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The quantity of education and preference for sons: Evidence from Taiwan's compulsory education reform☆

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ABSTRACT

This paper attempts to identify the causal effect of parental education on the male ratio at birth. To deal with the endogeneity of parental education, we exploit Taiwan's educational reform in 1968 making education compulsory up to the ninth grade. Based on a uniquely large and detailed administrative data set from Taiwan, our results show that the average education level of mothers is positively related to the male ratio at birth, both in the case of high-parity births and when mothers are at least 30 years old.

1. Introduction and literature review

The International Center for Research on Women reports that the link between female education and gender bias is far from clear (Pande, Malhotra, & Grown, 2005). On the one hand, researchers find that the acquisition of low levels of education, as opposed to no education, may give women the means to more efficiently put into practice deep-rooted gender preferences (Amin, 1990; Bhat, 2002; Das Gupta, 1987). Therefore, in areas with low levels of education, we may observe that female disadvantage in natality is more pronounced among educated mothers as opposed to uneducated mothers. On the other hand, once a higher-level education threshold (e.g., tertiary education) is achieved, higher demand for male children will be appeased (Pande & Astone, 2007). Coalescing these two ideas, Echvarri and Ezcurra (2010) suggest that the relationship between female disadvantage in natality and parental education can be non-monotonic. In particular, they hypothesize that the sex ratio at birth (male births per female births) is increasing at a decreasing rate until a threshold level of education is reached, at which point this relationship reverses: that is, the sex ratio imbalance declines with more education.

However, it is not easy to identify the causal effect of parental education on gender bias, because the direct measures of parental education are endogenous. To illustrate, consider a woman who decides to acquire more education to improve her socioeconomic status. The returns to this decision ultimately would depend on both the level of education attained and her unobserved innate qualities (e.g., ability, charisma, and beauty). Hence, the returns to education will be biased upward by these unobserved factors. A

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similar relationship may be found between education and preference for sons. While it may appear that education causes mothers to break away from more traditional roles (Lin, 2009), it is possible that educated women have pre-existing traits that cause them to acquire more education and to have a more equal-gender-role stance. Thus, while it may look as if education decreases the probability of having a male child, this relationship is likely to be spurious.

It is also possible that omitted variable bias would attenuate the effect of parental education on the probability of having a male child. For instance, one of the most cherished virtues in Confucianism, a tradition deeply rooted in many of the Asian countries with a high male ratio, is the concept of filial piety (or filial obedience). According to Mencius (a Chinese philosopher and ardent interpreter of Confucianism), the greatest unfilial behavior is to provide no male heirs. Confucianism also prescribes that the three most important human relationships are rulers and subjects, fathers and sons, and husbands and wives. This suggests an inherent ranking that subordinates individuals to their rulers, sons to fathers, and women to men (Ho, 1998). Under this patrilineal kinship system, family lineage and property are passed from fathers to sons, and the desire for male heirs is likely to materialize in the form of female disadvantage in natality. Tang (1995) dissects the impacts of Confucianism on Chinese reproductive behavior, pointing out that in pre-modern China it was in fact the more educated people who received more education about Confucianism. Hence, the relationship between education and the demand for male children may be affected by the interaction between traditional roles and education. That is, if education and tradition are passed from one generation to another, then we may find that education is positively correlated with the demand for male children. But, once again, this relationship may not necessarily be causal.

In this paper, we attempt to identify the causal effect of parental education on the male ratio at birth, which is defined as the ratio of male births divided by total live births. We first outline a simple model of the demand for children.[1] Then, we use Birth Certificate Records from Taiwan to test the main predictions of this model. We rely on the exogenous increase in parental education resulting from Taiwan's educational reform of 1968 making education compulsory up to the ninth grade. The parental birth date determines exposure to that reform; both the parental birth date and differential rates of school openings by county of residence provide sources of variation to aid our identification.

Our empirical results show that a mother's education has no effect on the male ratio of her children when she gives a birth before the age of 30, but has a significant positive effect on this outcome when she is at least 30 years old. Second, a mother's education has no effect on the male ratio of her first or second children, but has a significant positive effect on the male ratio at the third birth parity[2] or above. In addition, when a mother has already had at least one son, her education level has no effect on the male ratio, even for third- and higher-parity births (hereafter termed high-parity births). In general, the search for sons drives fertility rates upward. Finally, the father's education has no impact at all on the male ratio at birth.

2. The education reform of 1968 and the genetic health act of 1985

By the mid-1960s, education in Taiwan was practically universal, yet one out of every two primary school graduates did not progress to secondary school. That was due to both a highly competitive national examination and the lack of junior high schools. By the end of the 1960s the government of Taiwan had resolved to increase access to education by: extending compulsory education from primary school (children between the ages of 6 and 12) to junior high school (children between the ages of 6 and 15); abolishing the entrance examination; and undertaking the construction of 254 junior high schools over a six-year period. By the end of 1968, the number of junior high schools had increased by 50%. Chou, Liu, Grossman, and Joyce (2010) report that the intensity of this six-year school construction initiative varied significantly across regions. In 1968, the cumulative number of new junior high school openings per thousand children aged 12–14 ranged from 0.02 in Changhua County to 0.53 in Penghu County. By 1973, the variation in the intensity of school construction remained large, ranging from 0.07 in Changhua County to 0.91 in Penghu County (for details see Table 1 in Chou et al., 2010).

The impact of this education reform by the Taiwanese government was immediate. Junior high school enrollment increased from 62% in 1967 to 75% in 1968. The progressive construction and opening of public junior high schools increased junior high school enrollment to 84% by 1973. This extension of compulsory education from six to nine years is a natural experiment that allows us to identify the effect of higher education on the preference for boys. Parental birth date determines exposure to this reform. Specifically, parents born after September 1, 1955, or under the age of 13 by September 1, 1968, are affected by the educational reform and constitute our treatment group.[3] The effects of educational reform can be seen in Fig. B.1: we witness a sharp increase in the years of education after birth cohort 1956 (born between September 2, 1955 and September 1, 1956). This change in educational achievement is more pronounced for mothers.

The Genetic Health Act of 1985 introduced legalization of induced abortions. Developed by Taiwan's Department of Health, this act mission was “to protect the health of mothers and children and secure the happiness of families” (Wu, 2012). Under this law, it is a physician's duty to recommend an abortion when “necessary” (Fox, 2009). That is, although women's right to undergo an abortion

[1] First we construct a parents' utility function; then we discuss the optimal level of abortion usage in the following four cases: no abortion technology, exogenous increase in education, exogenous decrease in the optimal number of children, and optimal education level. The details of this model are described in Appendix A.

[2] Parity denotes the number of children a woman has borne.

[3] As part of the education reform, children under 15 years of age in 1968 also are allowed to resume their studies if they previously received only primary school education. However, Chou et al. (2010) have shown that these 13- and 14-year-olds are unlikely to return to school and therefore should be included in the control group (for details see Pages 49–50 in Chou et al., 2010).

Table 1
Summary statistics.

	Full sample	Birth parity			Mother's age at giving birth	
		1	2	≥3	< 30	≥30
Panel A. Mother						
Male ratio at birth (%)	52.30	51.92	51.76	53.31	51.95	52.72
Year of education	10.47	11.20	10.68	9.16	10.02	11.08
Observations	7449	7019	7055	7299	1701	6021
Panel B. Father						
Male ratio at birth (%)	52.24	51.87	51.73	53.44	51.96	52.48
Year of education	11.08	11.58	11.23	10.08	10.73	11.30
Observations	8728	8679	8656	8593	8607	8515

is not automatic, provided that their husbands agree (unless he is missing, unconscious, or deranged), women can undergo one under a wide array of circumstances.[4] As a result, abortions have been practiced widely in Taiwan. Using 1991–2 data from Taiwan's metropolitan areas, Wang and Lin (1995) show that nearly one out of every two women had a history of an induced abortion. Among them, approximately one of every two had had one abortion, one out of every three had had two, and one out of every six had had three or more. The exogenous increase in the access to abortions resulting from this law, in combination with the existing technology that helps to determine the gender of the fetus (e.g., ultrasound examination), plus the education reform of 1968, allows us to determine whether parents treated by the education reform are more likely to resort to abortion for the purpose of selecting the gender of their children.

3. Data

We use the Annual Birth Certificate Records (BCR) from Taiwan, which contain information for the entire population of Taiwan and were assembled by the Ministry of Interior Affairs. The BCR have detailed information on a variety of personal and demographic characteristics including infant's exact date of birth, gender, birth weight, gestational length, birth parity, county of birth, parents' age at the time of the infant's birth, parents' county of birth and exact date of birth, their schooling years, occupation, the hospital of delivery, and the confidential identification (ID) of both the infant and his/her parents. Because abortions before 1985 were very rare (Hung, 2004), we only use the BCR from 1985 on when abortions were widely practiced in Taiwan.

Our sample is constructed following Chou et al. (2010). Specifically, we include parents who were from less than age 1 to age 20 in 1968, based on their exact date of birth and the official cutoff date for school enrollment.[5] We further restrict the sample of mothers to ages 22 to 45 and the sample of fathers to ages 22 to 50 when they gave birth during our study period, from 1985 to 2006. We aggregate the data into cells denoting mother's or father's county of birth, mother's or father's cohort in 1968, and child's year of birth. There are 21 birth counties, 21 cohorts in 1968, and 22 child's years of birth, resulting in 9702 potential cells. After excluding cells with no births, we have 7449 and 8728 cells for mothers and fathers, respectively.[6]

We aggregate the data for the following reasons. First, according to Taiwan's data sharing policy, the individual-level BCR shall not be used outside of a secured government data management facility. Second, because the BCR cover all births in Taiwan, we have an extremely large sample that is better handled when aggregated—there are more than three million births in the sample of mothers and more than four million births in the sample of fathers. Third, among all of the regressors, only parental schooling varies by individual. Also, self-reported schooling could contain random measurement errors, which would be substantially reduced if data were aggregated. And finally, the instrumental variables we use are at the county/cohort level. Chou et al. (2010) and Lin, Qian, and Liu (2014) use aggregate data for the same reasons.

Table 1 compares the means of the male dichotomous indicator and the average educational years of parents, weighted by cell sizes. The male ratio at birth of the first two parities ranges from 51.73% to 51.92%, similar to the male ratio before the legalization of abortion (51.7%, not shown) in Taiwan, and to countries with no known son preference (Lin et al., 2014).[7] However, at the third parities and above the male ratios are 53.31% in the sample of mothers and 53.44% in the sample of fathers, respectively, suggesting a preference for sons. From Fig. B.2, we also notice that the male ratio remained around the natural rate before 1985, which is consistent with Case 0 of our mathematical model (for details see Appendix A): there is no sex-selective abortion, regardless of the

[4] These include: (1) She or her spouse acquires genetic, infectious or psychiatric disease detrimental to reproductive health; (2) Anyone within the fourth degree of kin relative of herself or her spouse acquires a genetic disease detrimental to reproductive health; (3) By medical consideration, pregnancy or delivery may cause life threatening risk or detrimental to her physical and mental health; (4) By medical consideration, risk of teratogenesis may present for the fetus; (5) Pregnancy as a result of being raped, lured into sex intercourse or in sex intercourse with a man prohibited to lawfully marry her; (6) Pregnancy or childbirth is likely to affect her mental health or family life.

[5] For example, parents are affected by the reform if they were born between 09/01/1955 and 12/31/1955, but are not affected if they were born between 01/01/1955 and 08/31/1955.

[6] There are more cells with no births in the sample of mothers because women become less fertile as they age.

[7] The male ratio for humans is approximately 0.515 (James, 1987).

education levels of parents, when the technology is not available. After 1985, the male ratio increased sharply; this was mainly due to the increase in the male ratio among high-parity births (parity ≥ 3). In the last two columns of Table 1 the statistics show that the male ratio for younger mothers (< 30 years old) and older mothers (≥ 30 years old) are 51.95% and 52.72%, respectively. On average, mothers in our sample have 10.47 years of education, while fathers have 11.08 years of education. We find that for both parents the level of education is negatively related to birth parities but positively related to mother's age. In other words, the descriptive statistics suggest that higher education is associated with lower birth parity and delayed motherhood.

Our findings are consistent with Lin et al. (2014). They use Taiwan's BCR data from 1980–92, and find that after the legalization of abortion in 1985, the male ratio at birth increases and the relative neonatal female mortality rate decreases at higher parities. The authors argue that mothers with a strong son preference are more likely to use sex-selective abortion when the cost of having an additional child is high. For example, older or higher-parity mothers may decide to abort a female fetus and continue to try for a boy. Similarly, Hank (2007) finds that sex selection is rare at lower parities.

4. Empirical specification

We want to verify whether the higher education of the Taiwanese population that resulted from the education reform of 1968 had a significant effect on the male ratio at birth in Taiwan. With the intercept and the disturbance term suppressed, the regression is described as follows:

$$M_{ajt} = \sum_{a=0}^{19} \alpha_a C_a + \sum_{j=1}^{20} \varphi_j X_j + \beta S_{ajt} + \sum_{t=1}^{21} \theta_t Z_t + \sum_{j=1}^{20} \sum_{t=1}^{21} \lambda_{jt} X_j Z_t. \tag{1}$$

The dependent variable is the male ratio at birth,[8] the ratio of male births divided by total live births, for parents of cohort a (with 20-year-olds in 1968 the omitted cohort), born in county j (with Taipei City the omitted county), and giving birth to a child in year t (with 1999 the omitted year). S_{ajt} is the cell mean of years of formal schooling completed; the coefficient of interest is β, an estimate of the impact of parental education on the male ratio at birth. In addition, C_a is a dummy variable for cohort a; X_j is a dummy variable for county j; and Z_t is a dummy variable for year of birth of child t. We include these dummy variables in the regressions to control for parental preferences as related to parents' cohort, year of giving birth, or regional practices. In the end, interactions between the county and year-of-birth-of-child dummies allow for parental son preference to change over time differently across counties. We run weighted regressions (weighted by the square root of cell sizes), and all regressions are clustered at the county level.

To solve the endogeneity problem, S_{ajt} is instrumented with the interaction of T_a and P_{aj}. Here, T_a equals one for cohorts that were affected by the education reform or were twelve years of age or younger by September 1, 1968, and zero otherwise; P_{aj} is defined as the program intensity measure of county j in the year when cohort a enters junior high school. Because the six-year plan to implement the 1968 legislation ended after 1973, children who started junior high school in or after 1973 are assigned the local program intensity measure of year 1973. The first stage is described as follows:

$$S_{ajt} = \sum_{a=0}^{19} \alpha_a C_a + \sum_{j=1}^{20} \varphi_j X_j + \beta T_a P_{aj} + \sum_{t=1}^{21} \theta_t Z_t + \sum_{j=1}^{20} \sum_{t=1}^{21} \lambda_{jt} X_j Z_t. \tag{2}$$

All other variables are defined as in Eq. (1).

5. Results

Table 2 presents both the OLS and 2SLS estimates of the effect of parental education on the likelihood of having a male child. The OLS results show that father's education has a positive impact on the male ratio, while mother's education does not. The first-stage results in column 2 suggest that education reform has a significant impact on the education level for both parents. Given that the cumulative number of new junior high school openings per thousand children aged 12–14 has a mean of 0.2 (not shown), on average the reform increases the education of mothers and fathers by 0.29 ($= 1.45 \times 0.2$) and 0.32 ($= 1.60 \times 0.2$) years, respectively. The 2SLS results suggest no impact of parental education on the male ratio at birth.

Next, we consider whether the marginal utility that parents derive from having a male child varies with the number of times the mother has given birth. To this end, we run the same set of regressions conditioning on birth parity (parity = 1, 2, or ≥ 3). The 2SLS results are shown in the first three columns of Table 3.[9] This exercise reveals that mother's education level has no impact on the male ratio at the first two parities, but increases the male ratio at the third and higher parities. In other words, consistent with Case 1 of our mathematical model (for details see Appendix A), if provided with technology that permits the effective practice of gender driven abortion, the more educated parents are significantly more likely to abort based solely on the gender of their unborn child. The coefficient of 3.30 (column 3, Panel A) implies that the male ratio for high-parity births will increase by 3.30 percentage points if mothers have one additional year of education. In contrast, father's education level has no impact on the male ratio at birth, regardless of parities.

We then examine how mother's age at giving birth affects the relationship between parental education level and the male ratio at

[8] To present the results and facilitate their interpretation, the values of the dependent variable (cell means) are multiplied by 100.

[9] The first-stage results of Table 3 are shown in Table C.1.

Table 2
The effect of parental education on the male ratio at birth.

	OLS	First stage	2SLS
Panel A. Mother			
Year of education	−0.047		1.10
	(0.66)		(0.84)
Treatment × program intensity		1.60***	
		(0.40)	
Observations	7449	7449	7449
Panel B. Father			
Year of education	0.34***		0.14
	(0.091)		(0.61)
Treatment × program intensity		1.45***	
		(0.51)	
Observations	8728	8728	8728

Notes: Standard errors, reported in parentheses, are adjusted for clustering at the county level. All regressions include 20 cohort dummies, 20 county dummies, 21 year-of-birth-of-child dummies, and interactions between the county and year-of-birth-of-child dummies.
*** $p < .01$.

Table 3
2SLS estimates of the effect of parental education on the male ratio at birth for subsamples.

	Birth parity			Mother's age at giving birth	
	1	2	≥3	< 30	≥30
Panel A. Mother					
Year of education	−3.91	−2.44	3.30**	−0.32	3.64***
	(4.62)	(1.88)	(1.43)	(0.74)	(0.90)
Observations	7019	7055	7299	1701	6021
Panel B. Father					
Year of education	0.86	−0.95	1.11	−0.36	0.81
	(1.32)	(1.23)	(1.09)	(0.76)	(0.53)
Observations	8679	8656	8593	8607	8515

Notes: Standard errors, reported in parentheses, are adjusted for clustering at the county level. All regressions include 20 cohort dummies, 20 county dummies, 21 year-of-birth-of-child dummies, and interactions between the county and year-of-birth-of-child dummies.
*** $p < .01$.
** $p < .05$.

birth. The results are presented in the last two columns of Table 3. We find that mother's education significantly increases the male ratio only among mothers who are at least 30 years old. This finding is consistent with Case 2 of the model described in Appendix A for $L > 0$. Furthermore, because education causes older mothers to abort females at higher rates, these results also suggest an interaction between age and education that exacerbates the preference for sons, such that $\frac{\partial L}{\partial age} > 0$. In addition, due to age related fertility factors (both the quality and number of eggs decrease with age), women who choose to give birth after age 30 may have a stronger son preference and therefore want to take the chance of having a son even after passing their peak fertility age. The estimate (column 5, Panel A) is large and statistically significant, implying that an additional year of education is associated with an increase of 3.64 percentage points in the male ratio at birth. In contrast, the results in Panel B show that the education level of fathers has no impact on the male ratio at birth for all of the subsamples.

Finally, in the case of high-parity births we test whether the marginal benefit that parents derive from their male child is conditioned on the gender of the existing children. To run this test, we use the same regression model, but this time we restrict the sample to include only high-parity births and run separate regressions for couples with at least one son and for couples with no sons prior to giving birth to the high-parity child.[10] The results of this analysis (Table 4) indicate that parental education has no effect on the male ratio at birth when the couple has had at least one son. In contrast, the impact of mother's education on the male ratio is large and statistically significant when the couple has had no boys prior to giving birth to the high-parity child. In particular, a single year increase in education will lead to an increase of 4.40 percentage points in the male ratio at birth, revealing a strong preference for sons in this subsample. Our statistics of mothers also indicate that parents with no sons in the first two parities are more likely to have a high-parity birth, probably in order to increase the chance of having a son. More specifically, the probability of having high-

[10] We use the same approach to check the impact of parental education on the male ratio of the second child, conditioning on the gender of the first child. The results (not shown) indicate that regardless of the gender of the first child, parental education has no significant impact on the male ratio of the second child.

Table 4
2SLS estimates of the effect of parental education on the male ratio at birth for high-parity births conditioning on the gender of the existing children.

	At least one son		No sons	
	First stage	2SLS	First stage	2SLS
Panel A. Mother				
Year of education		−0.74		4.40***
		(3.96)		(1.32)
Treatment × program intensity	1.58***		1.63***	
	(0.48)		(0.48)	
Observations	6776	6776	7189	7189
Panel B. Father				
Year of education		0.98		1.34
		(0.88)		(1.90)
Treatment × program intensity	1.51**		1.08*	
	(0.63)		(0.62)	
Observations	8208	8208	8487	8487

Notes: Standard errors, reported in parentheses, are adjusted for clustering at the county level. All regressions include 20 cohort dummies, 20 county dummies, 21 year-of-birth-of-child dummies, and interactions between the county and year-of-birth-of-child dummies.
*** $p < .01$.
** $p < .05$.
* $p < .1$.

parity birth is 25.39% if the first born is a boy, but this probability increases to 39.60% if the first born is a girl. Similarly, the probability is 30.74% if the second child is a boy and is 46.47% if the second born is a girl. In the end, if the first two children are girls, then the probability of having high-parity birth can be as high as 58.58%; if there is already at least one son at the first two parities, the probability drops to 28.11%. These statistics are consistent with the son-biased fertility-stopping rules, as parents are less likely to have additional children after having sons than daughters.

6. Conclusion

In this paper, we set out to identify the causal effect of parental education on the sex ratio at birth in Taiwan. To deal with the endogeneity of parental education, we consider Taiwan's 1968 educational reform making education compulsory up to the ninth grade. Our empirical results confirm the main predictions of the proposed model of the demand for children. In particular, provided that the technology for selecting the gender of the child is available, an exogenous increase in education from primary to secondary level causes a decline in the return from having girls relative to the return from having boys. In other words, the extra cost or loss from having a girl increases with more education. This tendency is exacerbated by the age of the mother and for high-parity births when the first two births are female. Our results suggest that, ceteris paribus, as the optimal number of children declines, the male ratio will continue to rise. Although it is not laudable to end pregnancies for the purpose of selecting gender, at least we know that the girls who do survive are truly wanted, and therefore more investment is made in them.

As Echvarri and Ezcurra (2010) suggest, the increase in parental education will first increase and later decrease the male ratio at birth. Based on our estimates, the 1968 reform that made education compulsory up to the ninth grade[11] does not increase parental schooling above the threshold at which this relationship reverses. Thus, how Taiwan's more recent education reform of 2011—increasing access to tertiary education—could impact the male ratio at birth remains an empirical question. We believe this will be a promising direction for future research, because it will provide important evidence on the non-monotonic relationship between parental education and the sex ratio at birth.

Appendix A. Modeling son preference

Consider the unitary model of the family proposed by Becker (1981). Let U represent the utility function of parents. U is a function of the expected return from children, C, and abortion usage, A.[12] Hence, parental utility can be represented by the following utility function:

$$U \equiv U(C, A; S, N^*, T).$$

S, N, and T are given exogenously. In particular, S is parental schooling, N^* is parents' optimal number of children and is assumed to

[11] Chou, Liu, Grossman, and Joyce (2007) find that the reform not only increased the completion of junior high school, but also had effects on the completion of higher levels of education beyond that.

[12] For our purposes, abortion usage refers to abortion driven by the preference for sons; that is, abortion that is not related to other causes.

be a deterministic function of time t such that $\partial N/\partial t < 0$. While the optimal number of children is also likely to be a function of parental characteristics, for simplicity we assume that the optimal number of children is agreed upon before the formation of the family. Finally, T is the availability of technology that permits the effective practice of gender driven abortion (i.e., the availability of technology that helps to determine the gender of the fetus and legal pregnancy termination). We assume that parents derive utility from the returns from children ($\partial U/\partial C > 0$) and disutility from abortion usage ($\partial U/\partial A < 0$).[13] Furthermore, we assume that the utility derived from the returns from children is independent of the level of abortion usage ($\partial^2 U/\partial C\partial A = 0$).

The expected return from children is defined as:

$$C = R_b N_b + R_g N_g,$$

where $R_b > 0$ is the return from the male child; $R_g = R_b - L$ is the return from the female child, and L is the differential cost of having a female child; $N_b = Nb(a)$ is the number of boys; $N_g = N(1-b(a))$ is the number of girls; and $b(a)$ is the proportion of males born to the couple, a linearly increasing function of abortion usage ($\partial b/\partial a > 0$ and $\partial^2 b/\partial^2 a = 0$). Clearly, $N = N_b + N_g$, and $A = \Sigma_N (a)$. Without loss of generality, we can assume that the return from having a girl is different from the return from having a boy, or $L \neq 0$. In particular, we hypothesize that L captures the extra cost or benefit associated with having a female child and is a function of both parental education and the proportion of boys, or $L(S,b(a))$ and $\partial L/\partial S$, $\partial L/\partial b < 0$. If $L > 0$, the extra cost of having a female child, L, for example, may reflect the fact that when parents expect to follow patriarchal and/or virilocal rules, their private return to investments in their daughters' health or education is expected to be lower than their private return to investments in their sons (Levine & Kevane, 2003).

We begin by assuming that parental education is fixed at S_L. For example, in the case of Taiwan, primary education was compulsory before the education reform of 1968, hence it is reasonable to claim that baseline individuals had at least a primary education. Then, S_L is a low level of education, but it is higher than no education at all.

Given the concavity of U, the optimal level of abortion usage is the solution to the following first order condition (F):

$$F = U_C \left[L - (1 - b(a)) \frac{\partial L}{\partial b} \right] N \frac{\partial b}{\partial A} + U_A N = 0.$$

At the optimum, parents choose their level of abortion usage up to the point where the aggregate net disutility from abortion usage just equals the net utility from the extra return from having another boy.

Case 0. No abortion technology.

Assuming that the natural probability of having a boy is equal to that of having a girl, if the abortion technology required to practice gender selection does not exist, then the expected return from having children is simply equal to $1/2\, N[R_g + R_b]$. That is, the more and the less educated parents on average should have equal chances of having a male child when they are unable to influence the gender of their children. Moreover, regardless of their level of education, parents should have a 50% chance of having a male child and a 50% chance of having a female child. Nevertheless, under this scenario, the preference for sons is likely to manifest itself through higher probabilities of survival for boys relative to girls (see Coale & Banister, 1994; Lin et al., 2014).

Case 1. Exogenous increase in education.

When there is an exogenous increase in education, say from S_L to S_M, and the technology to select an infant's sex is available, the effective or perceived return from having girls is closer to the return from having boys only if education is negatively related to male gender bias. In other words, the extra cost or loss from having a girl decreases with higher education ($\frac{\partial L}{\partial S} < 0$). From the optimality condition and the concavity of U it is clear that, relative to the baseline case, parents now would choose to have fewer gender related abortions; hence, they are more likely to have fewer boys. More educated parents will abort less, but they may continue to abort as long as the difference between the return from a male child is sufficiently higher than the return from a female child, such that the aggregate net disutility from abortion usage equals the net utility from the extra return to having another boy. The opposite will be true if education is positively related to son preference ($\frac{\partial L}{\partial S} > 0$).

Case 2. Exogenous decrease in the optimal number of children.

Now, let's assume that, ceteris paribus, t increases. Since $\partial N/\partial t < 0$, this implies that N decreases. By the implicit function theorem, we have

$$\frac{\partial a}{\partial N} = -\frac{\partial F_N}{\partial F_a} = \frac{-U_{CC}\left[R_b - (1 - b(a))L\right]\left[L - (1 - b(a))\frac{\partial L}{\partial b}\right] N \frac{\partial b}{\partial a}}{U_{AA}} < 0.$$

It follows that, when $L \neq 0$, as the number of optimal children falls, ceteris paribus, the number of gender related abortions increases. Under this scenario and the assumption of preference for sons ($L > 0$), ceteris paribus, mothers who have delayed parenting are more likely to abort female fetuses than mothers who have not. This can be expressed as ($\frac{\partial L}{\partial age} > 0$).

[13] The most significant cost of abortion is not necessarily monetary, but perhaps emotional and physical (Thorp, Hartmann, & Shadigian, 2003).

Case 3. Optimal education level.

Now, let's assume that there exists an optimal level of education S^* such that $L(S^*) = 0$. Under this scenario, parents will have no incentive to choose $A \neq 0$; hence $A = 0$ whenever $S = S^*$. Similarly, Case 2 implies that whenever $L(S^*) = 0$ we also have $\partial a/\partial N = -\partial F_N/\partial Fa = 0$. That is, regardless of what their optimal number of children is, optimizing parents will not resort to abortion for the purpose of selecting the gender of their children.

Appendix B

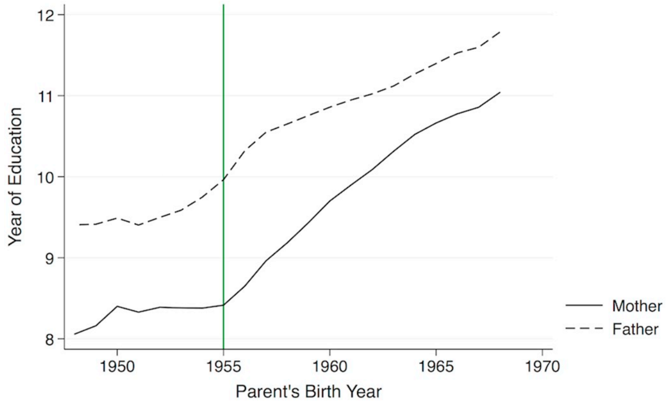

Fig. B.1. Parental education by birth cohorts.
Notes: The vertical line indicates the effect of the educational reform in 1968: birth cohorts on and to the left of the vertical line are not affected by the educational reform (control group), and birth cohorts to the right of the vertical line are affected (treatment group).

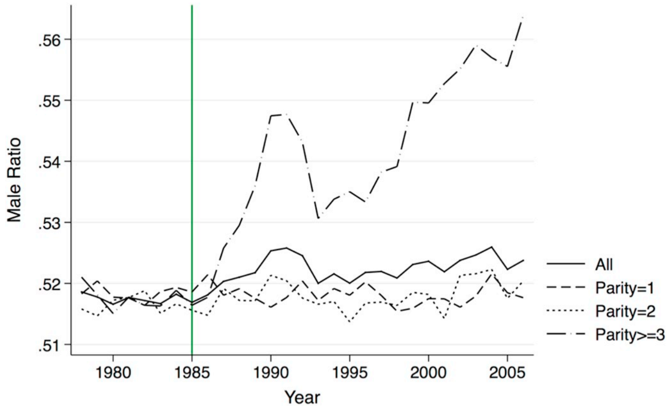

Fig. B.2. Trends in the male ratio at birth in Taiwan.
Notes: The vertical line indicates the year 1985 when the Genetic Health Act took effect.

Appendix C

Table C.1
First stage of Table 3.

	Birth parity			Mother's age at giving birth	
	1	2	≥3	< 30	≥30
Panel A. Mother					
Treatment × program intensity	0.79**	1.03**	1.69***	3.15**	1.29***
	(0.37)	(0.45)	(0.47)	(1.16)	(0.30)
Observations	7019	7055	7299	1701	6021

(*continued on next page*)

Table C.1 (*continued*)

	Birth parity			Mother's age at giving birth	
	1	2	≥3	< 30	≥30
Panel B. Father					
Treatment × program intensity	1.05***	1.11**	1.28**	1.57***	1.42***
	(0.34)	(0.48)	(0.61)	(0.43)	(0.46)
Observations	8679	8656	8593	8607	8515

Notes: Standard errors, reported in parentheses, are adjusted for clustering at the county level. All regressions include 20 cohort dummies, 20 county dummies, 21 year-of-birth-of-child dummies, and interactions between the county and year-of-birth-of-child dummies.

*** $p < .01$.

** $p < .05$.

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