Estimating a Dynamic Model of Sex Selection in China

Avraham Y. Ebenstein*

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Abstract

High ratios of males to females in China have historically concerned researchers (Sen 1990), and have increased in the wake of China's One Child Policy (1979). Chinese policymakers are currently attempting to correct the imbalance in the sex ratio through initiatives which provide financial compensation to parents with daughters. Others have advocated a relaxation of the One Child Policy to allow more parents to have a son without engaging in sex selection. In this paper, I present a model of fertility choice when parents have access to a sex selection technology and face a mandated fertility limit. By exploiting variation in fines levied in China for unsanctioned births, I estimate the relative price of a son and daughter for mothers observed in China's census data (1982-2000). I find that a couple's first son is worth 1.42 years of income more than a first daughter, and the premium is highest among less educated mothers and families engaged in agriculture. Simulations indicate that a subsidy of 1 year of income to families without a son would reduce the number of "missing girls" by 67 percent, but impose an annual cost of 1.8 percent of Chinese GDP. Alternatively, a 3-child policy would reduce the number of "missing girls" by 56 percent but increase the fertility rate by 35 percent.

*Robert Wood Johnson Scholar in Health Policy at Harvard University. I am grateful for helpful comments from David Card and Ronald Lee. I would also like to thank Jerome Adda, Rodney Andrews, Richard Crump, Simon Galed, Alexander Gelber, Gopi Shah Goda, Jonathan Gruber, Damon Jones, Claudia Sitgraves, Kevin Stange, Kenneth Train, and Ebonya Washington.

1 Introduction

In the wake of China's One Child Policy (1979), a growing imbalance in the number of male and female births has emerged in China. The 2000 census reflects that for parents bearing children in the last two decades roughly 9 million females are "missing" relative to naturally-occurring birth patterns, distorting the sex ratio.[1] A consensus has emerged that sex selection via infanticide and abortion is the principal explanation for the rising sex ratio in China (Yi et al. 1993, Junhong 2001). This pattern is also found in India, where slowing fertility in northern states has been associated with an increase in sex-selective abortions (Arnold et al. 2002). While scholarly work has focused on documenting the presence of sex selection, modeling of sex selection decisions has been limited.[2] Chinese government figures indicate that the female deficit at birth has continued to grow with the overall sex ratio at birth reaching 118 boys born for every 100 girls in 2005, providing further justification for a closer analysis of this phenomenon, and policies that may reduce the practice of sex selection.[3]

In order to reduce the imbalance in the sex ratio at birth, China has recently launched a nationwide initiative to subsidize parents with daughters, known as the "Care for Girls" campaign.[4] There is broad disagreement, however, regarding the required size and structure of monetary incentives necessary to reduce the practice of sex selection in rural China (Li 2007). Others have instead advocated for a relaxation of the One Child Policy to address the sex ratio distortion, which would allow more parents to have a son without resorting to sex selection (Yi 2007). However, policymakers fear that such a shift would lead to a large increase in fertility rates, and population control remains a stated goal of the Chinese government.

In this paper, I present and estimate a dynamic model of parental fertility choices using Chinese census data (1982, 1990, 2000) that aims to predict the impact of these policy options

[1] Sex ratio refers to the ratio of males to females.

[2] One notable exception is Kim (2005), who examines the predicted effect on the sex ratio and overall fertility in response to the introduction of ultrasound technology.

[3] Report issued by Chinese State Council and Central Committee (January 2007).

[4] China's "Care for Girls" campaign began in 2000 in 24 counties and subsidizes parents who have only daughters. Preliminary reports indicate the programs have lowered the sex ratio at birth. http://www.china-embassy.org/eng/xw/t273191.htm

on fertility rates, the sex ratio at birth, and the budgetary consequences of monetary subsidies to parents without a son. The model's parameter estimates identify the value in income to parents of having a son relative to a daughter, which characterizes the intensity and distribution of son preference in modern China, and provides information necessary for predicting the efficacy of financial subsidies to parents without a son. The model is estimated by exploiting quasi-random variation in the fines parents were forced to pay for violating the One Child Policy, which vary considerably by province, year, and parental ethnicity, and provide plausibly exogenous variation in the incentives to childbearing necessary for parameter estimation. Additionally, the model aims to make a theoretical contribution by explaining the recent patterns in China's sex ratio at birth in a rational choice framework.

The "Missing Girls" phenomenon was first explored by Amartya Sen (1990), who alerted western researchers to a "sex bias in relative care" – decades of mistreatment and neglect of China's women. He suggested this bias was responsible for the high Chinese sex ratio, and estimated that 50 million Chinese women and 100 million women worldwide were unaccounted for relative to natural birth and mortality rates. Sen also pointed to the painful choices faced by parents forced to comply with fertility limits well below their desired fertility, which coincided with the sharp increase in the sex ratio. As shown in Table 1, Sen's observation that the male fraction of births in China rose from 51.6% to 53.3% masks a pattern that emerges when the births are examined by parents' successive number of children (birth parity) and separately following daughters or sons. China's 2000 census reflects that the high overall sex ratio at birth is due to extremely large fractions of sons following daughters, and very low fertility for those who already have sons. The analysis also indicates that following sons, parents appear willing to engage in sex selection, to a lesser degree, to ensure the birth of a daughter, indicating a Chinese preference for gender balance.

The dynamic model of parental fertility choices presented in this paper serves to explain this pattern of "Missing Girls" in a rational choice framework. Building on existing models of home production (Becker and Lewis 1973), I consider a model of fertility behavior in which parents jointly determine the "quantity" and "quality" of children, in a context where gender represents a dimension of quality, and parents assign different relative prices to sons and daughters. The model aims to explain several stylized facts, such as the rise in the sex ratio of births in regions of stricter enforcement of China's One Child Policy (Johansson and Nygren 1991), and the aforementioned sex selection in favor of daughters following male births. Lastly, the model provides a framework for examining the impact of improvements in prenatal screening technology (e.g. ultrasound) – specifically how the falling price of sex selection may raise the sex ratio of births following daughters and lower the sex ratio of births following sons.

I estimate the model using regional variation in the financial punishments for violating China's One Child Policy, which, in fact imposes a one-child limit to urban parents and allows many rural couples a second or even third child. The fertility fines provide plausible exogenous variation in the net cost to childbearing in different regions of the country in different years, allowing for identification of the model parameters.[5] The parameterized model is able to reproduce a distribution of fertility outcomes similar to what is observed in the actual census data in Table 1, suggesting that several key features of the decision process underlying China's fertility are captured by the parameters. Since the model's parameters are identified by monetary fines on excess fertility in China, the parameter estimates also provide important information about parental preferences. I find that a first-born son is worth on average 1.85 years of income, and a first-born daughter is worth 0.43 years of income, with lower values associated with second and third children of either gender. Simulations using the parameterized model indicate that a 3-child policy would reduce the number of "missing girls" by 56 percent but increase the fertility rate by 35 percent. Alternatively, a subsidy of 1 year of income to families without a son would reduce the number of "missing girls" by 67 percent, but impose an annual cost of 1.8 percent of Chinese GDP.

The paper is organized as follows. Section 2 provides background information regarding China's fertility policies and the proliferation of ultrasound technology in rural China. In Section 3, I present the model and the intuitions generated regarding how parents will respond to increasing

[5]Recent work that has exploited the One Child Policy as a natural experiment that induced a reduction in fertility include Qian (2008) and Edlund et al. (2008). I describe how the fines are calculated in detail in the paper's appendix. I also examine whether changes in fertility enforcement are correlated with changes in fertility tastes that would bias the coefficients.

penalties on fertility and improvements in sex selection technology. In Section 4, I empirically estimate the parameters of the model of sex selection and perform a set of policy simulations using the calibrated model. I conclude in Section 5 with a brief discussion of fertility policy options for China based on the findings in this paper.

2 Background

Chinese parents have historically favored large families, and following a famine associated with Mao's Great Leap Forward (1958-1960), total fertility exceeded 6 births per mother throughout the 1960's (Banister 1987). The rapid population growth alarmed Chinese officials, and the Communist Party subsequently enacted a series of fertility control policies, culminating in the One Child Policy of 1979. Additional children were generally excluded from free public education and parents were subject to fines. Following a forced sterilization and abortion campaign in 1983 that created domestic unrest, Chinese policymakers began considering revisions to the policy. By allowing some mothers to have a second child, the government hoped to discourage violations and increase public support for the policy (Gu et al. 2007).

In 1984, the Chinese government instituted a localized fertility policy in which residents of different provinces were subject to different mandated limits (Greenhalgh 1986). Though the one child limit was enforced on urban residents, mothers of a daughter in several rural provinces were allowed to have a single additional birth (a "1.5 child policy") and families in remote areas a second or third child. Today, Chinese fertility policy imposes a 1 child limit on urban residents who make up about a third (35%) of the population, a 1.5 child policy limit on most rural areas (54%), and a 2 (10%) or 3 (1%) child policy limit for provinces in remote areas. The policy also grants exclusions to various groups, including Chinese ethnic minorities and those employed in dangerous occupations.

In China, parents have historically directed family resources to sons at the expense of daughters, and in some circumstances discarded daughters upon birth (Coale and Banister 1994).

In the 1960s, when fertility was high and infant mortality was low, this pattern was temporarily muted by the fact that most mothers were likely to have at least one surviving son without resorting to sex selection. However, while the female deficit was reduced, high fertility and low infant mortality were contributing to unsustainable population growth. Prior to the One Child Policy, during the late 1960s and early 1970s, the Chinese government promoted a "Two is Enough" policy, and the sex ratio following first- and second-born daughters began to rise.

While the extent of prenatal sex selection during this period was limited by the unreliability of traditional methods of identifying sex in utero, the introduction of ultrasound technology greatly facilitated the availability of sex-selective abortion. Population control officials had sent portable ultrasound machines to hundreds of cities across the nation in the early 1980s, and ironically, these machines were later used to aid in sex-selective abortion in these areas (Ertfelt 2006). These machines represented a major advancement, as ultrasound can reliably determine the sex of a fetus roughly 20 weeks into a pregnancy, allowing mothers to abort and re-conceive with less time and potentially less psychological distress than following infanticide. The 2000 census reflects that tighter fertility control and better sex selection technology combined to create an unprecedented increase in the sex ratio. In section 4, I present a model to consider how these two factors affect parental choices for the number and gender of their children.

3 Stylized Facts

The fertility patterns in Table 1 reflect several important empirical facts that merit further exploration in a behavioral model. First, the table indicates that the "missing girls" phenomenon is due to sex selection following daughters, and the 2000 data indicate a sharpening of this pattern. In the 1982 census data, when parents faced a weaker fertility control policy, after a single daughter 52% of births were male. By 2000, after the majority of parents were subject to a "1.5" child policy, 62% of births following a single daughter were male. This rise in the sex ratio of second births is a key component to the increase in China's sex ratio, and the high male fraction of births after a single daughter is responsible for 8 million of the 9 million girls observed in China's 2000 census sample (Ebenstein 2008). After two daughters in 1982, 54% of births were male, and in 2000, 70% of these births were male. The data thus reflect an increase in the share of parents who engage in sex selection at each parity.

A second fact that merits explanation is that the Chinese census data indicate that mothers with sons practice sex selection to ensure the birth of a daughter[6]: mothers with two sons who have a third child have a 61% chance of having a daughter (Table 1). Therefore, an appropriate model of behavior recognizes that the value of sons or daughters might be lower for those who already have a son or daughter.[7] It is also noteworthy that parents appear to prefer a first daughter to a third son, and even engage in sex selection to ensure the birth of a daughter following sons – indicating that son preference in China is more nuanced than what the overall sex ratio indicates. Specifically, the premium to a *first* son must be large, and there also must be some premium to a *first* daughter as well.

The third stylized fact that the model aims to explain is the increase in the sex ratio in regions of stricter enforcement of China's fertility policy and periods with stricter enforcement of the policy. The sex ratio of first births remained stable during the 1980's and rose during the government crackdown on 2nd births during the 1990's (see Figure 1). So, the model aims to explain how the enforcement of fertility limits will affect fertility rates and the sex ratio of births when parents have access to sex selection technology.

4 Theoretical Framework

In the following section, I present a simple model of parental fertility choice when parents exhibit sex preference and have access to a sex selection technology. The model is dynamic in that both

[6] Yi et al. (1993) find that aborted fetuses for mothers of sons are disproportionately male. The other known cause for low sex ratios following sons is the adoption of unwanted girls by Chinese families with no daughters (Johansson and Nygren 1991).

[7] Fertility surveys suggest that mothers in China prefer "preferably two or more (surviving children), and at least one surviving son" (Feng 1996). The preference for a daughter among parents who already have sons is partly driven by the expectation that daughters help more with family chores (Sun, Lin, and Freedman 1978).

fertility and sex selection decisions are made with knowledge of one's preferences and the anticipated decisions regarding future conceptions. First, I present a simple two-child model in which parents can either engage in sex selection for first or second births and second children are subject to a monetary fine. The two-child model provides the key insights regarding how couples evaluate whether to engage in sex selection when having their last or penultimate birth. The basic intuition generated by the framework is that increasing the punishment to excess fertility or lowering the cost of sex selection will increase the sex ratio of births and encourage parents to engage in sex selection at earlier parities. In the estimation section, I present results for an extended version in which parents are allowed up to three births, and sex selection is allowed in favor of either sons or daughters.

4.1 Solving the 2-Child Model by Backwards Induction

Suppose that parents are allowed only a single birth and a second birth K_2 will require the parents to pay a fine F. Parents, however, also have access to a 100% effective sex selection technology S that for a price A will convert a female conception into a male birth. One might imagine that A captures the cumulative cost of a sequence of conceptions and abortions until a male fetus is carried to full-term. Assume that a first boy B is worth θ, a first daughter is worth γ, and a second daughter is normalized to have no value (in excess of the cost to raise her). Also suppose for simplification that parents with a son never have a second birth. The decision tree is displayed in Figure 2.

Given that parents can anticipate the decisions that they will have to make in the course of determining the size and sex composition of their offspring, the model of sex selection can be solved by using the solution concept of backwards induction, beginning with the optimal decision at the final decision node (if that node is reached). For the third and final decision node in the model, the parent's decision-making problem becomes a single period maximization in which she chooses between GG or GB, knowing that she is expecting a second daughter and can exercise sex selection. The payoff to each option for the ith couple in the 3^{rd} stage (stage denoted by a superscript) is as follows.

$$V^3_{S_2=1} = \theta_i - A_i - F + \gamma_i + \epsilon^3_{S_2=1} \tag{1}$$

$$V^3_{S_2=0} = -F + \gamma_i + \epsilon^3_{S_2=0} \tag{2}$$

In the final stage, parents perform a static optimization over the choice to abort a second daughter S_2, perfectly observing the payoffs. The parents who choose sex selection receive an additional payoff of θ_i but incur a cost of A_i. The shocks are assumed to be distributed $ev(1)$, so the difference of the two shocks has a logisitic distribution[8], and provides the following closed form expression for the probability of sex selection in the final stage in terms of the model's parameters. The probability of practicing sex selection at the second parity $(S_2 = 1)$ is as follows.

$$\Pr(S_2 = 1) = \frac{e^{\theta_i - A_i}}{1 + e^{\theta_i - A_i}} \tag{3}$$

When the couple's benefit from a son θ_i is large relative to the cost of sex selection A_i, they are likely to choose sex selection. Mothers have equal probability of aborting or carrying to term when $\theta_i = A_i$, and the probability of aborting is higher when factors increase the value of a son θ_i or when technology lowers the price of sex-selection A_i.

At the 2^{nd} decision node, the parents face the decision to continue childbearing or to stop. The payoffs to having a second child $(K_2 = 1)$ and stopping, respectively, are as follows.

$$V^2_{K_2=1} = .51\theta_i - F + .49[E(V^3)] + \gamma_i + \epsilon^2_{K_2=1} \tag{4}$$

$$V^2_{K_2=0} = \gamma_i + \epsilon^2_{K_2=0} \tag{5}$$

The payoff to having a second child is the value of a son θ_i multiplied by the probability of conceiving a male $(.51)$, minus the fertility fine F, plus the anticipated value of reaching the 3^{rd} stage of the model if the conception is female $(E(V^3))$ multiplied by the probability that the conception

[8] See the appendix for a more complete description of the stochastic assumptions underlying the model and the calculation of the likelihood function.

is female $(.49)$. Note that the anticipated value of reaching the final stage (V^3) is the expected maximum of the two options the parents will face in that stage, which is to engage in sex selection or abstain. When a mother has a higher value of $\theta_i - A_i$ (the sex selection option), she will anticipate a higher payoff in the third stage (V^3) and be more likely to have a second child, and so higher fines induce a selection effect where the mothers most likely to have a second child are those willing to engage in sex selection. The probability of practicing sex selection at the second parity $(K_2 = 1)$ is as follows.

$$\Pr(K_2 = 1) = \frac{e^{.51\theta_i - F + .49[E(V^3)]}}{1 + e^{.51\theta_i - F + .49[E(V^3)]}} \tag{6}$$

Lastly, in the model's first round, parents who conceive a daughter decide whether to engage in sex selection (S_1). For parents subject to a harsh penalty on second births F, those who desire a son will be compelled to engage in sex selection at the first parity. For example, among parents who are both determined to have a son (large θ_i) and subject to the One Child Policy, when $F > .51A_i + \gamma_i$, parents will engage in sex selection at the first parity.[9] This implies that increasing punishments on second births will affect the sex ratio of first births, consistent with the increase in the sex ratio among first births in the One Child Policy region (Figure 2).

The model therefore generates the prediction that higher fines and reduction in sex selection costs will increase the sex ratio when parents prefer sons.[10] First, fines will discourage second births among those who do not place great weight on having a son or are unwilling (or unable) to practice sex selection, lowering the share of second births which are completely random. Second, fines will encourage parents who are willing to engage in sex selection to do so at an earlier parity

[9] For parents who are extremely likely to abort a female conception if they reach the final round, the decision to have another child can be simplified by plugging in $\theta_{1i} - A_i$ for $E(V^3)$ in equation (6). The decision to abort a female conception at the first parity can be expressed as $\theta_i - A_i - \gamma_{1i} - (\ \theta_i - F - .49A_i)$, or $F - .51A_i - \gamma_{1i}$. Intuitively, if the fine exceeds 51 percent of the cost of sex selection and the value of a first daughter, these parents are better served by avoiding the fine and aborting first-parity female conceptions until a son is born, since the only benefit to abstaining from sex selection at the first parity is a 51 percent chance of avoiding sex selection at the second parity, and the value of a first daughter.

[10] Note that this is also consistent with the patterns in the sex ratio at birth in China during the fertility crackdown of the late 1980's and early 1990's. The birth planning campaign was held after the diffusion of ultrasound in rural China, and the reduction in village fertility was accompanied by a rising sex ratio at birth (Greenhalgh and Winckler, 2005).

to avoid the fine. This has the consequence of increasing the share of mothers who fail to naturally conceive a son.

The model's results are easily translated to a 3-child limit, in which second and third births are subject to fines that vary by province, ethnicity, and other factors. Parents execute a sequence of 5 decisions in which sex selection is allowed in favor of either a son or daughter, with these decisions governed in a symmetric fashion following sons and daughters in the manner described above. The empirical results are reported for the extended model in Section 5.

4.2 Heterogeneity

I introduce individual observed heterogeneity by allowing the value of a couple's first son or daughter $(\theta_{1i}, \gamma_{1i})$ to take on a different value for parents of different observed characteristics. I impose a functional form assumption that θ_{1i} and γ_{1i} are each linear in a function of the mother's education and whether the family is engaged in farming.[11]

$$\theta_{1i} = \beta_1 + \beta_2 Educ_i + \beta_3 Farmer_i \tag{7}$$

$$\gamma_{1i} = \beta_4 + \beta_5 Educ_i + \beta_6 Farmer_i \tag{8}$$

These variables are chosen since they are available in China's census samples, and identify important predictors of the value to a couple's first son or daughter and improve the model's precision. The values of second and third sons or daughters are also estimated but are assumed invariant to the characteristics of the parents.

$$\theta_{2i} = \beta_7; \theta_{3i} = \beta_8; \gamma_{2i} = \beta_9; \gamma_{3i} = \beta_{10} \tag{9}$$

For A_i, I allow for heterogeneity in the behavior of parents at different distances from the nearest fertility clinic. Again, while the required travel time may have a direct impact on maternal behavior

[11] In Taiwan's KAP survey (2003), desired children and sex preference are negatively correlated with a mother's education. The value of sons and daughters may also be different for those engaged in farming. For example, Qian (2008) finds evidence that local sex ratios are higher in areas where the crops planted require more male labor.

via its impact on the cost of sex selection, it may be that it only proxies for access to a doctor willing to perform a sex-selective abortion. Nevertheless, this observed heterogeneity may allow for a tighter fit of the model.[12] I also directly allow the cost of sex selection to vary by year, since the model is attempting to capture the impact of technological innovation in sex selection (e.g. ultrasound) on the sex ratio at birth. Note that only the mothers in the 2000 census sample had access to ultrasound during their fertility window.

$$\begin{aligned} A_i &= \beta_{11} & \text{if } [Year_i == 1982 | Year_i == 1990] \quad (10) \\ A_i &= \beta_{12} Clinic_i + \beta_{13} & \text{if } [Year_i == 2000] \quad (11) \end{aligned}$$

In order to address potential concerns that the fines are determined in an endogenous manner, I allow the value of a first son or daughter to vary by policy region and year, so that the estimated parameters can be thought to be derived from a "differences-in-differences" framework.

$$\begin{aligned} \theta_{1i} &= \theta_1 + \{\beta_{14} \cdot [Policy_i == 1.5] + \beta_{15} \cdot [Policy_i >= 2] + \beta_{16} \cdot [Year_i >= 1990]\} \quad (12) \\ \gamma_{1i} &= \gamma_1 + \{\beta_{17} \cdot [Policy_i == 1.5] + \beta_{18} \cdot [Policy_i >= 2] + \beta_{19} \cdot [Year_i >= 1990]\} \quad (13) \end{aligned}$$

In this manner, the model explicitly incorporates variation in fertility preferences that may have existed prior to the policy's implementation, or may be particular to a census-year sample and not related to the underlying preference for sons. I provide further details regarding the identification of the model's parameters in the next section.

Lastly, I allow heterogeneity in the continuation value of completing the first three births without a son, since for parents in the 1982 or 1990 census samples, many who failed to have a son in the first three births have a son at the 4^{th} or even the 5^{th} parity. Since 4^{th} births are exceedingly rare in the 2000 census, the continuation value is assumed to be zero for these parents and so I

[12] An alternative to this specification would be to allow parents to be selected from a mixture distribution, in which some share of parents never abort. I have explored estimating the model in this manner and the estimation procedure indicates that roughly 52% of parents would practice sex selection, as estimated by MLE. I proceed with the simpler version of sex selection costs because the results are more stable, but the parameter estimates are reasonably close using either specification. The results are available from the author upon request.

specify the continuation value in the following manner.

$$E(V_6|GGG) = \beta_{20} \cdot [Year_i == 1982] + \beta_{21} \cdot [Year_i == 1990] \tag{14}$$

4.3 Identification

The likelihood function can be written in terms of the model's parameters which are estimated by choosing the value which best reproduces the empirical distribution of fertility outcomes. At the model's sex selection nodes following daughters, the algorithm will identify the *difference* between θ and A by using the information embedded in the share of parents who have a son at each parity. A high sex ratio can reflect either a high θ or low A, and so the relative values of each is identified. Conversely, for parents with only sons, observing large numbers of female births may reflect either a high γ or a low A. At the model's fertility nodes (stage 2 and 4), the algorithm will observe the fines F facing the parents and the share who choose to have a 2^{nd} or 3^{rd} child, which allows the algorithm to identify the *level* of the parameters for θ and γ. Once the optimal choice of θ and γ is chosen, and the difference between θ and A is identified, the value of A is identified as well.

The coefficients in (7) and (8) are identified from the heterogeneity in fine values across birth orders and across regions and time in China, and the coefficients in (10) are identified from the sex ratio distortion and from the estimate of θ and γ. The fine variation is necessary for the parameters governing θ, γ and A to be identified in terms of years of income, a quantity interesting for characterizing preferences and necessary for counterfactual policy simulation of monetary subsidies. Inasmuch as the fines are measured noisily, or are correlated with unobserved factors affecting son preference, the scale of the coefficients will be inefficiently estimated or biased. In the next section, I provide details regarding the calculation of the fines.

One might be concerned that provincial fine regimes are correlated with pre-existing patterns of son preference; that is, provinces with higher or lower son preference are more or less likely to enact strict fertility regulations and high fertility fines. For the fines to identify the parameters of son preference, the fines *should not* be correlated with patterns in the sex ratio prior to the implementations of the One Child Policy. The fines *should*, however, be positively correlated with the sex ratio in recent years, consistent with the claim that the female deficit is related to the stringency of fertility control. As shown in Table 2, the average fine in each prefecture is uncorrelated with the sex ratio following the policy, and positively correlated with the sex ratio following the implementation of the fine policy.

In column 1, I regress the male fraction of births in each of China's 345 prefectures prior to the policy (1975-1979) on the fine rate in each prefecture in 2000. The correlation between the male fraction of births and the fine is small (-.004) and statistically insignificant, suggesting that the fines in my data are not systematically related to pre-existing patterns of son preference.[13] In column 2, I perform the same regression but control for regional characteristics in each of the prefectures (e.g. share with electric or gas fuel) and again find only a weak correlation between the fines (-.007) and the male fraction of births. In column 3, I regress the male fraction of births in years *following* the policy (1996-2000) on the fine rate. During this recent window in the "post-policy" period, the fines are positively correlated with the sex ratio (.008) and the relationship is statistically significant at the 10% level. In column 4, I perform the same regression with controls for regional characteristics, and find that the estimated relationship is positive (.011) and statistically significant at the 5% level. This suggests that the impact of the fertility fines on the sex ratio in recent years is not simply related to pre-existing features of the regions.[14] Enforcement of fertility regulations is responsible for the connection between sex ratios and fertility fines, rather than a spurious regional correlation between lower fines and lower son preference. In the appendix I present further evidence that the fines provide for the necessary variation in the net prices to childbearing to estimate the model parameters.

The model's identification strategy can also be thought of as a "differences-in-differences" strategy, since I include policy region and year parameters that allow the value of either sons or

[13] The prefecture variable is only available in the 2000 census, so the male fraction of births is proxied by the male fraction of adults who report living in the same prefecture five years earlier.

[14] A legitimate concern may be that parents under higher urban fine regimes would have fewer children than those in rural areas, even in the absence of the policy. Fertility surveys still indicate that most parents would prefer to have at least 2 children (Zhang et al. 2006), and so the fertility limit (and therefore the fine) is a binding constraint for most parents.

daughters to vary flexibly across region and year. Therefore, pre-existing differences to mothers observed in a particular region or year will be absorbed by these coefficients. In a D-D design, the appropriateness of the identifying variation can be assessed by comparing the control and treated samples trends in the outcome variable, before and after the treatment. As shown in Figure 1, the sex ratio of first-born children remained similar in both the One Child Policy area and weaker regulations up to the late 1980's. In the late 1980's, when the One Child Policy was enforced in earnest, the sex ratio began to rise but remained similar in the areas where 2 children was allowed before and after the crackdown. While the exogeneity of the fines is fundamentally untestable, the data indicate a strong correlation between the timing of the policy's introduction and the increase in the sex ratio at birth in areas of strict enforcement.

5 Estimating the Model of Sex Selection

5.1 Data

The Chinese census samples (1982, 1990, 2000) provide a unique opportunity to assess the responsiveness of fertility outcomes to changes in the costs of childbearing. While almost no parents in the 1982 census faced fertility limits (since they were having their children between 1964 and 1981), the parents observed in the 2000 census were subject to strict fertility regulations enforced by fines and other punitive measures. Data on fines are taken from Scharping (2003), who provides a detailed account of the financial and non-financial punishments meted to mothers with unauthorized births between 1979 and 2000. The fines represent an important aspect of the fertility policy, as Scharping describes "Chinese policy has preferred the application of economic, administrative and disciplinary measures to resorting to criminal law."[15] The fine rates vary by province and year, and are also a function of one's registration (hukou) and ethnicity, implying they vary by individual for a given province and year. The fines are imputed to the mothers in the census sample, and I

[15] Scharping, T (2003). pp. 136.

provide a detailed description of how this is executed in the paper's appendix.[16]

The model is estimated using a matched sample of parents with 5 or fewer children, and the imputed fine rates that they faced when making fertility choices (see Table 3). The sample is restricted to mothers aged 35-40 who are likely to have completed their fertility.[17] For the mothers in the 1982 sample, the data reflect higher fertility, with the average mother having 3.18 births. In contrast, the mothers in the 2000 census averaged only 1.83 births, presumably since their peak fertility years followed the introduction of China's One Child Policy. For the 1990 and 2000 census samples, I exclude about 10% of mothers for whom the number of matched sons and daughters is different than the mother's reported fertility.[18] I also exclude those who report having lived in a different hukou for the 2000 sample, to ensure that the sample is composed of parents for whom the most accurate fine data can be assigned.[19]

Note while the model is designed to explain the practice of sex selection and its impact on the sex ratio at birth, I rely on data on living children for estimation of the model. Though females in China experience slightly worse-than-expected survival rates relative to Western patterns, the main contributor to the "missing girls" is pre-natal and neo-natal sex selection, rather than higher childhood mortality rates (Hill and Banister 2004). In fact, females in China who reach the age 1 have similar survival rates to males, indicating that sex selection is the main driver of China's "missing girls" and that the sample in Table 3 is roughly similar to the sex ratio of the family's births. An additional concern worth noting is the presence of "hidden girls": female births who are not registered by their family, since they are born in violation of the country's fertility policy.

[16] Note that the fine measure should be thought of as a proxy for all financial pressures on parents to minimize "out of plan" births. I can only impute the financial punishment, and other components of the total punishment and reward structure have to go unmeasured. It is known, however, that the financial fines are a major component, out-weighing, for example, rewards. This is documented in the China Health and Nutrition Survey (1993), in which the median reward is 60 yuan and the median fine is 2800 yuan. The non-financial penalties are informal and exercised optionally, and are assumed random in the data. The paper's results should be interpreted up to a scale in which the imputed fines presented here represent the full sum of financial punishment meted out for excess fertility.

[17] Very few women in China during the years of the One Child Policy give birth past 35 (Ding and Hesketh 2006).

[18] For 2000, the sex ratio of those dropped from the sample is 1.16, and the sex ratio of those remaining in the sample is 1.18, suggesting this decision is not critical. As in the previous section, the results are robust to the inclusion or exclusion of these mothers. Results available upon request.

[19] The results are robust to the inclusion or exclusion of the roughly 11% of the 2000 sample who switched hukou. Note that migration is only available in the 2000 sample.

However, since most "hidden girls" are registered by the age of 7 (upon school enrollment), the sample in Table 3 should roughly approximate the actual births that the family experienced (Cai and Lavely 2005). Lastly, I am unable to observe adoption in my data. Although foreign adoption of girls represents a trivial share of the "missing girls"[20], adoption of unwanted daughters by other villagers (who generally already have sons) is common within China. Although I cannot distinguish sex selection from within-China adoption, the practice should not affect the paper's core result regarding the female deficit associated with sex selection, since the adopting family will enumerate the daughter. As such, the sample used in Table 3 should be interpreted as the combined impact of female conceptions terminated and unwanted daughters adopted by a different family within China.

5.2 Parameter Estimation

In Table 4, I present the parameters identified by Maximum Likelihood Estimation (MLE) for the values of sons, daughters, and the costs of sex selection. The parameter estimates provide an additional layer of information regarding the patterns observed in Table 1 for the chance of having an additional child at each parity, and the observed sex ratio at each parity. As mentioned, provided the model is specified appropriately and the fines represent exogenous variation after accounting for policy region and year fixed-effects, these parameters reveal the willingness to pay for a 1st, 2nd, or 3rd son or daughter, and the implied cost of engaging in sex selection. The model's design is principally geared to picking up patterns in the first child of any particular gender, since sex selection is rare after parents achieve a gender mix (and ruled out by the model).

In panel 1, I present the estimated coefficients for the value of having a first son θ_{1i}. Note that parents receive this value whether the son is the first birth or a later birth. θ_{1i} is decreasing in mother's education, with each extra year of education reducing its value by 0.21 years of income. The data also indicate that households employed in the agricultural sector are more determined to

[20] In 2005, the United States naturalized nearly 8,000 Chinese adopted children, and over 95% of the children were female. The Chinese government reports a total of 60,000 adopted births sent to foreign countries between 1992 and 2006. (http://www.washingtonpost.com/wp-dyn/content/article/2006/03/11/AR2006031100942.html).

have a son, with these families assigning a full 3.04 years of extra income to a son, relative to those employed in other sectors of the economy. For farmers, a higher θ_{1i} might reflect their increased need for sons to work on the farm or it may reflect that they anticipate living with their adult son in retirement. The average value of θ in the entire sample is 1.85, which indicates that having a son is worth approximately 1.85 years of income, but is much higher among agricultural families and those with less education. I report in panel 2 that the value of a second and third son are much lower than the first, with these being valued at 1.06 and -0.25 years of income respectively.[21]

The parameter estimates for γ_{1i} indicate that the average value of a first daughter is 0.43 years of income (panel 1). Daughters appear to have lower value for those who are better educated, with each year reducing the value by -0.20 years of income. Farming families, who place large values on sons, also place more value on daughters as well, with a 2.20 years of income premium associated to a daughter among farmers. This implies that farmers assign nearly 2 more years of income to having a first son, and since farmers represent over half of the sample (59% in 2000), much of the "missing girls" phenomenon is driven by low-educated peasants who desire large families and face large penalties on third births. Note that sex selection in favor of sons after daughters also implies that additional daughters provide low value to parents, In panel 2, I report the values of a second (0.23) and third daughter (0.23), which are both lower than the value of a first daughter (0.43). These values are equivalent since the MLE choice of the parameters is executed subject to the constraint that the value of a second daughter is no lower than the value of a third daughter, which is binding at the parameter estimates. Note that the model is principally designed to identify the value of a first son or daughter, and the value of second and third sons or daughters is difficult to estimate precisely.

Panel 3 indicates that the cost of abortion A_i is increasing in the imputed distance from an abortion clinic, though each unit increase in the log distance from the nearest clinic associated with a 0.02 increase in years of income in the cost of sex selection.[22] The parameter estimates

[21] Greenhalgh (1994) cites one rural village in which villagers refer to a second son as *fudan zhong* or a "heavy burden", since a second son requires a new house at the time of his marriage, which may cost up to 10 years of annual income.

[22] This measure is imputed from the China Health and Nutrition Survey (1989) using information on the average

for the cost of sex selection before and after ultrasound reflect the increased attractiveness of sex-selective abortion relative to infanticide. For mothers observed in the 2000 census, they made fertility decisions following ultrasound's diffusion in China in the late 1980's, and the parameter estimate indicates that the average cost of sex selection declined from 5.44 years of income to 3.83 years of income. The parameter estimates suggest that ultrasound's diffusion, in combination with China's One Child Policy, led to the steep rise in the country's sex ratio. Note however that the coefficients on the costs of sex selection (A_i) provide less information than those on the factors affecting the value of sons and daughters since very little information is available regarding the factors affecting the ease of engaging in sex selection, such as access to ultrasound. Their primary function is not to provide evidence of causal relationships, but instead to facilitate a more flexible functional form that can better fit the data.

In Table 5, I report the results of a measure of the model's goodness of fit by showing the correspondence between the actual distribution of fertility outcomes and the distribution created from a simulation using the calibrated model. The table reflects that several of the patterns in fertility in Table 1 are captured by the model: declining fertility, rising sex ratios following daughters, and declining sex ratios following sons are observed in both the actual and simulated data. The sharp decline in fertility following sons is evident in the simulated data, reflecting that the model is capturing a key element in China's sharp rise in the sex ratio due to the strict fertility control among parents who already have a son. In addition, since the 2000 simulated agents face lower sex selection costs and higher fine rates, they are more likely to engage in sex selection at earlier parities. For example, the male fraction of births following a single daughter rose from 0.51 in 1982 to 0.57 in 2000, which reflects that high θ mothers are more likely in the recent data to avoid the harsh punishment on a third birth of either gender. While the in-sample forecasting in Table 5 does not imply that the model is valid for out-of-sample policy simulation, it does suggest that the simplified rule structure presented above captures many of the essential elements of the fertility decision, and provides an opportunity to explore the benefits and costs to changing these

distance in kilometers from a clinic imputed to the census with the parent's urban status and education. Those in urban areas with more education are assigned a shorter distance to the nearest clinic.

incentives.[23]

6 A Policy Application of the Sex Selection Model

Recently, the Chinese government has both re-instated the One Child[24] limit and declared that correcting the sex ratio at birth by 2016 is a national priority (Li 2007). However, China's recent experience suggests that these two interests may be at odds. Without either a reduction in son preference or an increase in the costs of sex selection, an alternative policy may be necessary to reduce the sex ratio. In the following analysis, I use the estimated model to examine two potential methods for reducing the sex ratio. In the first set of simulations, I explore how China's fertility rate and the sex ratio at birth would respond to either tightening or relaxing the fertility restrictions. Intuitively, since the fertility restrictions are partially responsible for the higher sex ratio, reducing these restrictions would partly "undo" this impact, by allowing more parents to have a son without engaging in sex selection. This induces a reduction in the number of "missing girls" at the expense of an increase in fertility. In the second set of simulations, I explore the potential efficacy of a subsidy to parents who fail to have a son, similar in spirit to the recent "Care for Girls" campaign, which provided financial incentives to parents who had only daughters.[25] The simulations indicate that such a policy could both lower fertility and reduce the sex ratio, but at a large financial cost to the government. The results of these simulations and the efficacy of these two policy options, are described below.

[23] I also perform this calculation where half the sample is used for estimation of the parameters, and the other half is used for comparing actual and simulated outcomes. Results are available from the author upon request.

[24] http://www.nytimes.com/2008/03/11/world/asia/11china.html

[25] The "Care for Girls" campaign chose 24 counties of China with extremely high sex ratios, and provided incentives to reduce the female deficit, including free public education of daughters. The program explicitly subsidizes parents with daughters, whereas I simulate parents having a lower value to sons. These are slightly different because a simulation where I increased the value of daughters could generate the perverse result that parents are subsidized for unauthorized births. Note however that since the "Care for Girls" campaign is instituted in counties with strict fertility limits, it is unlikely that births born in violation of the policy would be subject to the subsidies, and so the demographic effect of the subsidy I simulate would have similar empirical properties.

6.1 Changing Fertility Limits

In Table 6, I simulate birth outcomes under a set of policy changes to the regime faced by the mothers in the census sample of 2000. In panel 1, I compare the fertility outcomes of the actual sample to the baseline simulation in which fertility rules are determined by the MLE routine, which indicates a reasonably close correspondence between the sex ratios and fertility rates between the actual and simulated fertility outcomes. In panel 2, I simulate the impact of changing the current fertility regulations. First, I examine the impact of a removal of the "1.5" child exemption. This is interesting for two reasons. The model predicts a decline in fertility (1.81 to 1.75) and a rise in the sex ratio (1.14 to 1.15), consistent with an interpretation that this exemption is important to keeping the sex ratio of first births relatively undistorted. I then consider relaxations to the fertility regulations faced by this cohort of mothers by considering the impact of China adopting "two child" or "three child" policy by running simulations in which fertility decisions are made with respect to no fines on 2nd births (2 child policy) and no fines on 2nd or 3rd births (3 child policy).

Interestingly, the "two child" policy increases fertility to 2.00 but only reduces the sex ratio from 1.14 to 1.13. This can be explained in part by the large share of rural parents in these cohorts who were allowed a 2nd birth, and so there is only a mild benefit to such a policy. It also points to the fact that allowing additional births (lowering fines) does not have a strictly monotonic positive effect on the sex ratio. Imagine a parent who values daughters and sons, and is willing to comply with the policy after a daughter and have only 1 child if the fine she faces is greater than the value of a son. Lowering the fine could potentially induce a subsequent birth and sex selection if the cost to sex selection was sufficiently low relative to the premium of a first son versus a second daughter. However, the simulation indicates that the impact of a three child policy is dramatic, with simulated fertility rising to 2.43 and the sex ratio falling to 1.09, implying a much smaller female deficit and a 56 percent (1,439/2,560) reduction in the number of "missing girls". These simulations do not indicate how fertility would respond in China to a revision to the current policy, since these parameters are estimated for parents age 35-40 in 2000, who may have different preferences than the families who will be making their fertility decisions in the next decade. They also can only be interpreted with proper caveats regarding econometric assumptions embedded in its formulation, and data limitations in its estimation.

6.2 Subsidies to Parents without a Son

In panel 3 of Table 6, I simulate birth outcomes under a set of policies that subsidize families who fail to ever have a son for an increasingly generous program that would provide 3 months, 6 months, and up to 12 months of income to parents who complete their fertility without a son. The proposed plan would deduct from each household some portion of annual salary, to be distributed to those without a son, and is similar in spirit to China's "Care for Girls" campaign, which subsidizes parents who fail to have a son by supporting the education of daughters and providing cash payments to those who fail to have a son (Li 2007). In the first simulation shown in panel 1, I calibrate the model to reproduce the fertility patterns observed in the census data. Then, the model is re-executed with parents assigned incrementally lower values for θ_{1i}. So, for each couple I first impute θ_{1i} as a function of their observable characteristics using the coefficient estimates from the MLE. Then, I lower θ_{1i} by the amount of the proposed subsidy. I then recalculate the fertility and sex selection probabilities had the parents been behaving as if they had a lower value of θ_{1i}. The results indicate that the proposed policy would lower fertility and reduce the skew in the sex ratio. Intuitively, when mothers make fertility decisions, they experience a lower payoff to having a son, and so they are less inclined to have an additional child. Among those who have an extra child, they are less likely to pursue sex selection because the cost of sex selection relative to the payoff from having a son is lower as well. Both factors serve to reduce the total number of "missing girls".

The projected impact of a moderate subsidy in which mothers receive 3 months of household income when they fail to have a son decreases the sex ratio from 1.14 to 1.12, reducing the distortion to the sex ratio by roughly one fifth (17%).[26] Since the premium on a son has been mea-

[26] An alternative proposal that has been explored in rural areas is the direct subsidy of those who undergo sterilization for those with 2 daughters and no sons. While I would like to compare my results to those found in areas with this policy, the data are unfortunately unavailable.

sured in years of income, the anticipated impact on the government budget can be calculated for each policy. For the small-scale subsidy, the annual cost to the government of subsidizing mothers is .40 percent of GDP. If parents are subsidized for 12 months of income, the sex ratio drops to 1.08, only slightly higher than the natural rate (1.06), reducing the number of "missing girls" by 67 percent (1,705/2,560) in this sample. The cost per "saved girl" is rising slightly with the generosity of the subsidy, from 55,024 to 60,763 yuan per saved girls, as more generous policies involve higher spending on mothers who would complete fertility without a son even in the absence of a subsidy. These estimates are not meant to capture the exact impact of a potential subsidy, but characterize some of the potential trade-offs of a widespread introduction of a subsidy to parents who fail to have a son.

The model can also be thought to represent a forecast for fertility patterns if son preference were to decline over time or because of secular changes in China, such as the effective implementation of a wider old-age support program currently being discussed (Diamond 2005), or a diminution of son preference as witnessed in Korea (Chung and Das Gupta 2007). The motivation for a direct subsidy of sons is clear, as rural areas of China are unlikely to rapidly modify modes of peasant life that have existed for centuries in an acceptably short period of time. In recent efforts to make old age insurance in rural areas available, parents without sons were more likely to participate, indicating that the value of sons will continue provided families expect more old age support from sons than daughters (Ebenstein and Leung 2008). The proposed subsidy will limit sex-selection, discourage fertility, and mitigate the pain of an old age without sons, while improving the prospects of future men for the marriage market. The anticipated cost of such a program could also be lowered by taxing sons. Although I outline the costs of the program as a direct subsidy to those without a son, the model's predictions are valid if this policy was implemented as a tax to those who have a son.

7 Implications

In any population with stable growth and a historical preference for sons, some share of mothers will need to "fail to have a son" to maintain a sex ratio close to the natural rate. Intuitively, for a policy that requires mothers to have no more than N children, roughly $\left(\frac{1}{2}\right)^N$ mothers will need to fail to have a son for effective fertility control without sex selection. The simulation results indicate that the expected cost of a subsidy proposal is large, but would improve the incentive structure created by the current fertility policy in China. Stories in rural China today of widows working in the fields past the age of 70 serve as a warning to today's mothers that heeding fertility policies may be costly in the future. The historical experience for China indicates that parents were disinclined to leave this to chance, and in light of the technological innovations in ultrasound, parents with son preference were able to have a son at an early parity, with the phenomenon most pronounced in areas with the strictest fertility control. This pattern is also found in other countries with son preference, such Taiwan, Korea and India, and like China, sex ratios following daughters are highest among parents who desire the fewest children.

Though India has no current limit on fertility, the advancement of women and other modernizing forces have lowered the desired fertility of the country's educated women. As shown in Table 7, these fertility declines have been associated with higher sex ratios following daughters. Among third births following two daughters, 70% of high school graduates bear a son, whereas for illiterate mothers only 53% have a son. In Taiwan, a similar though weaker pattern is observed in the 2000 census, with 59% of high school graduates having a son, and only 55% among mothers with less than a primary degree. The higher sex ratios among the educated are somewhat surprising in light of lower son preference among the less educated[27], but are sensible in light of their lower desired fertility and potentially better access to sex selection technology (e.g. ultra-sound).

Existing research has noted a correlation between education and the sex ratio at birth and concluded the relationship is due to poorer parents preferring daughters in order to ensure their

[27] Fertility surveys in Taiwan indicate that higher educated women are less likely to report having a gender preference for births (Taiwan Knowledge, Aptitude, and Practice of Contraception Survey 2003).

children succeeding in a competitive marriage market (Edlund 1999). I present an alternative interpretation in the model presented here – specifically, the mechanism for a positive correlation between education and the sex ratio at birth is due to higher educated mothers wanting (or being forced[28]) to have fewer children, and therefore engage in sex selection at an earlier parity, leading to a higher overall sex ratio at birth. Alternatively, it may also be true that higher educated mothers have lower costs of sex selection, providing a second reason why one may observe a correlation between education and the male fraction of births.[29] As the model predicts, parents who incur a larger cost to additional children and better access to sex selection technology will engage in sex selection at earlier parities, and this is observed in both China and India.

8 Conclusion

Although rapid industrialization and large changes in fertility have reshaped China in the last 40 years, sex preferences have survived the transition. In an earlier era of high fertility, they were manifested in higher stopping probabilities following sons and had a muted effect on the overall sex ratio. Today, fertility in China has slowed but the imbalance in the sex ratio has become a pressing concern and the situation appears to be worsening. Chinese government figures indicate that the female deficit has worsened since the 2000 Census, with the overall sex ratio at birth reaching 118 boys born for every 100 girls in 2005.[30]

The imbalance in China's sex ratio is anticipated to leave roughly 22 million men from these cohorts unable to marry (Ebenstein and Jennings 2008). Although a quarter of young women married in Taiwan are from mainland China (Tsay 2004), no similar solution will present itself for the tens of millions of extra males in rural China. Recent reports that Chinese gangs are beginning to traffic in Vietnamese and North Korean women for would-be husbands are particularly

[28]In China, urban areas have stricter fertility limits and mothers also have, on average, more education.

[29]Note that the Trivers and Willard hypothesis (1973) also predicts a positive correlation between status and education, if a species can vary the male fraction of births in response to anticipated success in mating (since men have more variable mating outcomes). This hypothesis is not thought to apply among human populations in a matter that would affect the male fraction of births by more than a couple percentage points (Norberg 2004).

[30]Report issued by Chinese State Council and Central Committee (January 2007).

alarming and suggest the China marriage market squeeze could become an even larger policy issue. Economic realities as well as persistent religious beliefs make it unlikely that the problem will solve itself by parents choosing to prize daughters because of their scarcity.

The historical lesson to policymakers in family planning is that encouraging or forcing people to change their fertility behavior without addressing their fundamental preferences may have unanticipated consequences. The future course of the sex ratio in China is yet to be determined. In light of the Chinese government's decision to maintain the One Child Policy, policy must be formulated to deal with the need to discourage fertility *and* sex selection. This could be addressed by directly subsidizing mothers who fail to have a son. Empirical estimates presented here suggest that this could indeed be an effective option, with a 1-year subsidy reducing the number "missing girls" by 67%. Future research in this area should compare these estimates to the empirical results of China's current efforts to implement similar policies, such as the "Care for Girls" campaign. Chinese authorities may wish to consider experimentation by varying the size and structure of subsidies to parents in rural China who fail to have a son, in order to supplement the structural estimates here as well. China's high sex ratio at birth is a pressing policy issue, and this paper presents evidence that the practice of sex selection could be reduced dramatically through the implementation of corrective policies. Failing to act may prove costly for the next generation.

9 Appendix on Estimation of the Model

9.1 Econometric Model of Sex Selection

In this model, parents are assumed to choose the option at each decision node that maximizes the expected payoff given their anticipated choices tomorrow. They are unable, however, to perfectly anticipate future decisions due to stochastic factors that change the payoff to childbearing or sex selection. In China, several features of fertility policy make this assumption plausible. Since fines F are enforced by local officials, and enforcement is not perfect, they may appear stochastic to the couple (Scharping 2003). The cost of sex selection A also has a random element, since parents cannot know in advance precisely how many conceptions and abortions will be required to conceive a son. Let parents make choices to maximize V, the payoff (or value) of reaching any final branch of the decision tree, denote each path choice by D, and each option by the subscript j.

$$V_{D_j} = V^*_{D_j} + \epsilon_{D_j},\ j = 0, 1$$

Parents are aware of the anticipated payoff to each option $V^*_{D_j}$ prior to reaching the node, but in the period in which they make the decision D to pursue option j they observe an unanticipated error term ϵ_{D_j}, or "shock", that either increases or decreases the attractiveness of option j. Note that at each decision node, parents are faced with a binary choice since the decision to have a child is binary, and the decision to practice sex selection is binary. As such, the probability of making decision D to pursue option j can be written as follows.

$$\Pr(D = 1) = \Pr(V_{D=1} > V_{D=0}) = \Pr(V^*_{D=1} - V^*_{D=0} > \epsilon_{D=1} - \epsilon_{D=0})$$

Assume ϵ_{D_j}~$ev(1)\ iid$

The error term for each option is assumed to be independently and identically distributed extreme value, which has the convenient property that the difference between the two errors has a logistic distribution.[31] The extreme value distribution provides slightly fatter than normal tails, allowing for more aberrant behavior than a normally distributed shock, and also provides a closed-form solution for the likelihood function.[32]

The extreme value distribution is characterized by two additional parameters, τ and γ, which represent the scale and shift parameters respectively. In the context of the 2-child model presented in the paper, this yields the following closed-form solution for the expected value of the

[31] The shock associated with current outcomes is assumed to have variance λ, which is known as the scale parameter since it only affects the levels of coefficients, and not the relative size of each. λ is set equal to unity, which implies the parameters are identified in the same units as the fines (i.e. years of income).

[32] The claim that the difference in errors in each period is independent across periods requires that random factors affecting the attractiveness of options are uncorrelated with future or past shocks experienced by the individual.

payoff in the final stage.[33]

$$E(V^3) = E[\max(\theta_i - A_i - F + \gamma_i + \epsilon^3_{S_2=1}, -F + \gamma_i + \epsilon^3_{S_2=0})] \tag{7}$$
$$= \tau\{\gamma + \log(1 + \exp[\frac{\theta_i - A_i}{\tau}])\}$$

9.2 Likelihood Function for Basic 2-Child Model

In the model's simplest formulation, the likelihood of reaching each sex outcome can be written in terms of the three choice probabilities, which are expressed in the text in terms of θ, γ, A, and the fine regime imposed on a mother. Each mother in the sample is placed in one of four completed fertility outcome: B, G, GB, GG.[34] The following represents the likelihood function, and it is easily verified that the total probability of reaching one of these four outcomes is equal to 1.

$$\Pr(B) = [.51 + .49 \Pr(S_1)] \tag{1}$$
$$\Pr(G) = [.49 - .49 \Pr(S_1)] * [1 - \Pr(K_2)] \tag{2}$$
$$\Pr(GB) = [.49 - .49 \Pr(S_1)] * \Pr(K_2) * [.51 + .49 \Pr(S_2)] \tag{3}$$
$$\Pr(GG) = [.49 - .49 \Pr(S_1)] * \Pr(K_2) * [.49 - .49 \Pr(S_2)] \tag{4}$$

9.3 Robustness of Model Results

In order to examine the sensitivity of the results to particular specification choices, I estimate the parameters of the 3-child model separately for 2000 without allowing for the region and period parameters presented in the main results. The results, shown in Appendix Table 1, indicate that the value of a first-born son is 0.94, 1.47, and 1.86 in the census samples respectively. These results are reasonably similar to what is observed in the pooled sample (1.42), but I present in the main text parameters that include "fixed effect" model parameters to absorb region and period-specific factors that affect the value of a first son or daughter. Also note that the estimates are more precise in the 1990 census and 2000 census samples, where the majority of mothers were subject to fines, and therefore have more variation to exploit. In fact, the table reflects that in 1982, prior to the policy, the model is unable to produce statistically significant parameter estimates. This is encouraging that the model fails to produce precise parameter estimates in the pre-period, but produces much better estimates in the 2000 sample, where most of the parents faced the fines and therefore the parameters are better identified.

9.4 Calculating the Fines for Excess Fertility in China

The fertility policy in China is enforced by a complex system of financial disincentives for excess fertility, including reduction of land allotments, denial of public services, and fines for unautho-

[33] See Train (2003) for a thorough treatment of the estimation of discrete choice models. In the calculation of the model, I assume the scale parameter τ is equal to 1, and so the scale of the coefficients is set to the level of fines. I assume the location parameter γ is equal to zero.

[34] The likelihood function for the 3-child model is composed of 14 outcomes and is available online: http://www.demog.berkeley.edu/~ebenstei/restat/Three_Child_Model.pdf

rized births. The fines represent the critical variable in the model's estimation, and they are taken from Scharping (2003). The complete record of the published fine rates collected by Scharping are listed in Appendix Table 2, and they reflect wide variation in the punishments on excess fertility across province and year. While comprehensive fine rates for this period are not publicly available, a good deal of information regarding the strength of enforcement across regions, time, and ethnicity is available from smaller-scale surveys conducted during this period.[35] The algorithm used to combine these sources of information to impute the fine rates is described below, and the corresponding STATA code and data are available for download at the author's website.[36]

During the 1980's, the provincial regulations reflect that the vast majority of provinces collected the fine from wage earners in the form of regular deductions (Scharping 2003). For fines levied as wage deductions, I calculate the present value of the deduction at a 2 percent discount rate yielding a single amount of the fine in years of income. For example, in February 1980 Guangdong province ratified a fine of 10 percent of income from each parent for 14 years for an unsanctioned birth, which in my data is calculated as having a present value of 1.21 years of income. In the 1990's, fines began to be levied as a share of annual income, partly in response to difficulties in collections as fewer workers rely on the state for their livelihood. For example, Shanghai reported in 1981 that an unauthorized birth carried a 10 percent wage deduction from both parents for 16 years. In 1992, this amount was raised to an immediate payment of 3 years of household income. When provinces report a specific deduction as a share of annual income, like Shanghai, the fine variable used in the analysis is taken directly from these provincial regulations. For non-wage workers, such as the peasantry following de-collectivization, I am forced to assume the fines were in proportion to the published rates on wage-earners.

I use the published fine rates in Appendix Table 2 and aforementioned imputation procedure to create a data set of fine rates by province and year for 1979-2000. For provinces in which no fine information is available for 1979, I assume that each province instituted a baseline fine of 10 percent deductions for 14 years in 1979, consistent with historical accounts for the provinces for which regulations are available. When a province discloses their policy, I assume that the explicit policy of the new fine is constant for the remainder of the period. For every province, I have a direct observation of the size of the fine for at least one point in time.

In recent years, several provinces have moved to a system of enforcement which provides greater latitude to local officials in assessing the appropriate fertility fine. For example, in Beijing fines are assessed as "social support fees" for an unauthorized birth and the regulations indicate that the fine is assessed as an amount between 5,000 and 50,000 yuan. In these circumstances, I am forced to impute the fine with the fine charged by other provinces within the same fertility policy region (discussed below) for which I have reliable measures of the fine amount as a share of income.[37]

As discussed in the text, while unauthorized births are subject to severe fines, parents in certain circumstances are granted authorization for a second child, and these births carry milder financial consequences. Gu et al. (2007) classify each of the 31 provinces and autonomous regions

[35] The China Health and Nutrition Survey has fine data for 1989, 1991, and 1993, but the rates are only for a small number of communities (156 in 1989) in several provinces. As described in this appendix, the information in the CHNS is used to guide imputation of the fines to the national census.

[36] Future weblink.

[37] The following provinces require imputations in the recent years: Beijing (1-child policy), Inner Mongolia (1.5 child policy), Liaoning (1.5), Jilin (1.5), Jiangxi (1.0), Shandong (1.5), and Guangxi (1.5).

of China into a 1, 1.5, or 2 child zones, which broadly classifies the average number of children allowed to each couple. For parents in the 1 child zone, I presume that the entire value of the fine is levied on all second births. Parents in the 1.5 child zone who have a 1st-born daughter are in many (but not all) localities eligible for a 2^{nd} child permit. Local variability in the policy is unobserved in the census data but known to be important (Mcelroy and Yang 2000). For example, the China Health and Nutrition Survey (CHNS) documents that in Hubei province (classified in the 1.5 child zone) Han couples with a first-born daughter were not allowed a second child in 5 out 24 villages in the 1993 survey, and so I approximate this phenomenon with a fine rate of 25% of the baseline fine. For parents living in the 2-child policy zone and minority parents, I apply a fine equal to 10 percent of the provincial fine rate, to attempt to capture the closer to universal permits on 2^{nd} births to these parents. This value is chosen since all parents were eligible for a one-child bonus, and the CHNS reflects that the average annual one-child bonus (roughly 100 yuan) was approximately 10% of the average fine (roughly 1,100 yuan) in the villages sampled.

I also adjust upwards the penalty on 3^{rd} births in the 1 and 1.5 child zone to account for the premium punishments applied to couples that had a 3^{rd} child. Most provinces report more severe wage deductions or fines for 3^{rd} births, such as Shanghai which doubled the standard fine associated with a 2^{nd} birth. For parents within the 1-child zone, I assign a 100% premium to the punishment for a 3^{rd} birth relative to the base fine. The markup of 100% is chosen consistent with the reported policy in Zhejiang, Shanghai, Jiangsu, and Beijing, each of which explicitly dictated punishments on 3rd births to be twice the fine on 2nd births. For parents in the 1.5 child zone, I assign a 50% premium to a third birth, since this will only be the first unauthorized birth for many of these families. For minorities and residents of the 2 child zone, the fine on a third birth is equal to 50% of the provincial fine rate. This roughly matches the average difference in fines observed in the CHNS (1993), which indicates that the average fine was twice as large in areas where all couples are allowed a second child.[38]

The fine relevant for the analysis should be the *effective* fine, which would account for variability in the enforcement of fines. While in urban areas the fines are easily enforced, and excess fertility can be punished with the denial of state services, this is not always the case in the rural areas.[39] As such, I raise the fine assumed to apply to all individuals registered in an urban *hukou* an extra 50% spike to both second and third births in all zones. This partly based on Scharping's calculation that roughly half of all levied fines were collected, and so as an approximation between full collections and no collections, I raise the urban fine rate by 50%. The second justification is that I attempt to reconcile my fine distribution with data in Gu et al. (2007) on policy fertility.[40] They have access to more detailed data and can observe the large concentration of state workers in urban areas (who are subject to stricter rules and harsher punishments) and they produce a distribution of fines similar to those used in my analysis.

[38]Author's calculations from the 1993 CHNS community survey (1,950 versus 3,900 yuan).

[39]Scharping writes that before China began liberalizing its economy "...[T]ight state control of the urban economy made enforcement of these measures relatively easy." In recent years, the cities have experienced more difficulty deducting wages, but urban residents continue to be more reliant on social services and are therefore subject to more effective enforcement of the policy. pp. 136.

[40]Gu et al. (2007) place all urban residents into a 1-child fertility policy, regardless of their province of residence. I observe in my data that fertility rates are higher for urban residents in the 1.5 child and 2 child policy regions, and so I allow for urban residents to be subject to different fines in different regions.

9.5 Are the Fines Exogenous?

In Appendix Table 3, in an attempt to measure the exogeneity of the fines, I impute the fines to the 1982 census sample by assuming they were subject to the fine regime in place for parents in the 2000 census. I then stratify the parents in both the 1982 and 2000 census by fertility outcome, and compare the average fine faced among parents for each outcome. In the 2000 census, the average fine is higher among parents with fewer children and lower among parents with more children, as one would anticipate. For the 1982 census, however, the imputed fines have a weaker correspondence with completed fertility. If the fines were systematically related to pre-existing fertility tastes, the psuedo-fines would presumably be higher among those with fewer children. As such, it appears that the policy is causally influencing fertility, rather than simply reflecting pre-existing tastes.

I perform a second test of whether the fines can be thought to represent exogenous variation in the incentives to fertility in Appendix Table 4, where I examine whether fines are correlated with individual fertility outcomes in the pre-period. The fines appear to be predictive of who stop after one or two daughters even before the policy's implementation, since the large cities were subject later to higher fines but even in the pre-policy period did not generally have large families. However, the behavior at other parities suggests that the fines are not correlated with regional son preference. Also note that the model is estimated using policy region and year effects, presumably absorbing any differences in the value of sons prior to the policy's implementation. Intuitively, since I am using a "differences in differences" strategy, differences in the pre-period do not necessarily bias the coefficients. In addition the overall weak relationship between the sex ratio after daughters and the fine rates prior to the policy is suggestive that the fines are allowing for identification of the model in an unbiased manner, rather than simply identifying areas with stronger son preference.

Additional tests for the exogeneity of the fines to the latent regional preference for sons are included in Appendix Tables 5 and 6, where I demonstrate that the variation in the fine rates are not systematically related to factors affecting preferences for children (θ, γ) or sex selection technology A. The China Health and Nutrition Survey performed community surveys in 1989, 1991, and 1993, recording information regarding the inhabitants of villages and the fine rates for each year. In Appendix Table 5, I examine the partial correlation between the fines and factors that might affect the preference for sons or daughters. I record the average education of men, women, the average age at marriage, the village's per-capita income, and whether the village has farming, land, hospitals with ultrasound, and other relevant predictors of the parameters. The coefficients suggest that the areas where women have more education and marry later have higher fine rates, but they also suggest that villages with farming land also have higher fine rates. This suggests that the mechanism for determining fines in areas is not systematically linked to factors that would affect son preference. One coefficient that does appear relevant in determining fine levels is the per-capita income of residents, which is statistically significant in the regressions in column 1 and column 2. This is sensible since fines are generally levied in proportion to an individual's income, and it is sensible that richer villages reported higher fine rates. Aside from this regressor, however, here appears no systematic relationship between the factors that plausibly affect fertility tastes and the fine rates in the villages in the sample. In Appendix Table 6, I show that the fines are only weakly correlated with factors that would presumably proxy for the availability of sex selection, including whether the village has an ultrasound facility. None of these variables appears systematically related to the fine rates for the villages.

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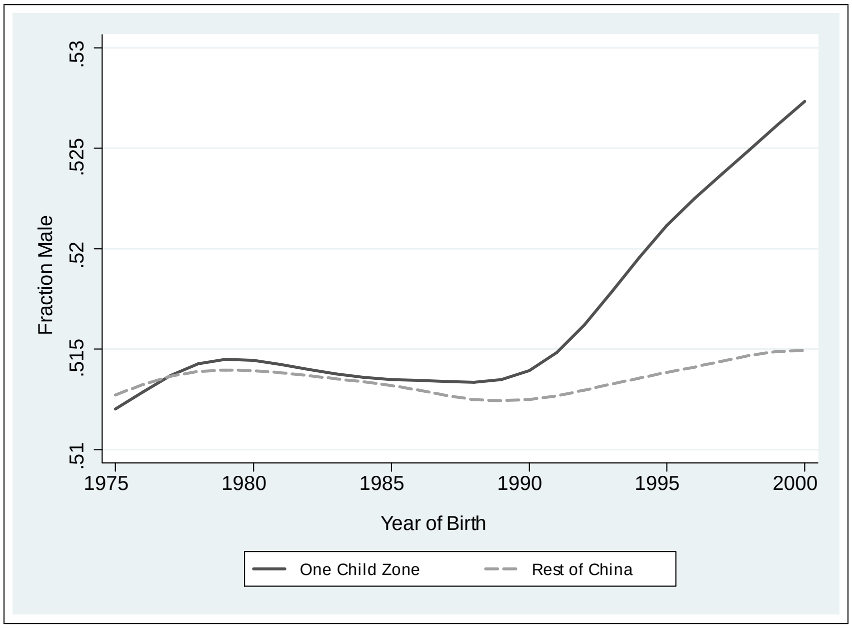
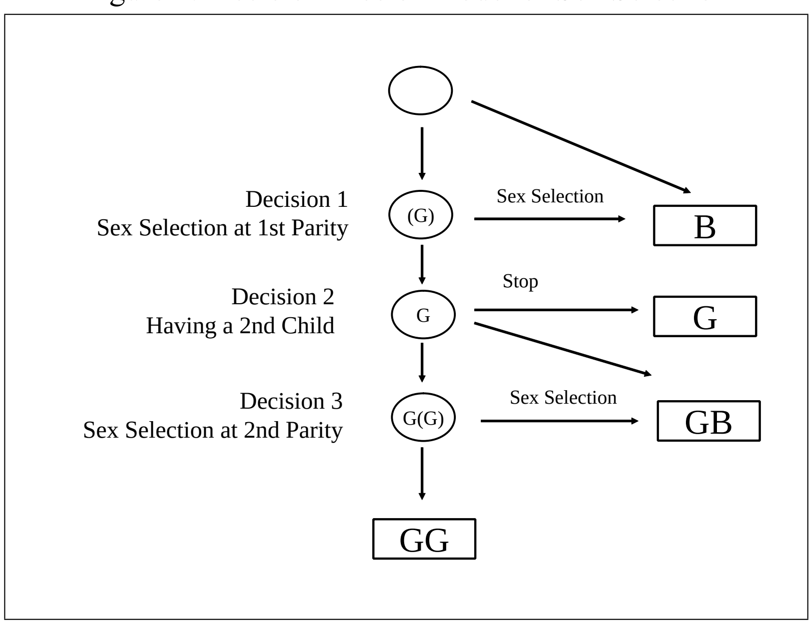
Figure 1: Rising Sex Ratio among First Births in China



Source: China census 1982-2000. The graph is created by calculated the running-mean smoother applied by the lowess command using STATA 9 software.

Figure 2: Decision Tree of Model of Sex Selection



The 2-child model consists of 3 decisions listed above. The completed fertility outcomes are in boxes and the intermediate outcomes are in ovals.

Table 1

Fertility Patterns in China by Sex of Existing Children

Parity	Sex Combination	Percent who have another child 1982	1990	2000	Fraction Male (of next birth) 1982	1990	2000
	Overall				0.516	0.520	0.533
1st	None				0.511	0.510	0.515
2nd	One boy	0.71	0.54	0.35	0.51	0.50	0.50
	One girl	0.75	0.60	0.49	0.52	0.55	0.62
3rd	Two boys	0.53	0.30	0.18	0.50	0.43	0.39
	One girl, one boy	0.54	0.29	0.16	0.52	0.52	0.53
	Two girls	0.68	0.55	0.46	0.54	0.61	0.70
4th	Three boys	0.40	0.24	0.17	0.48	0.40	0.37
	One girl, two boys	0.36	0.17	0.11	0.51	0.49	0.52
	Two girls, one boy	0.44	0.23	0.14	0.52	0.55	0.58
	Three girls	0.62	0.54	0.50	0.56	0.64	0.72

Source: China Census 1% sample (1982), 1% sample (1990), .10% sample (2000). Married women ages 21-40 and their matched children ages 0-18.

Notes: Data in thousands. Sex ratio (boys/girls) at birth is calculated by assigning weights to each male and female that account for differential mortality rates by age, sex, and year. China life tables taken from Banister (2004).

Table 2

Regression (OLS) Estimates of Male Fraction of 5-year Birth Cohort (LHS) on Fertility Fines (RHS)

	Five Years Before One Child Policy (1975-1979)		Five Years Before 2000 Census (1996-2000)	
	(1)	**(2)**	**(3)**	**(4)**
Fertility Fine	-0.0038	-0.0068	0.0083*	0.0111**
	(0.006)	(0.005)	(0.005)	(0.004)
Controls for Regional Characteristics	No	Yes	No	Yes
Observations	345	345	345	345

* significant at 10% ** significant at 5%. *** significant at 1%.

Source: China 2000 Census.

Notes: The fine is measured in years of household income, taken from Scharping (2003). Each regression examines the partial correlation between a 5-year age group and the fertility fines in 2000 by prefecture. China's 2000 census is broken into 345 prefectural boundaries, and this is the finest geographic breakdown available in the data. Controls for regional characteristics are the share of individuals with access to tap water, share with electric or gas fuel, share with concrete or brick households, and the average education of those 30-39 years old. The male share of births is proxied by the living share of those in each cohort. Standard errors are robust and clustered at the province level.

Table 3

Demographic Characteristics and Fine Rates of Mothers Ages 35-40, China

Statistic	1982	1990	2000
Total Children per Mother	3.18	2.23	1.83
Number of Boys	1.65	1.16	0.98
Number of Girls	1.53	1.07	0.85
Sex Ratio (Boys/Girls)	1.08	1.09	1.15
Size of Fine on 2nd births following a Son	0.016	0.514	1.264
Size of Fine on 2nd births following a Daughter	0.013	0.412	1.012
Size of Fine on 3rd births	0.046	1.320	2.900
Years of Education	2.459	3.556	8.336
Farmer (1 = Yes)	0.724	0.652	0.588
Imputed Distance to Fertility Clinic	0.941	0.862	0.615
Observations	28,170	36,279	38,501

Source: China census 1% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 35-40 and their matched children 0-18. For comparability with the 2000 census sample, one-tenth of the 1982 and 1990 1% samples are used for estimation of the model.

Notes: The fine is measured in years of household income, taken from Scharping (2003). Fines are different for those with a son versus daughter due to special provisions in certain provinces for a second allowed birth following a daughter. A family is considered to be a farming family if they report working in the agricultural sector. Years of education is inferred from a census question on completed education. The distance to a fertility clinic is imputed using the 1989 China Health and Nutrition survey responses which contains information on the distance to a clinic for each participant, and the average distance by education and rural/urban status to mothers in the census.

Table 4

Parameter Estimates for 3-Child Sex Selection Model, China 1982-2000

	Son	Daughter
Panel 1: Parameter Estimates for First-born		
Years of Education	-0.213***	-0.196***
	(0.05)	(0.05)
Farmer (1 = Yes)	3.04***	2.20***
	(0.51)	(0.32)
Constant	0.703	-0.077
	(1.29)	(0.93)
Average Predicted Value	1.85	0.43
Panel 2: Parameter Estimates for Second-born and Third-born		
Marginal Value of Second	1.059*	0.234
	(0.60)	(0.64)
Marginal Value of Third	-0.251	0.234
	(0.79)	(1.44)
Panel 3: Parameter Estimates for Costs to Sex Selection		
Distance from a clinic	0.02	
	(1.24)	
Constant (Year==2000)	3.82**	
	(1.55)	
Average Cost Post Ultrasound (Year==2000)	3.83	
Average Cost Prior to Ultrasound (Year < 2000)	5.44***	
	(1.48)	
Observations	102,950	
Log Likelihood ($\ln L$)	-232,414	

* significant at 10% ** significant at 5%. *** significant at 1%.

Source: See Table 3.

Notes: The estimation of the model is performed using MATLAB 7 software. The results above reflect the implied value of children in years of income for mothers of different demographic characteristics, as well as the implied dollar value of the costs of sex selection. Fixed effects are included for the policy region and period for the value o a first son or daughter (not shown).

Table 5

Sex Outcomes in China by Sex of Existing Children - Comparison of Actual and Simulated Fertility Patterns

		Actual Percent who have another child			Simulated Percent who have another child			Actual Fraction Male (of next birth)			Simulated Fraction Male (of next birth)		
Parity	Sex Combination	1982	1990	2000	1982	1990	2000	1982	1990	2000	1982	1990	2000
	Overall							0.52	0.54	0.56	0.52	0.53	0.55
1st	None							0.51	0.51	0.52	0.51	0.51	0.53
2nd	One boy	0.94	0.73	0.55	0.94	0.75	0.59	0.51	0.50	0.49	0.51	0.51	0.50
	One girl	0.95	0.81	0.70	0.95	0.80	0.70	0.53	0.55	0.59	0.51	0.53	0.57
3rd	Two boys	0.74	0.38	0.22	0.73	0.39	0.22	0.50	0.43	0.40	0.51	0.47	0.41
	One girl, one boy	0.75	0.38	0.20	0.75	0.38	0.19	0.52	0.52	0.54	0.51	0.50	0.52
	Two girls	0.86	0.66	0.54	0.86	0.63	0.45	0.55	0.61	0.69	0.51	0.54	0.64

Source: China Census 1% sample (1982), 1% sample (1990), .10% sample (2000). Married women aged 35-40 and their matched chlildren aged 0-18. See Table 3.

Notes: The above calculations reflect the fertility outcomes by simulating decision-making using the census samples for China (see Table 3) using the likelihood function described in the text and the parameter estimates from the Maximum Likelihood Estimation using MATLAB 7 software. Note that the actual fertility patterns will not exactly match those in Table 1, since the sample is composed of only mothers who are likely to have completed fertility (age 35-40).

Table 6

Counterfactual Policy Simulations using the Model, China 2000

	Fertility Outcomes				Subsidies to Mothers without a Son	
	Sex Ratio	Total Fertility	Total Births	Missing Girls	Total Subsidy (% of GDP)	Yuan Cost per "Saved Girl"
Panel 1: Comparison of Actual and Simulated Outomces						
Actual Outcomes	1.14	1.80	36,803	2,560		
Baseline Simulation	1.14	1.81	37,036	2,528		
Panel 2: Alternatives to Current Fertility Limits			Δ Total Births	Δ Missing Girls		
Remove "1.5" Child Exception	1.15	1.75	-2,164	397		
Two Child Policy	1.13	2.01	7,616	-185		
Three Child Policy	1.09	2.43	23,838	-1439		
Panel 3: Targeted Subsidy to those Without a Son						
Subsidy of 3 months	1.12	1.80	-447	-422	0.40%	55,024
Subsidy of 6 months	1.11	1.78	-906	-817	0.83%	59,092
Subsidy of 9 months	1.10	1.77	-1,371	-1184	1.28%	63,338
Subsidy of 12 months	1.08	1.76	-1,874	-1,705	1.77%	60,763

Source: China census .10% sample (2000). Mothers ages 35-40 (N=38,501), see Table 3. Total births and missing girls in thousands.

Notes: Panel 1 represents a comparision between the decisions observed by mothers in China's 2000 census, and a set of numerical simulations in which mothers are assigned a fertility outcome using a decision rule determined by Maximum Likelihood Estimation. Panel 2 presents simulations in which China no longer allows a 2nd birth to parents without a son, or allows all couples a 2nd birth,or allows all couples a 3rd birth (removing all fines on these births). Panel 3 presents a set of simulations in which parents who fail to have a son are directly subsidized by a share of their annual income.

Table 7

Male Fraction of Births and Total Fertility by Mother's Education, India and Taiwan

		India(2006)				Taiwan (2000)			
Parity	Sex Combination	Illiterate	Primary	Middle	HS+	<Primary	Primary	HS	BA+
1st	None	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52
2nd	One girl	0.53	0.53	0.53	0.58	0.52	0.52	0.52	0.52
3rd	Two girls	0.53	0.55	0.58	0.70	0.55	0.56	0.59	0.57
4th	Three girls	0.52	0.59	0.62	0.75	0.60	0.62	0.62	0.63
Total Fertility Rate		3.34	2.82	2.28	1.77	2.25	1.99	1.76	1.71

Source: Calculations for India based on the 2006 Demographic and Health Survey using all living children, ever-married women age 15-49. Calculations for Taiwan based on the 2000 census (100% sample), married women age 21-40 and their children age 0-18.

Appendix Table 1

Parameter Estimates for 3 Child Sex Selection Model, Separately Estimated

	1982		1990		2000	
	Son	Daughter	Son	Daughter	Son	Daughter
Panel 1: Parameter Estimates for First-born						
Years of Education	-0.23	-0.24	-0.38***	-0.33***	-0.32***	-0.26***
	(0.30)	(0.21)	(0.10)	(0.09)	(0.08)	(0.07)
Farmer (1 = Yes)	1.96	1.55	3.01***	2.28***	2.79***	1.72***
	(2.37)	(1.54)	(1.04)	(0.65)	(0.63)	(0.41)
Constant	0.39	0.25	1.027	0.257	2.91***	1.83*
	(1161)	(1209)	(1.08)	(1.02)	(1.07)	(0.82)
Average Predicted Value	0.94	-0.18	1.47	0.31	1.86	0.64
Panel 2: Parameter Estimates for Second-born and Third-born						
Marginal Value of Second	0.755	1.474	0.748	0.408	0.499	-0.078
	(1164)	(1)	(0.89)	(0.93)	(0.60)	(0.67)
Marginal Value of Third	0.755	1.474	-0.713	0.408	-1.264	-0.078
	(1163)	(1210)	(1.30)	(1.24)	(1.68)	(1.36)
Panel 3: Parameter Estimates for Costs to Sex Selection						
Distance from Clinic	4.72		1.171		2.58*	
	(78991)		(3.63)		(1.53)	
Constant	9.749		3.549		2.34*	
	(78991)		(4.03)		(1.35)	
Average Predicted Value	4.97		4.65		3.92	
Observations	28,170		36,279		38,501	
Log Likelihood (ln$L$)	-72,040		-82,019		-77,076	

* significant at 10% ** significant at 5%. *** significant at 1%.

Source: China Census 1% sample (1982), 1% sample (1990), .10% sample (2000). Married women aged 35-40 and their matched chlildren aged 0-18. See Table 3.

Appendix Table 2

Monetary punishments for excess fertility, China 1979-2000

Province	First Report	Second Report	Third Report	Fourth Report	Fifth Report
Beijing	1982: 7Y, 10%	1991: 1Y, 500%			
Tianjin	1988: 5Y, 20%	1997: 5Y, 20%			
Hebei	1982: 14Y, 10%	1989: 1Y, 250%	1997: 1Y, 250%		
Shanxi	1982: 7Y, 15%	1986: 7Y, 25%	1989: 7Y, 20%		
Inner Mongolia	1982: 14Y, 10%	1995: 1Y, 200%			
Liaoning	1979: 14Y, 10%	1980: 14Y, 10%	1988: 14Y, 10%	1992: 1Y, 500%	1997: 1Y, 500%
Jilin	1988: 1Y, 30%				
Heilongjiang	1982: 14Y, 10%	1983: 1Y, 120%	1989: 14Y, 10%		
Shanghai	1981: 16Y, 10%	1982: 3Y, 10%	1992: 1Y, 300%	1995: 1Y, 300%	1997: 1Y, 300%
Jiangsu	1982: 10Y, 10%	1990: 1Y, 300%	1995: 1Y, 300%	1997: 1Y, 300%	
Zhejiang	1982: 7Y, 5%	1985: 5Y, 15%	1989: 5Y, 50%	1995: 5Y, 50%	
Anhui	1979: 14Y, 5%	1988: 7Y, 10%	1992: 7Y, 10%	1995: 7Y, 10%	
Fujian	1982: 14Y, 5%	1988: 7Y, 20%	1991: 1Y, 300%	1997: 1Y, 300%	
Jiangxi	1997: 1Y, 300%				
Shandong	1996: 1Y, 100%				
Henan	1982: 7Y, 15%	1985: 7Y, 15%	1990: 7Y, 30%		
Hubei	1979: 14Y, 10%	1987: 5Y, 20%	1991: 5Y, 60%	1997: 5Y, 60%	
Hunan	1979: 14Y, 5%	1982: 5Y, 10%	1989: 1Y, 200%		
Guangdong	1980: 14Y, 10%	1986: 7Y, 20%	1992: 1Y, 350%	1998: 1Y, 350%	
Guangxi	1994: 1Y, 500%				
Hainan	1989: 7Y, 20%	1995: 1Y, 300%			
Chongqing	1997: 1Y, 300%				
Sichuan	1984: 7Y, 5%	1987: 7Y, 20%	1997: 7Y, 30%		
Guizhou	1984: 14Y, 10%	1998: 1Y, 500%			
Yunnan	1986: 1Y, 10%	1990: 7Y, 40%	1997: 7Y, 40%		
Tibet	1986: 1Y, 30%	1992: 1Y, 50%			
Shaanxi	1981: 7Y, 10%	1982: 7Y, 10%	1986: 7Y, 10%	1991: 7Y, 30%	1997: 7Y, 30%
Gansu	1982: 10Y, 10%	1985: 10Y, 10%	1989: 7Y, 30%	1997: 7Y, 30%	
Qinghai	1982: 7Y, 10%	1986: 7Y, 10%	1992: 7Y, 25%		
Ningxia	1982: 14Y, 10%	1986: 14Y, 10%	1990: 14Y, 30%		
Xinjiang	1988: 7Y, 10%	1991: 14Y, 30%			

Notes: Taken from Scharping (2003). Monetary punishments listed above as "Year of Report: Length of wage deduction, percent of annual salary". Fines that are levied as one-time punishments are listed above as being collected in a single year. Social support fees for additional births are included in the fine where possible. The manner in which fines are imputed for years where no report was available is outlined in the data appendix.

Appendix Table 3

Comparing fertility and average fine rates, Pre/Post One Child Policy

Fertility Outcome	Share with Completed Fertility (1982)	Average Simulated Fine Rate (1982)	Share with Completed Fertility (2000)	Average Actual Fine Rate (2000)
Boy	0.030	3.14	0.243	3.63
Girl	0.026	3.11	0.159	4.09
Boy, Boy	0.060	2.99	0.103	2.41
Boy, Girl	0.056	2.95	0.105	2.38
Girl, Boy	0.057	3.06	0.160	2.45
Girl, Girl	0.028	3.18	0.063	2.42
Boy, Boy, Boy	0.042	2.01	0.010	1.36
Boy, Boy, Girl	0.048	2.05	0.016	1.45
Boy, Girl, Boy	0.049	2.00	0.015	1.45
Boy, Girl, Girl	0.036	2.11	0.013	1.45
Girl, Boy, Boy	0.048	2.01	0.017	1.48
Girl, Boy, Girl	0.037	2.08	0.012	1.49
Girl, Girl, Boy	0.046	2.12	0.044	1.69
Girl, Girl, Girl	0.022	2.32	0.011	1.56
Four or more	0.415	1.53	0.030	1.38

Source: China census .10% sample (1982), .10% sample (2000). Mothers ages 35-40 and their children ages 0-18.

Notes: The first column reflects the share of parents with a particular fertility outcome among mothers 35-40 in the 1982 census. The second column reflects the average fine on third births imputed to parents with a particular fertility outcome assuming the parents were facing the fine regime assigned to the parents in the 2000 census. The third column reflects the share of parents with a particular fertility outcome among mothers 35-40 in the 2000 census. The fourth column reflects the average fine on third births imputed to parents with a particular fertility outcome in the 2000 census.

Appendix Table 4

Regression (OLS) estimates of Fertility Outcomes (LHS) on Fertility Fines (RHS) Following Daughters: Mothers aged 35-40, China 1982

	Share Having a 2nd/3rd/4th/5th Birth				Male Share of 2nd/3rd/4th/5th Births			
	2nd	3rd	4th	5th	2nd	3rd	4th	5th
Log of Fertility Fine	-0.076**	-0.096**	0.008	-0.022	-0.022	0.015*	-0.002	-0.005
	(0.003)	(0.008)	(0.017)	(0.030)	(0.030)	(0.009)	(0.016)	(0.028)
Mother's Education	0.00**	-0.01**	-0.02**	-0.02**	-0.015**	0.001	-0.001	0.006
	(0.001)	(0.002)	(0.003)	(0.007)	(0.007)	(0.002)	(0.003)	(0.006)
Farmer	0.03**	0.13**	0.19**	0.23**	0.23**	-0.02**	-0.03*	-0.01
	(0.004)	(0.009)	(0.020)	(0.041)	(0.041)	(0.011)	(0.018)	(0.034)
Sample Average	0.946	0.874	0.767	0.656	0.656	0.521	0.528	0.553
Observations	14,310	6,491	2,678	918	918	13,538	5,671	2,054

* significant at 5%. ** significant at 1%.

Source: China census .10% sample (1982).

Notes: These regressions use the 1982 census mothers with fines imputed as if they had been observed in the 2000 census.

Appendix Table 5

Regression (OLS) Estimates of Fine's Relationship to Son Preference, 1989-1993

	Dependent Variable: Log of Fine on Excess Fertility		
	1989	**1991**	**1993**
Years of Education, Men	0.02	0.03	0.01
	(0.06)	(0.06)	(0.05)
Years of Education, Women	0.06	0.096**	0.085*
	(0.05)	(0.05)	(0.05)
Female Age at Marriage	0.148**	0.09	0.06
	(0.06)	(0.08)	(0.06)
Per-capita Income in the Village	0.530**	0.514**	0.31
	(0.27)	(0.23)	(0.25)
Farming Income	0.00	0.00	0.00
	0.00	0.00	0.00
Farming Land in Area	0.400*	0.30	0.11
	(0.20)	(0.22)	(0.21)
Constant	-0.51	0.89	3.741**
	(1.92)	(2.01)	(1.80)
Observations	146	164	153
R squared	0.18	0.17	0.16
Average Fine in Yuan	1,735	3,260	3,611

* significant at 10% ** significant at 5%. *** significant at 1%.

Source: China Health and Nutrition Survey Community Survey, 1989-1993.

Notes: The fine is directly measured in the CHNS at the village-level. Education and age at marriage are reported at the individual-level and averaged across the village. The per-capita income measure and farming income measure are reported at the household level and averaged across the village. The variable identifying whether the village has farming land is reported at the village-level.

Appendix Table 6

Regression (OLS) Estimates of Fine's Relationship to Cost of Sex Selection, 1989-1993

	Dependent Variable: Log of Fine on Excess Fertility		
	1989	**1991**	**1993**
Ultrasound Facilities	0.003	0.136	0.209*
	(0.147)	(0.135)	(0.118)
Prenatal Care Facilities	-0.14	-0.06	-0.185*
	(0.11)	(0.12)	(0.10)
Rooms in Health Facilities (000s)	0.66	-0.30	0.70
	(0.77)	(0.61)	(0.67)
Beds in Health Facilities (000s)	0.39	0.06	0.10
	(0.36)	(0.52)	(0.35)
Constant	7.103***	7.597***	7.906***
	(0.14)	(0.16)	(0.11)
Observations	147	165	151
R squared	0.03	0.01	0.08
Average Fine in Yuan	1,735	3,270	3,620

* significant at 10% ** significant at 5%. *** significant at 1%.

Source: China Health and Nutrition Survey Community Survey, 1989-1993.

Notes: The fine is measured in yuan and is reported at the village level. The regressions measure the partial correlation between a village's fine for one additional child and (1) the total number of facilities in the village that provide ultrasound, (2) the total number of facilities that provide pre-natal care, (3) the total number of rooms in health facilities and (4) the total number of beds in health facilities.