some fake twins. If parents have strong children preference and do not care about the gender, then the gender composition of fake twins should be random,[30] so the height difference in both (observed) same-gender twins and different-gender ones should be larger. However, if parents have strong boy preference, and they report siblings as twins only if the first baby is girl and try to give birth to a boy in the next,[31] then the height difference within (observed) different-gender twins is expected to be larger. No matter which case it is, under fake twins hypothesis, we must have

(4) $E(HD|Twins^*, Fine = 1) > E(HD|Twins^*, Fine = 0)$,

and (5) $E(HD|DG^*, Fine = 1) > E(HD|DG^*, Fine = 0)$,

in which DG^* denotes the observed different-gender twins. Same as before, equations (4) and (5) are all based on observables so that can be tested in empirical analysis. Same to man-made twins hypothesis, the height difference also is expected to be larger under one-child policy according to fake twins hypothesis. However, fake twins hypothesis predict that height difference within different-gender twins should be larger under one child policy, which is different from the results in A.1. Such a difference provides us an identification strategy to differentiate the two hypotheses.

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[28]though it might start in some areas earlier

[29]Conditional that boys may be taller than girls conditional on the same age, height gap, when defined as the taller one's height minus that of shorter one's, is possible to be larger or narrower if the proportion of fake twins increase, when those with boy preference are more likely to report fake twins if they gave birth to a girl firstly. In the section 5.2.2, I try to replace it by the girls' height minus that of boy's in different-gender sample, and thus the following equation should be more reasonable, and so are equation (4) and (5).

[30]Though the probability of boys is slightly higher in natural born cases.

[31]Use ultrasound wave technology to select

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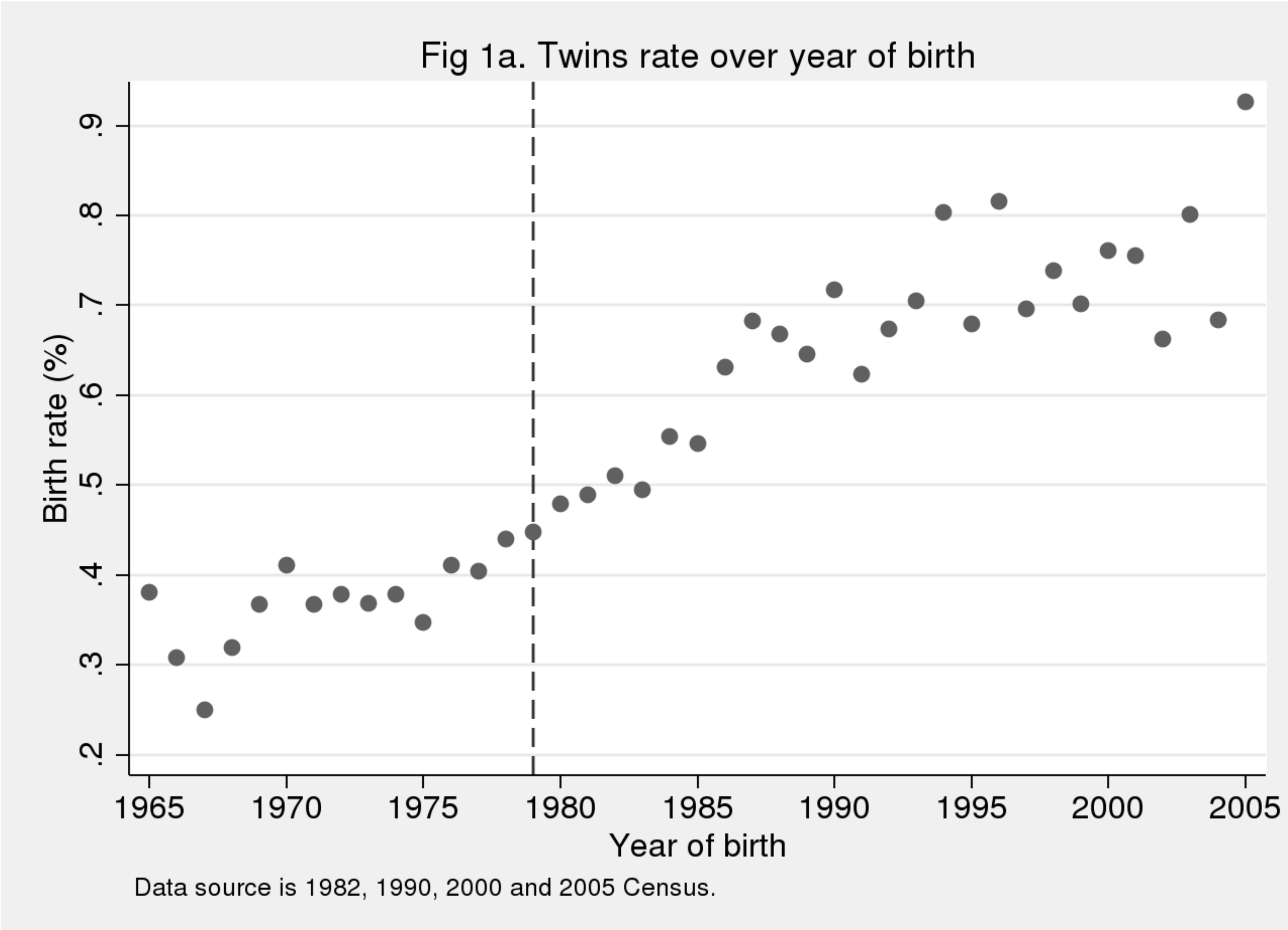


Fig 1a. Twins rate over year of birth
Birth rate (%)
.2
.3
.4
.5
.6
.7
.8
.9
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year of birth
Data source is 1982, 1990, 2000 and 2005 Census.

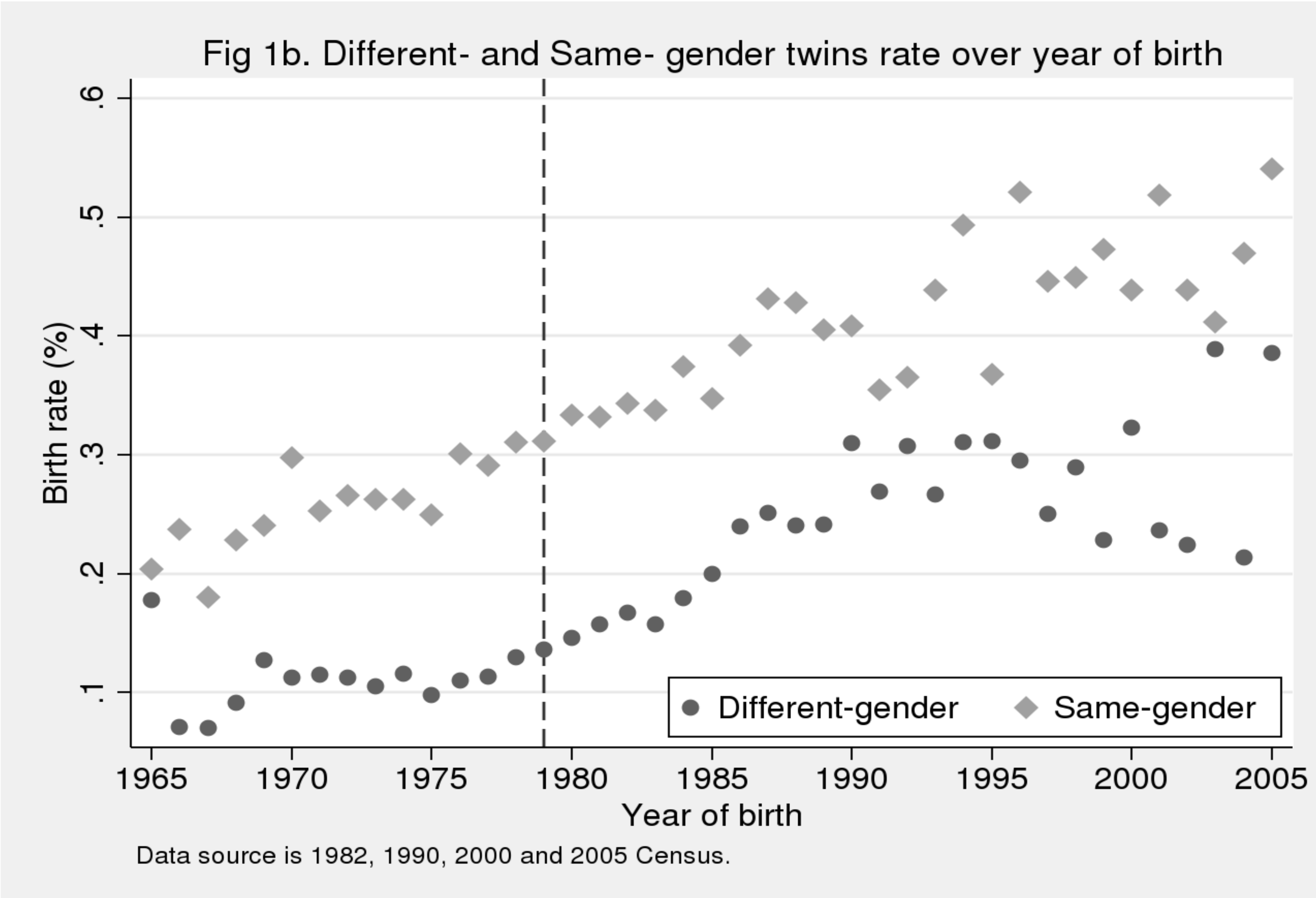


Fig 1b. Different- and Same- gender twins rate over year of birth
Birth rate (%)
.6
.5
.4
.3
.2
.1
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year of birth
Different-gender
Same-gender
Data source is 1982, 1990, 2000 and 2005 Census.

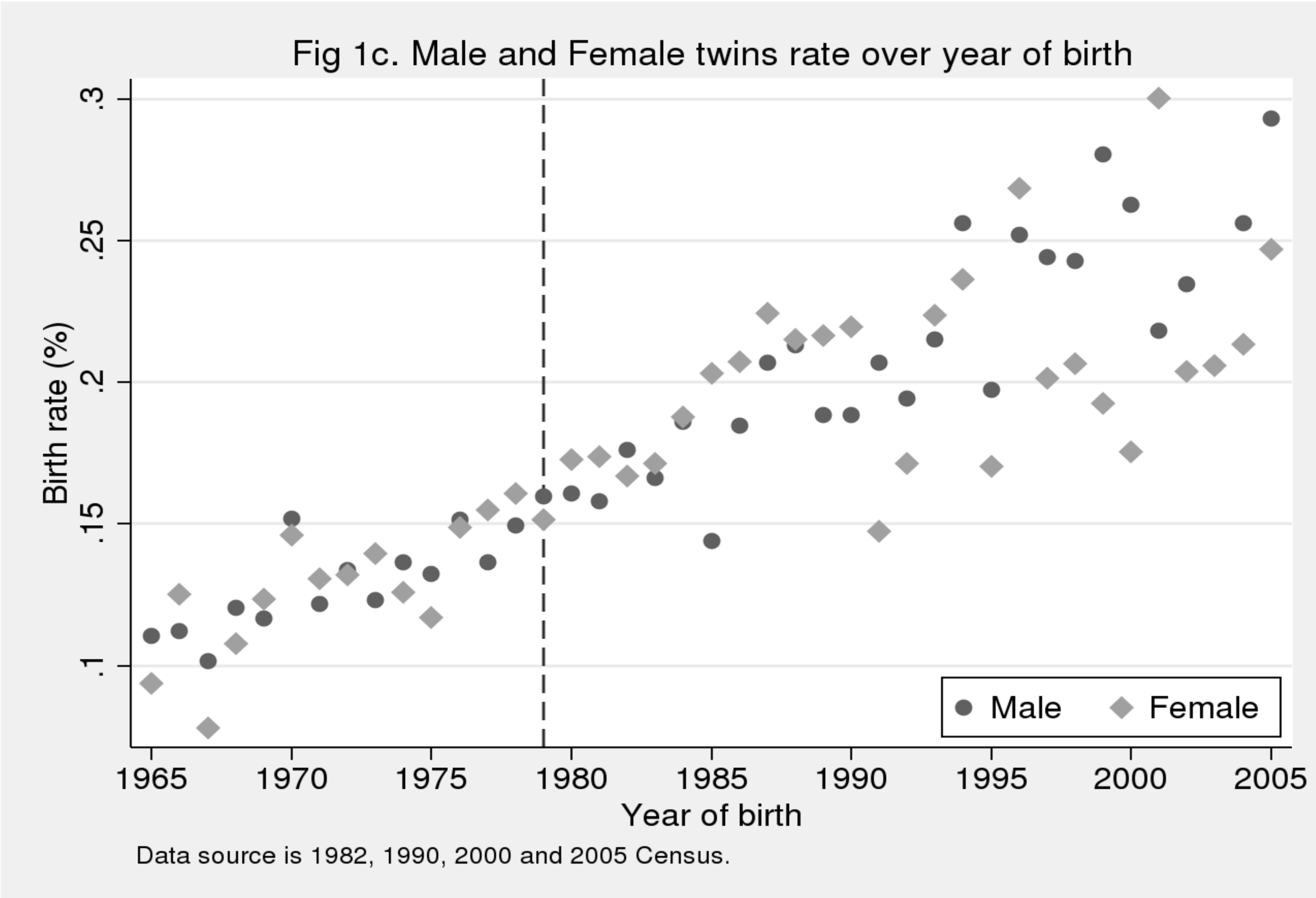
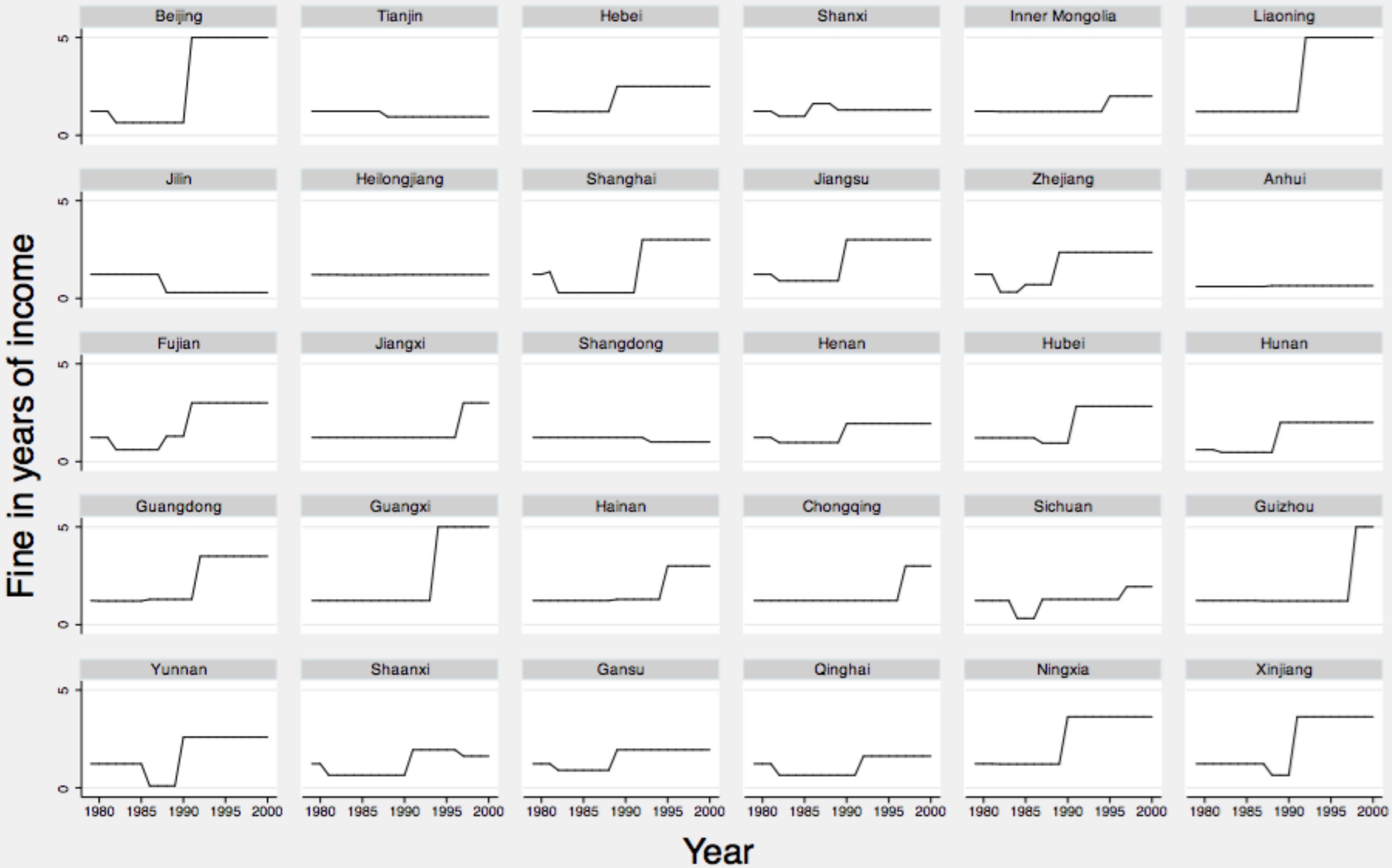


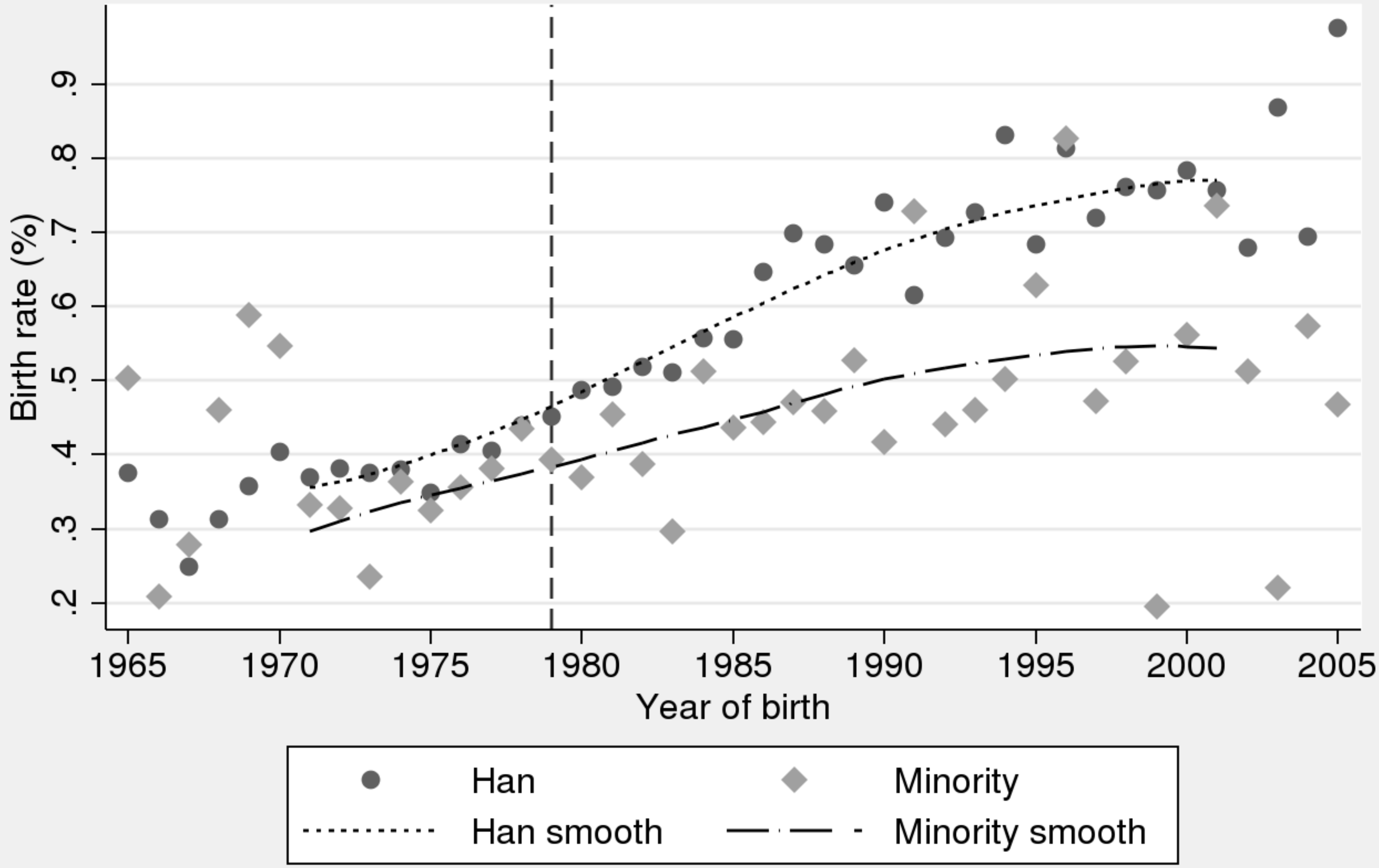
Fig 1c. Male and Female twins rate over year of birth
Birth rate (%)
.3
.25
.2
.15
.1
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year of birth
Male
Female
Data source is 1982, 1990, 2000 and 2005 Census.

Fig 2. One Child Policy Regulatory Fines, by Province

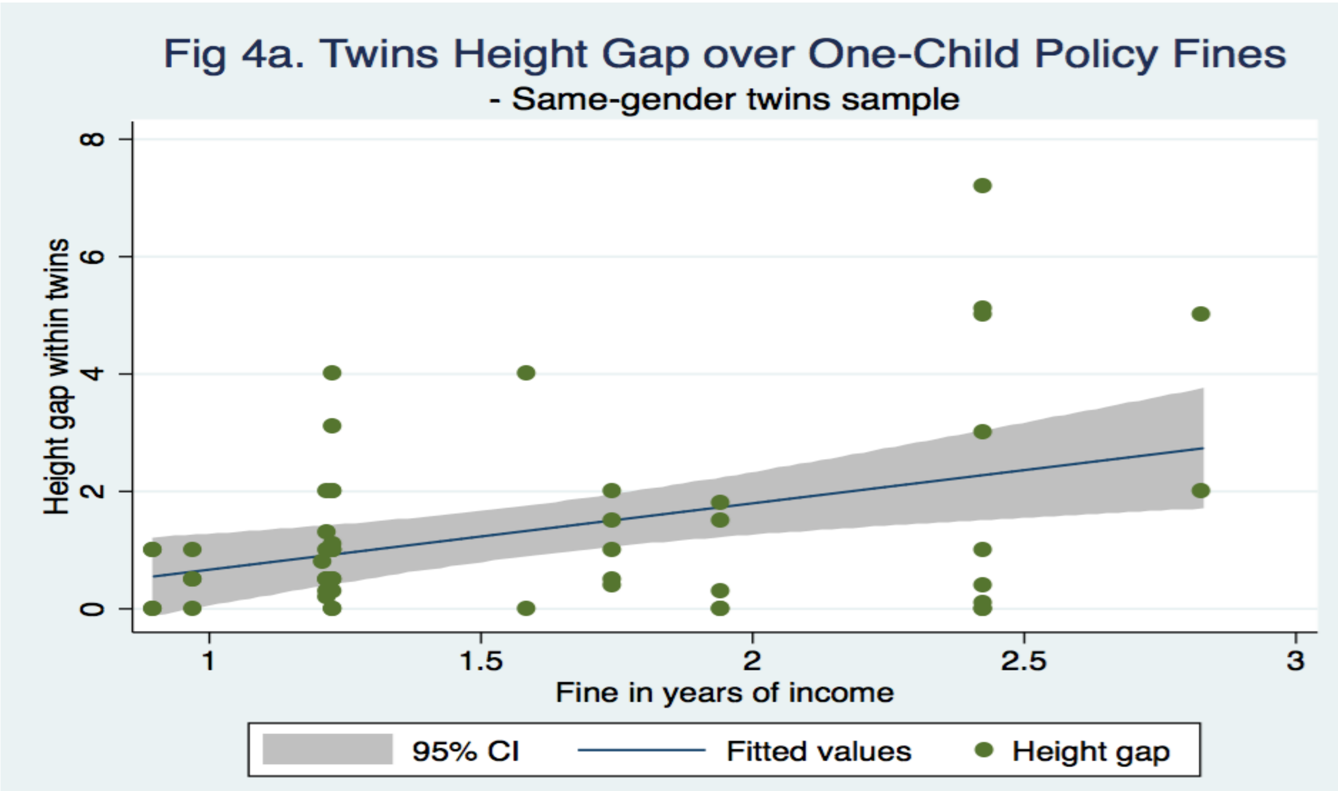


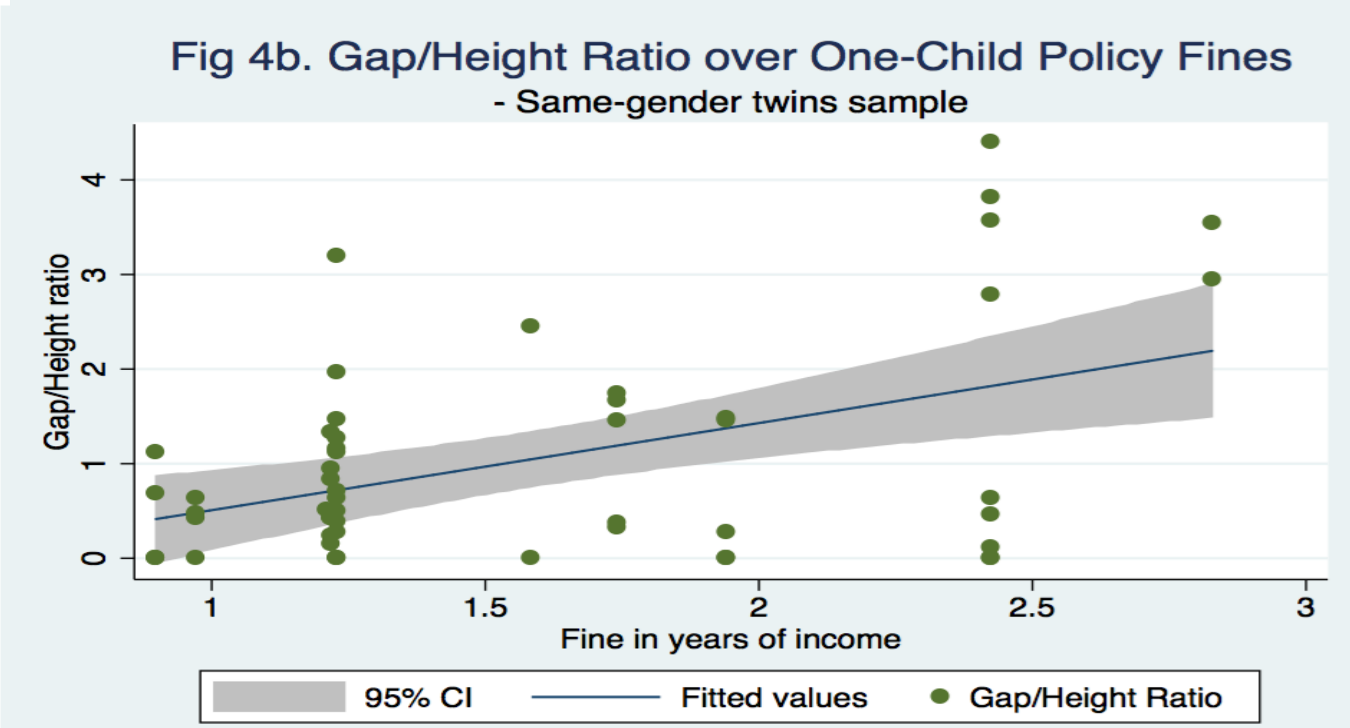
Data source is Ebenstein (2008).

Fig 3. Twins rate over year of birth, by parents ethnicity



Data source is 1982, 1990, 2000 and 2005 Census.





NOTE: Same-gender twins sample is from China Health Nutrition Survey, and policy fine data are from Ebenstein (2008). The shadowed area represents the 95% Confidence Interval.

Fig 5a. Twins Height Gap Over One-Child Policy Fines
- Different-gender twins

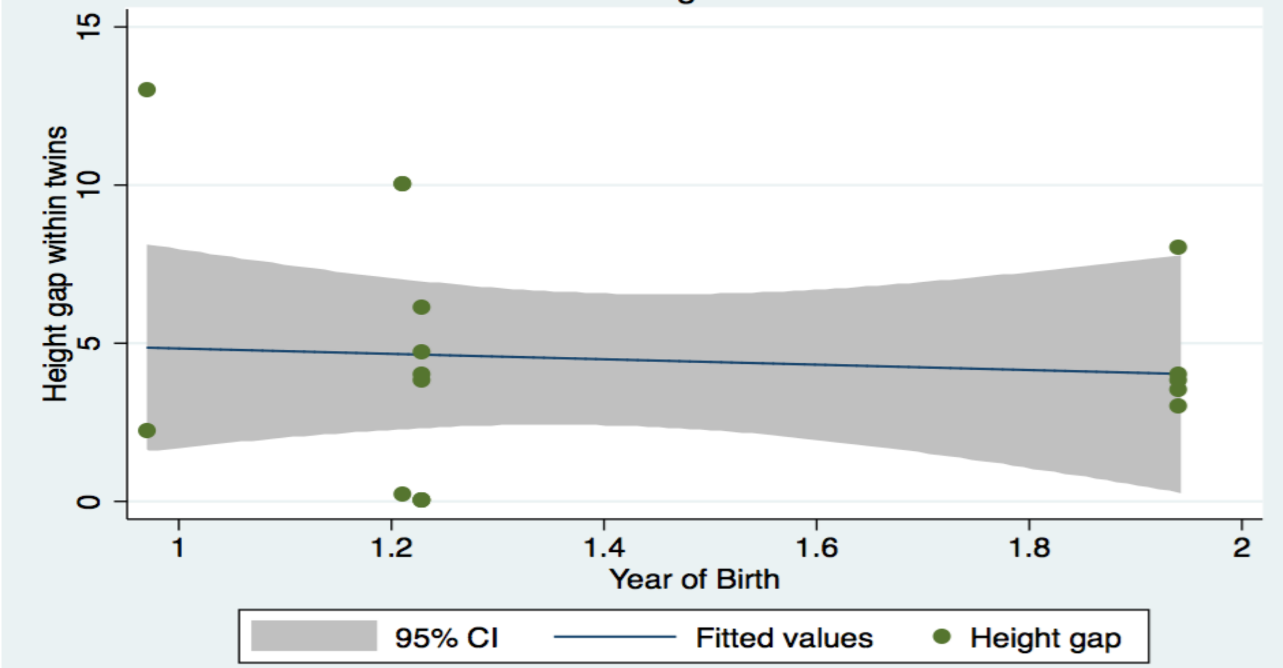
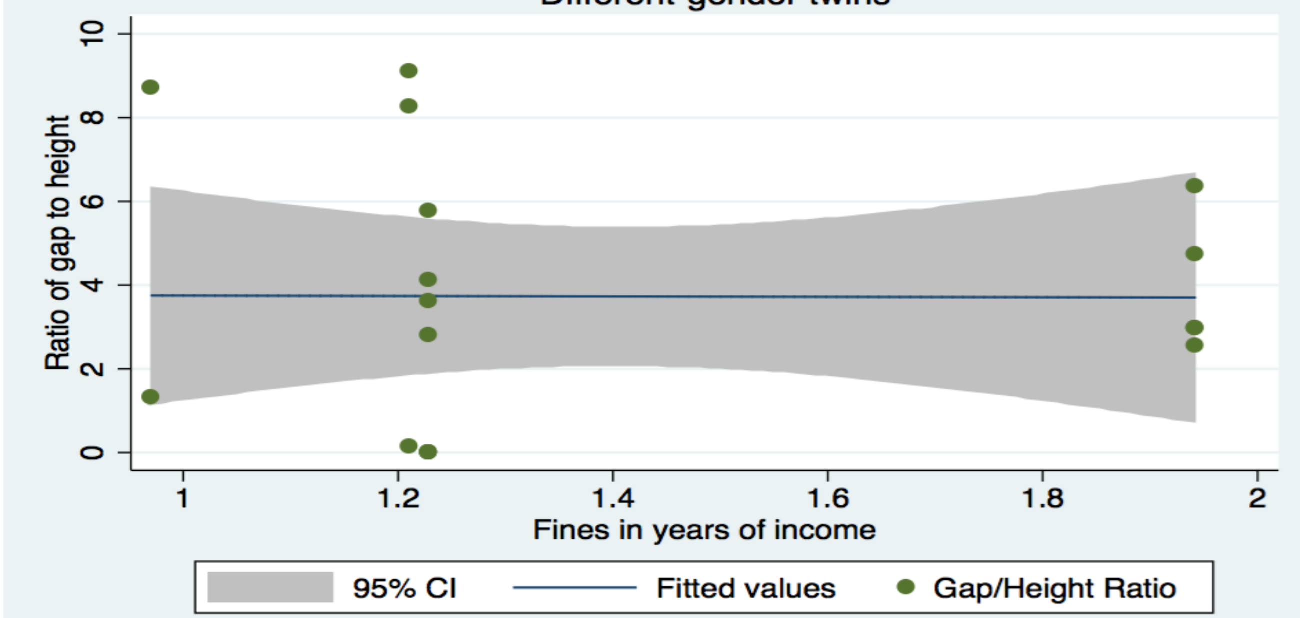


Fig 5b. Gap/Height Ratio Over One-child Policy Fines
- Different-gender twins



NOTE: Diffrent-gender twins sample is from China Health Nutrition Survey, and policy fine data are from Ebenstein (2008). The shadowed area represents the 95% Confidence Interval.

Table 1: Summary statistics

Variables	(1) Full sample	(2) Parents are Han: Full	(3) Parents are Han: Urban	(4) Parents are Han: Rural	(5) Either parent is minority
Fine in years of income	1.03	1.01	1.27	0.91	1.30
	(0.99)	(0.97)	(1.07)	(0.91)	(1.20)
Twins (%)	0.57	0.58	0.66	0.55	0.46
	(7.53)	(7.58)	(8.07)	(7.39)	(6.77)
Male twins (%)	0.18	0.19	0.23	0.17	0.14
	(4.27)	(4.31)	(4.77)	(4.12)	(3.68)
Female twins (%)	0.18	0.18	0.21	0.17	0.17
	(4.27)	(4.29)	(4.61)	(4.16)	(4.09)
Same-gender twins (%)	0.37	0.37	0.44	0.34	0.30
	(6.03)	(6.07)	(6.62)	(5.84)	(5.49)
Different-gender twins (%)	0.20	0.21	0.21	0.21	0.16
	(4.52)	(4.56)	(4.63)	(4.53)	(3.98)
Rural area	0.73	0.72	0.00	1.00	0.81
	(0.45)	(0.45)	0.00	0.00	(0.40)
Both parents Han ethnicity	0.93	1.00	1.00	1.00	0.00
	(0.26)	0.00	0.00	0.00	0.00
Age	8.06	8.09	8.72	7.84	7.65
	(4.67)	(4.67)	(4.69)	(4.64)	(4.63)
Mother's age when giving birth	23.26	23.29	24.31	22.89	22.83
	(2.97)	(2.95)	(3.05)	(2.82)	(3.18)
Mother's education level					
Illiterate	0.21	0.20	0.07	0.25	0.29
	(0.40)	(0.40)	(0.25)	(0.43)	(0.46)
Primary	0.38	0.38	0.24	0.44	0.41
	(0.49)	(0.49)	(0.43)	(0.50)	(0.49)
Middle high	0.30	0.31	0.41	0.27	0.22
	(0.46)	(0.46)	(0.49)	(0.44)	(0.41)
Senior high or above	0.11	0.11	0.28	0.04	0.08
	(0.31)	(0.31)	(0.45)	(0.20)	(0.28)
Birth order					
First	0.57	0.57	0.72	0.51	0.51
	(0.50)	(0.49)	(0.45)	(0.50)	(0.50)
Second	0.30	0.29	0.22	0.33	0.32
	(0.46)	(0.46)	(0.41)	(0.47)	(0.47)
Third or above	0.14	0.13	0.07	0.16	0.18
	(0.34)	(0.34)	(0.25)	(0.37)	(0.38)
Observations	4310227	4034009	893084	3140925	276218

Notes: Standard deviations in parentheses. The sample is children born before 2001.

Table 2: Twins rate before versus after one child policy

	(1) Born no later than 1979	(2) Born after 1979	(3) Difference (2) - (1)
Panel A: Parents Han ethnicity			
Policy fine rate		1.42	
		(0.86)	
Twins	0.39	0.66	0.264
	(6.26)	(8.08)	
Same-gender twins	0.28	0.41	0.133
	(5.26)	(6.39)	
Different-gender twins	0.12	0.25	0.132
	(3.40)	(4.97)	
Observations	1866384	2198616	
Panel B: Either of Parents Minority			
Twins	0.38	0.48	0.106
	(6.12)	(6.93)	
Same-gender twins	0.27	0.31	0.036
	(5.20)	(5.53)	
Different-gender twins	0.11	0.18	0.070
	(3.24)	(4.18)	
Observations	104496	175118	

Notes: Standard deviations are in parentheses, and standard errors are in brackets. Only the sample in which both parents belong to Han ethnicity is kept, and the children born later than 2001 are dropped.

Table 3: Twins birth and one-child policy fine rate

	(1) Full sample	(2) Parents Han	(5) Either Parent Minority
Panel A: Twins			
Policy fine rate	0.0587***	0.0652***	0.0118
	(0.0218)	(0.0232)	(0.0399)
Panel B: Different-gender twins			
Policy fine rate	0.0321**	0.0316**	0.0199
	(0.0146)	(0.0151)	(0.0326)
Panel C: Same-gender twins			
Policy fine rate	0.0266*	0.0336**	-0.00801
	(0.0150)	(0.0163)	(0.0317)
Observations	4,310,227	4,034,009	276,218

NOTE: Robust standard errors in parentheses are clustered in province-year level. *** p<0.01, ** p<0.05, * p<0.1. One child policy fine is measred in years of household income. Sampling weights are applied. Coefficients should be interpreted as percentage because all dependent variables have been multiplied by 100. Covariates include residency type, parents' ethnicity, province, birth year, birth order, age, survey year, mother's education level, mother giving birth age, if applicable.

The coefficients of twins explains up to 35 percent of twins increase in Table 2.

Table 4: Twins, one child policy and difference-in-differences

	(1)	(2)	(3)
Dependent variables	Twins	Different-gender twins	Same-gender twins
Birth year >= 1980 interacting with Parents are Han	0.117***	0.0433*	0.0740**
	(0.0396)	(0.0221)	(0.0329)
Observations	4,310,227	4,310,227	4,310,228
R-squared	0.001	0.001	0.002

NOTE: Robust standard errors in parentheses are clustered in household level. *** p<0.01, ** p<0.05, * p<0.1.Sampling weights are applied. Coefficients should be interpreted as percentage because all dependent variables have been multiplied by 100. Covariates include residency type, parents' ethnicity, province, birth year, birth order, age, survey year, mother's education level, mother giving birth age, if applicable.

Table 5: One child policy fine predicted by prior twins rate

VARIABLES	(1)	(2)	(3)	(4)
	Year +1		Year +2	
	One Child Policy Fine			
Panel A: Full sample				
Twins	0.00739		0.00468	
	(0.00609)		(0.00615)	
Different-gender twins		-0.000518		-0.00626
		(0.0103)		(0.0106)
Same-gender twins		0.0118		0.0108
		(0.00752)		(0.00750)
Observations	4,282,198	4,282,198	4,263,341	4,263,341
R-squared	0.806	0.806	0.805	0.805
F tests		0.00252		0.346
P values		0.960		0.556
Panel B: Sample born after 1979				
Twins	0.00227		-0.000913	
	(0.00701)		(0.00715)	
Different-gender twins		-0.00821		-0.0133
		(0.0116)		(0.0121)
Same-gender twins		0.00841		0.00639
		(0.00877)		(0.00884)
Observations	2,572,068	2,572,068	2,553,211	2,553,211
R-squared	0.771	0.771	0.770	0.770
F tests		0.712		0.874
P values		0.491		0.417

NOTE: Robust standard errors in parentheses are all clustered in province-year level. *** p<0.01, ** p<0.05, * p<0.1. Covariates include continous variables like boy's proportion, provincial time trend, and indicator variables, like having elder twins siblings, residency type, parents' ethnicity, province, birth year, birth order, age, survey year, mother's education level mother giving birth age, if applicable.

Table 6: Heterogenous effects of policy fine

	Dependent variabel is Twins		
	Parents Han	Subsamples by type of residence	
		Urban	Rural
Panel A: Policy Fine			
Policy fine rate	0.0652***	0.0827**	0.0570**
	(0.0232)	(0.0340)	(0.0273)
Panel B: Policy Fine interacting with birth order			
First birth order	0.0387	0.0752**	0.0135
	(0.0248)	(0.0354)	(0.0284)
Second birth order	0.131***	0.127**	0.126***
	(0.0283)	(0.0513)	(0.0335)
Third or higher	0.0601*	0.0495	0.0620
	(0.0327)	(0.0669)	(0.0384)
Panel C: Policy Fine interacting with mother's education level			
Illiterate	0.0540	0.197**	0.0195
	(0.0332)	(0.0823)	(0.0354)
Primary school	0.0777***	0.138***	0.0512*
	(0.0259)	(0.0478)	(0.0287)
Middle high	0.0671***	0.0620*	0.0736**
	(0.0253)	(0.0369)	(0.0312)
Senior high or above	0.0397	0.0682*	0.0325
	(0.0310)	(0.0403)	(0.0627)
Observations	4,034,009	893,084	3,140,925

NOTE: Robust standard errors in parentheses are clustered in province-year level. *** p<0.01, ** p<0.05, * p<0.1. One child policy fine is measred in years of household income. Sampling weights are applied. Coefficients should be interpreted as percentage because all dependent variables have been multiplied by 100. Covariates include residency type, parents' ethnicity, province, birth year, birth order, age, survey year, mother's education level, mother giving birth age, if applicable.

Table 7: Summary statistics in CHNS

Variable	(1) All twins	(2) By type of twins Same gender	(1) Different gender
Panel A: Biomarkers			
Height gap (cm)	2.18	1.30	4.65
	(2.74)	(1.59)	(3.68)
Mean of height (cm)	121.15	119.58	125.55
	(27.59)	(28.47)	(25.17)
Gap/Height Ratio	1.75	1.02	3.78
	(2.14)	(1.14)	(2.90)
Boy is taller in the pair (1 = Yes)			0.58
			(0.51)
Panel B: One-child policy			
Fine in years of income	1.47	1.55	1.26
	(0.66)	(0.68)	(0.56)
Panel C: Demographics			
Male twins (1 = Yes)	0.39	0.53	
	(0.49)	(0.50)	
Female twins (1 = Yes)	0.35	0.47	
	(0.48)	(0.50)	
Different gender twins (1 = Yes)	0.26		
	(0.44)		
Urban (1 = Yes)	0.26	0.19	0.47
	(0.44)	(0.40)	(0.51)
Mother's age when giving birth	27.57	26.79	29.86
	(3.64)	(3.10)	(4.24)
Age in years	8.48	8.42	8.63
	(4.64)	(4.82)	(4.20)
Observations	72	53	19

NOTES: Standard deviations are reported in brackets. Data source is China Health and Nutrition Survey. Twins are defined as children (aged below 18) born in the same household within the same month. For each pair of twins, height gap is defined as the height of the taller member minus that of the shorter one. Gap/Height ratio is defined as twins' height gap divided by the mean height of the pair, and the values reported are multiplied by 100.

Table 8: Height difference and one-child policy fine

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
	Height gap (cm)			Gap/Height Ratio (Mutiplied by 100)		
	Full sample		Same gender	Full sample		Same gender
Fine in years of income	1.434**		0.944***	1.227**		0.777***
	(0.541)		(0.157)	(0.447)		(0.129)
Interactions						
Same gender pair & Fine		1.591***			1.240***	
		(0.516)			(0.415)	
Different gender pair & Fine		0.502			1.145	
		(1.342)			(1.093)	
Same gender pair (1 = Yes)	-3.746***	-5.297**		-3.093***	-3.229*	
	(1.357)	(2.197)		(1.112)	(1.718)	
Mean of height (cm)	-0.0233	-0.0260	0.0233	-0.0139	-0.0141	0.0218
	(0.0776)	(0.0787)	(0.0334)	(0.0557)	(0.0563)	(0.0179)
Boy is taller in the pair (1 = Yes)	1.548	1.264		1.252	1.227	
	(1.458)	(1.500)		(1.135)	(1.191)	
Female twins (1 = Yes)			-0.911			-0.418
			(0.532)			(0.356)
Urban (1 = Yes)	0.622	0.600	1.097**	0.786	0.784	0.660**
	(0.935)	(0.916)	(0.511)	(0.676)	(0.681)	(0.312)
Age	0.429	0.482	-0.446	0.275	0.279	-0.476
	(0.600)	(0.617)	(0.622)	(0.421)	(0.427)	(0.356)
Age square /100	-0.125	-0.370	0.577	-0.0466	-0.0681	0.410
	(2.157)	(2.224)	(0.790)	(1.535)	(1.557)	(0.489)
Mother's age when giving birth	-0.171	-0.134	-0.249***	-0.181*	-0.178*	-0.208***
	(0.132)	(0.130)	(0.0518)	(0.102)	(0.103)	(0.0344)
Constant	4.887	5.579	6.682	5.589	5.650	6.319**
	(5.398)	(5.633)	(4.392)	(3.736)	(3.862)	(2.901)
Observations	72	72	53	72	72	53
R-squared	0.690	0.696	0.873	0.714	0.714	0.852
Year of birth group dummies	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummies	Yes	Yes	Yes	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes
Province interacting with time trend	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are clustered in province-year level. *** p<0.01, ** p<0.05, * p<0.1. Data source is CHNS. The twins sample used in this table are those born between 1979 and 2000. Height gap is defined as the height of the taller twin minus that of the shorter one, and gap/height ratio is defined as twins' height gap divided by the mean height of the pair. Each observation is derived from one pair of twins.

Table 9: Height difference and one-child policy fine

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Latest wave non-duplicated twins				Earliest wave non-duplicated twins			
	Height gap (cm)		Gap/Height Ratio		Height gap (cm)		Gap/Height Ratio	
Fine in years of income	2.536**		1.841**		1.055		0.837	
	(1.031)		(0.686)		(0.931)		(0.640)	
Interactions								
Same gender pair & Fine		2.552**		1.837***		1.146		0.799
		(0.971)		(0.660)		(0.993)		(0.676)
Different gender pair & Fine		2.249		1.917		0.123		1.226
		(3.211)		(2.368)		(2.099)		(1.678)
Same gender pair (1 = Yes)	-1.928*	-2.364	-1.690**	-1.573	-4.321***	-5.759	-3.602***	-3.001
	(1.016)	(3.893)	(0.775)	(3.032)	(1.564)	(3.790)	(1.302)	(2.853)
Mean of height (cm)	-0.0706	-0.0736	-0.0825	-0.0817	0.0455	0.0461	0.0107	0.0105
	(0.0832)	(0.0880)	(0.0635)	(0.0659)	(0.143)	(0.144)	(0.122)	(0.129)
Boy is taller in the pair (1 = Yes)	1.205	1.150	1.089	1.104	1.093	0.873	1.130	1.222
	(1.397)	(1.567)	(1.071)	(1.266)	(1.480)	(1.584)	(1.315)	(1.396)
Urban (1 = Yes)	1.017	1.001	0.616	0.620	0.418	0.400	0.674	0.682
	(1.353)	(1.346)	(1.014)	(1.026)	(1.228)	(1.257)	(0.901)	(0.948)
Age	1.315	1.355	1.219*	1.208*	-0.628	-0.576	-0.354	-0.376
	(0.818)	(0.946)	(0.623)	(0.676)	(1.199)	(1.272)	(1.031)	(1.092)
Age square /100	-4.462	-4.596	-4.321*	-4.286*	3.954	3.683	2.352	2.465
	(3.024)	(3.518)	(2.210)	(2.441)	(3.432)	(3.771)	(2.882)	(3.054)
Mother's age when giving birth	-0.0142	-0.0102	-0.0564	-0.0575	-0.197	-0.178	-0.160	-0.168
	(0.219)	(0.206)	(0.166)	(0.160)	(0.173)	(0.204)	(0.175)	(0.184)
Constant	0.641	1.151	5.674	5.538	3.398	3.973	6.092	5.852
	(6.533)	(9.693)	(5.129)	(7.317)	(9.971)	(10.07)	(7.555)	(8.320)
Observations	33	33	33	33	33	33	33	33
R-squared	0.829	0.830	0.839	0.839	0.825	0.829	0.843	0.844
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province interacting with time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are clustered in province-year level. *** p<0.01, ** p<0.05, * p<0.1. Data source is CHNS. The twins sample used in this table are those born between 1979 and 2000. Height gap is defined as the height of the taller twin minus that of the shorter one, and gap/height ratio is defined as twins' height gap divided by the mean height of the pair. Each observation is derived from one pair of twins.

Appendix Table 1: Twins in Japan

Year of birth	1995 Cesus Survey								
	By different gender			Total	By MZ or DZ		Twins rate (per 1000 deliveries)		
	Both male	Both female	Different gender		MZ	DZ	MZ	DZ	Total
1980	3667	3749	1871	9287	5545	3742	3.46	2.34	5.80
1981	3718	3846	1807	9371	5757	3614	3.76	2.36	6.12
1982	3640	3711	1836	9187	5515	3672	3.65	2.43	6.08
1983	3735	3854	1771	9360	5818	3542	3.86	2.35	6.21
1984	3627	3758	1773	9158	5612	3546	3.77	2.38	6.15
1985	3491	3672	1735	8898	5428	3470	3.77	2.41	6.18
1986	3406	3306	1750	8462	4962	3500	3.60	2.54	6.14
1987	3417	3405	1651	8473	5171	3302	3.83	2.45	6.28
1988	3300	3317	1722	8339	4895	3444	3.73	2.63	6.36
1989	3279	3376	1925	8580	4730	3850	3.73	3.03	6.76
1990	3162	3266	1829	8257	4599	3658	3.74	2.97	6.71
1991	3177	3226	1881	8284	4522	3762	3.74	3.11	6.85
1992	3317	3165	2017	8499	4465	4034	3.70	3.34	7.04
1993	3235	3316	2120	8671	4431	4240	3.74	3.58	7.32
1994	3521	3489	2280	9290	4730	4560	3.94	3.80	7.74
1995	3377	3488	2373	9238	4492	4746	3.77	3.98	7.75
Total	55069	55944	30341	141354	80672	60682	3.73	2.81	6.54

Note: From *Journal of Population Problems*, 1998: 13 -35.