# Fertility Choices and Sex Selection in Asia: Analysis and Policy

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**Abstract**

High sex ratios in China and India have historically concerned researchers (Sen 1990) and their recent increase has alarmed policymakers worldwide. This paper identifies sex selection via infanticide and abortion as the principal explantion for the sex ratio distortion, and rules out competing explanations such as biology (Oster 2005) or differential mortality rates. Consistent with recent work (Jha et al. 2006), I find that the sex ratio of first-order births is close to the natural rate and steeply rising following the birth of low-order daughters, indicating that mothers are practicing pre-natal sex selection or immediate infanticide. Sex ratios are found to be higher among those anticipating lower fertility, such as those under stricter government fertility limits. I present a model of a mother's fertility choice when she has access to a sex-selection technology and faces a mandated fertility limit. By exploiting variation in fines levied in China for unsanctioned births, I demonstrate that higher fine regimes discourage fertility but are associated with higher sex ratios among those who choose to have an additional child. I then estimate a structural model of parental preferences using China's 2000 census data that indicates that a son is worth 2.90 years of income more than a daughter, and the premium is highest among less educated mothers and rural families. I conclude with a set of simulations to model the effect on sex ratios and total fertility of a proposed subsidy to families who fail to have a son, and find that such a policy would reduce sex ratios and lower overall fertility.

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# 1 Introduction

When the People's Republic of China was founded in 1949, the country had a population of about 540 million. Only three decades later, its population was more than 800 million. This unprecedented population increase from the 1950s to the early 1970s created a global concern that China was destined for a "Malthusian collapse": unchecked population growth that eventually outstrips growth in the food supply and results in massive famine. Chinese fertility policy was redirected towards limiting fertility, culminating in the One Child Policy in 1979. The family planning program was declared a success by Chinese officials, as fertility fell from six children per mother to its current level of roughly two.

Researchers have also been historically concerned with a second demographic pattern found in China: the unusually high fraction of males in the Chinese population. In 1990, Amartya Sen 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's finding aroused the concern of policymakers and has provoked a wave of research on the topic: where did the "missing girls" go? In recent years, the female deficit has grown. In spite of a general improvement in infant health care in China, the number of male children below the age of 15 exceeds the number of female children by 13 percent. Some caution that the marriage prospects for the next generation of Chinese men are grim if the situation is not corrected.

Today, India is facing a similar dilemma. At current population growth rates, India is projected to overtake China as the world's most populous country by 2045. Decreasing fertility and increased availability of birth control in the last several decades have reduced the total fertility rate from 6 in the early 1950s to 2.73 in 2006, but this progress has been accompanied by a rising sex ratio at birth. While everyone agrees that India will face a crisis of resources if the population continues to grow, the cause of the rising sex ratio and its relationship to contemporary lowered fertility is still a matter of debate.

In this paper, I find that the female deficit observed in China and India among cohorts born in the last four decades is primarily the result of sex-selective abortion and (to a lesser degree) neonatal infanticide. I argue that the increase in the sex ratio (defined as number of boys divided by number of girls) observed in recent natality data in China and India can be attributed to mothers anticipating fewer births but still desiring at least one son. Consistent with recent work (Jha et al. 2006), I find that the sex ratio among first births is close to the natural rate (roughly 1.06, or 51% male) but that the sex ratio rises steeply with birth order and is entirely concentrated among mothers who are seeking a son, ruling out any possible biological explanation for the female deficit at birth (see Figures 1 and 2). I show that following daughters, male births are preceded by longer birth intervals, a finding consistent with parents' practicing sex selective abortion and infanticide. I also rule out other explanations for the female deficit such as differential childhood mortality, hepatitis, foreign adoption of girls, and purposeful exclusion of daughters from census enumeration. The distribution of sex ratios among educated women in Taiwan and India and among those under stricter fertility limits in China is also consistent with the hypothesis that declining fertility is a central factor in the magnitude of the distortion.

In light of evidence that high Asian sex ratios are caused by human decision, I present a structural choice model of parental fertility behavior when parents have a preference for having at least one son and have access to a sex selection technology. By exploiting variation in fines levied in China for unsanctioned births, I demonstrate that higher fine regimes discourage fertility but are associated with higher sex ratios *among* those who choose to have an additional child. I then estimate a structural model of parental preferences using China's 2000 census data that indicates that a son is worth 2.90 years of income more than a daughter, and the premium is highest among less educated mothers and rural families. I also present a set of simulations to model the effect on sex ratios and total fertility of a proposed subsidy to families who fail to have a son, and find that such a policy would reduce sex ratios *and* lower overall fertility.

The paper is organized as follows. Section 2 provides background information regarding China and India's fertility policies and the historical evolution of sex ratios at birth. Section 3 lays out a framework for considering how individual mothers may respond to undesirable sex outcomes when facing a fertility limit. Section 4 presents tables and evidence suggesting that sex preferences are distorting the sex outcome and timing of births at nodes in which a couple has only daughters. In Section 5, 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 6 with a brief discussion of fertility policy options for China and India.

# 2 Background

The two primary and interacting causes of high and increasing sex ratios in China and India are a preference for male children over female children and a national effort to reduce the number of children born to each woman. This section first contextualizes the phenomenon of son preference from a historical perspective and discusses the history and current practice of fertility control in these two countries. I conclude with a brief discussion of the social costs of artificially high sex ratios among Chinese and Indian youths. In both countries, fertility is a primary concern of policymakers and has been the subject of well-deserved scrutiny.

## 2.1 Son Preference - Roots and Proximate Determinants

The importance of sex preferences in fertility planning decisions has long been known. Ben-Porath and Welch (1976) were among the first economists to stress the importance of sex outcomes in fertility decisions and show data documenting the "sex-concern effect" in Bangladesh, Morocco, and the US. Interestingly, in the United States those with at least one boy and one girl are 14% less likely to continue childbearing than those with two boys or two girls (Angrist and Evans 1998). The patterns in China and India are more striking, however, and many argue these patterns are driven by widespread adherence to patriarchal values common in both countries.

Confucian teachings, popular in China, state that familial duties cannot be fully satisfied if the father has no son, and the Confucian structure of duty is quite explicit regarding the secondary role for women: "The perfect woman must obey her parents when a child, her husband when a wife, and her son when a widow."[1] Modern Chinese son preference is partly driven by remnants of this tradition, but is reinforced by a collection of customs that make a son more economically desirable. Chinese culture dictates that sons provide financial support for parents, and in the absence of social insurance, the elderly commonly reside with adult children. The obligation on daughters is weaker, in part because she is thought to be responsible for her husband's parents. The essence of this contrast is captured by a Chinese saying: "A son-in-law may perform one half of the duty of a son, but a daughter-in-law must do twice as much as a daughter."[2] Though many observers hope that the relative scarcity of daughters will reverse the Chinese preference for sons, this may be too optimistic. According to scholars of modern China, parents prefer an unmarried son to a married daughter, because the son will be able to provide for the parents during old age, while the daughter's obligation is to her new family unit.[3]

For parents in India, son preference is manifest both in the cultural legacy and in the economic realities of several states. According to traditional Hindu law, a woman cannot inherit property and so a system of dowries developed to make daughters more attractive to prospective mates. As in China, married women often leave their parent's home or village and join their spouses' families, a practice which affects parental incentives. As one Indian woman in a recent fertility survey described, "There is no point teaching a girl; she marries and goes away."[4] In this context, as in China, there is little reason to believe the increasing shortage of girls will be enough to change parents' attitudes towards daughters.

[1] Kang, H. 2004. p. 3.

[2] http://www.megaessays.com/viewpaper/10184.html

[3] Qian (2006) argues that regional variation in the sex ratio in China can in part be explained by the relative wages of males and females.

[4] Quote from one of 1,221 Indian parents interviewed in a survey covering school facilities in 188 villages in four Indian states for the Public Report on Basic Education (India Today, 1998). Taken from Foster and Rosenzweig (2001).

## 2.2 Fertility Trends and Fertility Control in China and India

Chinese parents have historically favored large families, and following a famine associated with Mao's Great Leap Forward, 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 successive 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 (Wang 2006).

In 1984, the Chinese government instituted a localized fertility policy in which residents of different provinces were subject to different mandated limits (Greenhalgh 1986). Though the one child limit was enforced on urban residents, a set of rural provinces allowed mothers of a daughter to have a single additional birth (a "1.5" child policy) and families in very 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%) and 3 (1%) child policy limit for provinces in very remote areas. The policy also grants exclusions to various groups, including Chinese ethnic minorities and those employed in dangerous occupations.

India's population growth in the past 50 years has also been extraordinary, increasing at more than 20% each decade. Following India's independence from Britain in 1947, infant mortality gradually fell but fertility remained high. By 1980, infant mortality rate had declined to 100 deaths per thousand infants while women continued to have an average of 4.5 births. As a result, year 2000 census data indicate that over 30% of India's 1.1 billion people are below the age of 25. Fertility policy in India is a pressing concern today, and policy must address how fertility patterns vary by region in India as well. In 1996, the total fertility rate was recorded below replacement (2.1) in 9 states, between 2.1 and 3 in 11 states, and over 3.0 in 12 states.

Though India attempted a policy similar to China's in the 1980s, public objection ended these efforts. Today, India has no explicit restriction on fertility, but several rural high-fertility states now offer a set of compelling financial incentives for fertility limitation.[5] These policies have also come under scrutiny, particularly in the case of a state offering landowners a "guns for sterilization incentive" that resulted in the forced sterilization of 5 tenant farmers (Bhatia 2005). Like China, India is finding it difficult to implement a politically viable and effective fertility policy.

## 2.3 Historical Sex Ratios in China and India

In China and India, 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). When fertility was high and infant mortality was low, this pattern was temporarily muted by the large share of mothers who were able to guarantee at least one living son without sex selection. However, the reprieve in the female deficit came at the expense of creating unsustainable population growth. As I will show, the forced reduction in fertility is leading more mothers to engage in sex selection to ensure the birth of at least one son.

In the late 1960s and the 1970s, as the Chinese government promoted its "Two is enough" policy, the sex ratio following first and second-born daughters began to rise. While the extent of prenatal sex selection was limited by the unreliability of traditional methods of identifying sex in utero, the introduction of ultrasound technology greatly facilitated the proliferation 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 for sex selective abortion in these areas.[6] 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

[5] For a useful discussion, see Rao (2004) "From Population Control to Reproductive Health".

[6] http://www.freerepublic.com/focus/f-news/1686210/posts

infanticide.

A parallel literature has documented these problems in India. As in China prior to the One Child Policy, high rates of female mortality in census data appear due to differential care in infancy. During the 1970s, infant care improved and daughters appear to have benefited more than sons, as the female deficit narrowed during this period (Clark 2000). In the 1980s, the female deficit began to increase following the diffusion of ultrasound, but this increase was distributed unequally between northern and southern states. In the 2001 Indian census, the overall sex ratio among those less than 6 years old was 1.08 (as compared with a sex ratio of 1.06 in the absence of human intervention), but the sex ratio in Punjab (a northern state) was 1.26. The diffusion of ultrasound and its impact on Indian sex ratios has gained attention in recent years. Indian policymakers quickly realized the dangers associated with this technology and in 1976 banned the use of ultrasound to determine the sex of a fetus.[7] However, it is widely accepted that doctors and prospective mothers conspire to violate Indian laws and selectively abort daughters. Jha et al. (2006) estimate that 10 million female fetuses have experienced early termination in the past two decades and find that higher educated women are actually more likely to practice sex selection than poorer women.

Similar biomedical advancements have allowed researchers to more closely examine the physiological connections between health and fetal sex. Norberg (2004) finds that married women are 1-2 percentage points more likely than single women to have sons even after controlling for maternal age, education, and other observable features. Oster (2005) proposes that high hepatitis rates in several Asian countries may be responsible for the high sex ratios observed in these countries. As I will later show using microdata from these countries, these theories cannot account for more than a trivial share of the female deficit observed in Asian countries.

[7]Note that abortion in India is still heavily regulated, with abortion only allowed in a limited set of circumstances where the mother is at a health risk or the child is suffering from severe physical or mental abnormalities. Failed contraception is conspicuously absent as a valid reason for choosing to abort a fetus. Arnold, Kishor, and Roy suggest that the number of illegal abortions conducted in India exceed the number of legal abortions (2001).

## 2.4 The Social Cost of Gender Imbalance

High sex ratios are having noticeable effects on the marital choices of young men in other East Asian countries with female deficits. In Korea and Taiwan, where ultrasound became widely available in the early 1980s, many men are marrying foreign-born women. In Taiwan, over a quarter of brides are from mainland China, and poorer men in Korea have found brides in Vietnam and Western Russia. Today, China is poised to experience a similar shift in the marriage prospects of men. Since ultrasound did not become widely available in China until the late 1980s, the cohorts with the largest female deficits are only now about to enter the marriage market. Poston and Glover (2004) estimate that 23 million Chinese boys born between 1978 and 2000 will fail to find Chinese brides. Note that the imbalance in the sex ratio in China was historically mitigated by strong population growth and increasing cohort sizes and the tendency of Chinese men to marry younger women, but slowing birth rates will actually exacerbate this problem in the coming years.

Why is this imbalance in the marriage market a problem for Chinese society? For the women and men who manage to marry, there is no loss generated by gender imbalance, but the men who cannot find a domestic bride must embark on a costly process of finding a partner from a different country, or never marry.[8] Moreover, this process also imposes costs on women, both Chinese women and from other countries in the region. Reports in Vietnam suggest that Chinese men who enter Vietnam for brides often kidnap and mistreat the women, and human rights groups have raised concern that forced prostitution is becoming widespread. Schmidt writes: "With so many prospective grooms and so few eligible women, it seems logical that the status of women might increase, but this has not happened. In fact, quite the opposite has occurred."[9]

Although high sex ratios have the subtle benefit of lowering the net reproductive potential of the population (Cai and Lavely 2005), policymakers in both countries consider the sex ratio distortion a major concern and have begun public campaigns to urge people to value daughters

[8]This is shown in a simple model of the marriage market outlined in the appendix to this paper available at the author's website.

[9]Schmidt (2002) writes: "In one particularly egregious case, a mentally retarded woman was kidnapped and traded to a man for a calf. The man did not provide adequate food and clothing for the woman and she died of exposure."

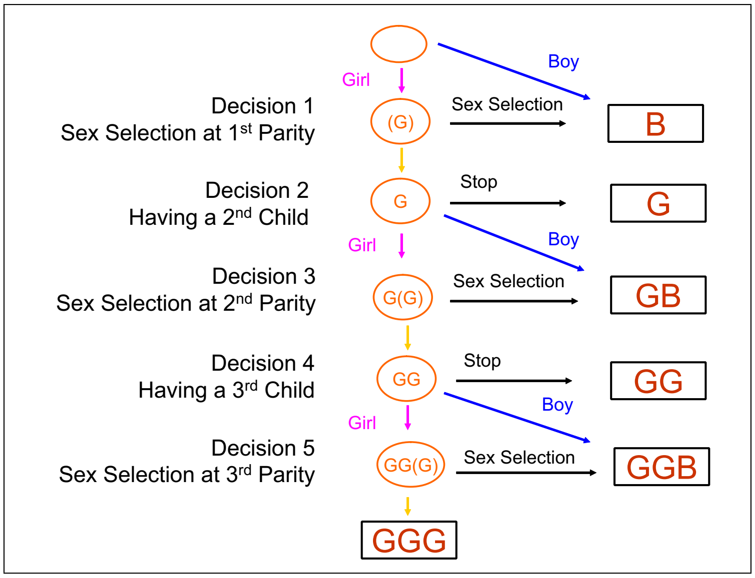
and to discourage doctors from revealing the sex of the fetus. However, a Chinese "Care for girls" campaign and ongoing efforts in India to shame aborters have accomplished little, however, and stricter discouragement of black market ultrasound appears to have only affected the price charged for the service (Zheng 2005). Estimates of the price for a black market ultrasound in rural villages range from 50-300 yuan ($6-$40), an amount that is far too low to dissuade desperate parents (Schmidt 2002).

If the incentives currently being offered to encourage daughters or discourage abortion are too small to affect decision-making, the demand will appear inelastic. However, if the government were to impose a tax or subsidy of appropriate weight, many mothers might reconsider sex selection. In China, fertility controls are enforced with large financial punishments to those having unlicensed births, and the fines present a unique opportunity to identify the relative monetary value of a son. The experience in China is also highly relevant to India, which will need to slow the growth of its own population in the years to come, and understanding the decision process that gives rise to the female deficit is critical for effective design of future fertility policy.

# 3 Theoretical Framework

## 3.1 Theoretical Model of Sex Selection

Suppose prospective parents face a mandated fertility limit of $K^*$. Those who have a son among their first $K^*$ births discontinue childbearing. Among those with only daughters, however, a fraction chooses to have a child of order $K^* + 1$. Suppose that parents are allowed only a single birth and a second birth $K_2$ will require the parents to pay a fine $F_2$. Among those who again fail to have a son, some have a third birth $K_3$ and pay a fine $F_3$. Following this birth, all mothers are forced to stop having children. Mothers, 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 parents who have not yet had a son assign a premium of $\theta$ to




having a boy $B$ rather than a girl $G$, and a girl provides no direct financial value in excess of the cost to raise her. Lastly, assume that the benefits and costs of fertility and sex selection can be completely monetized, and the marginal utility of a dollar of this benefit or cost is equivalent to the marginal utility derived from a dollar spent on consumption $C$.

In this model, mothers execute a sequence of 5 decisions. The parents begin with an initial conception, and know that they face a regime of fines on live births that vary by province. Following each conception the mother can either have an abortion or carry the child to term, and following each live birth they can choose to have another child or quit. Note that while in China these fines are explicit financial penalties, one may also think of the fine as a measure of a mother's opportunity cost of another child in foregone income for women in Taiwan and India.[10]

In the first stage, slightly more than half the mothers will randomly conceive a son ($p_b = .51$) and the parents receive a payoff of $\theta$. A mother carrying a daughter however is faced with two options. She can choose sex selection immediately and end the game with a final outcome of $B$ and a payoff $\theta - A$, or she can carry the daughter to full term and advance to the subsequent decision node $G$. In the second stage, mothers who have yet to have a son can choose not to have

[10]Ebenstein (2006) finds that mothers in Taiwan who have an additional child due to sex preference on average forego 1.3 years of labor earnings.

any more children, avoid all fines and the game ends with a zero payoff. For those who choose to have another child, slightly more than half conceive a son and end the game with $GB$ and a payoff of $\theta - F_2$. A mother who again conceives a daughter is faced with two options. She can choose sex selection immediately and end the game with a final outcome of $GB$ and a payoff $\theta - F_2 - A$, or she can carry the daughter to full term and advance to the subsequent decision node $GG$.[11]

In the fourth decision node, mothers with $GG$ can either end the game immediately with a payoff $-F_2$ or have another child. For those who choose to have another child slightly more than half the mothers conceive a son and end the game with $GGB$ and a payoff of $\theta - F_2 - F_3$. Mothers who conceive a daughter enter the fifth and final decision node, where she can choose sex selection and end the game with a final outcome of $GGB$ and a payoff $\theta - F_2 - F_3 - A$, or she can carry the daughter to full term and end the game with a payoff $-F_2 - F_3$.[12]

## 3.2 Econometric Model of Sex Selection

In this model, a mother is assumed to choose the option at each decision node that maximizes her payoff today and is optimal given her anticipated choices tomorrow. She is unable, however, to perfectly anticipate future decisions due to stochastic factors that change her 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 (Scharping 2003), they may appear stochastic to the individual. The cost of sex selection $A$ also has a random element, since mothers cannot know in advance precisely how many conceptions and abortions will be required to conceive a son. As such, a model of a mother's choice $j$ in each period facing uncertainty in future periods is presented below.

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

[11]Note that in the 2000 China census, female fetuses aborted by women at the 2nd parity represent 83% of the female deficit observed in the census among children ages 0-18.

[12]Assigning no density to more than three children matches the empirical evidence, and the nature of the policy. Scharping (2003) writes "Third births were subject to special conditions, and higher order births were strictly forbidden."

$$\Pr(D=1) = \Pr(V_{D=1} > V_{D=0}) = \Pr(V^*_{D=1} - V^*_{D=0} > \epsilon_{D=1} - \epsilon_{D=0}) \tag{2}$$

$$\text{Assume } \epsilon_{D_j} \sim EV(1)\ iid \tag{3}$$

Mothers observe an anticipated payoff to each option $V^*_{D_j}$, but in the period in which she makes the decision $D_j$ she observes an unanticipated "shock" $\epsilon_{D_j}$ that either increases or decreases the attractiveness of option $j$. 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.[13] The extreme value distribution provides slightly fatter than normal tails, allowing for more aberrant behavior than a normally distributed shock.[14] For the fifth and final decision node in the model, the individual's decision-making problem becomes a single period maximization.

$$V^5_{S_3=1} = \theta_i - A_i + \epsilon^5_{S_3=1} \tag{4}$$

$$V^5_{S_3=0} = 0 + \epsilon^5_{S_3=0} \tag{5}$$

$$\Pr(S_3 = 1) = \frac{e^{\theta_i - A_i}}{1 + e^{\theta_i - A_i}} \tag{6}$$

In this final period, mothers perform a static optimization over the choice to abort a third daughter, $S_3$, observing perfectly the payoffs of both options. When a mother's benefit of a son $\theta_i$ is large relative to her cost of sex selection $A_i$, she is increasingly likely to choose sex selection. Mothers have equal probability of aborting or carrying to term when $\theta_i = A_i$, and the probability of aborting is higher when factors increase the value of a son (higher $\theta_i$), or when technology lowers the price of sex-selection (lower $A_i$).

$$V^4_{K_3=1} = .51\theta_i - F_3 + .49E(V_5) + \epsilon^4_{K_3=1} \tag{7}$$

[13] 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 estimated by the maximum likelihood routine.

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

$$V^3_{K_2=0} = 0 + \epsilon^4_{K_3=0} \tag{8}$$

$$\begin{aligned}
\Pr(K_3 &= 1) = \frac{e^{.51\theta_i - F_3 + .49E(V_5)}}{1 + e^{.51\theta_i - F_3 + .49E(V_5)}} && (9)\\
E(V_5) &= E[\max(\theta_i - A_i + \epsilon^5_{S_3=1}, \epsilon^5_{S_3=0})] && (10)\\
&= \tau\{\gamma + \log(1 + \exp[\frac{\theta_i - A_i}{\tau}])\} && (11)
\end{aligned}$$

The conditions determining the choice at the next-to-last decision node to have a third child, $K_3$, indicate that the likelihood of having a third child is higher when the value of a son is large relative to the anticipated fine, and when the mother has a higher value of $\theta_i - A_i$ (the abortion option) and therefore anticipates a higher payoff in the fifth stage ($V_5$). Indeed, for mothers who are extremely likely to abort a female conception, the decision to have another child is determined by evaluating $\theta_i - F_3 - .49A_i$, which can be seen by substituting $\theta_i - A_i$ for $E(V_4)$ in equation (9). When the value of a son exceeds the value of the fine and the anticipated abortion costs, parents will choose to have a third birth $K_3$. Prior to reaching the third decision, however, mothers in this model are able to observe the sex of their second conception.

$$V^3_{S_2=1} = \theta_i - A_i + \epsilon^3_{S_2=1} \tag{12}$$

$$V^3_{S_2=0} = E(V_4) + \epsilon^3_{S_2=1} \tag{13}$$

$$\begin{aligned}
\Pr(S_2 &= 1) = \frac{e^{\theta_i - A_i - E(V_4)}}{1 + e^{\theta_i - A_i - E(V_4)}} && (14)\\
E(V_4) &= \tau\{\gamma + \log(1 + \exp[\frac{.51\theta_i - F_3 + .49E(V_5)}{\tau}])\} && (15)
\end{aligned}$$

As in the final round, the probability of aborting at the third decision node will be determined by the difference between the benefit of a son and the cost of abortion. One element to notice in the model is that the decision to abort a second parity daughter is positively related to the fine for third births. Note that a mother aborts when the payoff $\theta_i - A_i$ is greater than the alternative, which is to wait. For mothers who are planning to make sure that the last birth is a son, the decision to have an abortion at the second stage of the model is defined entirely in terms of the fine $F_3$ relative to the cost of abortion $A_i$. This can be seen by substituting $\theta_i - \ F_3 - .49A_i$ for $E(V_4)$ in equation (14), which shows that the mother's payoff to aborting minus the payoff of waiting is $F_3 - .49A_i$. Intuitively, if the cost of abortion is less than half the anticipated fine, parents are better served by avoiding the fine and aborting second-parity female conceptions until a son is born. In the second stage, parents have to choose whether to have an additional child $K_2$.

$$V^2_{K_2=1} = .51\theta_i - F_2 + .49E(V_3) + \epsilon^2_{S_2=1} \tag{16}$$

$$V^2_{K_2=0} = 0 + \epsilon^2_{K_2=0} \tag{17}$$

$$\begin{aligned} \Pr(K_2 &= 1) = \frac{e^{.51\theta_i - F_2 + .49E(V_3)}}{1 + e^{.51\theta_i - F_2 + .49E(V_3)}} && (18) \\ E(V_3) &= \tau\{\gamma + \log(\exp[\frac{E(V_4)}{\tau}] + \exp[\frac{\theta_i - A_i}{\tau}])\} && (19) \end{aligned}$$

In the initial stage, parents carrying a daughter have to choose whether to practice sex selection at the first parity $S_1$, or advance to the second stage of the model.

$$V^1_{S_1=1} = \theta_i - A_i + \epsilon^1_{S_1=1} \tag{20}$$

$$V^1_{S_1=0} = E(V_2) + \epsilon^1_{S_1=1} \tag{21}$$

$$\begin{aligned} \Pr(S_1 &= 1) = \frac{e^{\theta_i - A_i - E(V_2)}}{1 + e^{\theta_i - A_i - E(V_2)}} && (22) \\ E(V_2) &= \tau\{\gamma + \log(1 + \exp[\frac{.51\theta_i - F_2 + .49E(V_3)}{\tau}])\} && (23) \end{aligned}$$

The likelihood of reaching each sex outcome can be written in terms of the five choice probabilities, which are each written in terms of $\theta_i$ and $A_i$ and the regime of fines faced by each mother. Using these probabilities, I can estimate $\theta_i$ and $A_i$, and recover the premium to having a son, $\overline{\theta}$, as well as the average cost of sex selection, $\overline{A}$. I additionally assume that $\theta_i$ and $A_i$ are each a function of mothers' observable characteristics. $\theta_i$ is modeled as a function of mother's education, whether the family is engaged in farming, and whether the family lives in a multi-story dwelling. $A_i$ is a function of the travel time to the nearest fertility clinic and is allowed to take on a different value for the three abortion decisions, to allow flexibility and account for a different willingness to abort a first, second, or third daughter.

$$\theta_i = \beta_1 + \beta_2 Educ_i + \beta_3 Farmer_i + \beta_4 Highrise_i \tag{24}$$

$$A_i = \beta_5 Clinic_i + \beta_6(S_1) + \beta_7(S_2) + \beta_8(S_3) \tag{25}$$

# 4 Accounting for the "Missing Girls"

## 4.1 Data

The China, Taiwan and United States census samples contain basic demographic information for every man, woman and child surveyed.[15] Since there is no census question that matches mothers to children, I infer the relationship using the census question that identifies each household member's relationship to the head.[16] The census has no information for children no longer living at home, so I restrict the sample to mothers and children who are most likely to be living in the same household. The sample comprises all married women 21-40 who are successfully matched to at least one child. The matching algorithm matches over 90% of children to a mother and the sex ratio among matched children is almost identical to the sex ratio for the cohort as a whole, suggesting that unmatched children are not driving the results found in the matched sample used for this analysis.

[15] Sample size of the China census data: 1982 (1,002,691) 1990 (11,194,837) 2000 (1,180,111). Sample size of the Taiwan Population and Housing Census: 1980 (18,029,798) 1990 (20,003,405) 2000 (22,300,929). India data provided by the Demographic Health and Fertility Survey. Sample sizes of the data: 1992 (89,777) 1998 (79,967). Sample size of the United States PUMS: 1980 (11,343,120) 1990 (12,501,046) 2000 (14,081,466).

[16] The IPUMS-Minnesota matching rules for assigning the most probable child to mother are used for all data sets. Information on the IPUMS algorithm is available at http://www.ipums.umn.edu.

In lieu of Indian census data, I report tabulations of India's Demographic and Health Surveys (1992, 1998), which have large samples and contain retrospective fertility information for every birth in a respondent's life. Summary statistics for the samples for China, India, Taiwan, and the United States are shown in Table 1.

## 4.2 Sources of the Female Deficit

The key findings of this paper are motivated by the results in Tables 2 and 3. For the Asian countries, Table 2 shows a close correspondence between the number of living daughters and the male fraction of subsequent births. The high overall sex ratios for China and India are primarily caused by especially high sex ratios following daughters, with no distortion observed among first-born children.[17] Sons represent over 60% of births to mothers with 1 daughter, and over 70% of births to mothers with 2 daughters. Among parents in India, a similar but less pronounced bias is observed. Mothers of two daughters have a 55% chance of having a male third child. The results for Asian countries with son preference are all the more striking when compared to similar calculations for the United States. Sex selection is rare in the US, and so the US census data represent a reference point for what one would observe in a population without behavioral distortion. The US data shown in Table 2 suggest that in the absence of sex selection, mothers of daughters are more likely to have a *daughter*.[18] This finding is consistent with an existing biological literature that suggests an individual couple may have a sex ratio that is different from

[17]Researchers have cautioned that Chinese census data following stricter enforcement of the One Child Policy may not accurately reflect the number of females in the population. Mothers who give birth to a daughter and subsequently give birth to a son may choose to "hide" the earlier female birth in census responses. Bannister (2004) finds that the deficit of daughters is real: "...the high sex ratios in PRC (People's Republic of China) demographic data are approximately true, not merely an artifact of faulty data." Cai and Lavely (2005) confirm this finding, suggesting that 71% of the "missing" girls in the 1990 census are not enumerated in the 2000 census. Most experts for China suggest that girls are registered when they are enrolled in school (age 7), and the problem of unregistered births is less severe among girls age 6 or older, and will have a smaller effect on the results presented here using living children observed in the matched sample.

[18]In order to assess the biological impact of having daughters on the chance of having a son, I perform a regression using data from the United States in which the outcome variable is a male birth (among those who have a child) and the dependent variable is the number of female births observed. Covariates are included to demonstrate that this phenomenon exists even when one controls for the mother's education, age and the mother's age at the time of her first birth. All point estimates are highly statistically significant. Tables available from the author upon request.

the overall sex ratio observed in nature (Welch 1974).

In Table 3, I show the large impact of sex preference on parental stopping probability, with mothers in Asian countries more likely to have another birth following daughters. The high share of mothers having children following daughters, in combination with the high sex ratios at these parities, is clearly responsible for the high overall sex ratio in China and India. In the 2000 China census, mothers who have not yet had a son are far more likely to have another child, with mothers of two daughters being nearly three times as likely to have a third child as mothers of two sons (46% versus 18%). In India, less stringent fertility regulations allow a larger share of mothers to have a third child, but those without a son are 14 percent more likely to have another child than those with two sons. Since mothers in both China and India are less likely to have another child following sons, the high sex ratios following daughters have a pronounced impact on the overall sex ratio and explain the high overall sex ratio at birth despite the lack of sex selection at the first parity.

In Table 2, the recent survey data for China indicate that mothers with sons may also practice sex selection, to ensure the birth of a daughter. Mothers with two sons who have a third child have a 61% chance of having a daughter. Zeng et al. (1993) find that aborted fetuses for mothers of sons are disproportionately male, and this is consistent with qualitative evidence that Chinese parents prefer a daughter following sons. Greenhalgh (1993) 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. Others suggest that mothers in China prefer at least one daughter to help the mother with household chores.[19] The other known cause is the adoption of unwanted girls by Chinese families with no daughters.

While published figures indicate that only 10,000 adoptions occur per year in China, some have estimated that as many as 500,000 adoptions occur when one includes informal adoptions (Johnson 1993). Though adoption within China is common, external migration is much less common and cannot explain these results. Recipient countries document that fewer than 10,000 Chi-

[19]Fertility surveys in Taiwan confirm this result (Sun, Lin and Freedman 1998).

nese infants are sent abroad annually, and while 95% of those adopted are girls, this represents only a negligible share of the missing girls.[20] Although I cannot distinguish sex selection from within-China adoption, the practice should not affect the paper's core result regarding the female deficit associated with sex selection, since the adopting family will enumerate the daughter. In Taiwan and India, adoption is less common (presumably owing to no legal restriction on fertility) and the sex ratio following boys is only slightly lower than the natural rate. For China, however, Table 2 should be interpreted as the combined impact of female conceptions terminated and unwanted daughters adopted by a different family.

In Table 4, I attempt to account for the overall female deficit by examining the share of missing girls (or boys) following each observed sex combination. Using a baseline estimate that the natural sex ratio at birth is 1.059 (implying a natural share of male births of 51.4%), I can estimate the number of missing girls at each parity.[21] The results indicate that the female deficit observed in aggregate natality data is composed of a large female deficit following daughters, and a smaller female surplus following sons that slightly mitigates the deficit following daughters. Prenatal selection and infanticide can account for a female deficit of 11% of total matched births in China's 2000 census and a deficit of 6.2% in India's 1998 fertility survey.[22] In earlier East Asia census data (1982 China and 1980 Taiwan), I find that sex selection is less common and the net female deficit is small relative to total births. However, the pattern of high sex ratios at birth following sons and low sex ratios following daughters suggests the presence of human manipulation even in this earlier period. Likewise, the results for India's earlier survey suggest that Indian mothers practiced sex selection prior to the diffusion of ultrasound. In India, family resource allocation

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

[21] Banister (2004) writes: "In Caucasian and Asian populations where no prenatal sex-selection is practiced, the SRB is in the narrow range 105.0-107.0. For example, the annual recorded SRB in Japan during 1980-2000 was 105.2-106.0." I choose 1.059 as the natural sex ratio at birth in accordance with Coale (1991).

[22] These calculations are based on the matched sample of children and mothers aged 21-40. Others have used responses in retrospective fertility surveys and report higher baseline estimates for the female deficit at birth in China (e.g., Coale and Banister 1994). Differences between the methods include sampling variability, under-reporting of infant mortality, or possible omission of female births in fertility surveys. The analysis here is aimed at addressing the patterns in the sex ratio among mothers observed with their children, and as such may differ slightly from estimates presented elsewhere.

decisions may have allowed a disproportionate share of sons to survive and left all daughters (even those first-born) at a disadvantage relative to sons. As infant mortality improved, females appear to have increased their survival prospects at the first parity but are increasingly missing at higher parities following daughters.

When the missing girls are identified by parity, the rising sex ratios following daughters are almost entirely responsible for China's growing imbalance. Table 4 shows that in China, 83% of the missing girls in China's 2000 census can be explained by the distorted sex ratio among mothers having their second child following a daughter. This single decision accounts for 8 million of the 9 million missing girls in these data. While higher order births are even more distorted, they are less common, and thus the bulk of the increase in China's sex ratio is explained by childbearing behavior following a single daughter. Ironically, the "1.5 children" policy in China discourages higher order births following sons more than births following daughters, and this has the perverse effect of increasing fertility at parities with higher expected sex ratios and decreasing fertility at parities with lower expected sex ratios.

## 4.3 Identifying Sex-Selective Fertility

The biological connection between sex preferences and actual sex outcomes has captured the interest of both demographers and biologists. Trivers and Willard (1973) posited that women will be more likely to conceive a female under adverse environmental conditions, since males face stiffer competition in mating from other males. Norberg (2004), in a recent attempt to test this hypothesis, finds that married women are 1-2 percentage points more likely than single women to have sons even after controlling for maternal age, education, and other observable features. Oster (2005) attempts to incorporate an existing medical literature indicating that carriers of hepatitis exhibit sex ratios between 1.40 and 1.60 in cross-country estimates and 1.96 in a subsample of Alaskan Natives, before the introduction of the hepatitis vaccine in 1984. Oster suggests that high infection rates of hepatitis among cohorts may account for up to 75% of the missing girls in China, focusing on the 1982 and 1990 birth cohorts.

Yet, the data suggest otherwise. Biology cannot explain the distortion to the sex ratio observed in data on China and India for cohorts born since 1964. If hepatitis incidence did explain the high sex ratios observed in the earlier Chinese and Indian birth cohorts, as Oster suggests, one would observe a distortion to first births for the infected cohorts (Das Gupta 2006)—and that does not exist. In Figures 1 and 2, I present a graphical version of Table 2 which shows that the sex ratio among first-born children in China and India is close to the natural rate for the entire period in question, but rises steeply following daughters, precluding any explanation that does not account for this pattern. It is also significant that in China and India, hepatitis carriers generally contract the disease at birth, rather than via sexual contact. As such, hepatitis would be expected to affect the sex ratio at each parity, but the matched sample of mothers and children indicates that the entire distortion is found *following* daughters, whereas the sex ratio of first births is close to that found in the United States. Lin and Luoh (2006) analyze a large sample of Taiwanese births and find that hepatitis has only a small impact on the sex ratio in the sample: mothers whose hepatitis status is positive are slightly more likely to have a son (51.91% versus 52.15%) and find that this difference is robust across birth orders. In combination with evidence that only higher order sex ratios are distorted, hepatitis cannot explain anything more than a trivial share of the female deficit.

Another difficulty for the hepatitis explanation is that even following the introduction of the hepatitis vaccination, sex ratios continued to climb in China. Equally incongruous with the hepatitis hypothesis is the fact that minority groups in China tend to have higher hepatitis carrier rates (particularly in several remote areas, for example Tibet[23] and Xinjiang), but lower sex ratios at birth, possibly due to lower rates of son preference and weaker restrictions on fertility.[24] If hepatitis were responsible for the high Chinese sex ratio, these mothers would be expected to have a *higher* sex ratios at birth, further weakening the case for the role of hepatitis in this case. The evidence instead suggests a spurious correlation between son preference and hepatitis, perhaps driven by provinces in China such as Guangdong, which has the highest hepatitis carrier rate in

[23] http://www.usembassy-china.org.cn/sandt/tib-health.htm.

[24] http://www.findarticles.com/p/articles/mi_m0PCG/is_1_21/ai_n6155263/pg_9

the country (estimated at 75%[25]), a long historical tradition of son preference, and a high sex ratio among births following daughters.[26]

Maternal stress and sociobiological explanations also appear unlikely to explain the observed pattern of sex ratios following female births. While Norberg finds a 1-2 percentage point effect of maternal condition on the sex ratio, in Chinese census data the impact of having not yet had a son on the chance the birth is male is more than fifteen percentage points, controlling for characteristics of both parents.[27] Also, if mothers without a son experienced increased "stress" due to their situation, the sociobiology literature suggests that this would decrease the sex ratio at subsequent births. Both the direction and the anticipated magnitude of a sociobiological explanation are inconsistent with the observed patterns in sex ratios. In fact, many argue that sex ratios naturally fall with birth order, making the parity-dependent sex ratios observed in East Asia all the more likely to be the product of human choice.

In Table 5, I present evidence in support of an auxiliary prediction of the sex selection hypothesis. If sex selection is responsible for the distorted sex ratios following girls, birth intervals should be distorted for women who plausibly chose to abort a female fetus. Specifically, there should be a longer delay between an initial birth and a subsequent male birth than a subsequent female birth, due to the fact that a child born following an abortion should be born approximately 30 weeks later than a child born on a first attempt.[28] The expected interval distortion associated with infanticide is even larger, since ultrasound is available less than five months into pregnancy. Since boys are more likely to be preceded by a sex-selection induced delay, on average sons will be preceded by a longer birth interval than daughters. Consistent with this prediction, in the 1990 census data, following two daughters the share of mothers who have a son is 62% and male births arrive .09 years later than female births. In the 2000 census data, the percentage male for these

[25] http://www.travmed.com/maps/country.epl?c=China

[26] Author's calculation, available from website. The male fraction of first births in Guangdong is 52.9%, but the male fraction of second births following a daughter is 59.3%.

[27] Results of regressions available from author's website. Covariates include mother's age, mother's education, father's age, and father's education.

[28] A sex-identification procedure can only be administered roughly 20 weeks subsequent to conception, and a reasonable estimate of the time to re-conceive following abortion is 10 weeks. http://pregnancy.about.com/cs/gettingpregnant/l/blgettingpreg.htm.

mothers is 70%, and sons arrive .3 years later than daughters. Similar results are evident in the data for India and Taiwan, and a reasonable correspondence is observed between the lateness of male births and the share of births which are presumed to follow sex selection. These findings are strong evidence that the high sex ratios observed are the product of human decision. There exists no biological explanation that can account for these extended birth intervals preceding the desired sex.

### 4.4 Sex Ratios and Expected Fertility

As previously outlined, mothers in China who exceed their fertility limit are forced to pay a fine and are subject to a variety of other monetary punishments, including the seizure of property and forced dismissal from government employment. There are four fertility limits for four different categories of mothers. Residents of urban provinces are subject to the one child limit; rural dwellers are allowed a second child if the first child is a daughter (resulting in an average of 1.5 children per mother, the "1.5 child" policy); residents in autonomous regions are generally allowed a second birth; and ethnic minorities are subject to weaker regulations in almost all provinces (Feng et al. 2006). In Table 6, which stratifies births by mothers' fertility limit category and parity, one observes that in the 2000 census data mothers are more likely to have a son once they face a fine for childbearing. For example, at the first birth mothers facing different fertility policies have similar sex ratios at birth, but following one daughter, mothers facing the One Child Policy are 3 percentage points more likely to have a son than those facing less strict fertility limits. Following two daughters, mothers under the One Child Policy and mothers under the "1.5 child" policy are 2 and 1 percentage points more likely to have a son than mothers under the two child policy, respectively. In comparison, in the 1982 census data, which captures births prior to the implementation of the One Child Policy in 1979, mothers in these different categories had similar sex ratios at each parity. For mothers whose peak childbearing years were under the One Child Policy (2000 census data), at each parity those under the strictest fertility control are the most likely to have a son, which suggests a direct role for fertility control in the rising sex ratio at birth.

In both India and Taiwan, mothers face no mandated fertility limit but are choosing to have fewer children, due to many causes related to economic development. In lieu of fertility policy categories, Table 7 compares the sex ratio following daughters for mothers of different education levels. Educated Indian and Taiwanese women prefer fewer children, which is thought to reflect higher opportunity costs of childbearing in the labor market, and taste for child quality rather than quantity. In both countries, mothers with more education appear *more* likely to have a son than those less educated. More affluent women presumably have better access to sex selection technology, but these women are also anticipating fewer births. As such, an explanation that anticipated fertility limits play a role in sex selection decisions also explains this pattern well.

# 5 Structural Estimation and Policy Simulation

## 5.1 Data

The Chinese census of 2000 provides a unique opportunity to assess the responsiveness of fertility decisions to mandated fertility limits, since the peak fertility years for mothers in the sample are for the years following the introduction of China's One Child Policy in 1979. In order to focus on mothers with completed fertility, the sample is restricted to women aged 33-42. China's fertility policy imposes a minimum age for a woman to marry (between 20 and 23 years of age, depending on province), and out-of-wedlock pregnancies are generally subject to a forced abortion under the policy, so children are unlikely to have already left the home for mothers less than 43 years old. Following their peak fertility years women are often compelled to undergo sterilization, limiting pregnancies beyond this window of fertility, and so it is unlikely for mothers to have a child beyond the age of 32. In order to estimate the model of sex selection, I restrict the sample to those who have completed fertility of either (B, G, BB, BG, GB, GG, GGB, and GGG). Since fertility decisions following a male birth are not modeled, mothers who have a first-born son but choose to have another child (BG, BB) are included in the category of completed fertility of B. As discussed earlier, fertility is quite low after a son is born and fourth births are extremely rare, so this subsample accounts for 90% of the "missing girls" among these cohorts.[29]

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. Scharping reports that statistical figures for birth-control fines had been a well-guarded state secret until 1996, but an auditing report released this year on governmental spending on family planning revealed several measures of the aggregate levels of collections as well as regional variation in fine rates. Fertility fines are collected as either regular deductions from the incomes of both spouses or as a lump-sum fee, but were almost universally levied as a share of the family's annual income. A standard fine in rural areas required violators to receive 10% wage deductions for 14 years for each unauthorized birth.

Fertility fines in China, as well as other punishments for excess births, vary by observable characteristics of the parents. Feng (2006) describes how factors such as having already had a son, living in a particular province, or the year of the birth all have an impact on the likelihood that the birth would be "authorized" and thus subject to a smaller punishment. Families with more than one child in cities were often responsible for "social support fees" in addition to the fines, and forced to pay more for education, health care, and other state-sponsored services, implying a higher total fine. Scharping also describes in detail a system in which many provinces instituted modest fines for second births and much larger fines for third births. Families engaged in farming were generally given a permit for a second child, but permits for third births were less common and were often associated with fees in lieu of a fertility fine. The code used to calculate the fines facing each mother, as well the regional fine rates for the observed time period, are available at the author's website.[30]

A complicated system of exemptions (outlined in Feng et al. (2006)) granted parents exemptions from fertility fines if either parent was employed in a dangerous occupation (e.g. underground mining) or if an existing child was handicapped. These and other exceptions to the policy

[29] A comparison of the overall sample and the restricted sample is available at the author's website.

[30] Parents with a second child are also denied a "One Child Bonus" that was roughly 60 yuan per year in urban areas and a smaller amount in rural areas. The bonus is ignored for this analysis since its value was generally small relative to the fertility fines for the period in question (Scharping 2003).

are not observable in census data, however, and the fines used to estimate the model represent an approximation of the incentives facing parents in the census sample. Scharping also reports that fines are imperfectly enforced: birth planning commissions collected nearly 21.40 billion yuan in fines between 1985 and 1993 (relative to annual GDP of roughly 2 trillion yuan), and a crude tabulation of fertility patterns and average peasant income of roughly 900 yuan for this period implies that only half of the unauthorized births were fined. I also cannot observe the importance of other financial punishments for excess fertility, such as housing demolition or confiscation of property. In spite of these data limitations, however, the enforcement of fertility regulations varies significantly by characteristics that are observable in census data (year of the birth, location of the birth, and parents' ethnicity). The analysis presented here should be thought of as accurate to a scale that adjusts for the actual incidence of enforcement and the financial value of other punishments. The mean characteristics of mothers used for model estimation are reported in Table 9.

## 5.2 The Average Effect of Fertility Fines on Fertility Outcomes

In order to assess the relevance of the fertility fines relative to other factors, I report the reduced form relationship between fertility and fines in Table 9. I estimate the impact of the fine on the chance a mother has a birth following either one or two daughters, and on the chance these births are male, using all mothers and births in the 1990 and 2000 China census samples between 1979 and 2000. The results of ordinary least squares regression indicate that parents of daughters subject to higher fine regimes are less likely to have an additional child but are more likely to have a son if they choose to have an additional child. Increasing the fertility fine by a year of income lowers the chance of a second and third child by 28 and 24 percentage points, respectively. The fine also raises the chance that the next child will be male by 1.4 and 1.2 percentage points, respectively.

The results are all reported controlling for age and education of the parents, a dummy for whether the family is employed in the agricultural sector, and a time-trend variable. Farmers appear more likely to have a son at any parity, possibly due to a higher valuation of a son. The coefficient on child's year of birth indicates that the sex ratio is rising in recent years, even controlling for observable characteristics of the parents and the published fine rates. This is due in part to improving sex selection technology, but also to increasingly stringent enforcement of the fines. As reported by Scharping, "In recent years sanctions have become increasingly tougher, with nearly all provinces raising regular wage deductions...some have begun to fine non-contraception, even if this has not yet led to pregnancy or the birth of an extra child."[31] The regression results also suggest that higher fine regimes are associated with lower fertility and higher sex ratios, even controlling for the characteristics of the parents and other important factors.

Limitations in the reduced form analysis include the inability to accurately account for increases in fertility fines and stricter enforcement of fertility policies during the late 1990s. Although increases in fines during the 1980s and 1990s can be identified via changes in stipulated fines, published fine rates fail to capture the increasingly strict enforcement of punishments described by Scharping above. While structural modeling cannot capture unobservable changes in enforcement, the data used to estimate the structural model below is for mothers aged 33-42 in the 2000 census, whose fertility window preceded these unobserved changes.

## 5.3 Identification of the MLE Model

I estimate the structural model using Maximum Likelihood Estimation (MLE), which chooses the set of parameters ($\theta_i$, $A_i$) that best replicates mothers' observed choices given the decision rules outlined above. Since the probability of each decision can be expressed entirely in terms of a mother's $\theta_i$, and $A_i$, the estimation strategy chooses the most likely values for these parameters given the frequencies of each decision observed in the data. Son preference is modeled as a linear combination of a mother's education, whether she is in a family employed in the agricultural sector, and whether the family lives in a multi-story dwelling.

The model is identified by exogenous variation in fines administered in China, with the highest fines imposed on residents in areas closest to China's coastline and lower fine regimes in autonomous zones under looser administration by the central government. While fine schemes in

[31] Scharping (2003). p.137.

China are endogenous to one's province of residence and thus to provincial tastes for sons, it is not easy for individuals to move from their province of birth due to strict regulations on living outside of one's work zone (*hukou*).[32]

In particular, workers in rural areas have some flexibility in moving to urban areas, but are restricted in their mobility between rural areas, making it difficult for individuals to relocate to provinces with weaker fertility restrictions. Most scholars also believe that fertility during the window would have been higher in each of these regions if not for fertility control, and so the fines are most likely a binding constraint for the optimal behavior of mothers.

One might be concerned that provincial fine regimes are correlated with pre-existing patterns of son preference; that is, provinces with high son preference are less likely to enact strict fertility regulations and high fertility fines. While this endogeneity would bias estimates of the value of a son downward, it is unlikely that this problem exists in the data. The results cited in Table 6 of the previous section show that sex ratios of first-born children are similar in different regions, but appear to rise at the parity where the parent is most likely to be forced to pay a fine. If the fine were only correlated with regional tastes for sons, the observed sex ratio would be higher at all birth parities, but a difference in sex ratios is only observed for unauthorized births. Among mothers having a second or third child under the One Child Policy, sex ratios are highest even though son preference in these urban areas is presumably lowest. This suggests that 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.

## 5.4 Results of the Structural Estimation

Table 10 reports 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. For each policy regime, there is a close correspondence between the distribution of actual fertility outcomes and those predicted by a simulation of agents

[32] See Li and Zhang (2006) for more information regarding fertility fines.

using the probability rules specified by the likelihood function. 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.[33]

In Table 11, I present the coefficients on the covariates of son preference and abortion cost by policy regime. The son preference parameter $\theta_i$ is decreasing in mother's education and is higher for households employed in the agricultural sector, and the coefficients are statistically significant. These results imply that more-educated parents might be less dependent on sons as a source of old age support, and that more-educated mothers might be less influenced by Confucian traditions than their less-educated counterparts. For farmers, a higher $\theta_i$ might reflect their increased need for sons to work on the farm. The coefficient on living in a high-rise building is negative, possibly reflecting a lower value placed on sons by central urban dwellers. As expected, the cost of abortion $A_i$ is increasing in the distance from an abortion clinic. I also am able to estimate the attractiveness of abortion following a first, second or third daughter. Abortion appears more attractive (that is, less costly) at each successive parity, in part because a second or third daughter may provide less marginal benefit than the first and possibly because parents are anticipating no future births. The average value of the son preference parameter $\theta$ across individuals and policy regions is 2.90, which indicates that a son is worth approximately 2.90 years of income more than a daughter on average, but is much higher among rural mothers and those with less education. While these estimated coefficients are consistent with a priori expectations, 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.

[33] 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.

## 5.5 A Policy Application of the Structural Model

In China, increasingly strict fertility control without a corresponding decline in the benefit to parents of having at least one son is responsible for the rising sex ratio at birth following daughters. In light of the need to continue to restrict fertility in China, and the anticipated need for mothers in India to have fewer children, I propose in the following analysis a subsidy to mothers who fail to have a daughter. 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 historical experience indicates that mothers in these countries are disinclined to leave this to chance, and in light of technological innovations that will make it increasingly simple for mothers to perform sex selection, I outline below a proposal to reduce the payoff to having a son, and thereby lower the payoff to fertility and sex selection.

In Table 12, 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 6 months, 12 months, and up to 30 months to mothers 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. As shown, these policies have the desired effect of decreasing the number of unauthorized births (second and third order), and decreasing the number of "missing girls" among this population. 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 small-scale subsidy in which mothers receive 6 months of household income when they fail to have a son decreases the number of missing girls by approximately 1.2 million, a 15 percent decline.[34] Since the premium to having a son has been measured in years

[34] Table 12 indicates that fine collections total 1.45% of GDP in the base case simulation. This appears large relative

of income, the anticipated impact on the government budget is also shown for each policy. For the small-scale subsidy, the annual cost to the government of subsidizing mothers is .60 percent of GDP. This amount reflects the twofold impact of the policy on government revenue, as the program both requires funding to provide subsidies and decreases the revenue from fines on unauthorized births. The cost per "saved girl" appears at first to fall with the generosity of the subsidy, and then eventually rising as more generous policies involve higher spending on mothers who would complete fertility without a son even in the absence of a subsidy.[35]

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 through education (e.g. the "Care for Girls" campaign in China today). 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. Patterns in Taiwan suggest that son preference is robust even in the face of rapid industrialization.

The simulation results indicate that the expected cost of a subsidy proposal is large, but would improve the incentive structure created by 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, and also indicate a failure in the social support system. The sex selection decision, while perhaps understandable in light of current incentives, imposes a welfare cost on the next generation of men seeking brides. The proposed subsidy will limit sex-selection, discourage fertility, and mitigate the pain of an old age without

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to Scharping's estimate, who suggests that rural fine collections were between 2.5 and 3 billion annualy, or roughly .14% of annual GDP. However, Scharping's estimate excludes urban regulations such as "social support fees" (health, education, etc) which comprise a considerable share of the punitive cost of another child and are not included in these aggregate fine totals. My results should be interpreted as appropriate up to a scale where fines are perfectly enforced but are not complemented by other financial punishments.

[35] Auxiliary tables regarding features of the policy simulations available at the author's website. I show in one table the share of subsidy spent on mothers already completing fertility, which provides insight into why smaller subsidies are more efficient than larger subsidies in terms of "saved girls" per dollar of spending on the policy. I also estimate alternative policies, such as restricting subsidy eligibility to those with rural registration. Results are available from the author available upon request.

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, since I am using the premium to a son, the model's predictions are valid if this policy was implemented as a tax to those who have a son. This option, however, may have the undesirable consequence of taxing those who are awarded a son through random chance. In any event, the sheer scale of the proposed policy should serve to characterize the magnitude of the disease when one considers the cost of the cure.

# 6 Conclusion

Although rapid industrialization and large changes in fertility have reshaped China and India 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 and India has slowed but the imbalance in the sex ratio has become a pressing concern and the situation in China appears to be worsening. Chinese government figures indicate that the female deficit has worsened since the 2000 Census, with the overall sex ratio at birth reaching 118 boys born for every 100 girls in 2005.[36] While a quarter of young women married in Taiwan are from mainland China, no similar solution will present itself for the tens of millions of extra males in rural China or India. 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.[37] 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.

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

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

The 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. Since population control is still an important policy concern, few policymakers are suggesting that either China or India can afford to let mothers have more children. As such, policy must be formulated to deal with the need to discourage fertility *and* sex selection, and this could be addressed by directly subsidizing mothers who fail to have a son. Empirical estimates presented here suggest that this is indeed a feasible option, and failing to act may prove costly for the next generation.

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Figure 1: Male Fraction of Births Following Daughters in China

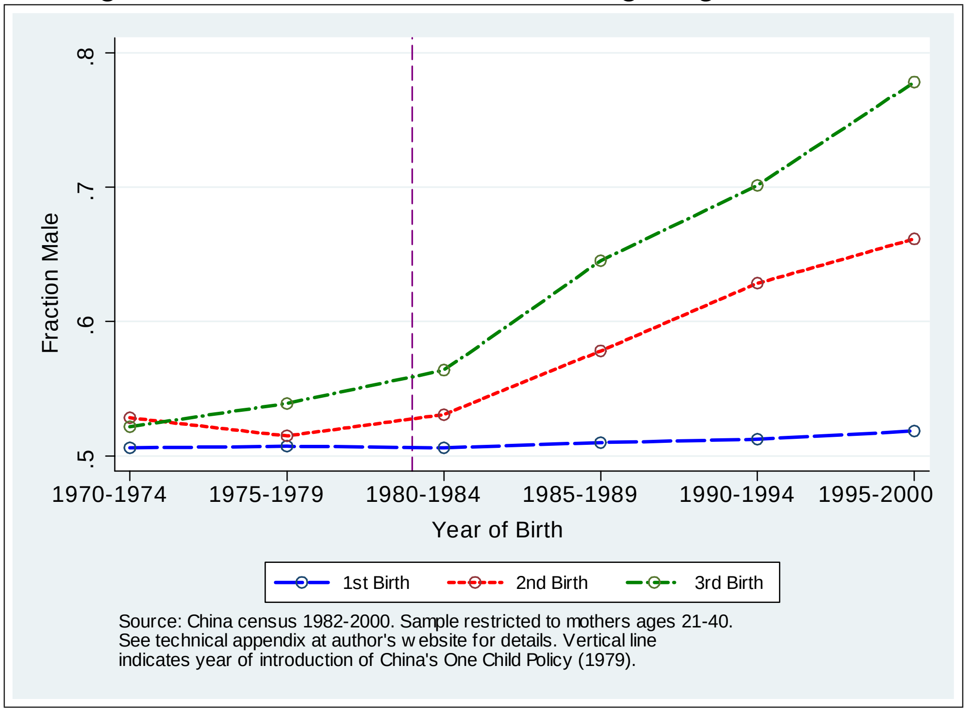
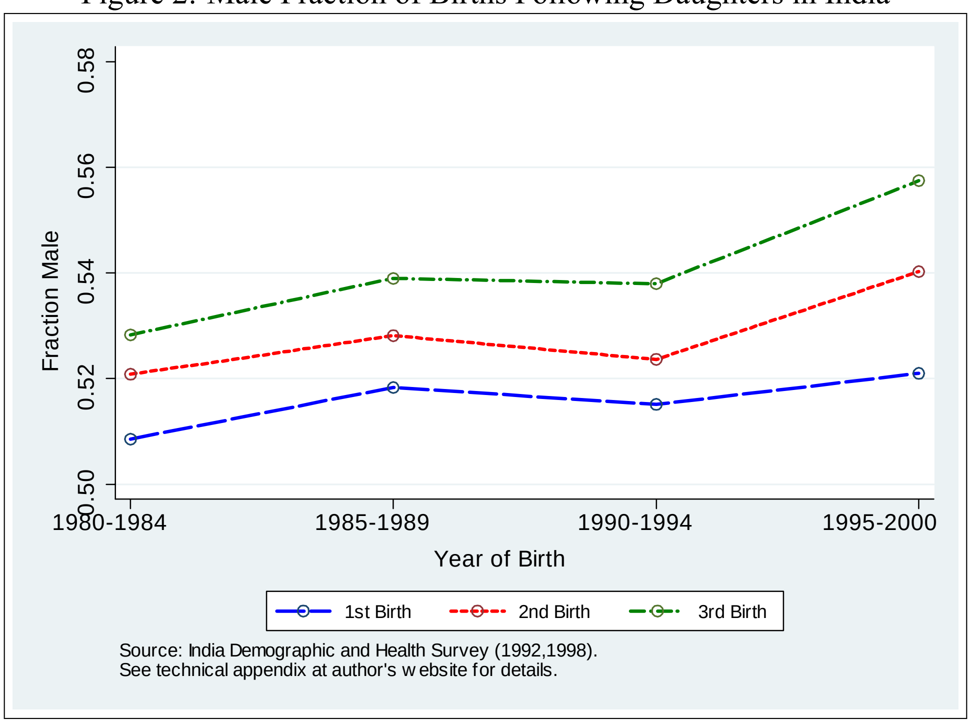



Figure 2: Male Fraction of Births Following Daughters in India



## Table 1. Matched Mothers and Children - Asian Countries and the United States, 1980-2000

| | China | | | India | | Taiwan | | | United States | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Statistic | 1982 | 1990 | 2000 | 1992 | 1998 | 1980 | 1990 | 2000 | 1980 | 1990 | 2000 |
| Mothers | 106,635 | 145,209 | 148,341 | 77,556 | 79,410 | 1,642 | 1,989 | 1,656 | 18,281 | 18,576 | 17,581 |
| Sons | 127,931 | 138,101 | 121,560 | 108,736 | 110,682 | 2,185 | 2,339 | 1,731 | 19,617 | 19,136 | 18,431 |
| Daughters | 121,485 | 127,010 | 105,461 | 101,277 | 101,133 | 2,033 | 2,149 | 1,595 | 18,596 | 18,155 | 17,610 |
| Children per Mother | 2.339 | 1.826 | 1.530 | 2.708 | 2.667 | 2.569 | 2.256 | 2.008 | 2.090 | 2.007 | 2.050 |
| Sex Ratio of Children | 1.053 | 1.087 | 1.153 | 1.074 | 1.094 | 1.075 | 1.088 | 1.085 | 1.055 | 1.054 | 1.047 |
| Sex Ratio at Birth | 1.061 | 1.085 | 1.143 | 1.074 | 1.094 | 1.079 | 1.093 | 1.087 | 1.064 | 1.061 | 1.051 |
| Female Deficit (0-18) | 0.18% | 2.59% | 8.38% | 1.46% | 3.54% | 2.01% | 3.37% | 2.80% | 0.46% | 0.16% | -0.78% |

Source: China Census .10% sample (1982), 1% sample (1990), .10% sample (2000). India Demographic and Health Survey (1992, 1998). Taiwan Population and Housing Survey (1980,1990,2000). United States Census IPUMS 5% sample (1980, 1990, 2000). Married women aged 21-40 for matched samples, ever-married women 15-45 for DHS fertility survey.

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, year, and country. China life tables taken from Banister (2004). Taiwan life tables provided by the Department of Statistics, Ministry of the Interior (MOI). US life tables based on calculations of the Social Security Administration (SSA). India statistics calculated directly from survey responses, weighted by probability of being sampled.

**Table 2. Male Fraction of Next Birth by Sex of Existing Children: 1980-2000**

| | | China | | | India | | Taiwan | | | United States | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parity | Sex Combination | 1982 | 1990 | 2000 | 1992 | 1998 | 1980 | 1990 | 2000 | 1980 | 1990 | 2000 |
| 1st | None | 0.51 | 0.51 | 0.52 | 0.51 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.51 |
| 2nd | One boy | 0.51 | 0.51 | 0.50 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |
| | One girl | 0.52 | 0.55 | 0.62 | 0.52 | 0.53 | 0.52 | 0.52 | 0.52 | 0.51 | 0.51 | 0.51 |
| 3rd | Two boys | 0.50 | 0.43 | 0.39 | 0.51 | 0.51 | 0.51 | 0.52 | 0.52 | 0.51 | 0.52 | 0.52 |
| | One girl, one boy | 0.52 | 0.52 | 0.53 | 0.52 | 0.53 | 0.52 | 0.52 | 0.52 | 0.51 | 0.51 | 0.51 |
| | Two girls | 0.54 | 0.62 | 0.70 | 0.52 | 0.55 | 0.53 | 0.54 | 0.56 | 0.51 | 0.50 | 0.50 |
| 4th | Three boys | 0.49 | 0.40 | 0.37 | 0.51 | 0.52 | 0.50 | 0.50 | 0.51 | 0.53 | 0.52 | 0.52 |
| | One girl, two boys | 0.51 | 0.49 | 0.52 | 0.51 | 0.52 | 0.52 | 0.52 | 0.53 | 0.51 | 0.51 | 0.51 |
| | Two girls, one boy | 0.52 | 0.55 | 0.57 | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 | 0.51 | 0.51 | 0.51 |
| | Three girls | 0.57 | 0.64 | 0.72 | 0.53 | 0.54 | 0.55 | 0.56 | 0.61 | 0.50 | 0.50 | 0.50 |

Source: See Table 1.

Notes: Male fraction of births is calculated by assigning weights to each male and female that account for differential mortality rates by age, sex, year, and country. China life tables taken from Banister (2004). Taiwan life tables provided by the Department of Statistics, Ministry of the Interior (MOI). US life tables based on calculations of the Social Security Administration (SSA). India statistics calculated directly from survey responses, weighted by probability of being sampled. Since these calculations are based on large sample census data (and a large fertility survey for India), all estimates are statistically significant. Tables with standard errors available at the author's website.

## Table 3. Percent having Another Child by Sex of Existing Children: 1980-2000

| | | China | | | India | | Taiwan | | | United States | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parity | Sex Combination | 1982 | 1990 | 2000 | 1992 | 1998 | 1980 | 1990 | 2000 | 1980 | 1990 | 2000 |
| 1st | One boy | 0.72 | 0.54 | 0.35 | 0.80 | 0.81 | 0.58 | 0.40 | 0.30 | 0.71 | 0.68 | 0.70 |
| | One girl | 0.75 | 0.60 | 0.49 | 0.81 | 0.82 | 0.64 | 0.46 | 0.33 | 0.71 | 0.68 | 0.70 |
| 2nd | Two boys | 0.53 | 0.30 | 0.18 | 0.67 | 0.62 | 0.58 | 0.40 | 0.30 | 0.43 | 0.40 | 0.42 |
| | One girl, one boy | 0.55 | 0.29 | 0.16 | 0.69 | 0.65 | 0.64 | 0.46 | 0.33 | 0.38 | 0.34 | 0.36 |
| | Two girls | 0.69 | 0.55 | 0.46 | 0.76 | 0.76 | 0.74 | 0.62 | 0.48 | 0.45 | 0.41 | 0.43 |
| 3rd | Three boys | 0.41 | 0.24 | 0.17 | 0.57 | 0.53 | 0.33 | 0.19 | 0.15 | 0.34 | 0.29 | 0.31 |
| | One girl, two boys | 0.36 | 0.17 | 0.11 | 0.52 | 0.47 | 0.27 | 0.14 | 0.12 | 0.32 | 0.26 | 0.29 |
| | Two girls, one boy | 0.44 | 0.23 | 0.14 | 0.63 | 0.61 | 0.51 | 0.31 | 0.18 | 0.33 | 0.27 | 0.29 |
| | Three girls | 0.62 | 0.54 | 0.50 | 0.72 | 0.72 | 0.65 | 0.50 | 0.34 | 0.35 | 0.30 | 0.32 |

Source: See Table 1.

Notes: The share having another child is calculated using all mothers age 21-40, which includes mothers who may have another birth. Calculations reflecting completed fertility patterns available at the author's website. Since these calculations are based on large sample census data (and a large fertility survey for India), all estimates are statistically significant. Tables with standard errors available from the author's website.

**Table 4. Accounting for the Female Deficit in Asia (000s) by Parity: 1980-2000**

| | | China | | | India | | Taiwan | | |
|---|---|---|---|---|---|---|---|---|---|
| Parity | Sex Combination | 1982 | 1990 | 2000 | 1992 | 1998 | 1980 | 1990 | 2000 |
| 1st | None | -1,309 | -1,358 | 214 | -52 | 437 | 2 | 24 | 13 |
| 2nd | One boy | -388 | -811 | -1,063 | 242 | 594 | 4 | 13 | 5 |
| | One girl | 881 | 3,579 | 7,745 | 547 | 826 | 12 | 9 | 6 |
| 3rd | Two boys | -296 | -1,065 | -641 | -53 | -52 | -1 | 1 | 1 |
| | One girl, one boy | 133 | 157 | 216 | 255 | 553 | 9 | 6 | 2 |
| | Two girls | 705 | 2,282 | 2,365 | 152 | 760 | 8 | 11 | 13 |
| 4th | Three boys | -105 | -158 | -52 | -22 | 10 | -1 | 0 | 0 |
| | One girl, two boys | -4 | -76 | 6 | -42 | 43 | 0 | 1 | 0 |
| | Two girls, one boy | 153 | 252 | 119 | 371 | 298 | 7 | 3 | 1 |
| | Three girls | 510 | 574 | 402 | 138 | 217 | 5 | 5 | 4 |
| | "Missing" Girls | 279 | 3,375 | 9,311 | 1,536 | 3,687 | 45 | 71 | 44 |
| | Female Births | 135,378 | 133,539 | 110,367 | 101,278 | 101,134 | 2,087 | 2,181 | 1,608 |
| | Share Missing | 0.21% | 2.53% | 8.44% | 1.52% | 3.65% | 2.14% | 3.28% | 2.72% |

Source: See Table 1.

Notes: These calculations represent the weighted average of the distortion to the fraction of sons born following a combination by the actual number of women who are observed with another child. These will not exactly match the number of births shown in Table 1.

## Table 5: Birth Interval Length Following Daughters by Sex of Next Child

| Country (Year) | Parity | Sex Combination | Fraction Male | Birth Interval Before Male | Birth Interval Before Female | Anticipated Delay | Actual Delay | Error |
|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | | | | | (2)-(3) | (4)-(5) |
| China (1990) | 2nd | One girl | 0.55 | 2.91 | 2.85 | 0.08 | 0.05 | 0.02 |
| | 3rd | Two girls | 0.62 | 2.80 | 2.66 | 0.19 | 0.14 | 0.06 |
| | 4th | Three girls | 0.64 | 2.77 | 2.58 | 0.23 | 0.20 | 0.03 |
| China (2000) | 2nd | One girl | 0.62 | 3.59 | 3.45 | 0.20 | 0.13 | 0.06 |
| | 3rd | Two girls | 0.70 | 2.64 | 2.33 | 0.31 | 0.30 | 0.01 |
| | 4th | Three girls | 0.72 | 2.73 | 2.26 | 0.34 | 0.48 | -0.13 |
| India (1998) | 2nd | One girl | 0.53 | 2.95 | 2.95 | 0.02 | 0.00 | 0.02 |
| | 3rd | Two girls | 0.55 | 2.86 | 2.82 | 0.07 | 0.05 | 0.02 |
| | 4th | Three girls | 0.54 | 2.82 | 2.74 | 0.06 | 0.08 | -0.02 |
| Taiwan (2000) | 2nd | One girl | 0.52 | 2.62 | 2.62 | 0.00 | 0.00 | 0.00 |
| | 3rd | Two girls | 0.56 | 3.15 | 3.03 | 0.09 | 0.12 | -0.03 |
| | 4th | Three girls | 0.61 | 3.15 | 2.92 | 0.18 | 0.22 | -0.04 |

Source: See Table 1.

Notes: Data on a child's month of birth are used for this calculation for China and India, and year of birth for Taiwan. The first column represents the fraction of male births following each sex combination. The second and third columns represent the average birth interval separated by whether the next birth is a boy or girl. The fourth column represents an algebraic manipulation of the "fraction male" assuming that sex selection requires on average 30 weeks and that the probability of aborting is independent of the number of attempts. The fifth column is the observed delay before male births and the sixth column is the difference between the anticipated delay and the actual delay. Tables with standard errors available at the author's website.

## Table 6. Male Fraction of Births and Total Fertility by Fertility Policy, China

| | | Prior to One Child Policy (China 1982 Census) | | | | Post One Child Policy (China 2000 Census) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parity | Sex Combination | One | 1.5 | Two | Minority | One | 1.5 | Two | Minority |
| 1st | None | 0.51 | 0.51 | 0.51 | 0.51 | 0.52 | 0.52 | 0.51 | 0.51 |
| 2nd | One girl | 0.53 | 0.53 | 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 | 0.69 | 0.65 |
| 4th | Three girls | 0.57 | 0.59 | 0.50 | 0.51 | 0.73 | 0.74 | 0.68 | 0.65 |
| Total Fertility Rate | | 2.23 | 2.42 | 2.82 | 2.85 | 1.35 | 1.55 | 1.65 | 1.76 |

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). Note that these calculations reflect fertility among all mothers age 21-40, who may not have completed their fertility. Tables with standard errors available at the author's website.

## Table 7. Male Fraction of Births and Total Fertility by Mother's Education, India and Taiwan

| | | India (1998) | | | | Taiwan (2000) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parity | Sex Combination | Illiterate | Primary | Middle | HS+ | <Primary | Primary | HS | BA+ |
| 1st | None | 0.52 | 0.51 | 0.51 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |
| 2nd | One girl | 0.52 | 0.52 | 0.55 | 0.53 | 0.52 | 0.52 | 0.52 | 0.52 |
| 3rd | Two girls | 0.54 | 0.56 | 0.55 | 0.60 | 0.55 | 0.56 | 0.59 | 0.57 |
| 4th | Three girls | 0.54 | 0.53 | 0.54 | 0.67 | 0.60 | 0.62 | 0.62 | 0.63 |
| Total Fertility Rate | | 3.24 | 2.89 | 2.45 | 2.19 | 2.25 | 1.99 | 1.76 | 1.71 |

Source: See Table 1.

Notes: Calculations of sex ratios and fertility rates for other survey years available from the author's website. Calculations based on the India DHS (1998) and Taiwan census (2000). Note that these calculations reflect fertility among all mothers age 21-40, who may not have completed their fertility. Tables with standard errors available at the author's website.

**Table 8. Regression (OLS) estimates of Fertility Outcomes (LHS) on Fertility Fines (RHS) Following Daughters: China 1979-2000**

| | Share Having a 2nd/3rd Birth | | Male Share of 2nd/3rd Births | |
|---|---|---|---|---|
| | Girl | Girl, Girl | Girl | Girl, Girl |
| Size of Fertility Fine | -0.280** | -0.244** | 0.014** | 0.012** |
| | (0.001) | (0.001) | (0.003) | (0.004) |
| Farmer | 0.20** | 0.06** | -0.001 | -0.004 |
| | (0.001) | (0.003) | (0.003) | (0.006) |
| Year of Child's Birth | -0.04** | -0.03** | 0.01** | 0.01** |
| | (0.0001) | (0.0003) | (0.0002) | (0.0005) |
| Sample Average | 0.481 | 0.464 | 0.564 | 0.621 |
| Observations | 676,216 | 186,493 | 428,175 | 124,411 |

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

Source: See Table 1.

Note: The fine is measured in years of household income, taken from Scharping (2003). 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 regressioı 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. Note that higher birth fines are associated with lower fertility rates and higher sex ratios among those who have another child. Farming families are more likely to have a 2nd and 3rd birth due to regulations allowing additional fertility. The year of child's birth indicates that during this window fertility is declining but the male fraction of births is rising, possibly due to increasingly stringent enforcement of fines in recent years (Scharping 2003). Additional control variables for the age and years of education of both the mother and father are included in all specifications, as well as province fixed effects. Year of child's birth for fertility regressions is based on the year of the mother's previous birth.

## Table 9. Demographic Characteristics and Fine Rates of Mothers Aged 33-42, China 2000

| Statistic | Full China | One Child Policy | 1.5 Child Policy | 2 Child Policy |
|---|---|---|---|---|
| Size of Fine on 2nd births | 1.314 | 1.977 | 1.290 | 0.182 |
| Size of Fine on 3rd births | 2.684 | 4.292 | 2.369 | 1.569 |
| Years of Education | 8.410 | 8.661 | 8.456 | 7.634 |
| Farmer (1 = Yes) | 0.53 | 0.49 | 0.53 | 0.61 |
| Multi-story dwelling (1=Yes) | 0.39 | 0.52 | 0.36 | 0.37 |
| Distance from Fertility Clinic | 0.57 | 0.54 | 0.57 | 0.66 |
| Observations | 71,595 | 14,928 | 48,919 | 7,748 |

Source: Model is estimated using mothers in the China 2000 census who are between 33 and 42 years of age and are observed with completed fertility of (B,G,BG,BB,GB,GG,GGB,GGG). Minorities are included under the 2 child policy.

Note: The fine is measured in years of household income, taken from Scharping (2003). Years of education is calculated from census question on completed education level. A family is considered to be a farming family if they report working in the agricultural sector in a census question on occupation. Distance from a fertility clinic (log distance in kilometers) is imputed to mothers from the China Health and Nutritional Survey using the respondent's education and urban/rural status.

**Table 10. Comparing Actual and Simulated Fertility Outcomes, China 2000**

| | Full China | | One Child Policy | | 1.5 Child Policy | | 2 Child Policy | |
|---|---|---|---|---|---|---|---|---|
| | Actual | Model | Actual | Model | Actual | Model | Actual | Model |
| Panel A: Fertility and the Sex Ratio | | | | | | | | |
| Total Fertility Rate | 2.36 | 2.36 | 2.25 | 2.26 | 2.39 | 2.38 | 2.40 | 2.40 |
| Missing Girls (000s) | 7,531 | 8,043 | 1,428 | 1,661 | 5,440 | 5,864 | 663 | 998 |
| Panel B: Fertility Outcome Comparison | | | | | | | | |
| Boy | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.52 | 0.52 |
| Girl | 0.19 | 0.19 | 0.28 | 0.26 | 0.17 | 0.18 | 0.15 | 0.15 |
| Girl, Boy | 0.17 | 0.18 | 0.13 | 0.14 | 0.19 | 0.18 | 0.18 | 0.18 |
| Girl, Girl | 0.07 | 0.06 | 0.05 | 0.05 | 0.07 | 0.06 | 0.09 | 0.07 |
| Girl, Girl, Boy | 0.05 | 0.05 | 0.03 | 0.03 | 0.05 | 0.05 | 0.05 | 0.05 |
| Girl, Girl, Girl | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |

Source: See Table 9.

Note: This table represents a comparision between the decisions observed by mothers, and a set of numerical simulations in which mothers are assigned a fertility outcome using a decision rule determined by Maximum Likelihood Estimation using MATLAB 7 software. See text and technical appendix (available at author's website) for information regarding likelihood function and a copy of the executable code used to simulate decisions. Note that the model assumes zero fertility following the birth of a son, and the calculations for fertility and the number of missing girls will not exactly match the overall China sample figures (see Table 4). The differences in "Missing Girls (000s)" under each policy in part reflect different numbers of mothers covered by each policy regime (see Table 9). The calculation of "Missing Girls" for the sample (see Table 9) are inflated to correspond to the results for the overall matched sample in the China 2000 census.

**Table 11. Parameter Estimates for Sex Selection Model, China 2000**

| | Full China | One Child Policy | 1.5 Child Policy | 2 Child Policy |
|---|---|---|---|---|
| Panel 1: Son Preference Coefficients | | | | |
| Years of Education | -0.27** | -0.35* | -0.27** | -0.23 |
| | (0.08) | (0.18) | (0.09) | (0.22) |
| Farmer (1 = Yes) | 2.80** | 2.49** | 3.02** | 3.35* |
| | (0.54) | (1.19) | (0.69) | (1.72) |
| Multi-story dwelling (1=yes) | -1.18** | -1.33 | -0.73 | -1.40 |
| | (0.42) | (0.94) | (0.49) | (1.42) |
| Constant | 4.11** | 4.43** | 4.25** | 2.12 |
| | (0.89) | (2.07) | (1.13) | (2.60) |
| Average Predicted θ | 2.90 | 1.94 | 3.32 | 1.87 |
| Panel 2: Cost of Sex Selection Coefficients | | | | |
| Distance from Fertility Clinic | 4.11** | 5.62 | 5.41** | 4.56 |
| | (1.29) | (5.65) | (1.89) | (4.80) |
| Cost of Sex Selection (S1) | 5.00** | 8.66 | 4.93** | 3.52 |
| | (0.78) | (10.02) | (0.89) | (2.78) |
| Cost of Sex Selection (S2) | 3.18** | 1.05 | 3.38** | 0.79 |
| | (1.34) | (4.50) | (1.65) | (5.51) |
| Cost of Sex Selection (S3) | 1.42 | -1.63 | 0.65 | 0.00 |
| | (2.01) | (5.86) | (2.33) | (7.03) |
| Average Predicted A1 | 7.36 | 11.71 | 8.02 | 6.54 |
| Average Predicted A2 | 5.54 | 4.52 | 5.69 | 5.61 |
| Average Predicted A3 | 3.78 | 1.42 | 3.73 | 3.02 |

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

Source: Same as Table 9.

Notes: The results above reflect the implied value of a son in years of income for mothers of different demographic characteristics, as well as the implied dollar value of the costs of sex selection. The results suggest lower educated mothers and farming families place a higher value on having a son, as measured by their propensity to have a child following daughters and the chance the birth is male. Those who live in multi-story dwellings appear to assign a lower value to a son. The coefficients for the cost of sex selection indicate that a mother's (imputed) distance from a fertility clinic is associated with a lower payoff to sex selection, as measured by her propensity to have a son. The coefficient on the parity-specific cost of sex-selection is declining with birth-order, suggesting that mothers may assign more value to a first or second daugther than a third.

**Table 12. Policy Simulations of Total Fertility and the Number of Missing Girls**

| | | Fertility Outcomes | | | Fiscal Impacts | | | |
|---|---|---|---|---|---|---|---|---|
| | Proposal | Total Fertility Rate | Missing Girls (000s) | Share without a Son | Total Subsidy (% GDP) | Fine Revenue (% GDP) | Total Cost (% GDP) | Yuan Cost per "Saved Girl" |
| **(1)** | Actual | 2.36 | 7,531 | 0.27 | —— | —— | —— | —— |
| **(2)** | Baseline Model | 2.36 | 8,043 | 0.27 | 0.00% | 0.72% | 0.00% | 0 |
| **(3)** | Subsidy of ½ year of income | 2.33 | 6,883 | 0.29 | 0.59% | 0.66% | 0.65% | 32,968 |
| **(4)** | Subsidy of 1 year of income | 2.31 | 5,292 | 0.31 | 1.25% | 0.61% | 1.36% | 28,922 |
| **(5)** | Subsidy of 1½ years of income | 2.29 | 3,352 | 0.33 | 1.96% | 0.56% | 2.13% | 26,537 |
| **(6)** | Subsidy of 2 years of income | 2.27 | 2,096 | 0.34 | 2.74% | 0.51% | 2.96% | 29,070 |
| **(7)** | Subsidy of 2½ years of income | 2.24 | 1,094 | 0.36 | 3.60% | 0.45% | 3.87% | 32,544 |

Source: Same as Table 9.

Notes: The fertility measure and "Missing Girls" calculations are for the cohort of mothers observed in the China 2000 census. Costs are denominated relative to a single year of GDP. In order, the columns refer to: average number of births per mother, estimated missing girls, fraction of sample with no son, total spending on subsidy, fine revenue for the policy, combined cost of subsidy and impact on fine revenue, budgetary cost per "saved girl" (Total cost/reduction in the number missing girls). The subsidy is a share of each province's average household annual income for urban and rural families among families in the China Household Income Survey (1995).