Estimating a Dynamic Model of Sex Selection in China

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Abstract

High ratios of males to females in China have historically concerned researchers (Sen 1990) and their recent increase has alarmed policymakers worldwide. 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 2000 census. I find that a son is worth .56 years of income more than a daughter, and the premium is highest among less educated mothers and families engaged in agriculture. I conclude with a set of simulations to predict the effect of revisions to China's fertility regulations, such as allowing all couples a second child and initiatives to subsidize parents who have daughters.

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, Ebenstein 2008). 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. 2001). While scholarly work has focused on documenting the presence of sex selection, modeling of the sex selection decision is absent from the literature.[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.[3]

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% to 53% masks a pattern that emerges when the births are examined by 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

[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 upon the introduction of ultrasound technology.

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

birth of a daughter, indicating a Chinese preference for gender balance.

In this paper, I present a dynamic model of parental fertility choices that serves to explain these patterns in a rational choice framework in which the number, order, and gender of each child is determined by parents when they have access to a sex selection technology. 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, 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 1-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.[4] 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 is 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 1.42 years of income, and a first-born daughter is worth .86 years of income, with lower values associated with 2nd and 3rd children of either gender. Using the parameterized model, I simulate the impact of a change in the country's fertility policy to a 2-child or 3-child

[4] Recent work that has exploited the One Child Policy as a natural experiment that induced a reduction in fertility include Qian (2005) and Edlund et al. (2008). Calculation of the fines and their relationship to pre-existing patterns in fertility tastes are contained in the appendix of this paper.

limit, and find that such policies lower the female deficit but induce a large increase in fertility. I also perform a set of simulations for a proposed subsidy to families who fail to have a son, similar to a policy being currently undertaken in China[5], and find that such a policy would reduce the sex ratio distortion and lower overall fertility.

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 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.

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

[5]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

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. 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 (see Figure 1).

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. I present in the next section 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 1982, when fertility policies were weaker, after a single daughter only 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, accounting for 83% of the missing girls in these data. After two daughters in 1982, 54% of births were male, and in 2000, 70% of these births were male. The data also 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]

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 (see Table 2) and periods with stricter enforcement of the policy (see Figure 2). 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. 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.

[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 (Johannson 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).

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 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 couple's 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_1, a first daughter is worth γ_1, and a second daughter is worth γ_2. Also suppose for simplification that parents with a son never have a second birth. The decision tree is displayed in Figure 3.

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 game-theoretic process 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.

$$V^3_{S_2=1} = \theta_{1i} - A_i - F + \gamma_{1i} + \epsilon^3_{S_2=1} \tag{1}$$

$$V^3_{S_2=0} = \gamma_{2i} - F + \gamma_{1i} + \epsilon^3_{S_2=0} \tag{2}$$

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_{1i} but incur a cost of A_i, and forego γ_{2i}. 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.

$$\Pr(S_2 = 1) = \frac{e^{\theta_{1i} - A_i - \gamma_{2i}}}{1 + e^{\theta_{1i} - A_i - \gamma_{2i}}} \tag{3}$$

When the couple's benefit of a son θ_{1i} is large relative to the cost of sex selection A_i, they are increasingly likely to choose sex selection. Likewise, if a second daughter γ_{2i} provides little incremental utility, this will increase the likelihood of sex selection. Mothers have equal probability of aborting or carrying to term when $\theta_{1i} - \gamma_{2i} = A_i$, and the probability of aborting is higher when factors increase the value of a son θ_{1i}, decrease the value of a a second daughter γ_{2i}, or when technology lowers the price of sex-selection A_i. Note that while the fine F affects the payoff to both options, it does not enter into the function describing the probability of aborting, since only differences in utility affect decisions.

At the 2^{nd} decision node, the parents face the decision to continue childbearing or to stop. As in the final decision node, their choice will be determined by comparing the expected payoff to

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

a second child with the payoff from completing fertility with only the first child. The payoffs to having a second child ($K_2 = 1$) and stopping, respectively, are as follows.

$$V^2_{K_2=1} = .51\theta_{1i} - F + .49[E(V_3)] + \gamma_{1i} + \epsilon^2_{K_2=1} \tag{4}$$

$$V^2_{K_2=0} = \gamma_{1i} + \epsilon^2_{K_2=0} \tag{5}$$

The payoff from the choice to have a second birth is the payoff to a son multiplied by the probability of conceiving a male, plus the expected payoff if a daughter is conceived ($E(V_3)$, the anticipated value of reaching the 3^{rd} stage of the model) multiplied by the probability of naturally conceiving a female, minus the expected penalty levied on second births. In contrast with the final decision node, the choice to continue is affected by the size of the fine F since parents do not face this fine if they do not have a second child. The anticipated value of reaching the final stage is the expected maximum of the two options the parents will face in that stage. The extreme value distribution is characterized by two additional parameters, τ and γ , which represent the scale and shift parameters respectively.[9]

$$\begin{aligned} E(V_3) &= E[\max(\theta_{1i} - A_i - F + \gamma_{1i} + \epsilon^3_{S_2=1}, \gamma_{2i} - F + \gamma_{1i} + \epsilon^3_{S_2=0})] \\ &= \tau\{\gamma + \log(\exp[\frac{\gamma_{2i}}{\tau}] + \exp[\frac{\theta_{1i} - A_i}{\tau}])\} \end{aligned} \tag{6}$$

Again, since the shocks are assumed to be distributed $EV(1)$, the probability of the parents having a second child, K_2, (and continuing to the final decision node) can be expressed as follows.

$$\Pr(K_2 = 1) = \frac{e^{.51\theta_{1i} - F + .49[E(V_3)]}}{1 + e^{.51\theta_{1i} - F + .49[E(V_3)]}} \tag{7}$$

This probability is determined by the payoff to a son multiplied by the probability of conceiving a male, the magnitude of the fertility fine, and the anticipated value of reaching the 3^{rd} stage of

[9] 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.

the model if the conception is female ($E(V_3)$) multiplied by the probability that the conception is female. This expression indicates that the likelihood is higher when the value of a son is large relative to the anticipated fine, and when the mother has a higher value of either γ_{2i} (a second daughter) or $\theta_{1i} - A_i$ (the sex selection option) and therefore anticipates a higher payoff in the third stage (V_3). Indeed, 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 (7). The payoff to a second birth can be expressed as $\theta_{1i} - F - .49A_i$, in this circumstance, and the parents with the best access to sex selection (yielding a lower A_i) would be most likely to try again. For these parents, however, many will choose not to have a second birth and instead engage in sex selection at the first parity. This decision is calculated as follows.

$$\Pr(S_1 = 1) = \frac{e^{\theta_{1i} - A_i - \gamma_{1i} - E(V_2)}}{1 + e^{\theta_i - A_i - \gamma_{1i} - E(V_2)}} \tag{8}$$

The decision to abort the first child is calculated with the anticipated fine on second births factoring into the decision to abort the first conception. Again, for parents who know they will engage in sex selection (if necessary) to ensure the birth of a son, 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] Details regarding the calculation of the likelihood function are available in the appendix.

The model therefore generates the prediction that a reduction in sex selection costs will increase the sex ratio when parents prefer sons, and that this effect will be magnified when parents are subject to fines on second or third births. First, fines will discourage fertility among those who do not place great weight on having a son or are unwilling (or unable) to practice sex selection.

[10] Note that this is 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).

Second, fines will encourage parents who want a son and are willing to engage in sex selection at earlier parities, to avoid the fine. Therefore, the model predicts a preponderance of male births for a couple's last allowed birth, and even higher sex ratios among births subject to fines. 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.

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]

$$\theta_{1i} = \beta_1 + \beta_2 Educ_i + \beta_3 Farmer_i \tag{9}$$

$$\gamma_{1i} = \beta_4 + \beta_5 Educ_i + \beta_6 Farmer_i \tag{10}$$

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.

$$\theta_{2i} = \beta_7; \theta_{3i} = \beta_8; \gamma_{2i} = \beta_9; \gamma_{3i} = \beta_{10} \tag{11}$$

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 (2006) 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.

$$A_i = \beta_{11} Clinic_i + \beta_{12} \cdot [Year_i == 1990] + \beta_{13} \cdot [Year_i == 1982] \tag{12}$$

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

$$\begin{aligned} \theta_i &= \theta_i * \exp(\beta_{14} \cdot [Policy_i == 1.5] + \beta_{15} \cdot [Policy_i == 2]) & (13) \\ \theta_i &= \theta_i * \exp(\beta_{16} \cdot [Year_i == 1990] + \beta_{17} \cdot [Year_i == 1982]) & (14) \\ \gamma_i &= \gamma_i * \exp(\beta_{18} \cdot [Policy_i == 1.5] + \beta_{19} \cdot [Policy_i == 2]) & (15) \\ \gamma_i &= \gamma_i * \exp(\beta_{20} \cdot [Year_i == 1990] + \beta_{21} \cdot [Year_i == 1982]) & (16) \end{aligned}$$

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.

[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.

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 (9) and (10) are identified from the heterogeneity in fine values across birth orders and across regions and time in China, and the coefficients in (12) 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.

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 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. However, changes in fertility tastes that are correlated with the fine rates not already accounted for by these parameters could yield biased parameter estimates. For example, a legitimate concern may be that parents under higher urban fine regimes would only choose to have one child even in the absence of the policy, and that the fine's true causal role in fertility decisions is overstated. 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. I also present considerable evidence in the appendix that the impact of the policy induced a large fertility reduction in China and a larger reduction in areas of stricter enforcement, providing for the necessary variation in the net prices to childbearing to estimate the model parameters.

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 parents in 1982 were facing no fertility limits, 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."[13] 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 provide a detailed description of how this is executed in the appendix.[14]

The model is estimated using a matched sample of parents with 3 or fewer children, and the imputed fine rates that they faced when making fertility choices (see Appendix Table 1). For

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

[14] 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.

the mothers in the 1982 sample, the data reflect higher fertility, with the average mother having 2.46 births. In contrast, the mothers in the 2000 census averaged only 1.77 births, presumably since their peak fertility years followed the introduction of China's One Child Policy. For the 2000 census, I exclude about 10% of mothers for whom the number of matched sons and daughters is different than the mother's reported fertility.[15] I also exclude those who report having lived in a different hukou, to ensure that the sample is composed of parents for whom the most accurate fine data can be assigned.[16]

5.2 Reduced Form Effect of Fertility Fines on Fertility Outcomes

The theoretical model presented in Section 3 predicts that higher fine regimes will dissuade parents from having large families but will induce sex selection among those who choose to have more than their mandated number of children. If indeed the policy is having this effect, one would anticipate that the fines are negatively correlated with the share of parents having second or third births, but positively correlated with the fraction of these births which are male. In Table 3, I present a set of regressions which are consistent with both of these predictions. The sample is restricted to parents who have not yet had a son to focus on the group of parents responsible for the female deficit observed in China, and mothers aged 35-40 who are likely to have completed their fertility.[17] The regressions are estimated using the mothers in this group and a pooled sample of births in the 1982, 1990 and 2000 China census samples, similar to the sample used in the estimation of the model.[18]

In columns 1 and 2 of Table 3, I estimate linear probability models of whether parents had a second child or third child on the log of the fine rate facing the parents and a set of control variables.[19] The results indicate that raising the fertility fine by 100% reduces the probability of

[15]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.

[16]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.

[17]Very few women in China during the years of the One Child Policy give birth past 35 (Ding and Hesketh 2000).

[18]The sample for the regressions is more inclusive and exploits the large sample of births from the 1990 census. In the estimation of the 3-child model, I restrict the sample to parents with 3 or fewer births.

[19]I include in all specifications province fixed-effects and control variables for the mother's age, the father's age, and

a second and third birth by 18.6 and 13.9 percentage points respectively. Better educated mothers appear less likely to have an additional child following daughters, possibly reflecting weaker son preference and lower dependence on sons for elderly support. Each additional year of education reduces the probability of a second and third birth by 1.2 and 0.5 percentage points respectively. Farming families are 28.7 and 21.1 percentage points more likely to have a second and third birth respectively. This is most likely due to greater reliance among peasants for their labor, and anticipated old-age support (Wang 2006).[20] In columns 3 and 4, I estimate linear probability models for the chance of observing a male birth after one or two daughters and the results indicate that an increase in the fine rate of 100% is associated with a 1.2 and 3.1 percentage point increase in the probability of a male birth respectively. The other covariates appear less important: the coefficient on mother's education and the coefficient on the family being employed in agriculture are small in magnitude and statistically insignificant. This suggests that among those having "out of plan" fertility, the group is composed of parents who want a son. So, conditioned on the punishment (the fine), the observable features of the parents are no longer very important in predicting the chance of a son.

5.3 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

the education level of both parents, and a fixed-effect for the year of the previous birth. The fines vary over province, year, ethnic group, and whether the household is registered in an urban area. Details of the fine imputation to the census sample is described in the appendix.

[20] This coefficient may also reflect that the fine variable cannot fully capture local variation in regulations which allow farming families greater leeway in having "out of plan" births. See the technical appendix for details regarding how I incorporate the provisions allowing a second birth to peasant families with a first-born daughter into the fine rates. The fines are not conditioned on whether the parents are employed in the agricultural sector, but rather on province and hukou status.

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 0.25 years of income. The data also indicate that households employed in the agricultural sector are more determined to have a son, with these families assigning a full 3.74 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 1.42, which indicates that having at least one son is worth approximately 1.42 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 .23 and -1.6 years of income respectively.[21]

The parameter estimates for γ_{1i} indicate that the average value of a first daughter is .86 years of income (panel 1). Daughters appear to have lower value for those who are better educated, with each year reducing the value by -0.15 years of income. Farming families, who place large values on sons, also place more value on daughters as well, with a 1.78 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 58% of the sample, 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 (.37)

[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.

and third daughter (-.69), which are both lower than the value of a first daughter (.86) . This reflects both the high sex ratios at parities when a parent chooses to avoid a daughter, and the low fertility following sons.

Panel 3 indicates that the cost of abortion A_i is increasing in the imputed distance from an abortion clinic, with each unit increase in the log distance from the nearest clinic associated with a 3.44 increase in years of income in the cost of sex selection.[22] The average cost of sex selection in 1982 was 4.10, indicating that for many parents the costs of sex selection exceeded the benefits. However, in the 2000 data the average imputed value for the cost of sex selection was 2.09, potentially due to the introduction of ultrasound. Parents making sex selection decisions compare the value of the anticipated birth with the value of a child of the desired sex. For example, at the third parity, the average parent will be choosing between a son worth 1.52 years of income and a third daughter worth -0.69 years of income. For these parents, the benefits of sex selection will be roughly as great as the costs (2.21 versus 2.01), yielding a prediction of a sex ratio of 3:1.[23] 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. There is a close correspondence between the distribution of actual fertility outcomes and those predicted by a simulation of agents using the probability rules specified by the likelihood function.[24] The table reflects that the patterns in Table

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

[23] Also note that the cost of sex selection is modeled as the total cost of the number of necessary abortion to choose the sex, which will be on average 2. So, parameter values like these imply that the mean number of abortion attempts per woman is 1.

[24] A comparison of the actual and simulated outcomes of the 14 fertility combinations with three or fewer children is available in Appendix Table 4.

1, where sex ratios are higher following daughters and lower following sons, is evident in the simulated data as well. The simulated data also reflect that the sex ratio following daughters is higher in 2000 than in 1982, which is sensible since these parents are facing higher financial penalties to fertility and lower costs of sex selection. While this in-sample forecasting 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 incentives.[25]

6 A Policy Application of the Sex Selection Model

Recently, the Chinese government has both re-instated the One Child[26] limit and declared that correcting the sex ratio at birth by 2016 is a national priority (Li 2007). 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.[27] The simulations indicate that such a policy could

[25] 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.

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

[27] The "Care for Girls" campaign 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

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.

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.[28] 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 (1.77 to 1.71) and a rise in the sex ratio (1.20 to 1.22), consistent with an interpretation that this exemption is important to keeping the sex ratio of first births relatively undistorted.[29] 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 1.20 to 1.18. 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

empirical properties.

[28]The full comparison of simulated and actual fertility outcomes is available in the technical appendix.

[29]This is similar to what occurred in the 1990's, where many rural areas cracked down on second births after a daughter and the sex ratio of first births began to rise. (Greenhalgh and Winckler 2005)

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 1.10, implying a much smaller female deficit. 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.

In light of government resistance to changing fertility limits, I examine how the demographic outcomes would respond to changes to the fines for the parents in the sample. I examine the trade-off between higher fines, which further distort the sex ratio, and lower fines, which mitigate the female deficit at the expense of an increase in fertility. In Figure 4, I present several simulations to examine the relationship between fine rates, fertility and the sex ratio. Consistent with the set-up, fine increases reduce fertility but lead to an increase in the sex ratio. The simulations indicate that if China's fertility program had imposed fine rates 50% higher on 2nd and 3rd births, fertility would have been 1.61 children per mother rather than 1.77 children, but the share missing would have been 1.22 instead of 1.20. Conversely, if the government had lowered the fine rates by 50%, fertility would have been 2.02 children per mother and the sex ratio would have only been 1.16. These relations demonstrate that the estimated model is able to capture the intuition generated by the theoretical prediction (and empirical finding) that harsher punishments induce parents to have fewer children but engage in sex selection at earlier parities yielding lower fertility and higher sex ratios.

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.[30] In the first simulation, I calibrate the model to reproduce the fertility patterns observed in the census data, so the baseline simulation is the same as in Appendix Table 4. 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 1.20 to 1.18, reducing the distortion to the sex ratio by roughly one fifth.[31] Since the premium on a son has been measured 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 .35 percent of GDP. If parents are subsidized for 12 months of income, the sex ratio drops to 1.11,

[30] 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 preliminary indications is that these programs are having an effect. In a joint venture of the Ford Foundation and UNICEF, the "Chaohu Experimental Zone Improving Girl-Child Survival Environment" was established in 2000 and succeeded in decreasing the sex ratio at birth (SRB) from 125 in 1999 to 114 in 2002. The government is currently attempting to expand the "Care for Girls" campaign to a national initiative. President Hu Jintao (2004) declared that the campaign was a top national priority and the government would stringently attempt to stop the country's SRB from increasing any further in 3 to 5 years (Li 2007).

[31] 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.

implying the share of females missing is only 3% of female births. The cost per "saved girl" is rising slightly with the generosity of the subsidy, as more generous policies involve higher spending on mothers who would complete fertility without a son even in the absence of a subsidy.

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 2004), or a diminution of son preference as witnessed in Korea (Das Gupta et al. 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. 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, 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 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 8, 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[32], but are sensible in light of their lower desired fertility and potentially better access to sex selection technology (e.g. ultra-sound). 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.

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

[32] 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 2000).

reaching 118 boys born for every 100 girls in 2005.[33]

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 alarming and suggest the China marriage market squeeze could become an even larger policy issue. Likewise, reports from India suggest that the marriage prospects for men are worsening in areas of skewed sex ratios and may be affecting dowry prices.[34] 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. Policymakers in India should consider the experience of China as they move to slow the growth of their own population.

The historical lesson to policymakers in family planning is this: 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, and failing to act may prove costly for the next generation.

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

[34] See Edlund (2001) for a useful discussion.

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.

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

$$\text{Assume } \epsilon_{D_j} \sim EV(1)\ iid$$

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.[35] 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.[36]

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.[37] 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

[35] The shock associated with current outcomes is assumed to have variance Lambda, which is known as the scale parameter since it only affects the levels of coefficients, and not the relative size of each. Lambda is set equal to unity.

[36] 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.

[37] The likelihood function for the 3-child model is composed of 14 outcomes and is available from the author upon request.

1.

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

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 1982, 1990, and 2000 without allowing for the region and year parameters presented in the main results. The results, shown in Appendix Table 3, indicate that the value of a first-born son is 1.61, 1.64, and 2.27 in the census samples respectively. These results are reasonably similar to what is observed in the pooled sample (1.42) but it could be that the value of a son is misestimated when the potential endogeneity of the policy is not properly accounted for and so in the text I present the estimation results when I allow for region and year varying parameters for the value of sons and daughters. In Appendix Table 4, I demonstrate that the fit of the model is reasonable for each sample, showing that the model framework can be used to reproduce fertility patterns across different census samples.

10 Appendix on Fines

10.1 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 unauthorized births. The fines represent the critical variable in the model's estimation, and I present here the method by which I impute fines to parents in the Chinese census data. While comprehensive fine rates for this period are not publicly available, a good deal of information regarding the strength of enforcement across regions and time is available.[38]

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, Guangong 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

[38] 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.

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 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 but Jinlin, I have a direct observation for at least one point in time of the regime.[39]

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.[40]

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 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.

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.[41] 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

[39] Jinlin's fine regime is therefore set to 1.21 for the entire period, and does not factor into the fixed-effects regression analysis.

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

[41] The markup of 100% is chosen consistent with the reported policy in Zhejiang, Shanghai, Jaingsu, and Beijing, each of which explicitly dictated punishments on 3rd births to be twice the fine on 2nd births.

CHNS (1993), which indicated the average fine was twice as large in areas where all couples are allowed a second child.[42]

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.[43] 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 assumption is also partly due to reconcile my fine distribution with data in Gu et al. (2007) on policy fertility. They have access to more detailed data and can observe the large concentration 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.

The STATA code used to calculate the fines facing each mother, as well as the fines by province for 1979-2000, are available at the author's website. A visual summary of the spatial dispersion of fines is presented in Figure 5, where I show the average fine on a third birth in each of China's 345 prefectural zones.

10.2 Are the Fines Exogenous?

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. If this paper's main hypothesis is valid, however, the fines *should* 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 Appendix Table 5, 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 (-.003) and statistically insignificant, suggesting that the fines in my data are not systematically related to pre-existing patterns of son preference.[44] 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 (-.0053) 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 (.0072) though the relationship is only statistically significant at the 15% level.[45] In column 4, I perform the same regression with

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

[43] 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.

[44] 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.

[45] Standard errors are clustered at the province level. The results are significant at the 5% level when they are not

controls for regional characteristics, and find that the estimated relationship is positive (.0114) 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.[46] 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 Appendix Table 6, in a second 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 third test of whether the fines can be thought to represent exogenous variation in the incentives to fertility in Appendix Table 7, where I examine whether fines are correlated with 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 8 and 9, 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.[47] In Appendix Table 8, 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

clustered at the province level. The standard error on the fine variable is large since there is little variation in the fine within a province and year. The results in the next section, which focus on individual fertility outcomes and individual fines, are more precisely estimated and more statistically significant.

[46] 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.

[47] The CHNS only records demographic is not sufficiently large to estimate the parameters of the model

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 9, 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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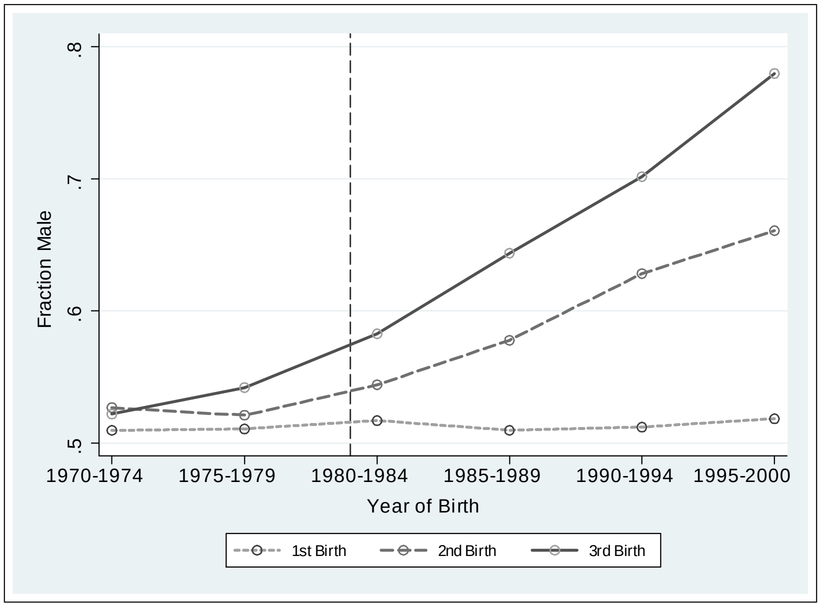
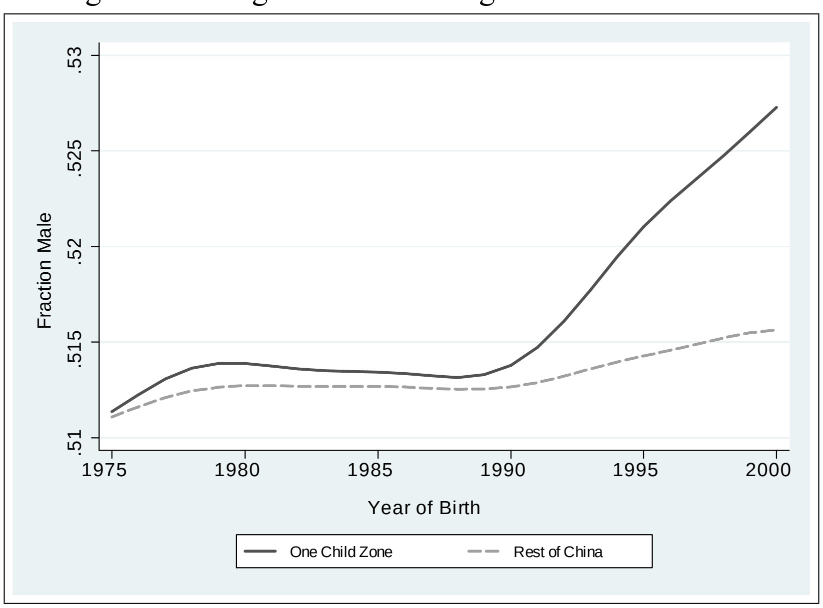
Figure 1: Male Fraction of Births Following Daughters in China



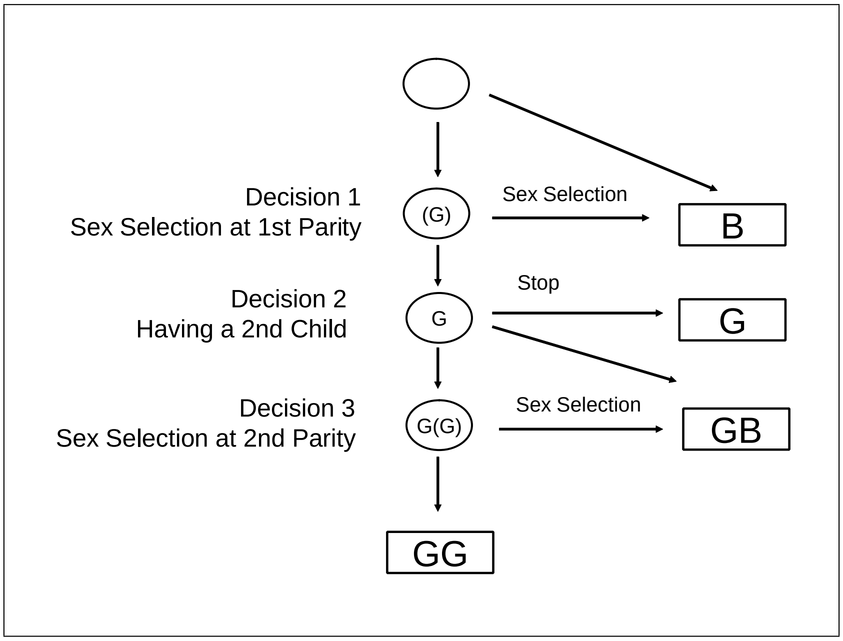
Source: China census 1982-2000. Sample restricted to mothers ages 21-40. See technical appendix at author's website for details. Vertical line indicates year of introduction of China's One Child Policy (1979).

Figure 2: Rising Sex Ratio among First Births in China



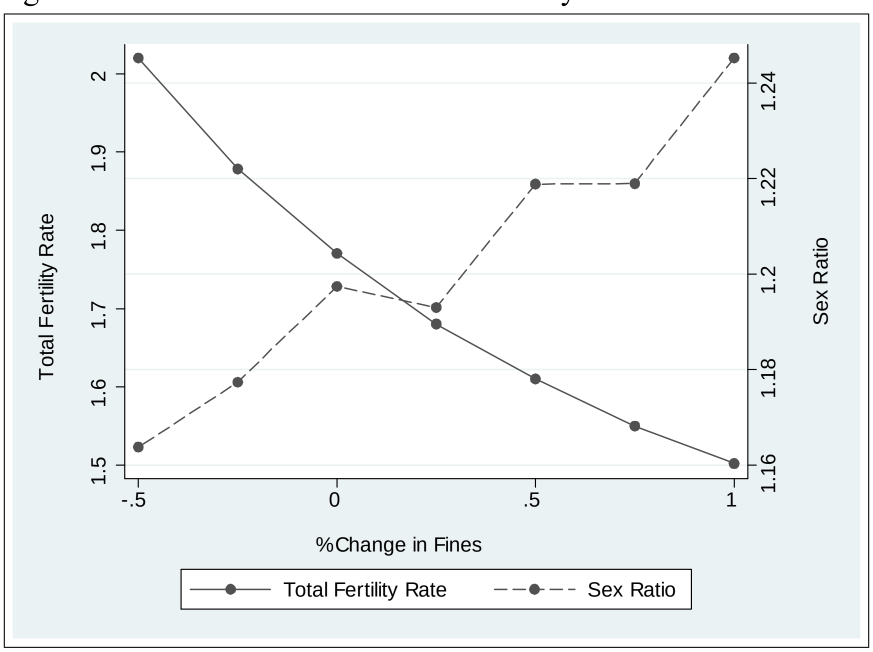
Source: China census 1982-2000. The graph is created by calculated the running-mean smoother applied by the lowess command using STATA 9 software.

Figure 3: Decision Tree of Model of Sex Selection



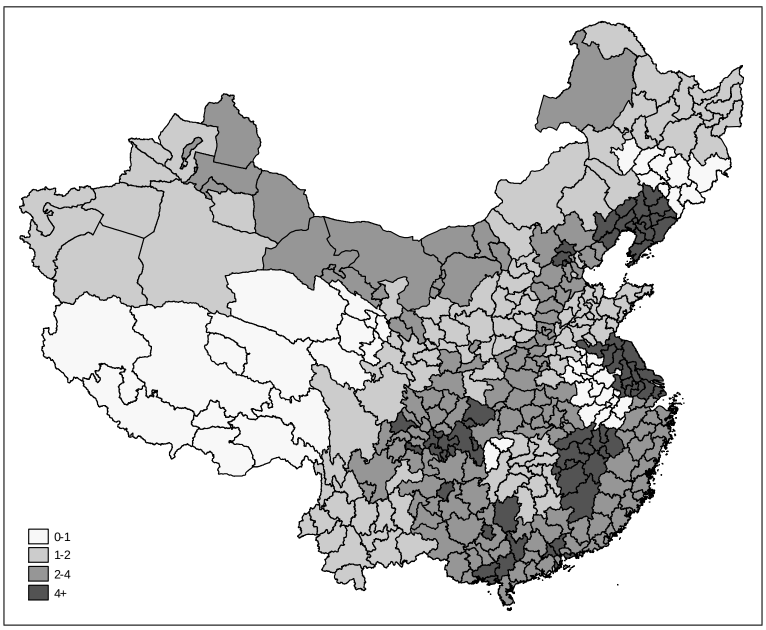
The model consists of 3 decisions listed above. The completed fertility outcomes are in boxes and the intermediate outcomes are in ovals.

Figure 4: Tradeoff between the Total Fertility Rate and the Sex Ratio



Notes: The results are calculated using simulated decisions of parents in China's 2000 census with 3 or fewer children. In order to illustrate the tradeoff between fertility regulations and sex selection decisions, I simulate decisions by subjecting parents to increases or decreases in the fine facing the parents for unauthorized births.

Figure 5: Fine Rates in China



Source: Scharping (2003). Fine measured in years of income. Darker shades correspond to higher penalties. Average fine is calculated for having a 3rd birth among residents of each prefecture using demographic information and the policy rule in the province.

Table 1. Fertility Patterns in China by Sex of Existing Children

		Percent who have another child			Fraction Male (of next birth)		
Parity	Sex Combination	1982	1990	2000	1982	1990	2000
	Overall				0.51	0.52	0.53
1st	None				0.51	0.51	0.52
2nd	One boy	0.72	0.54	0.35	0.51	0.51	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	0.55	0.29	0.16	0.52	0.52	0.53
	Two girls	0.69	0.55	0.46	0.54	0.62	0.70
4th	Three boys	0.41	0.24	0.17	0.49	0.40	0.38
	One girl, two boys	0.36	0.17	0.11	0.51	0.49	0.51
	Two girls, one boy	0.44	0.23	0.14	0.52	0.55	0.58
	Three girls	0.62	0.54	0.50	0.57	0.64	0.73

Source: China Census .10% sample (1982), 1% sample (1990), .10% sample (2000). Women ages 21-40 and their matched chlildren 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. Male Fraction of Births by Fertility Policy in China

		Prior to One Child Policy (China 1982 Census)				Post One Child Policy (China 2000 Census)			
Parity	Sex Combination	1	1.5	2	Minority	1	1.5	2	Minority
1st	None	0.51	0.51	0.51	0.51	0.52	0.52	0.51	0.51
2nd	One girl	0.53	0.52	0.52	0.52	0.65	0.62	0.62	0.58
3rd	Two girls	0.53	0.55	0.50	0.50	0.71	0.70	0.68	0.66
4th	Three girls	0.57	0.59	0.49	0.51	0.73	0.74	0.75	0.66

Source: See Table 1.

Notes: Based on average fertility rates and sex ratios for provinces under the three main fertility regimes in China described in Feng et al. (2005). Mothers under a "1.5" policy rule are generally allowed one additional birth following a first born daughter. Mothers who are non-Han (minority) are granted exceptions to the fertility control policy as well (Scharping 2003). Tables with standard errors available at the author's website.

Table 3. Regression (OLS) Estimates of Fertility Outcomes (LHS) on Fertility Fines (RHS) Following Daughters: China 1982-2000

	Did you have another child? (1=yes)		Among those with another child, was the next birth male? (1=yes)	
	Those with one daughter	Those with two daughters	Those with one daughter	Those with two daughters
Log of Fertility Fine	-0.186***	-0.139***	0.012*	0.031***
	(0.026)	(0.033)	(0.006)	(0.011)
Mother's Education	-0.012***	-0.005***	0.001	0.002
	(0.002)	(0.002)	(0.001)	(0.002)
Farmer	0.287***	0.211***	0.000	-0.014
	(0.020)	(0.020)	(0.007)	(0.014)
Sample Average	0.798	0.663	0.539	0.594
Observations	156,122	74,128	105,804	43,286

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

Source: Matched sample of mothers and children from census taken in 1982, 1990 and 2000 pooled and weighted by probability of being sampled. Sample restricted to mothers ages 35-40.

Notes: The fine is measured in years of household income, taken from Scharping (2003). Fines are zei for children born in a year prior to the One Child Policy (1979). Education is measured in years. The first two regressions examine the partial correlation between the fine for a 2nd/3rd birth and the chance parents have a 2nd/3rd child. The second two regressions are restricted to those who have a 2nd/3rd birth and examine the partial correlation between the fine paid for the 2nd/3rd birth and the chance the birth is male. All specifications include province fixed effects, a fixed-effect for the year of the previous birth, and control variables for the age and years of education of both parents.

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	-0.254***	-0.145***
	(0.06)	(0.04)
Farmer (1 = Yes)	3.742***	1.778***
	(0.48)	(0.35)
Constant	0.979*	0.634*
	(0.54)	(0.35)
Average Predicted Value	1.42	0.86
Panel 2: Parameter Estimates for Second-born and Third-born		
Marginal Value of Second	0.234	0.365
	(0.26)	(0.28)
Marginal Value of Third	-1.579	-0.693
	(1.05)	(1.03)
Panel 3: Parameter Estimates for Costs to Sex Selection		
Distance from a clinic	3.44***	
	(0.58)	
Year==1990	1.08**	
	(0.54)	
Year==1982	1.198	
	(1.15)	
Average Predicted Value in 1982	4.10	
Average Predicted Value in 1990	4.01	
Average Predicted Value in 2000	2.09	
Observations	92,262	
Log Likelihood ($\ln L$)	-202,978	

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

Source: China census .10% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 35-40 with 3 or fewer children. For comparability with the other census samples, one-tenth of the 1990 1% sample is used for estimation of the model.

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. Model is estimated with growth factors allowing sons and daughters to vary by year and policy region (not shown). The coefficients for year and policy region effects are assumed to scale the value of sons (or daughters) by a factor of $\exp(\text{param})$.

Table 5. Male Fraction of Births by Sex of Existing Children in Actual and Simulated Data, China 1982-2000

		Actual Fraction Male (of next birth)			Simulated Fraction Male (of next birth)		
Parity	Sex Combination	1982	1990	2000	1982	1990	2000
	Overall	0.56	0.55	0.56	0.54	0.54	0.56
1st	None	0.55	0.53	0.52	0.53	0.53	0.53
2nd	One boy	0.51	0.51	0.49	0.50	0.50	0.50
	One girl	0.60	0.58	0.62	0.58	0.57	0.61
3rd	Two boys	0.47	0.41	0.39	0.49	0.45	0.41
	Two girls	0.68	0.73	0.81	0.64	0.63	0.76

Source: China census .10% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 35-40 with 3 or fewer children. For comparability with the other census samples, one-tenth of the 1990 1% sample is used for estimation of the model.

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 6. Counterfactual Policy Simulations using the Model

	Fertility Outcomes				Revisions to One Child Policy	Subsidies to Mothers without a Son	
	Sex Ratio	Fertility Rate	Total Births	Missing Girls	ΔBirths / ΔFemale Deficit	Total Subsidy (% of GDP)	Yuan Cost per "Saved Girl"
Panel 1: Comparison of Actual and Simulated Outomces							
Actual Outcomes	1.20	1.76	35,710	4,122			
Baseline Simulation	1.20	1.77	35,990	4,160			
Panel 2: Alternatives to Current Fertility Limits			Δ Total Births	Δ Missing Girls			
Remove "1.5" Child Exception	1.22	1.71	-2,080	765	(2.72)		
Two Child Policy	1.18	2.00	8,447	-545	15.51		
Three Child Policy	1.11	2.46	25,560	-2605	9.81		
Panel 3: Targeted Subsidy to those Without a Son							
Subsidy of 3 months	1.17	1.76	-453	-761		0.35%	27,208
Subsidy of 6 months	1.14	1.74	-971	-1807		0.75%	24,399
Subsidy of 9 months	1.11	1.73	-1,480	-2520		1.19%	27,560
Subsidy of 12 months	1.10	1.72	-1,946	-3,073		1.65%	31,447

Source: China census .10% sample (2000). Mothers ages 35-40 with 3 or fewer children (N=37,301). Total births reported 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 prese 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 wom 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. Matched Mothers and Children (000s) - China, 1982-2000

Statistic	1982	1990	2000
Mothers	106,628	145,207	148,345
Sons	127,921	138,099	121,589
Daughters	121,491	127,009	105,478
Children per Mother	2.339	1.826	1.531
Sex Ratio of Children	1.053	1.087	1.153
Sex Ratio at Birth	1.061	1.085	1.143
Female Deficit (0-18)	0.17%	2.59%	8.39%

Source: China census .10% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 21-40 and their children ages 0-18.

Notes: 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).

Appendix Table 2. Demographic Characteristics and Fine Rates of Mothers Ages 35-40 with 3 or Fewer Children, China 1982-2000

Statistic	1982	1990	2000
Total Fertility Rate	2.46	2.01	1.76
Size of Fine on 2nd births following a Son	0.024	0.600	1.408
Size of Fine on 2nd births following a Daughter	0.019	0.477	1.114
Size of Fine on 3rd births	0.064	1.404	2.938
Years of Education	2.936	3.544	8.391
Farmer (1 = Yes)	0.644	0.636	0.581
Imputed Distance to Fertility Clinic	0.863	0.850	0.609
Observations	17,037	38,403	37,301

Source: China census .10% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 35-40 with 3 or fewer children. For comparability with the other census samples, one-tenth of the 1990 1% sample is used for estimation of the model.

Notes: The fine is measured in years of household income, taken from Scharping (2003). Years of education is calculated from a census question on completed education level. A family is considered to be a farming family if they report working in the agricultural sector. 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.

Appendix Table 3: Parameter Estimates for 3-Child Sex Selection Model, China 1982-2000 Separately

	1982		1990		2000	
	Son	Daughter	Son	Daughter	Son	Daughter
Panel 1: Parameter Estimates for First-born						
Years of Education	-0.117	-0.141	-0.242***	-0.253***	-0.263***	-0.250***
	(0.19)	(0.17)	(0.08)	(0.07)	(0.07)	(0.07)
Farmer (1 = Yes)	1.06	1.01	2.302***	1.959***	2.571***	1.633***
	(1.90)	(1.44)	(0.75)	(0.52)	(0.60)	(0.40)
Constant	1.27	-0.38	1.033	-0.091	2.984***	1.819*
	(2.33)	(2.44)	(0.87)	(0.84)	(0.96)	(0.83)
Average Predicted Value	1.61	-0.14	1.64	0.26	2.27	0.67
Panel 2: Parameter Estimates for Second-born and Third-born						
Marginal Value of Second	1.314	-0.552	0.832	-0.293	0.498	-0.494
	(1.86)	(1.05)	(0.69)	(0.70)	(0.59)	(0.59)
Marginal Value of Third	0.356	-0.781	-0.544	-0.431	-1.595	-1.117
	(2.23)	(2.46)	(1.20)	(1.32)	(1.78)	(1.97)
Panel 3: Parameter Estimates for Costs to Sex Selection						
Imputed Distance from a clinic	-0.46		0.480		2.526*	
	(4.63)		(2.01)		(1.42)	
Constant	4.143		3.543		2.511**	
	(4.63)		(2.31)		(1.25)	
Average Predicted Value	3.74		3.96		4.06	
Observations	17,037		38,403		37,301	
Log Likelihood (ln *L*)	-44,701		-85,198		-72,617	

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

Source: China census .10% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 35-40 with 3 or fewer children. For comparability with the other census samples, one-tenth of the 1990 1% sample is used for estimation of the model.

Appendix Table 4. Comparing Actual and Simulated Fertility Outcomes using 3-Child Model, China 1982-2000

	1982		1990		2000	
Fertility Outcome	Actual	Model	Actual	Model	Actual	Model
Boy	0.055	0.050	0.154	0.147	0.242	0.233
Girl	0.045	0.039	0.108	0.103	0.149	0.140
Boy, Boy	0.101	0.099	0.125	0.128	0.110	0.120
Boy, Girl	0.096	0.100	0.123	0.132	0.113	0.126
Girl, Boy	0.097	0.103	0.149	0.150	0.172	0.169
Girl, Girl	0.048	0.056	0.072	0.079	0.065	0.074
Boy, Boy, Boy	0.072	0.073	0.026	0.028	0.011	0.012
Boy, Boy, Girl	0.081	0.073	0.038	0.034	0.017	0.018
Boy, Girl, Boy	0.083	0.065	0.033	0.029	0.016	0.012
Boy, Girl, Girl	0.061	0.069	0.026	0.028	0.013	0.013
Girl, Boy, Boy	0.082	0.077	0.036	0.032	0.018	0.015
Girl, Boy, Girl	0.063	0.072	0.026	0.031	0.013	0.015
Girl, Girl, Boy	0.078	0.080	0.060	0.050	0.048	0.040
Girl, Girl, Girl	0.037	0.046	0.022	0.029	0.011	0.013
Observations	17,037		38,403		37,301	

Source: China census .10% sample (1982), 1% sample (1990), .10% sample (2000). Mothers ages 35 40 with 3 or fewer children. For comparability with the other census samples, one-tenth of the 1990 1% sample is used for estimation of the model.

Notes: This table represents a comparison between the decisions observed by mothers in China's 198 2000 census samples, and a set of numerical simulations in which mothers are assigned a fertility outcome using a decision rule determined by Maximum Likelihood.

Appendix Table 5. 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	-0.0030	-0.0053	0.0072	0.0114**
	(0.005)	(0.005)	(0.005)	(0.005)
Controls for Regional Characteristics	No	Yes	No	Yes
Observations	345	345	345	345

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

Source: China census .10% sample (2000).

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 eletric 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 who report having lived in the same prefecture 5 years ago. Standard errors are clustered at the province level.

Appendix Table 6. 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), 1% sample (1990), .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 7. 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 8. 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 9. 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) th 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.