Essays on Family Economics and Intra-household Bargaining

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Xiaodi Wang

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Abteilungssprecher:	Prof. Dr. Jochen Streb
Referent:	Prof. Michèle Tertilt, Ph.D.
Korreferent:	Prof. Minchul Yum, Ph.D.

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Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die vorliegende Dissertation selbstständig angefertig habe und die benutzten Hilfsmittel vollständig und deutlich angegeben habe.

Mannheim, 27. September 2018 Xiaodi Wang

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1 Preface

Since Becker (1973, 1974) first provided a unified approach to studying modern family economics, more and more research has focused on the interaction of decision-making within the household. Even if it is reasonable to assume a common set of preferences within the family, due to the nature of gender differences, many decisions are made through the interaction of household members rather than by a unitary family. These decisions relate to areas such as marriage and divorce, the division of household labor, as well as fertility choices. Therefore, when analyzing the effect of policies and demographic changes that may affect women and men differently, it is important to take the interaction of household members into consideration. Consequently, the goal of this dissertation is to understand which factors may affect intra-household bargaining, how important intra-household bargaining is, and the corresponding mechanism in answering economic questions.

This dissertation comprises three self-contained chapters, in which I investigate the effect of demographic changes and policies on intra-household allocations when the relative bargaining power is endogenously determined. In Chapter 2, I use a quantitative model to evaluate the effect of imbalanced sex ratios on female and male welfare in China. The imbalanced sex ratio affects the marriage market, which changes the relative bargaining power within the household, and hence individual labor supply and welfare. Chapter 3 further investigates the imbalanced sex ratio problem in China empirically and provides evidence in support of the arguments in Chapter 2. Chapter 4 studies the effect of a

counter-factual income tax reform from joint taxation to individual taxation on married female labor supply, when the relative after-tax income directly affects the relative bargaining power. The tax reform will lower the marginal tax rate for the second earner (typically the wife), which increases her after-tax income and thus her bargaining power. With a higher bargaining power, she can substitute less leisure time for work. The result holds both theoretically and quantitatively. A more detailed summary of each chapter is listed as follows:

Chapter 2 studies the effect of imbalanced sex ratios on female and male welfare in China. The ratio of men relative to women has surged significantly during the last 30 years in China. In this chapter, I quantify the effect of an increased sex ratio in China on female and male welfare through marriage and labor market outcomes. Specifically, I develop a unified model of marriage and divorce, imbalanced sex ratios, and intra-household bargaining. The model highlights three channels through which the sex ratio affects female and male welfare. First, since the sex ratio affects the outside option of marriage differently across gender, it alters the bargaining power within the household, which in turn changes the allocation of the marital surplus. Second, females have a higher likelihood of meeting a husband, and marriage is beneficial. Third, females can find better husbands as they become more selective in choosing husbands. The model is calibrated to match Chinese labor and marriage market data moments in 1990. A quantitative exercise of increasing the sex ratio from 1.07 to 1.2 shows that females are 9.5% better off while males are 14% worse off in consumption equivalent units measured by a new-born individual who is about to enter the marriage market. The change comes from variations of working hours and marriage rates. Total female working hours drop by 5.1% and total male working hours rise by 5.2%. The fraction of females that are married increases by 2.6 percentage points and that of males decreases by 7 percentage points. The model predictions are mostly in line with the actual data trend. Decomposing the results, I find

that the channel of a higher meeting probability for females contributes most in explaining the change of welfare.

Chapter 3 investigates the effect of an imbalanced sex ratio in China on the marriage market, the labor market and intra-household bargaining empirically. In this chapter, I provide empirical evidence that the imbalanced sex ratio affects the marriage and labor market and further improves female bargaining power. Specifically, I use county-level variations in sex ratios to study its impact on marriage market outcomes, female labor supply, intra-household allocations and female bargaining power. I find that the higher sex ratio is associated with a higher fraction of women ever married and a lower fraction of men ever married. In addition, female bargaining power increases with the sex ratio. With a higher bargaining power, wives reduce their labor force participation and housework hours, and they become healthier. All empirical findings are consistent with the model predictions in Chapter 2.

Chapter 4 analyzes the effect of a counter-factual tax reform on married female labor supply when her bargaining power is endogenous. The joint income taxation for married households in the U.S. imposes a higher marginal tax rate on the second earner, which is typically the wife. Therefore, policy makers have proposed a tax reform regarding individual taxation to stimulate married female labor supply and improve intra-household equality. In this chapter, I study the effect of this counter-factual tax reform on married female labor supply, taking its impact on the relative bargaining power into consideration. If the relative after-tax income affects the bargaining power, two additional effects will influence the female labor supply decision. On the one hand, a direct effect reduces her labor supply since the higher bargaining power enables her to enjoy more leisure time. On the other hand, an indirect effect increases her labor supply because the more she earns, the higher bargaining power she obtains, which in turn gives her an additional incentive to

work. The total effect depends on the magnitude of both effects. Calibrating the model to match the U.S. households working hours data, I find that this tax reform could generate a higher female labor supply. However, the magnitude is not as high as predicted in previous studies that do not consider the change in female bargaining power. Therefore, the direct effect dominates the indirect effect. The welfare implications reverse when female bargaining power is endogenous, where the female gains if her bargaining power changes after the tax reform but loses if it is fixed. The effect is stronger for non-college educated women.

2 What is the Effect of Imbalanced Sex Ratios on Women and Men in China?

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2.1 Introduction

The sex ratio, which is defined by the number of males per 100 females, has increased significantly in China since 1980. The driving force comes from the male-biased sex ratio at birth, especially after the implementation of the One Child Policy in 1978.[1] Figure 2.1 illustrates that the sex ratio at birth increased from natural levels of around 105 in the 1980s, to over 120 in the 2000s.[2] Such evolution significantly alters the composition of the population in China. According to the 2015 China Statistical Yearbook, there were over 33 million more men than women in China, and this number is still increasing. Such a gap could generate a significant impact on China's marriage and labor market, and

[1]The reason why the sex ratio is increasing is not the focus of this study, but Li, Yi, and Zhang (2011) and Bulte, Heerink, and Zhang (2011) find that 50% to 90% of the imbalanced sex ratio can be explained by the implement of the One Child Policy in China. Qian (2008) argues that the increased male to female income worsens female survival rates in China.

[2]The World Health Organization computes the statistics based on the UN World Population Prospect from 1990 to 2010, and suggests that the average number is 105. See `http://www.searo.who.int/entity/health_situation_trends/data/chi/sex-ratio/en/`.

possibly affect women and men differently. For this reason, this chapter examines the question, "What is the effect of the imbalanced sex ratio on female and male welfare?"

Source: China population Census and 1% population sample surveys

Figure 2.1: Sex Ratio at Birth in China

To answer this question, in this chapter I develop a unified model with three main features: a random matching process in the marriage market with endogenous marriage and divorce decisions, imbalanced sex ratios, and an intra-household bargaining process. Firstly, the marriage market is defined by a random matching process where single agents meet randomly with individuals of the opposite sex according to a meeting probability function. Marriage occurs if, and only if, both parties agree to marry. Divorce happens when one of the spouses wants to divorce. Secondly, the meeting probability depends on the population size of singles, which is a function of the sex ratio. Lastly, the intra-household allocation is determined by a Nash bargaining process, with being single as the outside option. Given that divorce is a credible threat, being single is more attractive to the female and consequently it raises her bargaining power.[3]

[3]The crude divorce rate, which is defined by the number of divorces per 1000 population, increased from 0.7 in 1990 to 2.8 in 2015 in China. In U.S. this number in 2014 was 3.2, suggesting that divorce is a valid threat in marriage.

The main contribution of this study is to provide a mechanism that links the sex ratio with the well-being of men and women. The mechanism can also explain the decreased female labor supply and the increased female marriage rate in the data. In particular, the impact of the imbalanced sex ratio on female and male welfare passes through three channels. These three channels are the bargaining channel, the meeting probability channel and the better husband channel. The bargaining channel works as follows: Given a larger male population size, when divorce is feasible, a married female may credibly threaten to get divorced. In addition, since females are scarcer, it is harder for the husband to find another wife if he is divorced. Therefore, such a threat can provide a better outside option for the female, which increases her bargaining power.[4] The higher bargaining power enables the female to enjoy a larger share of the marital surplus in the form of a reduction in working hours and more leisure time, which makes females better off.

The meeting probability channel directly affects the marriage market. When there are more males available, it is easier for females to find a husband. Given that marriage is beneficial due to the love shock and economies of scale, females are better off.

The better husbands channel affects welfare through an income effect. When there are more males available, females become more selective in choosing their husbands. The additional income effect of better husbands also makes them better off.

The model is calibrated to match the Chinese labor and marriage market statistics in 1990 using the minimum distance estimation method. In the experiment, the sex ratio is adjusted exogenously to the 2007 level while the other parameters are held constant. To investigate the effect of the imbalanced sex ratio, I compare model predictions for 2007 with the corresponding 1990 outcomes. Results suggest that the imbalanced sex ratio has a significant impact on female and male welfare. On average, females are 9.5% better off in consumption equivalent units, while males are 14.42% worse off. The change

[4]Chiappori, Fortin, and Lacroix (2002) study the intra-household allocation in a collective model framework. They validate the sex ratio in the marriage market as a distribution factor, which affects the intra-household bargaining position.

results from variations in labor market and marriage market outcomes. On the one hand, married female daily working hours drop from 7.71 hours to 7.38 hours. On the other hand, the fraction of females that are married increases from 80.94% to 83.54%. Both model predictions are in line with actual data trends. In contrast, married male working hours rise from 7.96 hours to 8.7 hours per day, and the fraction of men that are married falls from 76.65% to 69.62%.

The three channels previously mentioned contribute to higher female welfare. To investigate the role of each channel in the welfare change, I conduct a decomposition exercise by turning on each of the channels separately. Results suggest that women are mostly better off from the meeting probability channel, which accounts for about 60% of the increase. The higher female bargaining power explains about one-third of the welfare change. Females benefit from an average 12.05% increase in bargaining power, which enables them to obtain a larger share of the marital surplus by enjoying more leisure time and working less. On average, married women reduce working hours by 0.26 hours per day due to higher bargaining power. Compared with these two channels, females only benefit marginally from a better husband, which contributes to an 0.12% increase in female welfare. Due to the income effect from the husband, married females reduce their working hours by 0.07 hours. The effect on male welfare works the other way around.

This study contributes to the literature on sex ratios, marriage decision, and intra-household allocations. In the vein of the effect of sex ratios on marriage market outcomes, Becker (1973, 1974) first established the theory of the marriage market. Becker's theory uses a transferable utility model to argue that the change of sex ratios affects relative supply and demand in the marriage market. The theory is supported by recent empirical studies. Angrist (2002) documents that the imbalanced sex ratio of the second generation of immigrants in the U.S. led to a higher likelihood of female marriage. Abramitzky, Delavande, and Vasconcelos (2011) use WWI as an exogenous negative mortality shock to the male population and find that during the post WWI-period, men had a higher

likelihood of marriage in France. Similar results are found in China, where the imbalanced sex ratio increases women's probability of getting married (Edlund et al. (2013), Porter (2016)). My model framework provides a mechanism that can explain such empirical findings.

The other strand of literature focuses on the impact of sex ratios on intra-household allocations. Chiappori, Fortin, and Lacroix (2002) extend the Beckerian framework to a collective model, where the sex ratio is one of the distribution factors that affect the intra-household bargaining position. I extend the model to a Nash bargaining framework, and the results are consistent with their findings. Du and Wei (2010) investigate theoretically that the imbalanced sex ratio leads to a competitive savings behavior among males to increase their attractiveness in the marriage market, which contributes to the higher savings rate. Wei and Zhang (2011) further empirically validate Du and Wei (2010)'s theory in the case of China, suggesting that the imbalanced sex ratio affects intra-household allocations. Empirically, the negative effect of sex ratios on female labor force participation has been identified in the U.S., Australia and China (Angrist (2002), Grosjean and Khattar (2018) and Edlund et al. (2013)). This study further provides a quantitative support of the role of sex ratios in intra-household allocations.

The second contribution of this study is the quantitative model framework. To my knowledge, this is the first study that provides a unified quantitative model with imbalanced sex ratios, marriage and divorce decisions and an intra-household bargaining process. The matching model of the marriage market has been applied in many quantitative studies (Aiyagari, Greenwood, and Guner (2000), Greenwood et al. (2016)), but these studies usually treat a married household as one decision unit and ignore the interaction within the household. Greenwood, Guner, and Knowles (2003) incorporate a Nash bargaining framework into the married household decision problem to quantify the marriage and fertility effect on the distribution of income. The intra-household bargaining is further extended and implemented in quantitative works by Siegel (2017), Knowles (2013) and

Voena (2015), but they all assume a one-to-one matching between two genders in the marriage market. The only quantitative studies with imbalanced sex ratios are Knowles and Vandenbroucke (2015) and Rıos-Rull, Seitz, and Tanaka (2013), but both papers only study marriage market outcomes and ignore intra-household decisions.

The rest of the chapter is organized as follows: Section 2.2 describes the model setup. Section 2.3 presents the calibration procedure. The experiment of an increased sex ratio is discussed in Section 2.4. Section 2.5 decomposes the effect on welfare into three channels. Section 2.6 concludes.

2.2 Model setup

2.2.1 Demographics

The economy is populated by males (m) and females (f), who are different in population sizes. They are either single (S) or married (M). Denote the single female population size to be S_f and the number of single males to be S_m. Similarly, the married counterpart is given by M_f and M_m.[5] The sex ratio is imbalanced, denoted by $\phi > 1$, which varies exogenously. The female population is normalized to be 1, and therefore the male population is ϕ.

Agents face a mortality risk at the rate of δ. It is assumed to be the same for all agents. For married couples, they die together. Upon death, the individual will be replaced by a new-born doppelganger. Each period δ amount of females is replaced, while the replaced male population size is $\delta\phi$ due to the imbalanced sex ratio. The new-born individual is endowed with the same productivity (z_m and z_f) as the dead counterpart, and the productivity levels are drawn from distributions $z_f \in Z_f$ and $z_m \in Z_m$. Once the productivity is drawn, it remains constant in his/her lifetime.

[5]The time index is suppressed for simplicity.

2.2.2 Preferences

Agents derive utility from consumption (c) and leisure time. Each person has one unit of time endowment each period, and it can be divided between market work (ℓ) and leisure. Consumption is assumed to be a public good, which captures the economies of scale of a married family.[6]

The utility function is separable and a constant relative risk aversion (CRRA) over consumption and disutility of labor.[7] It takes the functional form of:

$$U(c, \ell) = \frac{c^{1-\gamma}}{1-\gamma} - \psi_g \frac{\ell^{1+\mu}}{1+\mu},$$

where γ is the inverse of the consumption elasticity, μ is inverse of the Frisch elasticity of labor supply, and ψ_g captures the disutility of labor, which is gender specific.[8]

[6] I assume that consumption is jointly utilized by both spouses. Some examples of goods consumed are houses, children and home appliances, which can be non-exclusively shared by both spouses. Public consumption within married households is considered to be a large component of household consumption (Lam (1988), Lundberg and Pollak (2007) Becker and Becker (2009) and Browning, Chiappori, and Lewbel (2013)).

[7] Home production is ignored in the model for two reasons. First of all, there are no data available on home production time before 2010, which is not the period of interest. In addition, my mechanism still works with home production. As will be discussed later, wives work less. But the reduced working hours are replaced by leisure time instead of home production due to the higher female bargaining power. With the higher bargaining power, females can enjoy more leisure time instead of working more in either the market or the home.

[8] The disutility of labor parameter ψ_g is set to be gender-specific because I assume that there is a gender wage gap that will generate much lower married female working hours than male hours in the model. But in the data, married female working hours are almost the same as husbands', so I need at least another parameter to lower female working hours to match the data. The disutility of labor parameters are the most suitable choices.

2.2.3 Budgets

Denote the exogenous wage rate to be w. Assume that there is a gender wage gap κ between males and females as females only earn a fraction of male wage rate:

$$w_m = w$$
$$w_f = \kappa w_m$$

Within each period, the agent consumes all the labor income, so the budget constraint of a single agent of gender g is given by:

$$c = w_g z_g \ell.$$

Married households pool their income together for their public consumption:

$$c = w_m z_m \ell_m + w_f z_f \ell_f$$

2.2.4 Marriage

The marriage market is characterized by a random matching process between singles of the opposite sex. Within each period, a single agent has a chance of meeting a potential spouse in the marriage market. The meeting probabilities depend on the share of the single population of the opposite sex (Schoen (1981)):

$$\omega_f = \frac{S_m}{S_f + S_m}$$
$$\omega_m = \frac{S_f}{S_f + S_m}.$$

Note that the meeting probability is endogenous as a function of the distribution of singles, which is determined by the sex ratio. When the sex ratio is more imbalanced,

single females will have a higher likelihood of meeting a partner while single males are more likely to find no match. If singles do not meet anyone, they stay in the single pool.

Once the two potential spouses meet, they draw a match-specific marriage quality shock $q \in Q$ from a distribution $F(q)$. To be more specific, $q \sim N(q_s, \sigma_s^2)$, where q_s and σ_s represent the mean and standard deviation of the marriage quality shock distribution for an unmarried couple. Within the marriage, the marriage quality shock is assumed to follow the distribution $G(q'|q)$, which evolves according to an autoregressive progress given by:

$$q' = (1 - \rho_m)q_m + \rho_m q + \sigma_m \sqrt{1 - \rho_m^2}\sigma,$$

where q_m and σ_m represent the long-run mean and standard deviation, ρ_m is the autocorrelation coefficient, and $\sigma \sim N(0, 1)$.

If both agents accept the marriage, they get married, but if either agent rejects the marriage, they have to stay single. The incentive of getting married exists in economies of scale due to public consumption and the marriage quality shock. When the marriage quality shock for the married households updates, the married couple decide whether to stay in the marriage or get divorced. If one of them wants to get divorced, they become single.

2.2.5 Intra-household allocations

The consumption and labor choice of single households is static. For a given gender g, he/she maximizes his/her period utility given the budget constraint:

$$\begin{aligned} U(c, \ell) &= \max_{c,\ell} \frac{c^{1-\gamma}}{1-\gamma} - \psi \frac{\ell^{1+\mu}}{1+\mu} \\ s.t. \qquad & c = w_g z_g \ell \end{aligned} \tag{2.1}$$

For married households, the intra-household allocation is determined through a Nash

bargaining process. Since divorce is a credible threat, being single is the outside option of the bargaining. Therefore, the consumption and labor decision of married households is given by:

$$\max_{c^M,\ell_f,\ell_m} (V_m^M(z_g, z_{-g}, q; S_g, S_{-g}) - V_m^S(z_m; S_g, S_{-g}))(V_f^M(z_g, z_{-g}, q; S_g, S_{-g}) - V_f^S(z_f; S_g, S_{-g}))$$
$$s.t.\ c^M = w_m z_m \ell_m + w_f z_f \ell_f, \tag{2.2}$$

where V_m^M, V_m^S and V_f^M, V_f^S are value functions of men and women being married and being single respectively. The value functions will be defined in detail later.[9] Note that the value of being single is a function of the meeting probability ω_g, which depends on the single population distributions. A higher sex ratio will increase the single male population size and thus the likelihood for a female of meeting a spouse. Given the benefit of marriage, the value of being single for females goes up. Therefore, females face a better outside option, which increases her bargaining power. With a higher bargaining power, she can obtain a larger share of the marital surplus within the household, by enjoying more leisure time.

2.2.6 Value functions

2.2.6.1 Value of being single

Now let me define the value function of being single. Consider a single agent of gender $g \in \{f, m\}$ with productivity type z_g. The aggregate states of single population distributions are S_g and S_{-g}. Given the optimal allocation of single households in the current period, which generates the indirect utility $U_g^{S*}(z_g; S_g, S_{-g})$, the individual enters the next period with a discount factor β and the survival probability $1 - \delta$. In the next period, the

[9] Given this functional form, I assume an equal bargaining weight on both spouses. However, it does not mean that the bargaining power is equal. In fact, the bargaining power is endogenous and depends on the outside option. As will be shown later, under current assumptions, the bargaining power can be measured by a function of value functions, and it varies with the sex ratio.

individual has $\omega_g(S_g, S_{-g})$ probability of meeting the potential spouse given the normalized distribution of the partner $\hat{S}_{-g}(z_{-g}; S_g, S_{-g})$, which will be defined later. Once they meet, they draw a common marriage quality shock q from the distribution $F(q)$. They will get married if, and only if, both of them are better off being married than being single:

$$V_g^M(z_g, z_{-g}, q; S_g, S_{-g}) \geq V_g^S(z_g; S_g, S_{-g}) \text{ and } V_{-g}^M(z_g, z_{-g}, q; S_g, S_{-g}) \geq V_{-g}^S(z_{-g}; S_g, S_{-g}) \tag{2.3}$$

Let the indicator function $\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g})$ represent the marriage decision. It equals 1 if both want to get married and equals 0 if one of them rejects.

$$\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g}) = \begin{cases} 1, & if \text{ (2.3) } holds, \\ 0, & otherwise \end{cases} \tag{2.4}$$

Note that $\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g}) = \mathbb{1}_{-g}(z_g, z_{-g}, q; S_g, S_{-g})$ given that the marriage decision is a joint decision of both spouses.

If the individual does not meet anyone with probability $1 - \omega_g(S_g, S_{-g})$, he/she has to stay single.

Therefore, for gender $g \in \{f, m\}$, the value function of being single is given by:

$$\begin{aligned} V_g^S(z_g; S_g, S_{-g}) \;=\; & U_g^{S*}(z_g; S_g, S_{-g}) \\ & + \beta(1-\delta)\{\int_Q \int_Z [\omega_g(S_g, S_{-g}) V_g^M(z_f, z_m, q; S_g, S_{-g}) \mathbb{1}_g(z_f, z_m, q; S_g, S_{-g}) \\ & + \omega_g(S_g, S_{-g})(1 - \mathbb{1}_g(z_f, z_m, q; S_g, S_{-g})) V_g^S(z_g; S_g, S_{-g}) \\ & + (1 - \omega_g(S_g, S_{-g})) V_g^S(z_g; S_g, S_{-g})] d\hat{S}_{-g}(z_{-g}; S_g, S_{-g}) dF(q)\}, \end{aligned} \tag{2.5}$$

where $\hat{S}_g(z_g; S_g, S_{-g})$ is the normalized distribution of singles with gender g, which is given by:

$$\hat{S}_g(z_g; S_g, S_{-g}) = \frac{S_g(z_g)}{\int_{Z_g} S_g(z_g)}$$

The first term in the continuation value stands for the case that both spouses agree to get married. The second term represents the case that at least one of the potential spouses rejects the marriage. The last term describes the case that the individual does not meet anyone. The sex ratio affects not only the meeting probability $\omega_g(S_g, S_{-g})$, but also the normalized distribution $\hat{S}_{-g}(z_{-g}; S_g, S_{-g})$.

2.2.6.2 Value of being married

The value function of being married is defined similarly to the value of being single. Consider a married individual of gender g. The couple's productivity type combination is given by z_f and z_m, and the realization of marriage quality shock to both spouses is q. The aggregate state variables are the single population distributions S_g and S_{-g}. Given the optimal intra-household allocation derived from the Nash bargaining problem defined in equation (2.2), the married individual obtains the indirect utility $U_g^{M*}(z_f, z_m; S_g, S_{-g})$. On top of it, there is a utility gain of q from the marriage quality shock. In the next period, the marriage quality shock q updates to q' according to the distribution $G(q'|q)$, and the two spouses decide whether to get divorced or not.

Divorce occurs if one of the two spouses wants to get divorced:

$$V_g^M(z_f, z_m, q; S_g, S_{-g}) < V_g^S(z_g; S_g, S_{-g}) \text{ or } V_{-g}^M(z_f, z_m, q; S_g, S_{-g}) < V_{-g}^S(z_{-g}; S_g, S_{-g}) \tag{2.6}$$

Therefore, the indicator function $\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g}) = 1$ if they both want to stay married, and takes the value of 0 if any of them wants to get divorced.

$$\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g}) = \begin{cases} 1, & if \text{ (2.6) } holds, \\ 0, & otherwise \end{cases} \tag{2.7}$$

So for gender $g \in \{f, m\}$, the value function of being married is specified as follows:

$$\begin{aligned} V_g^M(z_f, z_m, q; S_g, S_{-g}) &= U_g^{M*}(z_f, z_m; S_g, S_{-g}) + q \\ &+\beta(1-\delta)\{\int_Q [V_g^M(z_f, z_m, q'; S_g, S_{-g}) \mathbb{1}_g(z_f, z_m, q'; S_g, S_{-g}) \\ &+V_g^S(z_g; S_g, S_{-g})(1 - \mathbb{1}_g(z_f, z_m, q'; S_g, S_{-g}))] dG(q'|q)\}, \quad (2.8) \end{aligned}$$

where the first term in the continuation value illustrates the case of remaining in marriage, and the second term represents divorce.

2.2.7 Timing

The timing within a period is illustrated in Figure 2.2. At any period, a single agent of gender $g \in \{f, m\}$ and productivity z_g first meets the potential spouse of productivity type z_{-g} with probability ω_g. If they meet, they draw a common marriage quality shock q. If he/she does not meet anyone, he/she makes a consumption and labor choice as a single household by equation (2.1). For those who meet, they decide whether to get married or not by comparing the value of being married with the value of being single according to equation (2.3). For those who are already married, once their marriage quality shock updates from q to q', they renegotiate the intra-household allocation by equation (2.2) as well as the divorce decision by equation (2.6). As the marriage decision and intra-household bargaining take place at the same time, the threat of divorce affects intra-household bargaining.

2.2.8 The stationary equilibrium

The married household allocations are determined by a Nash bargaining process, where the outside option is being single. As discussed above, the value of being single is a function

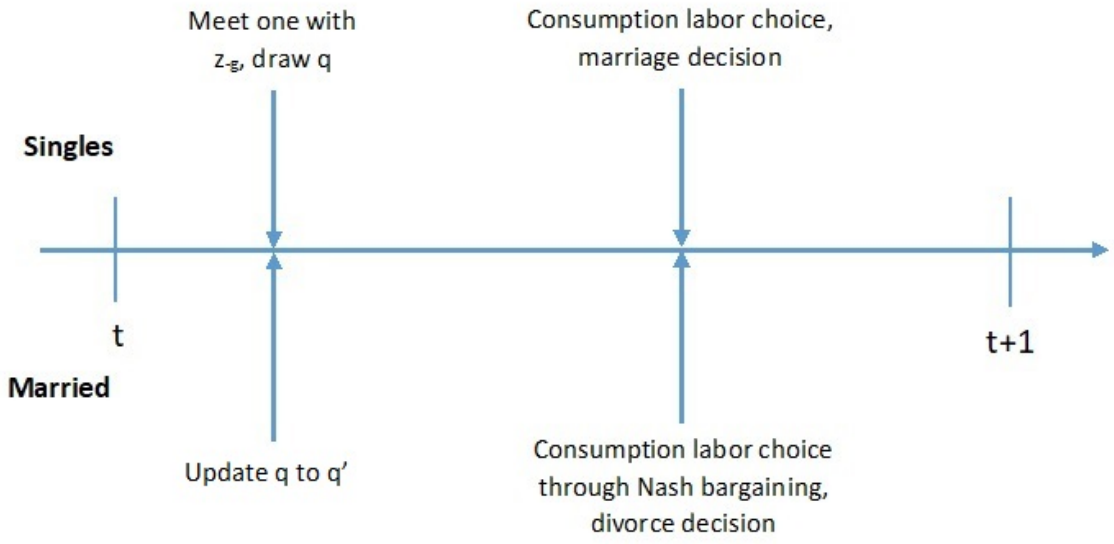


Figure 2.2: Timing of the Model

of the meeting probability. Since the meeting probability depends on the distribution of singles, it requires the knowledge of steady state population distributions.

The steady state distribution of the single female is defined by:

$$\begin{aligned} S_f(z_f') &= (1-\delta)\omega_f(S_f,S_m)\int_Q\int_{Z_m}\int_{Z_f}^{z_f'}[1-\mathbb{1}_f(z_f,z_m,q;S_f,S_m)]dS_f(z_f)d\hat{S}_m(z_m;S_f,S_m)dF(q) \\ &\quad +(1-\delta)\int_Q\int_Q\int_{Z_m}\int_{Z_f}^{z_f'}[1-\mathbb{1}_f(z_f,z_m,q;S_f,S_m)]dM_f(z_f,z_m,q_{-1})dG(q|q_{-1}) \\ &\quad +(1-\delta)(1-\omega_f(S_f,S_m))\int_{Z_f}^{z_f'}dS_f(z_f) \\ &\quad +\delta, \end{aligned} \tag{2.9}$$

The first term represents single females who survived the last period, meet a male but do not get married in this period. The second term captures females whose marriages dissolve. The third term stands for single females who fail to meet any male. The last term is the death replacement. Since the female population size is normalized to be 1, and all females face the same mortality rate δ, the death replacement is simply δ.

Analogously, the distribution of single males is defined by:

$$\begin{aligned} S_m(z'_m) &= (1-\delta)\omega_m(S_f,S_m)\int_Q\int_{Z_f}\int_{Z_m}^{z'_m}[1-\mathbb{1}_m(z_f,z_m,q;S_g,S_{-g})]dS_m(z_m)d\hat{S}_f(z_f;S_f,S_m)dF(q) \\ &\quad +(1-\delta)\int_Q\int_Q\int_{Z_f}\int_{Z_m}^{z'_m}[1-\mathbb{1}_m(z_f,z_m,q;S_f,S_m)]dM_m(z_f,z_m,q_{-1})dG(q|q_{-1}) \\ &\quad +(1-\delta)(1-\omega_m(S_f,S_m))\int_{Z_m}^{z'_m}dS_m(z_m) \\ &\quad +\delta\boldsymbol{\phi} \end{aligned} \tag{2.10}$$

The single male population is larger relative to single females due to the imbalanced sex ratio. Since the male population is ϕ, given the same mortality rate, $\delta\phi$ number of males is replaced by singles. The difference is captured by the last term in the distribution function – the death replacement.[10]

The steady state distribution of the married individual of gender g is given by:

$$\begin{aligned} M_g(z'_g,z'_{-g},q') &= (1-\delta)\omega_g(S_g,S_{-g})\int_Q^{q'}\int_{Z_g}^{z'_g}\int_{Z_{-g}}^{z'_{-g}}\mathbb{1}_g(z_g,z_{-g},q;S_g,S_{-g})d\hat{S}_{-g}(z_{-g};S_g,S_{-g})dS_g(z_g)dF(q) \\ &\quad +(1-\delta)\int_Q^{q'}\int_Q\int_{Z_g}^{z'_g}\int_{Z_{-g}}^{z'_{-g}}\mathbb{1}_g(z_g,z_{-g},q;S_g,S_{-g})dM_g(z_g,z_{-g},q_{-1})dG(q|q_{-1}). \end{aligned} \tag{2.11}$$

The first term captures the survived individuals changing their marital status from single to married. The second term measures the survived marriages. The marriage market clears in the stationary equilibrium, which means $M_f = M_m$, and this condition defines a fixed-point problem.

Now the stationary equilibrium of the economy can be defined as follows:

Definition 2.1: A stationary equilibrium is allocations for single and married households, c_g^S, ℓ_g^S, c^M, ℓ_f^M and ℓ_m^M; a set of value functions for singles and married individuals,

[10]Even though in each period there are more death replacements of males, the single male population size is not explosive. To illustrate this, suppose there are 100 females and 110 males in the economy and 80 of them are married. Therefore, the sex ratio is 1.1. Assume the mortality rate is 10%. Within each period, 10 females are dead, 8 of which are married and 2 are single; 11 males are dead, 8 of which are married and 3 are single. After the death replacement, there are 28 single females and 38 single males. As 8 of them get married in the next period, it generates a stationary equilibrium.

$V_g^S(z_g; S_g, S_{-g})$ and $V_g^M(z_g, z_{-g}, q; S_g, S_{-g})$; a matching rule for singles and married couples $\mathbb{1}_g(z_g, z_{-g}, q)$; and stationary distributions of singles and married couples $S_g(z_g)$ and $M_g(z_g, z_{-g}, q)$ for $g = m, f$, such that the following conditions hold:

- The allocations c_g^S, ℓ_g^S solve the single household problem (2.1), and c^M, ℓ_f^M and ℓ_m^M solve the married household Nash bargaining problem (2.2).
- The value function $V_g^S(z_g; S_g, S_{-g})$ defines the single's problem (2.5) given her/his indirect utility function $U_g^S(c_g^*, \ell_g^*)$ from problem (2.1), the value function for a married person $V_g^M(z_g, z_{-g}, q; S_g, S_{-g})$, the meeting probability $\omega_g(S_g, S_{-g})$, the matching rule for singles $\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g})$, and the normalized distribution of singles $\hat{S}_g(z_g; S_g, S_{-g})$.
- The value function $V_g^M(z_g, z_{-g}, q; S_g, S_{-g})$ defines the married person's problem (2.8) given her/his indirect utility function $U_g^M(c_g^*, \ell_g^*)$ obtained from problem (2.2), the value function for a single $V_g^S(z_g; S_g, S_{-g})$, and the matching rule for a married couple $\mathbb{1}_g(z_g, z_{-g}, q')$.
- The matching rule $\mathbb{1}(z_g, z_{-g}, q; S_g, S_{-g})$ is determined by equations (2.4) and (2.7), given the value functions $V_g^S(z_g; S_g, S_{-g})$ and $V_g^M(z_g, z_{-g}, q; S_g, S_{-g})$.
- The stationary distributions $S_g(z_g)$ and $M_g(z_g, z_{-g}, q)$ evolve according to equations (2.9), (2.10) and (2.11) given the matching rule $\mathbb{1}_g(z_g, z_{-g}, q; S_g, S_{-g})$.

2.2.9 Solving the Nash bargaining problem

Solving the model involves a complicated fixed-point problem. On the one hand, the allocations of married households require knowledge of value functions that depend on the meeting probability and distributions. On the other hand, the distributions depend on optimal allocations and value functions.

It is challenging to solve the Nash problem directly given the Nash product of value functions of the two counterparts. However, since a Nash problem is Pareto optimal, the Nash problem defined in (2.2) can be mapped to a Pareto frontier. Therefore, the Nash problem can be transformed into a maximization problem of a weighted sum of utilities, whose solution pins down the allocation on the Pareto frontier:

$$\begin{aligned} \max_{c,\ell_f,\ell_m} \quad & \theta U_f(c,\ell_f) + (1-\theta)U_m(c,\ell_m) \\ s.t. \quad & c = w_m z_m \ell_m + w_f z_f \ell_f, \end{aligned} \tag{2.12}$$

where $\theta = \frac{V_m^M(z_g,z_{-g},q;S_g,S_{-g}) - V_m^S(z_m;S_g,S_{-g})}{(V_m^M(z_g,z_{-g},q;S_g,S_{-g}) - V_m^S(z_m;S_g,S_{-g})) + (V_f^M(z_g,z_{-g},q;S_g,S_{-g}) - V_f^S(z_f;S_g,S_{-g}))}$.

Lemma 2.1: When consumption is a public good, the Nash bargaining problem of a married household defined in equation (2.2) is equivalent to the problem of maximizing the weighted sum of utilities defined in equation (2.12).

Proof: see Appendix 2.A.

θ is the Pareto weight attached to the wife, which measures her bargaining power in the household. If the marriage is feasible, θ lies between 0 and 1. Upon a match, $\theta < 0$ if the male wants to stay single, and $\theta > 1$ if the female does not want to accept the marriage. Note that the weight is endogenous, which depends on states $(z_g, z_{-g}, q; S_g, S_{-g})$. One can obtain a higher bargaining power if he/she has a higher productivity level, a lower realization of the marriage quality shock, or a smaller single population size, as it increases the value of being single and thus leads to a better outside option. As the sex ratio increases, the value of being single for females goes up, which leads to a higher value of θ, so female bargaining power rises.

The detailed algorithm to solve the structural model is explained in Appendix 2.B.

2.3 Calibration

To analyze the impact of changing sex ratios on marriage market and labor market outcomes, I solve the model numerically. The base year for calibration is set to 1990. Although the sex ratio started to increase after the implementation of the One Child Policy in 1978, I still use 1990 as the base year for two reasons. Firstly, the sex ratio in 1990 was 1.072, which is close to the natural sex ratio of 1.05. Secondly, the labor supply data at the intensive margin is only available after 1989. Therefore, I choose 1990 as the base year where I have information on individual gender, marital status, educational level and working hours. The microdata sets from which I extract information are the 1990 Chinese Census and the 1991 China Health and Nutrition Survey (CHNS). The data targets are working hours of married individuals, the fraction of individuals that are married, and the marital sorting of different educational groups. Some parameters are assigned using a priori information, while the remaining parameters are calibrated to match data moments by the minimum distance estimation method.

In the next section, the model is simulated by using the sex ratio in 2007 to access the role of the imbalanced sex ratio in marriage and labor market outcomes. The reason why the year 2007 is chosen as the reference year is that the sex ratio reached its peak of 1.2 in 2007. It is assumed that the economy is at steady state in both reference years.

2.3.1 Parameters based on a priori information

Some of the parameters are taken directly from the literature or from independent evidence. These parameters are summarized in Table 2.1.

The utility function parameters are taken from the literature, where the inverse of the consumption elasticity is $\gamma = 2$ as in Hall (1988) and the inverse of the Frisch elasticity is $\mu = 3$ as estimated by Chetty et al. (2011). The length of a model period is 1 year, so the discount factor takes the value of $\beta = 0.96$. Since I am interested in the marriage and labor

Table 2.1: Pre-determined parameter values

Parameters	Value	Explanation
Utility		
γ	2	Inverse of consumption elasticity (Hall (1988))
μ	3	Inverse of Frisch elasticity (Chetty et al. (2011))
β	0.96	Discount factor
δ	1/33	Normalized mortality rate between age 18 and 50
κ	0.80	Gender wage gap (Zhang et al. (2005))
ϕ	1.072	Sex ratio (1990 Census)
z_f, z_m	1	Educational premium
	1.075	(less than primary school=1, primary completed=1.075,
	1.191	secondary completed=1.191, university completed=1.375)
	1.375	(Liu (1998) and Zhang et al. (2005))
Z_f	0.3035	Distribution of female education (1990 Census)
	0.5782	
	0.1148	
	0.0035	
Z_m	0.1433	Distribution of male education (1990 Census)
	0.6821	
	0.166	
	0.0086	

market outcomes, the population I am focusing on is between 18 and 50 years old, which corresponds to an average lifespan of 33 years.[11] So the mortality rate being $\delta = 1/33$ gives an average life expectancy of 33 years. All data targets for the estimation are calculated for the population within this age range. The gender wage gap was $\kappa = 0.8$ in 1990, taken from Zhang et al. (2005), who control for the educational level and experience. According to the 1990 China Census, the sex ratio of the age group of interest was $\phi = 1.072$.

Lastly, the levels and distributions of productivity are measured by educational attainment. The productivity types are classified into 4 categories, which correspond to "Less than primary school", "Primary school completed", "Secondary school completed" and "University completed". The productivity level z_g is measured by the education premium, and it is assumed to be identical between women and men who have the same educational level. The productivity level of "Less than primary school" is normalized to 1. As estimated by Liu (1998) and Zhang et al. (2005), the education premium of "Primary school completed", "Secondary school completed" and "University completed" relative to "Less than primary school" on average is 7.5%, 19.1% and 37.5% respectively between 1989 and 1992. Therefore, the productivity levels are $z = \{1, 1.075, 1.191, 1.375\}$ for these four categories.

The distributions of educational attainment Z_g are taken directly from the 1990 Census data. They are different between women and men. In 1990, men on average had a higher educational attainment than women. For males, 14.33% of them had less than primary school education, 68.21% complete primary school, 16.6% finished their secondary education, and 0.86% had a college degree or above ($Z_m = \{0.1433, 0.6821, 0.166, 0.0086\}$). For females, 30.35% of them did not complete primary education, 57.82% had their primary education finished, 11.48% completed secondary school, and only 0.35% obtained a college degree or higher ($Z_f = \{0.3035, 0.5782, 0.11148, 0.0035\}$).

[11] In China, the official female retirement age is between 50 and 55. Therefore, I restrict the population of interest to be under 50 years old to avoid forced retirement.

2.3.2 Parameters estimated by the minimum distance estimation method

The remaining 7 parameters, namely 2 disutility of labor parameters $\{\psi_f, \psi_m\}$ and 5 marriage quality shock parameters $\{q_s, \sigma_s\ q_m, \sigma_m, \rho_m\}$, are estimated by the minimum distance estimation method.

The data targets are: *(i)* married female and male working hours, *(ii)* marriage market outcomes.

The working hours of married women and men are calculated from the 1991 CHNS data. The data set reports the average hours an individual worked per day from the last year (1990). The married population is defined by currently married or cohabiting couples, while the single population includes those who never married, are separated/divorced, and widowed. Note that the fraction of the population with a college degree or higher was very small in the 1990 Census data, and the number of college graduates in the 1991 CHNS data set was even smaller (less than 80). So instead of targeting the working-hours data for each education group, I take the average married female and male working hours as two calibration targets.[12] On average, married females and married males worked almost the same number of hours (approximately 8 hours) per day.[13]

The marriage market outcomes I focus on are the fraction of females that are married and the assortative mating pattern, which is measured by the number of marriages for all possible combinations of education between two spouses. The data targets of marriage market outcomes are calculated from the 1990 Census data. Given the sex ratio and the fraction of females that are married, when the female population size is normalized to be 1, the fraction of males that are married can be directly obtained from a back-of-the-envelope

[12]The 1991 CHNS also reports the number of days and months an individual works. I also normalize the average weekly working hours and the average yearly working hours into daily hours for comparison. After the normalization, there is very little difference between husbands and wives' working hours in all the results. Therefore, I directly use the average daily working hours as data targets, which is also a more precise measure of working hours.

[13]Zero working hour data are also included in the calculation.

calculation. Therefore, I do not take the fraction of males that are married as a data target. In the data, about 81% of females are married.

In terms of the sorting pattern, the number of marriages with one partner being highly educated was very low relative to the other groups since there were less than 1% of the population with a college degree. Therefore, I normalize the assortative mating targets by dividing the number of marriages of each education combination by the married female population size for each female educational level. The normalization eliminates the effect of the long tail of the education distribution. As a result, for every female educational level, the measure of assortative mating sums up to 1.[14] After the normalization, most marriages occur between husbands and wives with the same educational level.

In total, I have 19 data targets. Two of them capture labor market outcomes, which are the married female working hours and the married male working hours. The other 17 data targets are marriage market outcomes. One of them captures the overall fraction of the population that are married, which is the fraction of females that are married. The other 16 represent the assortative mating pattern.

Let η be the vector of 7 parameters to be estimated, and $g(\eta)$ be the vector of moments generated by the model as a function of parameters. Denote g^{data} be the vector of 19 data moments obtained from the 1991 CHNS and 1990 Census. So the vector of distances between data moments and model moments is given by $G(\eta) = g^{data} - g(\eta)$.[15] Then the minimum distance estimator is defined as:

$$\hat{\eta} = \arg\min_{\eta} G(\eta)' W G(\eta),$$

[14]The normalization by the population size of each educational group combination is crucial in the calibration to capture marriage market outcomes. One example is, after the normalization, the share of marriages with the same education level prevails in the college-educated groups (as shown in Table 2.3). However, without the normalization, it would only account for 0.2% of the population.

[15]Here I use the absolute deviation instead of the percentage deviation because the data targets are more or less in the same magnitude. The working hours are normalized to be between 0 and 1, and the other targets are measured by shares, which are also between 0 and 1.

where W is a positive semi-definite weighting matrix.[16]

Table 2.2 reports the calibrated parameter values.

Table 2.2: Calibrated parameters

Parameters	Explanation	Value
ψ_f	Disutility of labor of female	16.136
ψ_m	Disutility of labor of male	19.755
q_s	Mean of single's marriage quality distribution	-0.4964
q_m	Mean of married marriage quality distribution	0.399
ρ_m	Persistence of married marriage quality distribution	0.9654
σ_s	Variance of single's marriage quality distribution	2.0586
σ_m	Variance of married marriage quality distribution	1.0065

Females have a lower disutility of labor than males (16.136 versus 19.755). The lower disutility of labor leads to a higher number of female working hours, while the gender wage gap discourages her to work. Therefore, the model is able to generate similar working hours between husbands and wives to match the data. The mean of the marriage quality shock for singles is negative ($q_s = -0.4964$). As consumption in the married household is a public good, which is already enough to motivate singles to get married, the negative value of the love shock offsets some of the benefits from marriage to match the marriage market data. The variance of the marriage quality shock for singles is larger than that for already married individuals (2.0586 versus 1.0065), which gives singles incentive to wait longer until they meet a better match. Once the two meeting partners get married, the marriage quality shock is very persistent ($\rho_m = 0.9654$).

The performance of the model is illustrated in Table 2.3, where the model moments and data moments are displayed. Overall, the model can replicate many of the data moments. The working hours can be matched well. The model can also mimic the overall marriage market as the fraction of females that are married is relatively well matched. In

[16]The weights are chosen such that I put equal weight on the labor market targets and marriage market targets. Since there are only 2 labor market moments and 17 marriage market moments, I set the weights on married female and male working hours to be 8.5 and the weights on each of the marriage market targets to be 1.

terms of the sorting pattern of the model, it can capture the hump-shaped assortative mating pattern for lower-educated female groups, where most marriages take place when the husband has completed his primary education. Unfortunately however, some of the assortative mating moments are off the target, especially for the highly-educated groups. This mismatch has two possible explanations: Firstly, the population of the higher-educated group is too small, which leads to a very low meeting probability between higher-educated types in the model. Even if they would like to marry each other, there are very few realized marriages given that they are unlikely to meet another college-educated partner. In addition, the model is over-identified, as there are 19 data moments but only 7 parameters calibrated.

Table 2.3: Data and model moments

Statistics	Data moment				Model moment			
Working hours								
Wife	7.87				7.71			
Husband	7.93				7.96			
Marriage								
Fraction of Married Females	0.809				0.806			
Sorting (% of married females of each type)	husband				husband			
wife	<primary	primary	middle	uni	<primary	primary	middle	uni
<primary	0.3532	0.5915	0.0551	0.0002	0.1474	0.7024	0.1421	0.0077
primary	0.048	0.7937	0.1556	0.1331	0.1423	0.706	0.1441	0.0076
middle	0.0139	0.3757	0.5688	0.0416	0.135	0.6428	0.2152	0.007
uni	0.0004	0.0453	0.2284	0.726	0.1168	0.5556	0.3101	0.0175

Data source: 1991 CHNS and 1990 Census

2.4 The impact of the imbalanced sex ratio in 2007

In this section, I simulate the model for 2007 by only changing the sex ratio to 1.2 exogenously while holding the other parameters constant to access the role of the imbalanced sex ratio. Then I compare the results of the two steady states.[17] In particular, the outcomes of interest are: (i) female and male welfare implications, (ii) female and male

[17] I only conduct the static comparison, because the model framework only allows me to compute variable values in the stationary distribution. The transition path with marriage/divorce decisions can be obtained in a life-cycle framework, for example by Knowles and Vandenbroucke (2015), but it is not the main focus of this chapter.

working hours, (iii) female and male marriage and divorce decisions and the degree of assortative mating. The results are presented in Table 2.4.

Table 2.4: The impact of the imbalanced sex ratio: model predictions

	1990	**2007**
Welfare (% change)		
Female		9.5%
Male		-14.42%
Labor market		
Total female working hours	8.08	7.67
Total male working hours	8.13	8.56
Married female working hours	7.71	7.38
Married male working hours	7.96	8.7
Marriage market		
Fraction of married females	80.94%	83.54%
Fraction of married males	76.65%	69.62%
Marriage rate	2.07%	2.93%
Divorce rate	0.82%	0.93%
Reservation value of marriage quality, female	-0.0439	-0.0374
Reservation value of marriage quality, male	-0.045	-0.0483
Degree of assortative mating	0.456	0.4935
Other changes		
Married household consumption	0.9541	0.9675
Female bargaining power	0.4895	0.5485

2.4.1 Effect on welfare

Since the population sizes in two stationary distributions are different, it is problematic to measure the welfare change of the single and married population separately. A single woman in the low sex ratio economy may be able to get married if she is in the high sex ratio economy. Therefore, I take an ex-ante new-born agent who just enters the marriage market as a reference.

Consider a new-born agent of gender $g \in \{f, m\}$ with productivity type z_g, who just enters the economy as a single individual. The value function for the new-born individual is given by:

$$\tilde{V}_g(z_g; S_g, S_{-g}) = \int_Q \int_Z (\omega_g(S_g, S_{-g}) \max\{V_g^{S*}(z_g; S_g, S_{-g}), V_g^{M*}(z_g, z_{-g}, q; S_g, S_{-g})\} + (1 - \omega_g(S_g, S_{-g}))V_g^{S*}(z_g; S_g, S_{-g}))d\hat{S}_{-g}(z_{-g})dF(q),$$

The new-born single agent meets a spouse of type z_{-g} with probability ω_g and draws the marriage quality shock q. Given the optimal allocations of being single and being married, the individual decides whether to get married by comparing the value of being married with the value of being single. If the agent meets no one with probability $1 - \omega_g$, he/she has to stay single.

Then the welfare change is measured in consumption equivalent units for the new-born women and men. As illustrated in the first part of Table 2.4, on average, women benefit from the more imbalanced sex ratio by gaining 9.5%. Three channels contribute to the change. Firstly, the higher bargaining power enables married females to obtain a larger share of the marital surplus by enjoying more leisure.[18] Secondly, more females can get married due to a higher probability of meeting a potential husband. Given the beneficiary of marriage (economies of scale and the love shock), women gain even more. Thirdly, some of the females can marry a better husband, and they benefit from the income effect. In contrast, male welfare drops by 14.42%. It arises not only from the additional working hours but more importantly from the lower likelihood of finding a wife. In the next section, a decomposition exercise is conducted to illustrate the relative importance of each channel.

[18] Household public consumption only plays a marginal role, which is almost constant (from 0.9541 to 0.9675).

2.4.2 Effects on labor market

The "Labor market" part of Table 2.4 illustrates the impact of the increased sex ratio on labor market outcomes. The model predicts that, on average, total female working hours drop by 5.1% from 8.08 to 7.67 hours per day, and total male working hours increase by 5.2% from 8.13 to 8.56 hours per day. Two aspects can explain the change: First, the higher female bargaining power enables wives to take more marital surplus by enjoying more leisure time. Therefore, married female working hours fall.[19] On the contrary, husbands need to work more as his bargaining position worsens. Second, as will be shown later, there is a compositional effect from the change of the share of the married population. Given that married females work less than single females (8.08 vs. 9.47 hours in the model) and more women are able to get married, total female labor supply falls. The opposite happens to males.[20]

The model prediction is in line with the data trend. From 1990 to 2007, data suggest that married female working hours dropped by 10.85% from 7.83 to 7.01 hours per day (1991, 2006 CHNS). The model predicts the same direction of variation, where married female working hours decrease from 7.71 to 7.38. The increased female bargaining power in the intra-household allocation problem can explain most of the decline of married female working hours. Husbands are willing to transfer more resources to wives so that they will stay in the marriage. In the model setup, this is realized by husbands allowing wives to work less and enjoy more leisure time. As measured by the Pareto weight θ, female bargaining power has increased by 12.05% on average, and all types of females are able to obtain a better bargaining position. Particularly lower educated women benefit

[19] If home production is included, female working hours should still fall due to the higher bargaining power. Ignoring home production in the model will give an upper bound of the estimation of the reduced married female labor supply.

[20] In the model, single household labor supply does not react to the sex ratio change, as the sex ratio does not enter the single household optimization problem. On top of that, I assume there is no capital accumulation and no change in wage rates, so single household labor supply does not change. In the data, both single female and single male working hours fall by about 0.2 hours, which can be explained by the income effect due to the increased wage rates.

most, as illustrated in Table 2.5.[21]

Table 2.5: Change of female bargaining power by productivity type

	<primary	primary	secondary	college
1990	0.4761	0.4917	0.512	0.5456
2007	0.5378	0.55	0.5676	0.5953
% Change	12.96%	11.85%	10.85%	9.12%

Unfortunately, contradicting the data, the model predicts that husbands should increase their working hours as their bargaining power falls. In the data, married male working hours barely change. Two possible reasons can explain the difference. Firstly, empirical studies find that the elasticity of female labor, especially married female labor, is higher than male labor (Triest (1990), Eissa (1995) and Keane (2011)), so married male labor supply reacts less to the change of the sex ratio. However, in my model, the Frisch elasticity is assumed to be identical between women and men, which is standard in quantitative studies (Aiyagari, Greenwood, and Guner (2000), Greenwood, Guner, and Knowles (2003) and Greenwood et al. (2016) etc.). Secondly, the only variation in the model is the sex ratio from 1990 to 2007, and all the other parameters are fixed at the 1990 level. But during the period of interest, the distribution of education also shifts to the right tail in the data, where a much larger share of the population can obtain a higher educational level. The significantly increased return to education could be one explanation in the drop of male working hours.[22]

2.4.3 Effect on marriage market

In 2007, more women were able to get married, and correspondingly, fewer men could find a wife. In the data, the fraction of females that are married increased from 80.47%

[21] The income effect of marriage may play a less important role. Yao and Tan (2005) show that the increased male income in China can only explain less than 10% of the drop in female labor supply.

[22] During this period, the gender wage gap was almost constant, which increased to 0.76 between 1990 and 1997, but fell to 0.78 in 2007.

to 81.38%, and the fraction of males that are married dropped from 74.44% to 71.35% (1990, 2010 Census). The model predicts the same trend as the data. In the model, the fraction of females that are married increased from 80.94% in 1990 to 83.54% in 2007, while the fraction of males that are married dropped from 76.65% to 69.62%. For females, the changes happen due to: (i) the increased bargaining power making marriage more attractive, and (ii) there being more males available on the marriage market, which gives females a wider choice of husbands. The opposite happens to males.

According to the model, overall, the marriage rate increased from 2.07% in 1990 to 2.93% in 2007 due to the benefit of marriage. At the same time, the divorce rate rose from 0.82% to 0.93%. It is more likely for married couples to get divorced in the high sex ratio economy since married women have a better outside option. The larger number of single men available encourages married women to get divorced and wait for a better husband.

When the sex ratio is higher, women can also find a better husband. They become more selective in finding a partner. Measured by the reservation value of the marriage quality shock, females become 14.8% more selective while males become 7.3% less selective. The change of selectivity can also be illustrated by Figure 2.3. It shows the marriage policy functions of women and men separately for a given level of the marriage quality shock. As shown in the top two graphs, when the sex ratio is higher, fewer females would like to accept the marriage given the type of the potential husband. Since the marriage decision is a joint decision, the fraction of males that are married decreased due to the increased selectivity of females. For males, they become less selective, as shown by the bottom two graphs in Figure 2.3. Instead, they were more willing to marry lower-educated females than before.

The degree of assortative mating increases, which is measured by the fraction of married couples who have the same education level. When the sex ratio is low, the model estimates that 45.6% of couples have the same educational level, but this number increases to

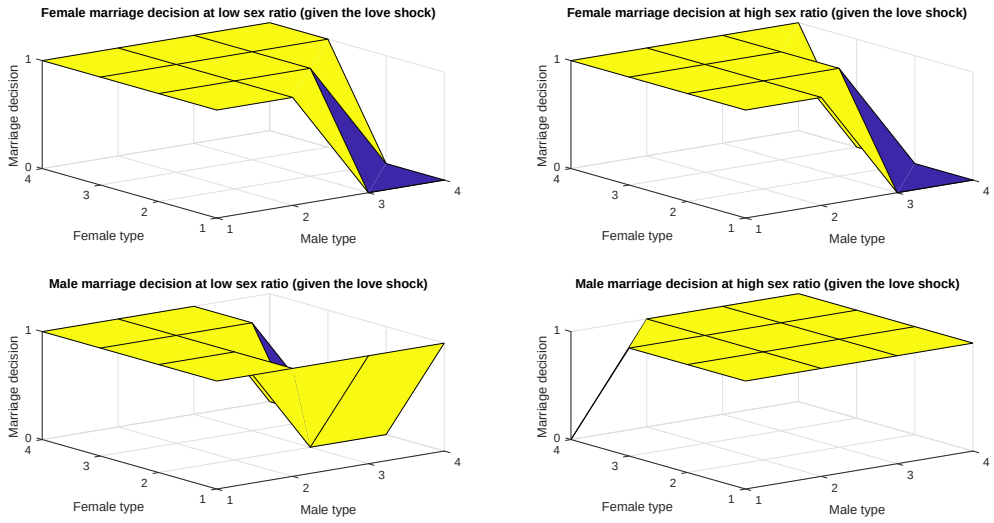


Figure 2.3: Marriage Policy Functions Before and After the Sex Ratio Changes

49.35% when the sex ratio reaches 1.2. Since males are less selective, and there are more low-educated males available in the high sex ratio economy, more low-educated women are able to find a husband. Therefore, the degree of assortative mating increases. This finding is in line with the empirical literature (Edlund et al. (2013)).

2.5 Decomposition exercises

The effect of a higher sex ratio on female and male welfare passes through 3 channels: the bargaining channel, the channel of women having a higher probability of meeting husbands, and the channel of females finding a better husband. The bargaining channel is captured by the bargaining weight θ, the higher meeting probability channel is represented by the meeting probability ω_g and the better husband channel is defined by the marriage policy function $\mathbb{1}_g$. To pin down the effect from each of the three channels, I use 1990 as the benchmark year, then change the sex ratio to the level in 2007. Then I turn on each channel separately while holding the other two channels fixed at the 1990 level. Therefore, the effect of each channel can be captured by comparing each variable value with its 2007

counterpart in column (5) of Table 2.6. The closer the two values are, the more important the channel is in explaining the change. The results are shown in Table 2.6.

Table 2.6: Decomposition exercises

	1990	Higher bargaining power	Higher meeting prob.	Better husband	2007
	(1)	(2)	(3)	(4)	(5)
Welfare (% change)					
Female		3.48%	5.93%	0.12%	9.5%
Male		-5.43%	-8.87%	-0.02%	-14.42%
Labor market					
Working hours (wife)	7.71	7.45	7.71	7.64	7.38
Working hours (husband)	7.96	8.54	7.96	8.03	8.7
Marriage market					
Fraction of females, married	80.94%	81.26%	84.62%	80.78%	83.54%
Fraction of males, married	76.65%	75.87%	70.51%	76.69%	69.62%

2.5.1 A higher female bargaining power only

The bargaining channel effect can be captured by the change of the endogenous bargaining weight θ. To pin down the effect from this channel, I allow the weight to change according to $\theta = \frac{V_m^M - V_m^S}{(V_m^M - V_m^S)+(V_f^M - V_f^S)}$ while holding the meeting probability ω_g and marriage policy functions at the same level as 1990.[23] Therefore, the bargaining weight varies with the sex ratio, but single agents still have the same meeting probability of spouses, and once they meet a potential spouse, they have to make the same marriage decision as if they were in the low sex ratio economy. Then the model is simulated with the 2007 sex ratio. The results are listed in the second column of Table 2.6.

The results suggest that the bargaining channel can explain about one-third of the increased female welfare. Women are 3.48% better off, and men are -5.43% worse off due to the variation in the bargaining power. The change results from a higher married

[23]Note that even when the meeting probability is fixed, the relative single population size still varies, which affects the normalized single population distribution in the value function. Consequently, the bargaining weight still changes with the sex ratio.

fraction and lower working hours of females. The 78% change of the lower married female labor supply can be explained by the higher bargaining power. For husbands, they have to work 0.58 hours longer. Regarding the marriage market, the fraction of females that are married increases by 0.32 percentage points, as the higher bargaining power makes marriage more attractive to females. The fraction of men that are married drops by 0.78 percentage point as the marriage is less beneficial due to the lower bargaining power.

2.5.2 A higher meeting probability only

The higher meeting probability channel is measured by the change of the meeting probability ω_g. In particular, the meeting probability evolves with the relative single population size by $\omega_g = \frac{S_{-g}}{S_g+S_{-g}}$, while the bargaining weights and the marriage decision policies are fixed at 1990 levels. As a result, single females have a higher meeting probability to meet a husband, but once they meet, the marriage decision is still the same as in the low sex ratio economy, and their bargaining power remains the same as before. Column (3) in Table 2.6 presents the simulated outcomes.

The higher meeting probability channel is the most relevant channel to explain the change of welfare. It contributes to 5.93% of female welfare gain and 8.87% of male welfare loss. The effect is generated by the impact of the sex ratio on the marriage market. While married individual working hours barely react to the increased sex ratio, the increased meeting probability for women is essential in explaining the variation of marriage market outcomes. It accounts for 3.68 percentage points in the increase in the fraction of females that are married. On the contrary, fewer men are able to find a wife with 6.14 percentage points. Compared with the utility gain from leisure, marriage is more beneficial due to economies of scale and the love shock. Therefore, the change of the female and male marriage behavior most affects their welfare.

2.5.3 A better husband only

The better husbands channel is captured by allowing the marriage decision to be endogenous while holding the bargaining weight and meeting probabilities constant at the 1990 level. Therefore, while the bargaining weights and the meeting probabilities are the same as in the lower sex ratio economy, singles can choose to get married or to wait for a better match. The results are illustrated in column (4) of Table 2.6.

Overall, the better husbands channel only plays a marginal role in the change of welfare. Women are only 0.12% better off, and men are -0.02% worse off. When the marriage decision is endogenous, married female labor supply falls by 0.07 hours. Due to the income effect, the better husband enables the wife to work less. On the contrary, husbands work 0.07% more. The impact on the fraction of females and males that are married is also small. More females choose to stay single by 0.16 percentage points, and the number of men who can find a wife increases by 0.04 percentage points. This is because females are more selective in choosing husbands and males are less selective.

2.6 Conclusion

The sex ratio in China has been growing significantly during the last 30 years. The imbalanced sex ratio generates more than 30 million additional males than females, which has a substantial impact on China's labor and marriage market.

To investigate its effects, I develop a unified model of marriage and divorce, imbalanced sex ratios, and an intra-household bargaining process. The intra-household allocation problem of married households is determined by a Nash bargaining process with being single as the outside option. Marriage is attractive for two reasons, the love shock and economies of scale from household public consumption. The meeting probability in the marriage market depends on the population size of singles of the opposite sex. Therefore,

it is more likely for the scarcer gender to find a spouse. The sex ratio affects female and male well-being through the bargaining channel, the channel of a higher meeting probability of husbands, and the channel of finding a better husband. When the sex ratio rises, it leads to a better outside option for females, which increases their bargaining power. The higher bargaining power enables married women to enjoy more leisure. Besides, the additional men in the marriage market make it easier for females to find a husband, and in addition, to find a better husband, thus generating a stronger income effect. All of them contribute to the change of welfare.

The model is calibrated to match the Chinese data moments in 1990 when the sex ratio was low. The data targets are chosen to capture married households' working hours and marriage market patterns. The calibrated parameter values are reasonable, and the model overall fits the data well. Then I increase the sex ratio exogenously to 1.2 to simulate 2007 outcomes. Results suggest that females are 9.5% better off due to the change in labor and marriage market outcomes while males are 14.42% worse off. The change results from variations of working hours and marriage rates. Total female working hours drop by 5.1% and total male working hours rise by 5.2%. The fraction of females that are married increases by 2.6 percentage points and that of males decreases by 7 percentage points. The degree of assortative mating rises with the sex ratio since females are more selective in choosing their partners. The model predictions are broadly in line with the data trends.

In addition, a decomposition exercise is conducted to pin down the effects of the three channels on welfare changes. The higher meeting probability is the most important channel to explain the welfare change, and the one which most affects the marriage market. The bargaining channel is also essential due to its impact on the labor market. It also makes marriage more attractive to females. The better husband channel, which affects the labor choice through the income effect, only plays a marginal role.

Appendix

2.A Proof of Lemma 2.1

To prove that the two questions defined in (2.2) and (2.12) are equivalent, I will show that the first order conditions of the two problems when the solutions are interior are exactly the same.

The first order conditions of problem (2.2) are given by:

$$\begin{aligned} c: \ & c^{-\gamma}(V_f^M - V_f^S) + c^{-\gamma}(V_m^M - V_m^S) = \lambda \\ \ell_f: \ & -\psi \ell_f^{\mu}(V_m^M - V_m^S) = \lambda w_f z_f \\ \ell_m: \ & -\psi \ell_m^{\mu}(V_f^M - V_f^S) = \lambda w_m z_m \\ B.C.: \ & c = w_m z_m \ell_m + w_f z_f \ell_f, \end{aligned}$$

where λ is the Lagrange multiplier.

Collecting terms to eliminate λ gives:

$$
\begin{aligned}
-\psi \ell_f^{\mu}(V_m^M - V_m^S) &= c^{-\gamma}[(V_f^M - V_f^S) + (V_m^M - V_m^S)]w_f z_f \\
-\psi \ell_m^{\mu}(V_f^M - V_f^S) &= c^{-\gamma}[(V_f^M - V_f^S) + (V_m^M - V_m^S)]w_m z_m \\
c &= w_m z_m \ell_m + w_f z_f \ell_f,
\end{aligned}
$$

The first order conditions of problem (2.12) are:

$$
\begin{aligned}
c: \ & c^{-\gamma}\theta + c^{-\gamma}(1-\theta) = \lambda \\
\ell_f: \ & -\psi \ell_f^{\mu}\theta = \lambda w_f z_f \\
\ell_m: \ & -\psi \ell_m^{\mu}(1-\theta) = \lambda w_m z_m \\
B.C.: \ & c = w_m z_m \ell_m + w_f z_f \ell_f,
\end{aligned}
$$

where λ is the Lagrange multiplier and $\theta = \frac{V_m^M - V_m^S}{(V_m^M - V_m^S) + (V_f^M - V_f^S)}$.

Eliminating λ and replacing θ:

$$
\begin{aligned}
-\psi \ell_f^{\mu} \frac{V_m^M - V_m^S}{(V_m^M - V_m^S) + (V_f^M - V_f^S)} &= c^{-\gamma} w_f z_f \\
-\psi \ell_m^{\mu} \frac{V_f^M - V_f^S}{(V_m^M - V_m^S) + (V_f^M - V_f^S)} &= c^{-\gamma} w_m z_m \\
c &= w_m z_m \ell_m + w_f z_f \ell_f,
\end{aligned}
$$

which are the same as the FOCs of problem (2.2).

Therefore, the two problems are equivalent to each other.

2.B Numerical algorithm

The model is solved numerically in Matlab. The algorithm to solve the structure model involves a complicated fixed-point problem. The following steps illustrate the algorithm in detail:

1. Solve for the single household allocations and obtain the indirect utilities of being single.

2. Initialize the guesses of distributions $S_{f,0}$, $S_{m,0}$, $M_{f,0}$ and $M_{m,0}$; value functions $V^S_{f,0}$, $V^S_{m,0}$, $V^M_{f,0}$ and $V^M_{m,0}$, continuation values $cont_f$ and $cont_m$ for married households and the initial bargaining weights θ_0.

3. Solve married household allocations with bargaining weights θ_0 by solving the problem (2.12).

4. Update indirect utilities U^M_m and U^M_f.

5. Then the bargaining weight is updated by:

$$\theta = \min\{\max\{\frac{U^M_m + cont_m - V^S_{m,0}}{(U^M_m + cont_m - V^S_{m,0}) + (U^M_f + cont_f - V^S_{f,0})}, \lambda\}, 1-\lambda\},$$

   where λ is a small number. This guarantees that the weight is between 0 and 1.

6. Update the value functions of being married given the indirect utilities.

7. Given the updated value functions, determine marriage decisions and divorce decisions by comparing value functions of singles and married as equations (2.4) and (2.7).

8. Update meeting probabilities given distributions.

9. Given marriage and divorce decisions and meeting probabilities, update continuation values, value functions, and distributions according to equations (2.5), (2.8), (2.9), (2.10) and (2.11).

10. Calculate the distances between V_m^S and $V_{m,0}^S$, between V_f^S and $V_{f,0}^S$, between V_m^m and $V_{m,0}^m$, between V_f^M and $V_{f,0}^M$, between S_m and $S_{m,0}$, between S_f and $S_{f,0}$, between M_m and $M_{m,0}$, and between M_f and $M_{f,0}$.

11. Update the guesses of value functions and distributions by a convex combination of their own values and new values in value function and distribution iterations and update the bargaining weight θ_0 by θ.

12. Check if the distance is small enough. If not, go back to step 3.

Note that the bargaining weight is between 0 and 1. If it reaches the corner, it means at least one of the spouses rejects the marriage. This is consistent with marriage policy functions.

3 The Imbalanced Sex Ratio and Female Bargaining Power: Evidence from China

3.1 Introduction

The sex ratio, which is defined by the number of males per 100 females, is considered to be one of the most important factors in determining the relative bargaining power between husbands and wives. Becker (1973, 1974) first established the theory that the sex ratio affects the marriage market through supply and demand, which further influences the distribution of the marital surplus. Chiappori, Fortin, and Lacroix (2002) develop a collective framework, and the sex ratio is one of the distribution factors that affect the intra-household bargaining position. In Chapter 2, I use a Nash bargaining model to investigate the impact of the imbalanced sex ratio in China on female and male welfare through labor and marriage market outcomes. While previous studies mainly explore how the sex ratio affects intra-household bargaining in theory, limited evidence is found on its direct effect on the bargaining power. Instead, they investigate the sex ratio effect on intra-household allocations as an indirect measure of the bargaining power. Therefore, the goal of this study is to empirically investigate how the sex ratio affects the

relative bargaining power and hence intra-household allocations, and to test the empirical implications of the model in Chapter 2. The underlying research questions are: How does the imbalanced sex ratio affect married female bargaining power? How does the imbalanced sex ratio affect female and male marriage market and labor market outcomes differently? And how does the imbalanced sex ratio affect intra-household allocations?

In this chapter, I use county-level variations in sex ratios in China to study its impact on marriage market outcomes, female bargaining power, and intra-household allocations. The mechanism is that the imbalanced sex ratio affects the marriage market directly, and therefore improves the outside option of women, which in turn increases her bargaining power. The change of relative bargaining power further alters intra-household allocations. When there are more men available in the marriage market, it is easier for women to find a partner. Since marriage is beneficial due to economies of scale, women obtain a better outside option, which leads to a higher female bargaining power. With a higher bargaining power, women can enjoy a larger share of the marital surplus. For instance, married women can enjoy more leisure by working less both in the market and at home and allocate more resources to themselves and their children. A more detailed explanation can be found in Chapter 2.

I focus on China because since the implementation of the One Child Policy in 1980, there have been an excessive number of men relative to women.[1] In the late 2000s, over 120 boys were born for every 100 girls. The county-level variations of the sex ratio are even larger, which ranged from 0.57 to 1.9 in 2000.

To conduct the analysis, I merge sex ratios obtained from the 1990 and 2000 Chinese Census data with the 1989, 1991, 1993 and 2000 China Health and Nutrition Survey (CHNS) data at the county level. The Census data contain individual demographic

[1] Li, Yi, and Zhang (2011) and Bulte, Heerink, and Zhang (2011) find that 50% to 90% of the imbalanced sex ratio can be explained by the implementation of the One Child Policy in China. The traditional son preference and the availability of selective abortion technology increases the sex ratio constantly (Chu (2001), Yi et al. (1993)).

information and labor force participation status. Individual demographic information, time use, decision power in major household purchases, and individual health status are reported in the CHNS data sets. I use the 2000 Census county-level data to test the sex ratio effect on female and male marriage and divorce decisions as well as married female labor force participation decisions. Then the individual level data from the merged data set are used to test the sex ratio effect on female decision power and intra-household allocations. The decision power is captured by whether the individual is involved in major household purchases. Intra-household allocations are measured by the time spent on household chores, female health status, children's health, as well as male cigarette and alcohol consumption.

The identification strategy is based on cross-county variations of sex ratios.[2] Overall, I have 938 counties in the 1990 Census, 2870 counties in the 2000 Census and 75 counties in the merged data set. In China, most policies are implemented at the provincial level. Therefore, the province fixed effect is included in all county-level analyses to control for the provincial government's policy impact on economic development, which affects the marriage and labor market directly. Besides the province fixed effect, to avoid selection biases, I also include many county-level and individual level controls in the regressions. Some of the controls are measures of local economic development, such as population size, literacy rate, tap water access rate, whether the individual lives in a rural/urban area, and educational level. In addition, some aim to control for factors that affect sex ratios, including the migration rate at the county level, the migration status at the individual level, and the share of minorities in the county who are not influenced by the One Child Policy.

[2]Ideally, a difference-in-difference method across county and year will improve the identification. However, the CHNS data is a repeated cross-sectional survey, which means the surveyed individuals vary across years. Therefore, only county-level analysis can be conducted in the merged data, which leaves only 75 observations available. Consequently, the results obtained by the difference-in-difference method are insignificant. The cross-sectional variation is the best identification strategy I can get from the data sets.

I document clear evidence that the higher sex ratio is associated with a higher fraction of women ever married and a lower fraction of men ever married. Measured by the decision power in purchasing household goods, married female bargaining power significantly increases with the sex ratio. The higher sex ratio is also negatively correlated with married female labor force participation rate. Moreover, wives reduce their housework hours relative to their husbands, which suggests that married women increase their leisure time due to her increased bargaining power. Married women and their children are also healthier in counties with a higher sex ratio. All results are robust to adding control variables. The results are consistent with model predictions in Chapter 2.

This study contributes to the empirical literature about sex ratios and intra-household bargaining and provides empirical evidence to support quantitative model predictions. As discussed earlier, previous studies about the sex ratio effect on intra-household allocations concentrate on theoretical models (Becker (1973, 1974) and Chiappori, Fortin, and Lacroix (2002)). Based on different model setups, they prove that the sex ratio can affect intra-household allocations by changing the marriage market. Several empirical studies focus on this perspective and document that the higher sex ratio can lead to a higher likelihood of marriage for females. Abramitzky, Delavande, and Vasconcelos (2011) use WWI as an exogenous mortality shock to male population in France. The authors document a significant increase in the likelihood of marriage for males including a greater likelihood of them marrying women of higher social classes. Similar results are found for the U.S. and China by Angrist (2002) and Porter (2016). Their studies show that the marriage rate of the scarcer females increases with the sex ratio. I test the marriage market implication in China with the Census data at the county level, which is more representative than the CHNS data used by Porter (2016).

Other empirical studies investigate the sex ratio effect on the relative bargaining power. However, due to the lack of a direct measure of the unobserved bargaining power in the data, studies identify the bargaining power indirectly by exploring intra-household

allocations. Angrist (2002), Grosjean and Khattar (2018) and Edlund et al. (2013) argue that the higher sex ratio lowers the female labor force participation rate in the U.S., Australia, and China. The reason for this lowering of female labor force participation is because female bargaining power increases with the sex ratio. Wei and Zhang (2011) find that the higher sex ratio contributes to the higher savings rate in China. Due to the higher female bargaining power in the marriage, men save more before marriage to gain a better bargaining position, which pushes the saving rate up. In a closely related paper, Edlund et al. (2013) examine the imbalanced sex ratio effect on crime rates, female labor market outcomes, and intra-household bargaining. They use the CHNS and income survey data at the provincial level and measure the bargaining power directly by spouse's involvement in the decision making of purchasing household TVs, radios, and electric fans. I use Census data instead, which is more representative, and further extend the measure of the bargaining power by the decision making of purchases with a much richer basket of household goods. I also provide different indirect measures of the bargaining power with intra-household allocations as a compliment.

Limited quantitative studies have been conducted to analyze the sex ratio effects. Knowles and Vandenbroucke (2015) and Rıos-Rull, Seitz, and Tanaka (2013) focus on the marriage market outcomes. In Chapter 2, I incorporate a Nash bargaining framework into the matching model of the marriage market to study the effect of the imbalanced sex ratio on female labor supply and marriage decisions in China. I find that the higher sex ratio reduces female labor supply and increases the fraction of females that are married. This chapter empirically tests these model predictions, and results are indeed consistent with all predictions.

The remainder of this chapter is organized as follows: Section 3.2 describes the data. Section 3.3 presents the estimation models and the results. Section 3.4 concludes.

3.2 Data description

The data sets used in the analysis are the 1% samples from the 1990 and 2000 Chinese Censuses and 1989, 1991, 1993 and 2000 China Health and Nutrition Surveys (CHNS).

The Census data contain demographic information about individual age, gender, marital status, ethnicity, region of residence, living conditions, and labor force participation status. Therefore, they provide the most precise measure of county-level sex ratios. Overall, there were 938 counties in the 1990 Census, and 2870 counties in the 2000 Census.

The CHNS are repeated panels collected in nine provinces in 1989, 1991, 1993, 1998, 2000, 2004, 2006 and 2011.[3] The nine provinces are Heilongjiang, Liaoning, Shandong, Jiangsu, Henan, Hubei, Hunan, Guizhou, and Guangxi, covering regions with different income levels. In each province, 4 to 16 counties are randomly selected, and in every survey year over $11,000$ individuals participated in the survey.[4] Individual educational level, health status, time use, and expenditures are reported in the CHNS data sets. For this reason, they are more suitable for studying intra-household allocations. However, due to the sampling method of a multistage random cluster process, it is problematic to use the sex ratio calculated from the CHNS. Instead, I merge the CHNS data with sex ratios calculated from the Censuses at the county level to conduct the analysis of intra-household allocations.[5]

To study the sex ratio effect on labor and marriage market outcomes and intra-household allocations, I restrict the population age range to be between 18 and 50 years old. I choose this age range for two reasons. Firstly, the official female retirement age in China is between 50 and 55. Secondly, over 93% of the population are currently married by the

[3] The surveys are conducted by the National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention, Carolina Population Center, the University of North Carolina at Chapel Hill, and the Fogarty International Center.

[4] Detailed description of the data set can be found at `http://www.cpc.unc.edu/projects/china/about/proj_desc/survey`.

[5] After matching all counties with their Census counterpart, I have in total 75 counties in 8 provinces. The province of Heilongjiang is excluded because I cannot match the county identifiers with the Census.

age of 50, and this number starts to fall for older cohorts due to mortality. Therefore, I restrict the population of interest to be under 50 years old.

Table 3.1 presents all variables used in the analysis, and Table 3.2 provides detailed information of data sources.

1. Sex ratios: The county-level sex ratios are measured by resident sex ratios, which is calculated by the number of males over the number of females living in the county. However, many studies are concerned about within-country migration. This affects not only the resident sex ratios but also the local labor and marriage market (Edlund (2005), Porter (2016)), which leads to a selection bias. People may migrate to more developed areas to secure better job opportunities or for marriage purposes. However, this is not a major concern in this study. As the resident population constitutes the local labor market, the resident sex ratio can explain changes in the labor market. In addition, according to the 2000 Census, migration for marriage only accounts for less than 1% of the total number of migrants, for which reason the impact of migration on the marriage market is limited. As a robustness check, I also control for the migration status of each individual throughout my entire analysis. It can be concluded that the resident sex ratio is the suitable measure in this study.

   In 1990, the average sex ratio was 1.047, with a standard deviation of 0.0785. The value ranged from 0.7142 to 1.6909. In 2000, the mean increased to 1.06, and the variations among counties also became larger. The 2000 sex ratio is used to analyze the marriage market, labor market, female health and children's health outcomes, whereas the 1990 sex ratio is used in female home production and relative bargaining power analysis.

2. Female labor force participation: The female labor force participation rates are calculated at the county level for the year 2000. Overall, the female labor force

participation rates were very high at an average of 83%. The variations were also substantial, ranging from 34% to full participation.

3. Marriage market behaviors: Variables that capture the marriage market are the fraction of females/males that are married, the fraction of females/males that are single, and the divorced counterparts. In 2000, among all counties, around 80% of the population was married, 19% had never been married, and only about 1% of the population was divorced.

4. Intra-household bargaining:

   - Decision power: In the CHNS expenditure survey, married individuals are asked: "Do you participate in buying decisions of...?" and "Who is the decision maker in buying...?" Thus, the answers to these questions can capture the relative bargaining power within the household. The goods basket includes radios, stereos, VCRs, TVs, washing machines, fridges, air conditioners, sewing machines, electric fans, and cameras. I calculate the probability of participating and the probability of making decisions in purchasing the goods basket as the measure of the bargaining power. Since these questions were only asked in the first three waves in the CHNS, I calculate the measure from the 1989, 1991 and 1993 CHNS asset surveys. As shown in Table 3.1, statistics suggest that most wives were involved in purchase decisions, but most final decisions were made by husbands.

   - Female and male home production hours: Home production hours are obtained from the 1989, 1991 and 1993 CHNS time use surveys. Home production hours consist of time used in buying food, preparing food, washing clothes, cleaning the house, taking care of parents, and child care for married households. Since there were a large number of missing values in the time use surveys after 1993,

I only utilize the first three waves. Overall, wives spent about 2 hours more than husbands in home production per day.

- Female and male health: The CHNS provide information for adults about their self-reported health status. The scale ranges from 1 to 4, where 4 stands for "excellent" while 1 means "poor". On average, female health status is between "fair" and "good", but slightly worse than men's health.
- Children's health: As a measure of children's health, the CHNS also reports whether the child aged 6 to 18 is over-weight or not. It takes the value of 1 if the child is over-weight and 0 if he/she is normal. In 2000, about 7% of children were over-weight.
- Female and male cigarette consumption: Conditional on smoking, the number of cigarettes smoked per day is reported at the individual level in the CHNS physical examination surveys. On average, in 2000, male smokers consumed over 17 cigarettes per day, while women smoked about 3 cigarettes less than men per day. Note that as reported in Table 3.2, there are only 74 observations in the female sample, compared to over 4000 observations in the male sample.
- Female and male beer consumption: The CHNS physical examination surveys report how many bottles of beer an individual drinks per week, conditional on drinking beer. The average male weekly beer consumption was 3.7 bottles per week in 2000 with women drinking an average of 2.2 bottles. But again, the sample size of women is also much smaller than that of men.

5. Other controls: Additional control variables at the county level comprises of economic controls and sex ratio controls. The economic controls include the population size, literacy rate, and tap water access rate. These controls are intended to capture regional economic development, which may affect the resident sex ratio, marriage, and the labor market. The sex ratio controls are the share of migrants and the share

of minorities. The former controls for the impact of migration on the local sex ratio, and the latter controls for the population who are not under the restriction of the One Child Policy. Individual level controls include years of education completed, age, and whether the individual lives in a rural area or urban area.

3.3 Results

First of all, the imbalanced sex ratio affects the marriage market. The marriage market condition then changes the relative bargaining position within the household, where women benefit from the scarcity. As a result, the higher female bargaining power changes intra-household allocations. Therefore, the first step of the analysis is to test the sex ratio effect on marriage market outcomes.

3.3.1 Sex ratios and marriage market outcomes

To study the sex ratio effect on intra-household allocations, I first investigate how the imbalanced sex ratio may affect marriage market outcomes, which have a further impact on outside options for females. I use the 2000 Census data aggregated at the county level to conduct the estimation. The results are derived from estimating the following regression form:

$$y_i = \beta_0 + \beta_1 ln(\mathrm{sr}_i) + \beta_2 X_i + \delta_i + \epsilon_i \tag{3.1}$$

where y_i is the outcome of interest, which includes the fraction of females/males that are currently married, divorced, or have never been married for county i. sr_i is the corresponding sex ratio, defined by the number of males over the number of females aged between 18 and 50. X_i is a vector of county-specific controls, including the population share of minorities, the literacy rate, the fraction of households having access to tap water, and the migration rate. δ_i is a vector of province dummies to control for province fixed

Table 3.1: Summary statistics of variables

Variable	Mean	Std. Dev.	Min	Max
Sex ratio				
Sex ratio (1990)	1.047	0.0785	0.7142	1.6909
Sex ratio (2000)	1.0603	0.1941	0.5758	1.8902
Marriage market				
Married fraction, female	0.8298	0.0662	0.2783	0.9382
Married fraction, male	0.7462	0.0580	0.4168	0.8790
Single fraction, female	0.1610	0.0615	0.0566	0.7198
Single fraction, male	0.2410	0.0577	0.1111	0.5705
Divorced fraction, female	0.0092	0.0108	0.0004	0.1392
Divorced fraction, female	0.0128	0.0068	0.0018	0.0688
Labor market				
Female Labor Force Participation	0.8302	0.1236	0.3403	1
Female home hours	4.532	1.619	0	9.143
Male home hours	2.568	0.918	0	6.381
Intra-household allocations				
Major purchase (participation)	0.8166	0.3110	0	1
Major purchase (decision)	0.1953	0.3155	0	1
Female health	2.5914	0.7469	1	4
Male health	2.8168	0.7286	1	4
Children's health	0.0709	0.3224	0	1
Female cigarette consumption	14.31	7.8	0	30
Male cigarette consumption	16.91	8.94	0	60
Female beer consumption	2.24	2.13	1	14
Male beer consumption	3.67	4.3	1	74
County level controls				
Population Size (1990)	28509	24149	215	79478
Population Size (2000)	31900	27558	384	93625
Literacy rate	0.8852	0.1119	0.1378	0.9945
Minority rate	0.1615	0.2897	0	0.9978
Migration rate	0.1146	0.1164	0.0015	0.9204
Tap water access rate	0.4662	0.3152	0	1
Individual level controls				
Education (years, 1990)	7.348	3.765	0	18
Rural (1990)	0.6740	0.4688	0	1
Education (years, 2000)	10.41	4.222	0	18
Rural (2000)	0.6750	0.4684	0	1

Table 3.2: Data sources

Variable	Observations	Source
Sex ratio (1990)	938	1990 Chinese Census, 1% sample
Sex ratio (2000)	2870	2000 Chinese Census, 1% sample
Married fraction, female	2870	2000 Chinese Census, 1% sample
Married fraction, male	2870	2000 Chinese Census, 1% sample
Single fraction, female	2870	2000 Chinese Census, 1% sample
Single fraction, male	2870	2000 Chinese Census, 1% sample
Divorced fraction, female	2870	2000 Chinese Census, 1% sample
Divorced fraction, female	2870	2000 Chinese Census, 1% sample
Female Labor Force Participation	2870	2000 Chinese Census, 1% sample
Female home hours	2384	1989, 1991 and 1993 CHNS time use survey
Male home hours	2022	1989, 1991 and 1993 CHNS time use survey
Major purchase (participation)	4484	1989, 1991 and 1993 CHNS asset survey
Major purchase (decision)	4484	1989, 1991 and 1993 CHNS asset survey
Female health	957	2000 CHNS physical examination survey
Male health	5845	2000 CHNS physical examination survey
Children's health	2211	2000 CHNS media use survey
Female cigarette consumption	74	2000 CHNS physical examination survey
Male cigarette consumption	4076	2000 CHNS physical examination survey
Female beer consumption	308	2000 CHNS physical examination survey
Male beer consumption	2908	2000 CHNS physical examination survey
Population Size (1990)	938	1990 Chinese Census, 1% sample
Population Size (2000)	2870	2000 Chinese Census, 1% sample
Literacy rate	2870	2000 Chinese Census, 1% sample
Minority rate	2870	2000 Chinese Census, 1% sample
Migration rate	2870	2000 Chinese Census, 1% sample
Tap water access rate	2870	2000 Chinese Census, 1% sample
Education (years, 1990)	4484	1989, 1991 and 1993 CHNS education survey
Rural (1990)	4484	1989, 1991 and 1993 CHNS education survey
Education (years, 2000)	6844	2000 CHNS education survey
Rural (2000)	6898	2000 CHNS education survey

effect.[6] β_1 is the parameter of interest, and I take the log form of the sex ratios in all analyses such that the results can be directly interpreted as percentage changes.

Given that more males are available in the marriage market, the fraction of females that are currently married should increase, and the fraction of females that have never been married should fall. The opposite should happen to men. Results are illustrated in Table 3.3 and Table 3.4 for women and men respectively.

Columns (1) and (4) in Table 3.3 suggest that the fraction of females that are currently married is positively correlated with the sex ratio. A 1% increase in the sex ratio is associated with about a 0.1 percentage point higher fraction of females that are married. On the other hand, as illustrated in columns (2) and (5), the fraction of females that have never been married is negatively correlated with the sex ratio. Consequently, a higher sex ratio does indeed make it easier for women to find a husband. There is no significant effect of the sex ratio on the divorce rate. Table 3.4 shows that the results reverse for men, as they are less likely to find a wife. The additional county-specific controls slightly reduce the estimated effects but do not change the results qualitatively.

3.3.2 Sex ratios and female labor market outcomes

In this study, I investigate the sex ratio effect on female labor supply at the extensive margin.[7] All variables are aggregated at the county level. The following regression is used to estimate the sex ratio effect:

$$y_i = \beta_0 + \beta_1 ln(\mathrm{sr}_i) + \beta_2 X_i + \delta_i + \epsilon_i \tag{3.2}$$

[6] Province fixed effect is included, as provinces are very unequally developed in China. In addition, provincial level policies may affect outcome variables differently.

[7] The census data only report labor supply at the extensive margin. The CHNS time use questionnaires ask about individual working hours but only in the 1989 wave, and the answer rate to this question was very low. Using this sample results in less than 100 observations. Therefore, in this study I focus on the extensive margin.

Table 3.3: Sex ratios and female marriage market outcomes. 2000 Census. OLS.

	Dependent Variable					
	(1) Currently Married	(2) Never Married	(3) Divorced	(4) Currently Married	(5) Never Married	(6) Divorced
ln(Sex ratio)	0.102*	-0.102*	0.000332	0.138***	-0.133***	-0.00442
	(0.0580)	(0.0557)	(0.00494)	(0.0428)	(0.0426)	(0.00446)
Controls						
Minority rate				-0.0532**	0.0443**	0.00897**
				(0.0201)	(0.0173)	(0.00407)
Literacy rate				0.155**	-0.137**	-0.0181***
				(0.0652)	(0.0609)	(0.00570)
Access to tap water				-0.0186	0.00890	0.00973***
				(0.0129)	(0.0133)	(0.00176)
Immigration rate				-0.270***	0.252***	0.0183***
				(0.0519)	(0.0553)	(0.00591)
Province fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2871	2871	2871	2871	2871	2871
Adjusted R^2	0.360	0.343	0.437	0.595	0.555	0.584

Standard errors in parentheses

Source: 2000 Census, at the county level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.4: Sex ratios and male marriage market outcomes. 2000 Census. OLS.

	Dependent Variable					
	(1)	(2)	(3)	(4)	(5)	(6)
	Currently Married	Never Married	Divorced	Currently Married	Never Married	Divorced
ln(Sex ratio)	-0.169***	0.162***	0.00523	-0.146***	0.140***	0.00399
	(0.0427)	(0.0406)	(0.00334)	(0.0359)	(0.0341)	(0.00360)
Controls						
Minority rate				-0.0479**	0.0443**	0.00335
				(0.0193)	(0.0180)	(0.00288)
Literacy rate				0.137**	-0.140**	0.00305
				(0.0513)	(0.0524)	(0.00320)
Access to tap water				-0.00285	-0.00269	0.00554***
				(0.0107)	(0.0101)	(0.00133)
Immigration rate				-0.144***	0.145***	-0.00176
				(0.0297)	(0.0306)	(0.00347)
Province fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2870	2871	2870	2870	2871	2870
Adjusted R^2	0.437	0.442	0.296	0.549	0.549	0.340

Standard errors in parentheses

Source: 2000 Census, at the county level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

where y_i is the female labor force participation rate in county i. sr_i defines the county-level sex ratio. The controls are the same as in the previous analysis, where X_i is the vector of county specific controls, and δ_i is the vector of province dummies. β_1 is the parameter of interest in the estimation.

Table 3.5: Sex ratios and female labor force participation, county-level, 2000 Census. OLS.

	(1)	(2)	(3)
Ln(Sex ratio)	-0.159**	-0.183***	-0.134***
	(0.0619)	(0.0568)	(0.0370)
Controls			
Minority rate		0.0173	0.0278
		(0.0183)	(0.0194)
Literacy rate		0.00342	-0.0387
		(0.0384)	(0.0392)
Access to tap water		-0.0738***	-0.0685***
		(0.0214)	(0.0215)
Migration rate		-0.541***	-0.438***
		(0.0764)	(0.0986)
Fraction of females, married			-0.078**
			(0.0238)
Province fixed effect	Yes	Yes	Yes
Observations	2870	2870	2870
Adjusted R^2	0.381	0.513	0.522

Standard errors in parentheses

Source: 2000 Census, at the county level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Columns (1) and (2) in Table 3.5 present the results with or without county-specific controls. The female labor force participation rate falls when the sex ratio grows. Specifically, a 1% increase in the sex ratio correlates with about a 0.16 percentage point decrease in the female labor force participation rate. The effect is stronger when additional county

specific-controls are included. Overall, the estimated magnitude is similar to studies in other countries. Angrist (2002) finds that a 1% increase in the sex ratio of the second generation of immigrants reduces married female labor force participation by a 0.1 percentage point. A larger effect is found in Australia by Grosjean and Khattar (2018), where a 1% increase in the historical sex ratio is associated with a 0.3 percentage point reduction in female labor force participation.

Two reasons explain the drop in female labor force participation: First, the higher female bargaining power enables wives to take a larger share of the marital surplus by enjoying more leisure. Therefore, they will reduce their labor supply in the market. At the extreme, they will drop out of the labor force. Second, there is a compositional effect of an increased share of the married female population. On average, married women are more likely than singles to stay at home either for home production or to enjoy leisure time. When there are more females getting married, total female labor supply falls. To identify the bargaining channel effect, I control for the fraction of females that are married in each county on top of the other controls. Column (3) in Table 3.5 illustrates the result. Compared with the estimated result in column (2), the sex ratio effect is smaller if the fraction of females that are married is a control variable, suggesting that both channels contribute to the negative impact of the sex ratio on female labor force participation. The difference indicates that the change of female bargaining power plays a more important role in explaining the sex ratio effect than the compositional change of the married female population.

One may be concerned that in the high sex ratio counties, female labor supply is lower because women spend more time on home production rather than on leisure. If this is the case, we can observe that in the high sex ratio counties, female labor supply drops, and at the same time her home production hours increase, while her bargaining power is not affected. Therefore, in the next subsection, I will test if female bargaining power increases with the sex ratio and more importantly, if female home production time falls

with the sex ratio.

3.3.3 Sex ratios and bargaining power

The sex ratio effects on marriage market outcomes suggest that females have a better outside option when the sex ratio increases. Therefore, female bargaining power rises. Most empirical studies estimate the relative bargaining power indirectly by exploring intra-household allocations, with a particular focus on private consumption goods. The CHNS data sets provide many indirect measures, but more importantly, questions related to a direct measure of the bargaining power are also asked in the asset surveys. For instance, individuals are asked whether he/she is involved in decision making and whether he/she is the decision maker in major household purchases. Therefore, following the idea proposed by Edlund et al. (2013), I calculate the probability of an individual participating in decision making, and the probability that he/she is the decision maker. However, different from Edlund et al. (2013), who only consider electric fans, TVs, and radios, which only takes a small share of home durable purchase into account, I extend home durable goods to all goods covered in the survey by adding stereos, VCRs washing machines, fridges, air conditioners, sewing machines, and cameras. Thus, my measure of relative bargaining power contains more information. Another difference is that I use cross-county variations instead of cross-province variation as the identification strategy. By doing so, I have 75 counties each year instead of only 8 provincial level variations.[8]

This analysis uses the 1989, 1991 and 1993 waves of CHNS asset surveys. Since the CHNS is a repeated cross-sectional survey, I simply pool the three waves data together.

[8]The official CHNS data sets report the eight province names, which can be matched directly to the Census data. However, the CHNS data sets only provide city and county identifiers not their names. Furthermore, the identifiers are not the same as those in the Census. That is probably the reason why Edlund et al. (2013) only use the data at the provincial level. I managed to obtain all county names matched with the identifiers from the Chinese Center for Disease Control and Prevention, which is in charge of conducting the CHNS. Consequently, I am able to match the CHNS with the Census data by county names.

Therefore, the sex ratio is recalculated at the county level from the 1990 Census as an approximation. The sample is further restricted to married individuals. In addition, different from the Census, urban population in the CHNS data is over-sampled, which accounts for more than half of the sample size. Consequently, the residential area (rural/urban) of an individual is added as a control variable in the analysis.

The following regression model is estimated:

$$y_{ij} = \beta_0 + \beta_1 ln(\text{sr}_j) + \beta_2 \text{female}_i + \beta_3 \text{female}_i \times ln(\text{sr}_j) + \beta_4 X_{ij} + \epsilon_{ij} \tag{3.3}$$

where y_{ij} is the outcome of interest of individual i in county j, including the probability of participating in decision making and the probability of being the decision maker in major household purchases. It takes values between 0 and 1, where 0 means that the individual does not participate in the decision-making process or the individual is not the decision maker when purchasing home goods. 1 stands for the case that the individual participates in all decision making or he/she is the decision maker for all home goods purchases. sr_j represents the county-level sex ratio. female_i is the indicator function of whether the individual is female or not. X_{ij} is a vector of county-level and individual-level controls, which are the population size of the county (in log), individual educational level in years, and whether the individual lives in the rural area or not. β_3 is the estimated parameter of interest. It represents how the gender gap of the outcome varies with the sex ratio.

Table 3.6 reports the results. As expected, female bargaining power increases with the sex ratio. A 1% increase in the sex ratio will make wives 0.1 percentage points more likely to be involved in decision making and 0.16 percentage points more likely to become the decision maker relative to husbands. The amounts are much smaller than in the analysis of Edlund et al. (2013), where the estimated numbers are 0.16 and 0.21 respectively. Moreover, captured by the coefficients of "female", wives have on average a lower bargaining power than husbands. With county-specific and individual-specific

controls, the sex ratio effect on females participating in decision making is slightly lower, but the estimated value of females being the decision maker becomes more significant.

Table 3.6: Sex ratios and the decision power. OLS.

	Dependent Variable			
	(1)	(2)	(3)	(4)
	Participate	Decision maker	Participate	Decision maker
Female× ln(Sex ratio)	0.105**	0.164*	0.109**	0.166**
	(0.0329)	(0.0709)	(0.0350)	(0.0693)
Female	-0.348***	-0.394***	-0.323***	-0.396***
	(0.0721)	(0.0817)	(0.0694)	(0.0781)
ln(Sex ratio)	-0.0764*	-0.140**	-0.153**	-0.0779
	(0.0368)	(0.0498)	(0.0445)	(0.0665)
Controls				
ln(population size)			0.000679	0.0859*
			(0.0563)	(0.0368)
Education (years)			0.00748***	-0.000883
			(0.00201)	(0.00167)
Rural			-0.0430*	0.0379*
			(0.0202)	(0.0181)
Observations	4484	4484	4483	4483
Adjusted R^2	0.088	0.126	0.1	0.128

Standard errors in parentheses

Data source: 1989, 1991, 1993 CHNS and 1990 Census

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.3.4 Sex ratios and intra-household allocations

With a higher bargaining power, females are able to gain a larger share of the marital surplus. The following variables are the relevant measures of the intra-household allocation outcomes: wives' home production time, the health status of wives, children's health, and

the amount of individual tobacco and beer consumption.[9] While I use the 1990 sex ratio and 1989, 1991 and 1993 CHNS data to estimate the effect on female home production time, the estimations of female health, children's health measured by obesity and tobacco and beer consumption are based on the 2000 sex ratio and 2000 CHNS data.

The regression strategies of female home production and female health status are the same as equation (3.3), which answers: For those who live in the high sex ratio area, how much can a wife reduce her home production time and to what extent can she improve her health compared to a husband?

The sex ratio effect on children's obesity is estimated by the following regression:

$$y_{ij} = \beta_0 + \beta_1 ln(\text{sr}_j) + \beta_2 X_{ij} + \epsilon_{ij} \tag{3.4}$$

where y_{ij} is the indicator of over-weight of child i in county j. It takes the value of 0 and 1, where 0 stands for normal weight and 1 for over-weight. sr_j represents the county-level sex ratio. X_{ij} is a vector of county-level and individual level controls, which are the population size of the county (in log), the age of the child, and whether the child lives in the rural area or not. β_1 is the estimator of interest.

As cigarettes and beer are mainly consumed by men in China, I restrict the sample to the male population, and modify the regression function (3.3) to estimate the sex ratio effect:

$$y_{ij} = \beta_0 + \beta_1 ln(\text{sr}_j) + \beta_2 X_{ij} + \epsilon_{ij} \tag{3.5}$$

where y_{ij} captures how many cigarettes the male smokes per day, and how many bottles of beer he drinks per week. The controls are the same as equation (3.3).

Table 3.7 and Table 3.8 report the results of the sex ratio effect on intra-household allocations.

[9] As discussed in Section 3.2, less than 10% of beer and 2% of tobacco are consumed by women. Therefore, the measure is mainly male tobacco and beer consumption.

Table 3.7: Sex ratios and intra-household allocations I. OLS.

	Dependent Variable					
	(1)	(2)	(3)	(4)	(5)	(6)
	Home hours	Health status	Child's obesity	Home hours	Health status	Child's obesity
Female× ln(Sex ratio)	-1.917***	0.0959*		-1.907***	1.117*	
	(0.255)	(0.0466)		(0.253)	(0.529)	
Female	4.507***	-0.262***		4.495***	-0.186***	
	(0.201)	(0.0377)		(0.216)	(0.0476)	
ln(Sex ratio)	0.679***	-0.1467***	-0.118	0.858***	-1.094***	-0.136**
	(0.176)	(0.256)	(0.00775)	(0.157)	(0.295)	(0.0555)
Controls						
ln(population size)				0.873	0.117*	-0.00485
				(0.873)	(0.0498)	(0.0202)
Education (years)				-0.00139	0.0805***	0.0101*
(Age for child's health)				(0.0119)	(0.0115)	(0.00452)
Rural				0.108	0.159**	-0.0718**
				(0.101)	(0.0634)	(0.0210)
Observations	4265	6802	2213	4264	6748	2196
Adjusted R^2	0.246	0.029	0.000	0.247	0.064	0.012

Standard errors in parentheses
Data source: 1989, 1991, 1993, 2000 CHNS and 1990, 2000 Census
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.8: Sex ratios and intra-household allocations II. OLS.

	Dependent Variable			
	(1)	(2)	(3)	(4)
	Cigarette	Beer	Cigarette	Beer
ln(Sex ratio)	4.284	-4.414	3.133	-4.448*
	(5.922)	(2.821)	(6.133)	(2.215)
Controls				
ln(population size)			-0.172	-0.137
			(0.434)	(0.453)
Education (years)			-0.364*	0.246
			(0.167)	(0.171)
Rural			0.688	0.350
			(0.736)	(0.408)
Observations	4076	2908	4055	2903
Adjusted R^2	0.001	0.005	0.004	0.009

Standard errors in parentheses

Source: 2000 China Health and Nutrition Survey

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The effects of an increased sex ratio on home production time are presented in Columns (1) and (4) of Table 3.7. Home production time is defined by the sum of hours spent on buying food, preparing food, washing cloth, cleaning the house, taking care of parents, and child care per day. The results indicate that the gap of home production hours between the husband and wife falls by 1.9 hours per day if the sex ratio increases by 1%. In addition, the coefficients of "female" suggest that wives, on average, spend about 4 hours more than husbands in home production. The additional controls barely change the estimated outcome.

If the sex ratio increases, while wives reduce their time spent on household chores, husbands need to increase their home production time. This change in the division of tasks reduces the gender gap in home production. The finding is consistent with the theory of intra-household bargaining. If women have a higher bargaining power, they can enjoy more leisure rather than working more, both in the market and at home. Ideally, I would like to directly measure the impact of the sex ratio on married female leisure enjoyment. But the labor supply data at the intensive margin is only available in the 1989 CHNS, and the response rate to this question was too low. Only less than 100 wives provided their working hours information, which leads to an insignificant regression result.

Columns (2) and (5) show the sex ratio effect on female health status, which is measured by a self-reported health scale from 1 to 4 with 1 being "excellent". When women obtain a higher bargaining power, they are able to keep more household resources to improve their health. This expectation is supported by the empirical result. Relative to the husband, the health status of the wife increases by almost one scale if the sex ratio increases by 10 percentage points. Given that females have, on average, a 10% worse health status than males (see Table 3.2), the imbalanced sex ratio significantly improves female health. By adding controls, the sex ratio effect becomes stronger.

A further implication of the higher female bargaining power is its impact on children. Empirical studies suggest that a higher female bargaining power is associated with more

resources allocated to children, such as food, clothing, and children's educational outcomes (Handa (1996), Lundberg, Pollak, and Wales (1997), Attanasio and Lechene (2002), Basu (2006)). Analogously, if female bargaining power increases, children's health should improve. The CHNS media use surveys provide a measure of whether a child is over-weight or not. The estimated outcomes in columns (3) and (6) imply that children are about 14% less likely to be obese when the sex ratio increases by 1%. When there are controls in the regression, the result is insignificant. However, once controls are added, it is significant at the 0.05 confidence level. The reason for this difference is the introduction of the age control. Older children are more likely to be over-weight. Once I control for children's age, the sex ratio plays a more important role. The finding is consistent with Porter (2016), who shows that a higher sex ratio improves children's Z-scores in China, which is a measure of children's short-term nutritional health.

The higher female bargaining power, on the other hand, will reduce the household resources allocated to the husband. Therefore, I further investigate whether the higher sex ratio is associated with lower consumption in two male-dominated goods, namely cigarettes and beer. Table 3.8 presents the estimated results. According to columns (1) and (3), there is a positive but insignificant effect of the sex ratio on husbands' tobacco consumption. The results seem to contradict the bargaining theory which suggests that husbands with a lower bargaining power should reduce their private consumption. In addition, if wives care about the health of their husbands, the amount of smoking should be even lower. One possible explanation is that for families with sons, the head of the household (typically the husband), is under much higher pressure as soon as the boy approaches marriageable age due to the marriage market competition. To cope with the pressure, the husband significantly increases his cigarette consumption (Chen (2018)), which counteracts the lower bargaining power effect and makes the result insignificant. As regards alcohol consumption, which is reported in columns (2) and (4), the coefficients on beer consumption is negative, suggesting that husbands have lower alcohol consumption

in high sex ratio regions. The result is significant at the 0.1 confidence level if all controls are included. As male bargaining power is lower in high sex ratio counties, his alcohol consumption falls.

3.4 Conclusion

The sex ratio in China has grown significantly during the last 30 years. How does the imbalanced sex ratio affect intra-household bargaining and allocations? In this chapter, I investigate this problem empirically and test the model implications proposed in Chapter 2. I use county-level variations in sex ratios to study its impact on marriage market outcomes, female labor supply, intra-household allocations and female bargaining power. Merging the county-level sex ratios calculated from the Census data with the China Health and Nutrition Survey data, I find that females are more likely to find a husband while males are more likely to stay single. The higher sex ratio is also associated with a higher female bargaining power. With a higher bargaining power, females are able to keep a larger share of the marital surplus. They reduce both the market working hours and the time spent on household chores, which means that they can enjoy more leisure. The higher bargaining power also enables females to improve both their health and that of their children. The results are robust to migration status, educational level, and regional economic development controls.

While policy makers worry about the "missing women" causing gender imbalance and hurting women in China, my findings suggest that the imbalanced sex ratio actually benefits those women who are born and makes them better off. In the long run, when sex ratio returns to its natural level, policy makers should keep in mind that female bargaining power will also react to the demographic change.

4 Female Bargaining Power and Labor Supply: A Study of Eliminating Joint Taxation

4.1 Introduction

The U.S. federal income tax based on the family unit has been controversial in policy debates for years. Implemented in 1948, the family-based taxation system differentiates between single and married households.[1] Married households pay taxes based on the sum of two spouses' income, which implies that the marginal tax rate for both spouses is the same, regardless of the individual income level. Since the husband is typically the primary earner in the household, the joint tax scheme generates a higher marginal tax rate for the wife. The higher marginal tax rate distorts the wife's incentive to work, and the greater the income gap the more this distortion becomes. Such distortion is one of the major concerns of policy makers. Therefore, the Congressional Budget Office (1997) and the President's Advisory Panel on Federal Tax Reform in 2005[2] have proposed a tax reform regarding individual taxation. They believe that reducing the marginal tax rate

[1] Table A1 in Appendix 4.A shows the tax brackets and tax rates of the 2018 U.S. income taxation schedule for single and married households.

[2] See Dalsgaard (2005) and United States Congressional Budget Office (1997) for a summary of the proposals on tax reforms. The full proposal can be found at `http://govinfo.library.unt.edu/taxreformpanel/final-report/index.html`.

for married females would increase their labor supply and improve gender equality.[3]

This argument is supported by both empirical and quantitative studies. Many empirical studies find that the elasticity of labor supply differs by gender and marital status (e.g., Blundell, Duncan, and Meghir (1998), Heim (2007), Guner, Kaygusuz, and Ventura (2014) and Doepke and Tertilt (2016)), where the elasticity of female labor, especially married female labor is higher than that of male labor (Triest (1990), Eissa (1995) and Keane (2011)). Their results suggest that the tax reform could significantly affect married female labor supply. Quantitative studies estimate that female labor would increase by about 10% after eliminating joint taxation. Taking marriage decisions into consideration, Chade and Ventura (2002) study the effect of tax reforms on married female labor supply and find a maximum increase of 10.1%. Bick and Fuchs-Schündeln (2017) present a quantitative model of taxes and female labor supply across countries, and they estimate the married female labor supply to be around 8% higher under the individual tax scheme in the U.S. Guner, Kaygusuz, and Ventura (2011) provide the highest estimate among these quantitative works. Considering life-cycle components, including fertility, human capital and wage profile, they solve a general equilibrium model and find that this tax reform can generate an additional 11.4% married female working hours.

However, all of the existing quantitative studies have one missing component: They treat a married household as one decision-making unit and ignore the possible decision interaction within the household. Scholars have stressed the importance of individual behaviors and the bargaining process in analyzing intra-household allocations such as female labor supply (Manser and Brown (1980), McElroy and Horney (1981), Lundberg and Pollak (1993)). Consequently, the impact of the tax reform on the intra-household decision process should be considered in the tax reform analysis.

[3]Married couples are also allowed to file their tax return separately. However, if they choose separate filing, their access to tax benefits will be severely limited. According to the IRS data, there are less than 1% of married households filing separately, and most of them live separately or have unpaid taxes.

In this chapter, I investigate the following questions: If female bargaining power is determined by relative after-tax income, how would the tax reform from joint taxation to individual taxation affect married female labor supply on the intensive margin? How would this tax reform change the welfare of the husband and wife? The main contribution of this study is to incorporate intra-household bargaining into the tax reform problem to study its effect on married female labor supply, when relative after-tax income directly affects female bargaining power.

Instead of treating the household as a decision unit, in this study, I assume that the married couple bargain over their private consumption and labor supply. Therefore, besides the income and substitution effects discussed in the literature, intra-household bargaining implies two additional effects. On the one hand, the increased female bargaining power generates a direct effect. Due to higher relative after-tax income after the tax reform, the higher bargaining power enables her to enjoy more leisure rather than supply more labor. On the other hand, an indirect effect occurs as she endogenizes the impact of her labor supply on her bargaining power. Given that the more she earns, the higher bargaining power she obtains, she would have the incentive to work even more. Since the two additional effects drive female labor supply in opposite directions, the total effect of the tax reform still depends on the magnitude of the income and substitution effects, the direct effect, and the indirect effect.

To capture the new mechanism, I build a semi-cooperative bargaining model. Husbands and wives bargain over their private consumption and labor supply through a two-stage game. Specifically, the husband and wife decide non-cooperatively on their labor supply in the first stage, then cooperatively on individual consumption in the second stage. The bargaining power in the cooperative decision problem is a function of the relative after-tax income of the household. Based on this model, I provide both a qualitative and a quantitative analysis of the tax reform, by comparing its impact on married female labor supply in the standard fixed-weight model with the endogenous bargaining model's

prediction. In the fixed-weight model, female bargaining power remains constant after the tax reform, while in the endogenous bargaining model, it is endogenously determined by relative after-tax income, which further depends on her labor supply decision. The tax scheme is represented by a tax function that captures the progressivity, tax allowance and different treatments between single and married households. Therefore, the tax reform is captured by the change in the tax function for married households, which is a function of individual labor supply.

Calibrating the models to match the 2003 U.S. married household working hours data, I find that the tax reform could increase married female labor supply by 1.2% in the endogenous bargaining model. But in the fixed-weight model, the effect is much larger, where female working hours increase by 3.5%. Such a difference suggests that the direct effect dominates the indirect effect, and married females tend to enjoy more leisure given a higher bargaining power. The welfare implications reverse. When female bargaining power is endogenous, the wife gains 4.5% in consumption equivalent units, while the husband loses 0.9%. But she loses 2.3% of consumption and her husband gains 1.2% if her bargaining weight is fixed. The effect is stronger for non-college educated wives. The reason is that in the endogenous bargaining scenario, with a higher bargaining power, the wife is able to keep a larger share of total household income for private consumption and substitutes less leisure time for work.

This study combines two strands of the economic literature. In addition to the literature on the tax reform and labor supply discussed above, this study also fits into the family economics literature about intra-household bargaining. In this vein, Becker and Becker (2009), Chiappori (1992), Manser and Brown (1980), McElroy and Horney (1981) and Lundberg and Pollak (1993) establish the theoretical framework of intra-household decision making. Depending on different efficiency assumptions, the collective model and the cooperative Nash bargaining model assume efficient outcomes. In contrast, the non-cooperative Nash bargaining and the separate spheres bargaining model assume inefficiency

or partial efficiency. Empirical studies provide more and more evidence of partial efficiency in intra-household allocation (Akresh (2005), Ashraf (2009) and Angelucci and Garlick (2015)). Therefore, I combine a collective model with a non-cooperative Nash bargaining model to capture the partial efficiency. The gender wage gap, the relative educational level, and the sex ratio are found to be factors that determine the relative bargaining power (Mazzocco (2007), Iyigun and Walsh (2007), Chiappori, Fortin, and Lacroix (2002) and Goldin (2006)). In this study, I assume the after-tax income to be the distribution factor in intra-household bargaining. This chapter also contributes to quantitative studies that are built on the bargaining framework. Knowles (2013) uses a cooperative bargaining model to analyze the change in the U.S. married household labor supply pattern in response to the reducing gender wage gap. He finds that the bargaining process can explain the relatively constant female to male leisure ratio over the last 40 years. Siegel (2017) studies how the narrowing of the gender wage gap in the U.S. can explain the change in fertility rate if female bargaining power is endogenous. He finds a negative impact of the female bargaining position on the fertility rate. Voena (2015) uses a non-cooperative model to study the effect of the change of divorce laws on married household allocations with limited commitment. This study adopts the idea of intra-household bargaining implemented in these studies and extends the bargaining specification to a semi-cooperative bargaining framework.

The rest of this chapter is organized as follows. Section 4.2 provides empirical evidence from the literature for the argument that relative after-tax income affects female bargaining power and allocations. Section 4.3 presents the model setup. Section 4.4 provides a qualitative analysis of the tax reform effect. Section 4.5 presents the calibration. Section 4.6 discusses the policy experiment and its implications quantitatively. Section 4.7 concludes.

4.2 Empirical evidence on bargaining and after-tax income

Since the establishment of the theory of modern family economics by Gary Becker back in the 1960*s*, many empirical studies have tried to test various implications of intra-household decisions. Regardless of their tests of either who makes decisions in the household, or whether the decision-making process is efficient or not, their results provide empirical evidence that the relative gross income, and even relative after-tax income, can change female bargaining power in household decision making. The change in the relative bargaining position further affects intra-household allocations.

Studies have shown that relative gross income determines intra-household allocations. Lundberg, Pollak, and Wales (1997) use a policy reform in the UK in the late 1970*s* as a natural experiment to test the unitary model assumption of income pooling. Before the reform, the child benefit scheme was granted through a tax allowance, which typically reduced the husband's tax liability. After the reform, the tax allowance was replaced by paying a similar amount of money to the mother, therefore leaving the total household income unchanged. However, using the Family Expenditure Survey Data, the authors show that this reform significantly increased the wife's expenditure on her and her children's clothing, while the husband's clothing consumption decreased. This result indicates that those who receive the income matter for intra-household allocations.

Similar results are also found in developing countries. Attanasio and Lechene (2002) test the same assumption of income pooling based on the Progresa program in Mexico, where the program gave money to women in the poorest families in rural areas. They find direct evidence that the wife's decision-making power measured by different indicators, is positively correlated with her relative income in the family. In addition, the increased female decision power also enables her to spend more on children's education, health, and

household public goods.

While most empirical studies suggest that the relative gross income affects intra-household allocations, the key assumption of this study is that relative after-tax income determines the relative bargaining power. To illustrate that the after-tax income may affect intra-household bargaining, I take the German withholding tax system as an example, which is a joint taxation scheme similar to the U.S.[4] It allows married couples to choose between a tax class combination of III and V and a combination of IV and IV.[5] For a given income level, the tax rate in class V is the highest, and class III is the lowest. When the couple choose the combination of class III and class V, it is optimal for the primary earner (typically the husband) to be in tax class III, which implies a lower marginal tax rate as if the second earner (the wife) did not earn any labor income. However, a much higher tax rate is imposed on the second earner in class V. In contrast, if they choose the tax class combination between IV and IV, each of them pays their withholding tax individually regardless of the partner's income.

Consider one simple example under the German withholding tax system. Suppose that annually the husband earns pre-tax €60,000, and the wife's pre-tax income is €20,000. If they choose the tax class combination between III and V, their after-withholding-tax income (or so-called take-home money) amounts to €67,144. But if they choose the IV and IV combination, their take-home money reduces to €64,613. The larger the income gap between two spouses, the more beneficial it is for the family to choose the combination that potentially harms the second earner. After the tax filing, the difference between the real tax liability and the withholding tax will be refunded to the family at the end of the fiscal year. However, considering the adjustment cost and interest saved over the year, the family can still benefit from optimally choosing the withholding tax class combination in

[4]The difference is that the taxable income is defined by the total household income in the U.S., while Germany uses the average income of the household as the measure. Accordingly, the tax bracket varies.

[5]The default setting is the combination of tax class IV and IV, but when both spouses agree, they can change to III and V. This change can be made only once a year.

the first place. However, given this benefit, according to a study by Stöwhase (2011) who analyzes the German withholding tax data, more than 20% of married German households do not minimize their withholding tax. One possible explanation is that relative after-tax income directly affects female bargaining power, such that she is willing to temporarily forgo some income to obtain more equal income and a better bargaining position. Based on this finding, in this study, I assume that the relative bargaining power is determined by relative after-tax income to capture the tax reform effect on female bargaining power.

4.3 Model

This section presents a static intra-household decision problem under different tax schemes. I first show the model framework in this section, then in the next sections illustrate both qualitatively and quantitatively how the direct and indirect effects play a role in female labor supply.

4.3.1 Economic environment

Consider an economy populated by heterogeneous agents indexed by gender $g \in \{f, m\}$. They differ by their marital status, with superscript S and M denoting single and married respectively, and their productivity z_f and z_m. The productivity levels are drawn from distributions $z_f \in Z_f$ and $z_m \in Z_m$. The productivity is measured by educational attainment, so an agent could be male or female, single or married, and non-college educated or college educated. Agents are endowed with one unit of time and divide the time between working hours (n) and leisure (ℓ).

Women and men differ in two aspects. While men earn the labor income at the wage rate of w, there is a gender wage gap of ϕ for women, so the marginal return to labor is lower for women. In addition, following Knowles (2013), I assume that women and men could have different attitudes toward leisure and therefore have different disutility of

labor. The two exogenous parameters determine the different time allocation patterns between women and men.

4.3.2 Preferences

Agents derive utility from their private consumption (c) and leisure.[6] The utility function is given by a CRRA specification separable over consumption and disutility of labor. For males, it is given by:

$$U_m(c,n) = \frac{c^{1-\sigma_c}}{1-\sigma_c} - \gamma_m \frac{n^{1+\sigma_n}}{1+\sigma_n},$$

where γ_m represents the male's disutility of labor, and σ_c and σ_n are the inverse of the elasticity of private consumption and the inverse of the Frisch elasticity. Similarly, the utility function of females is written as:

$$U_f(c,n) = \frac{c^{1-\sigma_c}}{1-\sigma_c} - \gamma_f \frac{n^{1+\sigma_n}}{1+\sigma_n}.$$

Note that the elasticities are assumed to be the same for males and females. The only difference is the disutility of labor parameter.

4.3.3 Prices

The wage rate is exogenously given by w.[7] Thus, male wage rate is given by $w_m = w$ and female wage rate is $w_f = \phi w$. For simplicity, I assume there is no capital income.[8]

[6] For simplicity, I exclude home production time. If home production is included in the model, the model will provide an upper bound of the estimated effect of the tax reform on female labor supply. As married females gain a higher bargaining power, they will still reduce their labor supply both at home and in the market to enjoy more leisure.

[7] Endogenous price will not have a large impact on the result. The higher married female labor supply and the lower married male labor mitigate the general equilibrium effect.

[8] In the CPS data, capital income only accounts for about 10% of total household income, and among which only the short term capital income is taxed under the income taxation. Since I focus only on working-age population whose major income is labor income and assume the wage rate to be exogenous, capital is not a major concern in my analysis.

4.3.4 Household decision problem

Given the specifications of prices and taxes, the budget constraint of a single household of gender g can be written as:

$$c + T^S(Y) = Y$$
$$Y = z_g w_g n.$$

Their labor income is used for their private consumption and tax payment, and the tax is assumed to be a dead weight loss.[9]

Therefore, the decision problem of a single agent of gender g is:

$$\max_{c,n} \frac{c^{1-\sigma_c}}{1-\sigma_c} - \gamma_g \frac{n^{1+\sigma_n}}{1+\sigma_n}$$
$$s.t.\ c + T^S(Y) = Y$$
$$Y = z_g w_g n.$$

Married households pool their income for their private consumption and tax payment with a family as a taxable unit:

$$c_m + c_f + T^M(Y) = Y$$
$$Y = z_m w_m n_m + z_f w_f n_f.$$

The decision-making of married households is through a two-stage semi-cooperative bargaining process. In the first stage, they bargain non-cooperatively over their labor

[9] If the tax revenue is redistributed to all households through a lump-sum transfer, the results will not change qualitatively. As will be shown later, wives take advantage of her higher bargaining power to enjoy more leisure and consume more, and husbands have to work more and consume less. This additional income effect of the transfer will reduce both male and female labor supply and increase their consumption, but the magnitude is always larger for females due to the higher female bargaining power. Therefore, females are further better off, and males are less worse off.

supply, taking the spouse's choices as given. In the second stage, they cooperatively decide on their private consumption, given the optimal labor choices. This assumption is similar to the framework proposed by Gobbi (2018), where she assumes that two spouses jointly decide on their labor supply, but their spending on childcare is chosen non-cooperatively. The idea behind this assumption is that a married individual is informed of the other spouse's consumption, for example, through bank statements, but he/she cannot directly observe the partner's effective hours of work. The semi-cooperative bargaining assumption is also supported by many empirical studies. Dependent on the location and age, households can be efficient or inefficient (Akresh (2005) and Angelucci and Garlick (2015)). By investigating detailed time allocation and consumption data, Lise and Yamada (2014) find limited commitment of married households in Japan. Therefore, I model the bargaining process to be semi-cooperative.

Accordingly, the allocation problem of the husband is given by:

$$\begin{aligned}
&\max_{n_m} U_m(c_m, n_m) \\
&\text{s.t. } c_m = \underset{c_f, c_m}{\operatorname{argmax}}\, \theta(n_f, n_m; z_f, z_m) U_f(c_f, n_f) + (1 - \theta(n_f, n_m; z_f, z_m)) U_m(c_m, n_m) \quad (4.1)
\end{aligned}$$

where θ is the bargaining weight attached to females and $\theta \in (0, 1)$. For the wife, the maximization problem is:

$$\begin{aligned}
&\max_{n_f} U_f(c_f, n_f) \\
&\text{s.t. } c_f = \underset{c_f, c_m}{\operatorname{argmax}}\, \theta(n_f, n_m; z_f, z_m) U_f(c_f, n_f) + (1 - \theta(n_f, n_m; z_f, z_m)) U_m(c_m, n_m). \quad (4.2)
\end{aligned}$$

In the fixed-weight model, θ is constant. However, as discussed in Section 4.2, there have been empirical studies suggesting that relative after-tax income matters for intra-household bargaining. Therefore, in the endogenous bargaining model, the bargaining weight changes with relative after-tax income. For this reason, I assume the functional

form of the bargaining weight to be:

$$\theta(z_f, z_m) = (\frac{w_f n_f z_f (1 - T^M_{avg}(Y_f))}{w_m n_m z_m (1 - T^M_{avg}(Y_m)) + w_f n_f z_f (1 - T^M_{avg}(Y_f))})^{\alpha} + \kappa, \tag{4.3}$$

where T^M_{avg} represents the average tax rate for married individuals. α captures the curvature of the bargaining function, and κ captures the level effect.[10]

The idea of setting the bargaining weight to be directly determined by relative after-tax income comes from recent theoretical literature. Iyigun and Walsh (2007) and Chiappori, Dias, and Meghir (2015) have incorporated the individual endogenous educational choice into the bargaining weight function, which further affects intra-household allocations. Since education is an approximation of the individual income level, I follow their argument to allow the bargaining weight to be a function of relative after-tax income of the household.

4.3.5 Income taxation

The tax schedule is represented by a tax function taken from Guner, Kaygusuz, and Ventura (2014). The functional form is given by:

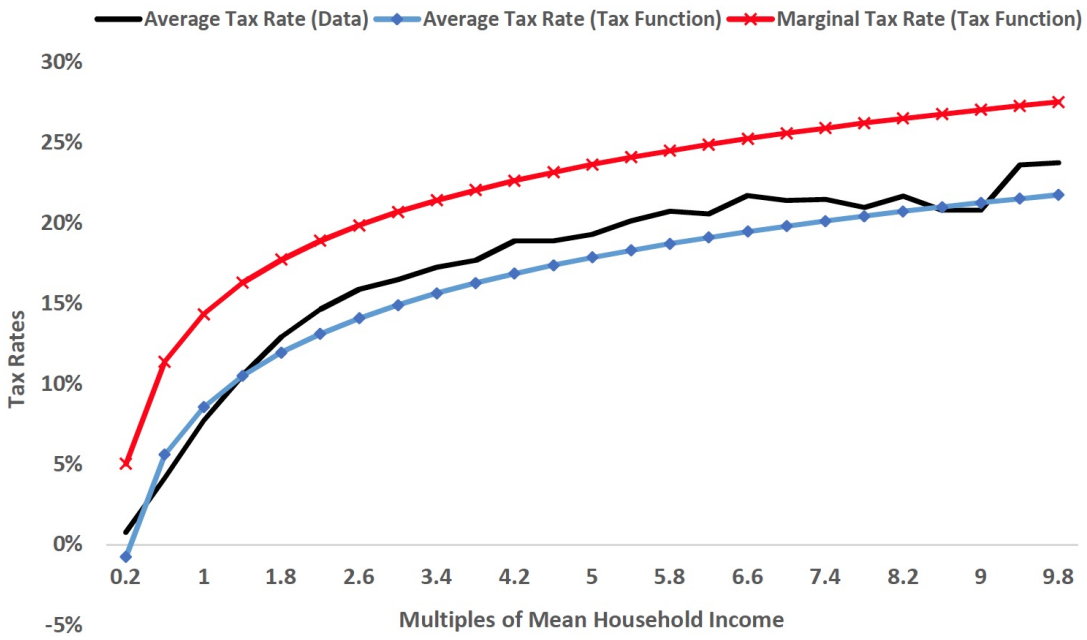
$$T(Y) = \delta_1 + \delta_2 \log(Y/\bar{Y}), \tag{4.4}$$

where Y is the taxable income of the household, and $\bar{Y}$ is the average household taxable income in the economy. The higher the taxable income relative to the average household income, the higher tax burden to the household. δ_1 and δ_2 are the two parameters capturing the curvature and the level of the tax schedule.

[10] Standard bargaining models may not apply in this tax reform problem. The collective model assumes that the bargaining weight is exogenously determined, which is not the case in my analysis. The Nash bargaining model usually treats being single as the outside option, but the tax reform considered in this study does not affect single households, so the outside option remains the same. The use of the separate spheres bargaining model or the non-cooperative bargaining model is also not suitable in this scenario. This is because it is impossible to distinguish between the tax liability of the husband and that of the wife under the joint taxation. Therefore, I cannot separate the budget constraints of the two spouses from each other in the non-cooperative case.

The values of δ_1 and δ_2 are estimated separately for single and married households based on the 2000 U.S. IRS tax file data. For married households, the pair of parameters takes the value of (0.085, 0.058) and for single households, it is estimated to be (0.105, 0.034). With this tax function, the average tax rate is given by $T(Y)$, and the marginal tax rate is $T(Y) + \delta_2$.

Figure 4.1 illustrates the marginal tax rate and the average tax rate for married households estimated by the tax function and the average tax rate in the data.[11] Given the average household income, the more the household earns, the higher the tax rates. In addition, the estimated average tax rate is negative for the lowest income bins, as the tax function takes tax allowance into consideration. Therefore, this tax function is able to capture not only the progressivity of the tax system, but also the tax allowance for married households.



Source: Internal Revenue Service 2000 Public Use Tax File and author's calculations

Figure 4.1: Average and Marginal Tax Rates for Married Households (Data and Estimates)

[11] The tax data are available in the supplementary material in Guner, Kaygusuz, and Ventura (2014).

The tax reform is fully represented by the change of the tax function for married households. Under the joint taxation, the tax liability for married households is a function of $T(Y_m + Y_f)$, and after the tax reform, it changes to $T(Y_m) + T(Y_f)$. Note that the coefficients of the tax function are assumed to be unchanged after the tax reform to capture the same tax allowance for married households.

4.3.6 Subgame perfect Nash equilibrium

The subgame perfect Nash equilibrium of the two-stage semi-cooperative bargaining problem is defined as follows:

Definition 4.1: For given productivity $\{z_f,z_m\}$, a set of parameters $\{\sigma_c,\sigma_n,\alpha,\kappa,\delta_1,\delta_2\}$, wage rates $\{w_f,w_m\}$, tax function T^M defined in (4.4), and the bargaining weight function θ defined in (4.3), the subgame perfect Nash equilibrium (SPNE) of the two-stage semi-cooperative game is the profile of strategies $\{c_f,c_m,n_f,n_m\}$ that solves the couple's utility maximization problem (4.1) and (4.2).

The subgame perfect Nash equilibrium exists and is unique.[12]

[12]The two-stage semi-cooperative bargaining problem can be solved backwards. In the cooperative bargaining stage, the objective function is a weighted sum of strictly concave utility functions. Therefore, the objective function is also strictly concave. The joint budget constraint gives a strictly convex, compact, and non-empty set. Therefore, for given labor choices n_f and n_m, the optimal consumption bundle always exists and is unique. However, in the non-cooperative stage, it is not trivial. While the objective functions are strictly concave, it is difficult to show that the budget constraints are strictly convex, compact, and non-empty sets. The budget constraints are defined by argmax functions, and more importantly, the concavity/convexity of the bargaining weight function is undetermined. Therefore, instead of providing a theoretical proof that the equilibrium exists and is unique, I use a numerical method to illustrate the existence and uniqueness of the equilibrium. In particular, I solve the two-stage semi-cooperative problem by the grid search method. I vary the number of grids of labor supply from 1000 up to 50000, and all calculations result in the same equilibrium outcome, which suggests that the equilibrium exists and is unique.

4.4 The direct, indirect and total effect: a qualitative analysis

The focus of this study is how married female labor supply varies after the tax reform. Before investigating the problem quantitatively, I first provide a qualitative analysis.

The two-stage semi-cooperative bargaining model can be solved by backward induction in two steps:

- Step 1: Taking the optimal labor choices n_f^* and n_m^* as given, the married household solves a cooperative bargaining problem for c_f and c_m:

$$\max_{c_f, c_m} \theta(n_f^*, n_m^*) U_f(c_f, n_f^*) + (1 - \theta(n_f^*, n_m^*)) U_m(c_m, n_m^*)$$
$$\text{s.t. } c_m + c_f = z_m w_m n_m^* + z_f w_f n_f^* - T^M(n_f^*, n_m^*)$$
$$\text{given } n_m^*,\ n_f^*$$

  First order conditions give:

$$c_m = F(\theta(n_f^*, n_m^*), n_f^*, n_m^*)$$
$$c_f = G(\theta(n_f^*, n_m^*), n_f^*, n_m^*)$$

- Step 2: Given the optimal consumption functions c_f^* and c_m^* obtained in Step 1, each spouse solves his/her problem for labor choices n_f and n_m, taking the partner's labor supply as given:

$$\max_{n_f} U_f(c_f^*, n_f)$$
$$\text{s.t. } c_f^* = G(\theta(n_f, n_m), T^M(n_f, n_m), n_f, n_m)$$
$$\text{given } n_m^*$$

and

$$\max_{n_m} U_m(c_m^*, n_m)$$
$$\text{s.t. } c_m^* = F(\theta(n_f, n_m), T^M(n_f, n_m), n_f, n_m)$$
$$\text{given } n_f^*$$

First order conditions give:

$$\frac{\partial U_f(c_f, n_f)}{\partial c_f}[\frac{\partial c_f(\theta, T^M, n_f, n_m)}{\partial \theta}\frac{\partial \theta(n_f, n_m)}{\partial n_f} + \frac{\partial c_f(\theta, T^M, n_f, n_m)}{\partial T^M}T^M_{mar}(n_f) + \frac{\partial c_f(\theta, n_f, n_m)}{\partial n_f}] + \frac{\partial U_f(c_f, n_f)}{\partial n_f} = 0$$
$$\frac{\partial U_m(c_m, n_m)}{\partial c_m}[\frac{\partial c_m(\theta, T^M, n_f, n_m)}{\partial \theta}\frac{\partial \theta(n_f, n_m)}{\partial n_m} + \frac{\partial c_m(\theta, T^M, n_f, n_m)}{\partial T^M}T^M_{mar}(n_m) + \frac{\partial c_m(\theta, n_f, n_m)}{\partial n_m}] + \frac{\partial U_m(c_m, n_m)}{\partial n_m} = 0$$

where T^M_{mar} represents the marginal tax rate for married households.

To intuitively illustrate the additional channels resulting from intra-household bargaining, I simplify the model by the following assumptions: (1) The utility function is a log utility ($\sigma_c = 1$ and $\sigma_n = 1$), and (2) Agents are homogeneous in their productivity ($z_f = z_m = 1$).[13]

The literature only focuses on the fixed weight case, where θ is not affected by the tax reform. They find that the substitution effect dominates the income effect, and consequently, married female labor supply increases.

However, once the bargaining weight is endogenous as a function of female labor supply,

[13]In the next section of the quantitative analysis, the assumptions will be relaxed.

the first order condition becomes:

$$\frac{1}{c_f}[Y_f + Y_m - T^M(Y_f, Y_m)]\frac{\partial\theta(n_f, n_m)}{\partial n_f} + \frac{1}{c_f}\theta(n_f, n_m)[w_f(1 - T^M_{mar}(n_f))] = \gamma_f\frac{1}{n_f}$$

Two additional effects influence the first order condition, namely the direct effect and the indirect effect measured by $\theta(n_f, n_m)$ and $\frac{\partial\theta(n_f,n_m)}{\partial n_f}$. To understand the two effects, I decompose the first order condition equation into two parts. First of all, the direct effect is the case when relative after-tax income affects the relative bargaining position, but the household member does not internalize the impact of the labor choice on the bargaining power, which means $\frac{\partial\theta(n_f,n_m)}{\partial n_f} = 0$. Correspondingly, the first order condition becomes:

$$\frac{1}{c_f}\theta(n_f, n_m)[w_f(1 - T^M_{mar}(n_f))] = \gamma_f\frac{1}{n_f}.$$

In this case, the bargaining weight is a function of female labor supply. Since the income and substitution effects cancel out with each other under the log utility, c_f does not change. The tax reform reduces the marginal tax rate for females, so $T^M_{mar}(n_f)$ falls. At the same time, it leads to a higher female bargaining power because the lower marginal tax rate increases her relative after-tax income. Therefore, θ rises, which suggests that the value of the left-hand side of the first order condition increases. Therefore, her labor supply increases less than that in the fixed weight case, or even falls. The female benefits from the tax reform effect on her bargaining power. With the higher bargaining power, the wife enables herself to enjoy more leisure and work less (than the fixed weight case). The direct effect setup corresponds to the Household Equilibrium concept proposed by Basu (2006). He suggests that the bargaining weight is endogenously determined by the relative income of two spouses, but both parties treat the weight exogenously when they make their allocation decisions.

Now add the indirect effect term $\frac{1}{c_f}[Y_f + Y_m - T^M(Y_f, Y_m)]\frac{\partial\theta(n_f,n_m)}{\partial n_f}$ into the first order

condition. It is unclear how the indirect effect changes married female labor supply, as the sign of the second order derivative is undetermined. Either a lower total household income or the $\theta(n_f, n_m)$ function being concave can lead to a higher female labor supply. In this case, women have an incentive to work even more to increase her bargaining power. Otherwise, her labor supply decreases and reinforces the direct effect. It may happen due to the convexity of the bargaining function, as a small increase in female after-tax income can be transformed into a large increase in female bargaining power, which enables females to work even less.

Note that the previous analysis results from strong assumptions on parameters. Therefore, it only presents qualitatively the two additional effects raised from the endogenous bargaining problem. However, results suggest that the direct effect reduces female labor supply, while under certain conditions, the indirect effect stimulates female labor after the tax reform. Therefore, the total effect is still ambiguous and needs to be quantified to answer the question how the tax reform would affect married female labor supply if the bargaining weight is endogenous.

4.5 Calibration

To quantify the tax reform effect on married female labor supply and further decompose it into the direct and indirect effect, I calibrate the fixed-weight model, the direct-effect model (where the indirect effect part is ignored) and the endogenous bargaining model to match the U.S. married household labor supply data in 2003. The microdata sets from which I extract information are the 2003 American Time Use Survey combined with the March CPS data (ATUS-CPS). The data targets are married female and married male working hours. Most parameters are pre-determined from the literature and calculated from the data. The remaining parameters are calibrated to match the data moments by the minimum distance estimation method.

4.5.1 Parameters based on a priori information

Table 4.1: Pre-determined parameter values

Parameters	Value	Explanation
Elasticities		
σ_c	2	Inverse of consumption elasticity (Hall (1988))
σ_n	3	Inverse of Frisch elasticity (Chetty et al. (2011))
Prices		
w	1	Normalization
ϕ	0.737	Gender wage gap (CPS 2000)
Tax function		
δ_1^S	0.105	Tax function parameters of single and married households (Guner et al. 2014)
δ_2^S	0.034	
δ_1^M	0.085	
δ_2^M	0.058	
Productivity		
z_f, z_m	1 1.6	College wage premium (Piketty (2014), Valletta (2017), Autor (2014))
Z_f	0.743 0.257	Distribution of female education (2003 CPS)
Z_m	0.711 0.289	Distribution of male education (2003 CPS)

Table 4.1 summarizes the parameters exogenously picked from the literature or calculated from the data. The utility parameters are taken from empirical estimations. Hall (1988) estimates the intertemporal elasticity of consumption based on different data sets and finds the inverse of the consumption elasticity σ_c to be 2. Chetty et al. (2011) provide an estimate of the Frisch elasticity and estimate it to be 3.[14]

The wage rate is normalized to be 1. The gender wage gap ϕ is obtained from the 2000 CPS data. It takes the value of 0.737, which means on average female wage rate is only 73.7% of male wage rate. As discussed, the parameter values of the tax function are taken from Guner, Kaygusuz, and Ventura (2014), with (δ_1^M, δ_2^M) being (0.085, 0.058) for

[14]Guner, Kaygusuz, and Ventura (2014) take the value of the Frisch elasticity between 2.5 and 5. Therefore, the higher female labor supply after the tax reform that they estimated is not generated by a higher Frisch elasticity but more likely by children in the model, which is also the case in Bick and Fuchs-Schündeln (2017).

married households, and (δ_1^S, δ_2^S) being (0.105, 0.034) for single households.

Agents are heterogeneous in their productivity. The productivity is measured by the educational level. Two types of educational levels are considered in the analysis, namely college education and non-college education. Therefore, the productivity level is measured by the college wage premium, and the distributions of female and male productivity correspond to the distributions of their educational attainment. As estimated by Piketty (2014), Valletta (2017) and Autor (2014), based on different data sets, the U.S. college wage premium in 2000 ranged from 40% to over 80%. I take the average of 60%, which coincides with the estimation by Piketty (2014). The college wage premium is assumed to be identical for women and men. The distributions of educational attainment are obtained from the 2003 CPS data. Overall, 25.7% of women had a college degree, while 28.9% of men finished their college education.[15]

4.5.2 Parameters estimated by the minimum distance estimation method

There are 4 remaining parameters to be calibrated, 2 are the disutility of labor γ_f and γ_m, and the remaining 2 are the parameters in the bargaining weight function α and κ.

The 4 parameters are selected to match the U.S. married household aged $18-65$ labor supply data from the 2003 American Time Use Survey combined with the Current Population Survey (2003 ATUS-CPS). The data targets are: non-college educated married female average daily working hours, college-educated married female average daily working hours, non-college educated married male average daily working hours, and college-educated married male average daily working hours.

In the 2003 ATUS-CPS data set, individuals reported their usual weekly working hours for their primary job and other income-generating activities. I take the sum of

[15] I assume a random matching between different educational groups. Therefore, the educational distribution of married couples is the same as the aggregate distribution.

both elements and normalize the value to daily working hours. Zero working hours are also included in the calculation, but observations of those who are out of the labor force are excluded. A married individual is defined as a person who is officially married. Cohabitation is not considered as marriage since the joint taxation only applies to officially married couples. As a result, wives work less than husbands on average. A non-college educated husband works 7.7 hours per day, and a college-educated husband works 8.3 hours per day. A non-college educated wife works 6.7 hours per day, and a college-educated wife works 7.1 hours per day. A more detailed description of the data set can be found in Appendix 4.B.

Overall, I have 4 parameters to be calibrated, and 4 data targets to match. The minimum distance estimation method is then applied in the calibration.

Let η be the vector of the 4 parameters to be estimated and $g^{model}(\eta)$ be the vector of moments generated by the model as a function of parameters. g^{data} denotes the vector of the 4 data moments. Then the parameter values are estimated such that the vector of distances between data moments and model moments is minimized.[16] The minimum distance estimator is defined by:

$$\hat{\eta} = \arg\min_{\eta} \sum_{i} (g_i^{data} - g_i^{model}(\eta))^2,$$

Table 4.2: Calibrated parameters

	Endogenous-weight model	Fixed-weight model (and direct-effect model)	Parameter description
γ_f	39.352	50.922	Disutility of labor, female
γ_m	46.427	45.437	Disutility of labor, male
α	0.3888	0.3888	Curvature of bargaining function
κ	-0.0096	-0.0096	Level of bargaining function

[16] I use the absolute deviation instead of the percentage deviation because the data targets are of the same magnitude.

Table 4.2 reports the calibrated parameter values of 3 models. Note that the parameters in the fixed-weight model and the direct-effect model are calibrated to be the same. The reason is that I set the bargaining weights before the tax reform to be the same in the two models. By doing so, I am able to make them comparable as two models can generate the same time allocation before the tax reform. Consequently, there are only two utility parameters in the fixed-weight model and the direct-effect model to be calibrated. The data targets are the average married female/male working hours (6.8 and 7.84). The parameters in the bargaining weight function cannot be jointly calibrated since the bargaining weight is an exogenous parameter in the fixed-weight and direct-effect model. However, the two parameter values should take the same values as in the endogenous bargaining model, since working hours, tax rates, and the bargaining weights before the tax reform are exactly the same.

The calibration results suggest that females have a lower disutility of labor than males when the bargaining power is endogenous, but the relationship reverses when the bargaining weight is exogenous. The reason is that when female bargaining power is endogenous, her labor supply is determined not only by the disutility of labor, but also by the bargaining weight function. So females do not need a large disutility of labor to generate relatively low female labor supply. But in the fixed-weight model, female labor supply depends on the disutility of labor only, and the parameter value has to be large enough to match the data. In addition, when comparing models, the increased labor supply after the tax reform is caused by the bargaining process, but not because females put a higher weight on leisure in the endogenous bargaining model. The curvature parameter in the bargaining function is smaller than 1, indicating that female bargaining power is a concave function of her after-tax income. As discussed earlier in the qualitative analysis, the indirect effect will lead to a higher married female labor supply after the tax reform if the function is concave. It will be verified quantitatively in the next section. The level parameter only plays a minor role in determining female bargaining power.

Table 4.3 shows the model fit by comparing the model moments with the data moments. Overall, the model is able to capture the data moments relatively well. In the endogenous-weight model, I overestimate the working hours of non-college educated husbands and wives but slightly underestimate that for college-educated groups. In terms of the non-targeted moments, in the indirect-effect model/fixed-weight model where I only target at the average married female/male working hours, the non-targeted married female working hours by type are also well-matched.

Table 4.3: Data and model moments

Statistics	Data	Endogenous-weight model	Fixed-weight model
Non-college educated wife's hours	6.7	6.78	6.71
College educated wife's hours	7.1	7.05	7.07
Average wife's hours	6.8		6.8
Non-college educated husband's hours	7.7	7.80	7.80
College educated husband's hours	8.2	8.15	7.90
Average husband's hours	7.84		7.84

4.6 Policy experiment and results

How would the tax reform from joint taxation to individual taxation affect married female labor supply if the bargaining weight is endogenous? Does the bargaining process matter for female labor supply decisions? And how would the tax reform change the welfare of the husband and wife? I answer these questions in this section by comparing three different models: the fixed-weight model, the direct-effect model, and the endogenous bargaining model. I use the calibrated parameters to illustrate the effect of the counter-factual tax reform computationally with these three models.

4.6.1 The tax reform

The tax reform is characterized by the change of the tax function for married households. To be more precise, the tax function under the joint taxation before the tax reform is given by:

$$T^M(Y) = \delta_1^M + \delta_2^M \log((Y_f + Y_m)/\bar{Y}),$$

where $\bar{Y}$ is the married household income.[17] So the tax liability of the married household depends on total household income. After the tax reform, it is defined as:

$$T^M(Y_f) = \delta_1^M + \delta_2^M \log(Y_f/\bar{Y})$$
$$T^M(Y_m) = \delta_1^M + \delta_2^M \log(Y_m/\bar{Y}),$$

where each of the household members pays his/her own tax. The parameters of the tax function are assumed to be unchanged to capture the tax allowance for married households.

Therefore, the budget constraint of married households should be rewritten as:

$$c_m + c_f + T^M(Y_m) + T^M(Y_f) = w_m(1 - \ell_m) + w_f(1 - \ell_f)$$
$$Y_m = w_m(1 - \ell_m)$$
$$Y_f = w_f(1 - \ell_f).$$

4.6.2 Results

In the policy experiment, only the tax function changes while the other parameters are fixed at the calibrated values. The main results are reported in Table 4.4 and Table 4.5. Table 4.4 shows the tax reform effects on married female labor supply, and Table 4.5 illustrates the welfare implications of the tax reform.

[17] For married households, $\bar{Y}$ is twice as large as single households.

Table 4.4: Effects of the tax reform on labor supply

Labor supply		before	after	change (%)
Exogenous weight	male (< col)	7.80	7.59	-2.7%
	male (>col)	7.90	7.75	-1.9%
	male average	7.84	7.63	-2.6%
	female (< col)	6.71	6.97	3.8%
	female (>col)	7.07	7.21	2.0%
	female average	6.80	7.04	3.5%
Direct effect	male (< col)	7.80	7.73	-0.9%
	male (> col)	7.90	7.84	-0.76%
	male average	7.83	7.76	-0.86%
	female (< col)	6.71	6.76	0.75%
	female (> col)	7.07	7.18	0.28%
	female average	6.80	6.85	0.74%
Endogenous weight	male (< col)	7.82	7.80	-0.2%
	male (> col)	8.15	8.12	-0.4%
	male average	7.92	7.89	-0.4%
	female (< col)	6.78	6.87	1.3%
	female (> col)	7.05	7.09	0.6%
	female average	6.85	6.93	1.2%

As shown in Table 4.4, on average the tax reform increases married female labor supply by 3.5% if the bargaining weight is fixed. However, once the bargaining weight is allowed to change with female labor supply, the increase of married female labor supply is much smaller. As shown in the direct-effect model, she only works 0.74% more after the tax reform, since the additional bargaining power enables the wife to enjoy more leisure. Once the indirect effect forms part of the first order condition, her labor supply increases by 1.2%. Non-college educated women increase their labor supply more than college-educated ones in all models. The tax reform effect on married female labor supply is higher than the estimated outcome of the direct effect, indicating a positive effect on her incentive to gain a higher bargaining power. However, the increase is not as large as the prediction in the fixed-weight model. Therefore, it can be concluded that the direct effect dominates the indirect effect. Consequently, the effect of the tax reform on married female labor supply dampens if the bargaining weight is endogenous.

Table 4.5: Effects of the tax reform on welfare

welfare		change (%)
Exogenous weight	male (< col)	1.3%
	male (> col)	0.9%
	male	1.2%
	female (< col)	-2.5%
	female (> col)	-1.8%
	female average	-2.3%
Direct effect	male (< col)	-0.7%
	male (> col)	-0.6%
	male average	-0.7%
	female (< col)	2.1%
	female (> col)	0.8%
	female average	1.7%
Endogenous weight	male (< col)	-0.9%
	male (> col)	-1.0%
	male average	-0.9%
	female (< col)	5.4%
	female (> col)	1.9%
	female average	4.5%

Table 4.5 presents the welfare implications due to the tax reform. The change is measured in consumption equivalent units. In the fixed-weight model, the tax reform decreases the welfare of married females by 2.3%, while the husband gains 1.2% on average. Married women are worse off due to lower consumption and less leisure time. As shown in Table 4.6, both husbands and wives have to reduce their consumption when the weight is fixed, but wives suffer more. On the contrary, the husband can enjoy more leisure, which compensates for his consumption loss. However, the welfare implications reverse once the bargaining weight is endogenous. In the direct-effect model, the wife gains 1.7% while the husband's well-being falls by 0.7%. Once the indirect effect plays a role, she gains 4.5% even with higher labor supply, and the husband suffers from a 0.9% loss in well-being. A married female benefits from the tax reform due to the improved bargaining position, and the effect is stronger for non-college educated women than college-educated ones. Table 4.7 illustrates that on average, married female decision power increases by 3.0%. The

bargaining power of non-college educated women increases by 3.5%, and consequently, her well-being improves. While her bargaining power does not change in the fixed-weight model, it increases by 0.8% in the direct-effect model and by 3% in the endogenous bargaining model. If female bargaining power is fixed, the husband is able to benefit from her additional income after the tax reform. However, when her bargaining power increases with her after-tax income, the wife is able to keep a larger share of total household income for private consumption and work less compared to the fixed-weight case. As illustrated in Table 4.4 and Table 4.6, when female bargaining power is endogenous, the wife can enjoy more leisure compared with the fixed-weight scenario, and she is able to consume more for herself.

Table 4.6: Effects of the tax reform on private consumption

Consumption		before	after	change (%)
Exogenous weight	male (< col)	0.3389	0.3384	-0.15%
	male (>col)	0.4651	0.4633	-0.39%
	male average	0.3754	0.3746	-0.2%
	female (< col)	0.4978	0.4961	-0.34%
	female (>col)	0.6031	0.602	-0.51%
	female average	0.5248	0.5235	-0.28%
Direct effect	male (< col)	0.3389	0.3375	-0.41%
	male (> col)	0.4651	0.4583	-1.4%
	male average	0.3754	0.3724	-0.8%
	female (< col)	0.4978	0.4995	0.34%
	female (> col)	0.6031	0.604	0.15%
	female average	0.5248	0.5264	0.3%
Endogenous weight	male (< col)	0.3336	0.3319	-0.51%
	male (> col)	0.4701	0.4617	-1.8%
	male average	0.373	0.3694	-1%
	female (< col)	0.5038	0.5077	0.77%
	female (> col)	0.6469	0.6488	0.29%
	female average	0.5406	0.544	0.63%

The results of the tax reform suggest that lower-educated women benefit more, so the tax reform can not only reduce the gender inequality within the household, but also the

Table 4.7: Effects of the tax reform on the bargaining power

Bargaining weight		before	after	change (%)
Exogenous weight	male (< col)	0.3147	0.3147	0.0%
	male (> col)	0.3908	0.3908	0.0%
	male average	0.3367	0.3367	0.0%
	female (< col)	0.6532	0.6532	0.0%
	female (> col)	0.6925	0.6925	0.0%
	female average	0.6633	0.6633	0.0%
Direct effect	male (< col)	0.3147	0.2975	-5.5%
	male (> col)	0.3908	0.3814	-2.4%
	male average	0.3367	0.3183	-4.6%
	female (< col)	0.6532	0.6598	1.0%
	female (> col)	0.6925	0.6948	0.5%
	female average	0.6633	0.6687	0.8%
Endogenous weight	male (< col)	0.3147	0.2912	-7.5%
	male (> col)	0.3908	0.3786	-3.1%
	male average	0.3367	0.3164	-6.0%
	female (< col)	0.6532	0.6759	3.5%
	female (> col)	0.6925	0.7056	1.9%
	female average	0.6633	0.6835	3.0%

gender inequality across households. More importantly, given the different results of the fixed-weight model and the endogenous bargaining model, this policy experiment suggests that intra-household bargaining plays a very important role in analyzing policies that can affect married males and females differently. Ignoring the bargaining process within the household, we may miss its impact on allocations.

4.7 Concluding remarks

In this chapter, I study the effect of a counter-factual income tax reform from joint taxation to individual taxation on married female labor supply when female bargaining power is endogenous. The endogenous bargaining power generates two additional effects, the direct effect and the indirect effect, which drive female labor supply in opposite directions. The direct effect reduces female working hours because the wife can enjoy

more leisure due to the higher bargaining power. The fact that the wife endogenizes the impact of her labor supply on her bargaining power generates the indirect effect, such that the incentive of gaining higher bargaining power encourages her to supply more labor. While the literature, which typically assumes a fixed bargaining weight, suggests a large increase in married female labor supply after the tax reform, I show that the effect dampens if the intra-household bargaining process is endogenous. This result suggests that the direct effect dominates the indirect effect. So instead of working more to gain a better bargaining position, the wife prefers to take advantage of her higher bargaining power and enjoys more leisure. In addition, the tax reform may have different welfare implications. Married females gain if her bargaining power is endogenous and lose if her bargaining power is fixed.

Even though this chapter only shows a static version of the bargaining problem, and the specification of the bargaining weight function could affect the magnitude of the quantitative results, this study still provides an illustration of how the intra-household bargaining can affect allocations within the family. More importantly, the key implication of this study is that intra-household bargaining is essential for the analysis of policies which may affect husbands and wives differently.

Appendix

4.A 2018 U.S. income taxation schedule

Table A1: Taxable income bracket and marginal tax rate

Marginal Tax Rate	Single & Separate Filing	Married Joint Filing
10%	0-9,525	0-19,050
12%	9,526-38,700	19,051-77,400
22%	38,701-82,500	77,401-165,000
24%	82,501-157,500	165,001-315,000
32%	157,501-200,000	315,001-400,000
35%	200,001-500,000	400,001-600,000
37%	>500,001	>600,001
Standard Deduction	12,000	24,000

4.B Data description

The microdata set used in this chapter is the 2003 American Time Use Survey combined with the Current Population Survey data (ATUS-CPS).[18] The combined data set includes individuals who participated in both surveys during the year. In the data set, the individual reports his or her age, marital status, highest level of education completed, employment status, and detailed daily time use data.

[18]More details can be found at `https://www.bls.gov/tus/datafiles_2003.htm`.

I restrict the sample to married individuals aged between 18 and 65. Individuals who are out of the labor force are excluded from the sample, but those who are temporally not working are considered. All observations with missing values are excluded. As a result, I have 12,612 observations in the sample, with 48.3% of them being male, and 51.7% being female.

Individuals are divided into two educational groups: non-college educated and college-educated. The college-educated group includes those who completed their college degree (associate degree from vocational/occupational college, bachelor's degree, master's degree or higher), and the rest are classified as non-college educated. Overall, 44% of married individuals in the sample are college educated.

The outcome variable of interest is individual working hours. Following Aguiar and Hurst (2007), I define the working hours as the sum of time spent on work for pay in the main job and other jobs and other work-related activities. Other work-related activities include commuting to work, meals/breaks at work, searching for jobs, and applying for unemployment benefits. On average, husbands work 7.84 hours per day, while wives work 6.8 hours per day.

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Curriculum Vitae

2012 – 2018	University of Mannheim (Germany) *PhD in Economics*
2010 – 2011	The Australian National University (Australia) *Master in International and Development Economics*
2006 – 2010	Shanghai University of Finance and Economics (China) *Bachelor in Economics*