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Essays on Institutions Governing Marriage and Outcomes over the Life Cycle

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by

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ABSTRACT OF THE DISSERTATION

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Professor Marcus Berliant, Chair

In this thesis, I study how institutions that govern marriage can affect marital choices and economic decisionmaking within marriage. The institutions that I study encompass both formal institutions, like laws that govern family formation, or more informal ones, like customs mandating the amount and direction of transfers at marriage or the level of commitment within marriage. This thesis consists of three chapters, and each chapter tackles a specific research problem under the broad research agenda.

In the first chapter of my thesis, I study how changes in divorce and property division laws affect the rates of marriage formation, marital sorting patterns, and decisions within marriage such as asset accumulation and divorce. Through the 1970s and 80s, many states in the United States enacted changes to their divorce and property division laws. While divorce laws changed from mutual consent to unilateral, property division laws in the event of divorce changed from title-based to equitable division, favoring the low-income earner in property settlements. From the high income earner's point of view, equitable division acts as a tax on asset accumulation within marriage, reducing the incentive to marry. To quantify the effect of these legal changes, I embed a dynamic collective model of marriage with endogenous asset accumulation, labor supply and divorce into a frictionless marriage-matching model. I estimate the model using data from marriages under a mutual consent, equitable division regime and simulate behavior under other legal regimes. I find that equitable division laws reduce the rate of marriage, and account for 18% of the long-term decline in the rate of marriage in the United States. Moreover, consistent with the data, equitable division laws reduce the rates of asset accumulation, female labor force participation and divorce. Further, both unilateral divorce and equitable division laws lead to substantial losses in economic efficiency.

In the second chapter of my thesis, I study the effect of norms governing marital transfers on intrahousehold allocation of resources, and the implications thereof on the nutritional outcomes of children. in India, which serves as the setting for the research in this chapter, daughters' weddings are very expensive and severely constrain the household budget in poor families. In such households, saving for marriage expenses could crowd out resources for the purchase of food, thus affecting children's nutritional outcomes. Consistent with this hypothesis, I find that the presence of an additional unmarried daughter is associated with a greater deterioration in children's nutrition amongst caste groups that, by custom, are obligated to incur higher marriage expenses. Given that early childhood nutrition correlates with later life outcomes, high marriage expenses could adversely affect economic outcomes in adulthood.

In the final chapter of my thesis, we (my co-author and thesis supervisor, Marcus Berliant, and I) study the role of commitment within marriage on the welfare properties of the marriage market equilibrium. We observe that the set of stable marriage matches is different depending on whether allocation within marriage is determined by binding agreements in the marriage market (BAMM) or by bargaining in marriage (BIM). With transferable utility, any stable matching is utilitarian efficient under BAMM, but not under BIM. Is it possible to implement the efficient matching under BIM? We show that if one side of the market is sufficiently sensitive relative to the other, if the more sensitive side can be ranked by sensitivity, and if their preferences are hierarchical, the top trading cycles algorithm results in an efficient matching.

Chapter 1

Family Law, Marriage, and Household Decisions

1.1 Introduction

Over the latter half of the past century, the United States, like much of the developed world, experienced a decrease in the rate of marriage and an increase in the rate of divorce (see Figures 1.1 & 1.2). These long-term trends are of interest to economists because they affect welfare, both of adults and of young children, a larger fraction of whom now grow up in less stable (and blended) families — living arrangements that correlate with worse outcomes for children (see Ginther & Pollak (2004)).

In this paper, I quantify the extent to which changes in divorce and property division laws contributed to these long-term trends, i.e., the decrease in the rate of marriage and the increase in the rate of divorce, and affected economic welfare. To be more specific, I study how these legal changes affected rates of marriage formation, marital sorting patterns (i.e., who marries whom), and decisions within marriage such as asset accumulation and divorce; and quantify changes in welfare, as viewed through the lenses of efficiency and distribution.

Beginning in the late 1960s and through the 1980s, a large number of states in the United States changed their divorce laws from a *mutual consent* to a *unilateral* divorce regime. Unlike *mutual consent* divorce laws, *unilateral* divorce laws allow any spouse to obtain divorce without the consent of the other. Contemporaneously, many states also changed their laws governing the division of marital property in the event of divorce from a *title-based* to an *equitable* division regime. In contrast to *title-based* statutes that provide for the division of marital property in accordance with property titles, *equitable* division laws mandate that a judge decide on a fair division of marital property in the event of divorce, usually favoring the low-income earner in property settlements. From the high income earner's point of view, equitable division acts as a tax on asset accumulation within marriage, reducing incentives to marry and accumulate assets within marriage.

With a view to studying how marriage decisions and behaviors within marriage change in response to changes in *divorce* and *property division* laws, I formulate a dynamic collective model of marriage with endogenous asset accumulation, labor supply and divorce. I embed the model of the collective household in a frictionless empirical marriage-matching model. In the model, individuals enter the marriage market with pre-determined levels of human capital, and match with individuals of the opposite gender, agreeing on spousal decision weights applicable to the problem of the collective household.

In order to quantify the effect of the legal changes, I estimate parameters of the model by targeting data from marriages under a *mutual consent, equitable division regime*, and simulate behavior under the other three legal regimes, namely, *mutual consent, title-based; unilateral, title-based*; and *unilateral, equitable*. I find that divorce and property division laws affect the rate of marriage and divorce but do not affect the rate of assortative matching. The introduction of *equitable division* in any divorce law regime reduces the rate of marriage, and accounts for about 18% of the long-term decline in the rate of marriage. The rate of divorce decreases when *equitable division* laws are introduced, but increases with the introduction of *unilateral divorce* laws. Overall, the change in legal regime from *mutual consent, title-based* to *unilateral, equitable* accounts for only about 11% of the long-term increase in the rate of divorce. Further, *equitable division* reduces the rate of asset accumulation within marriage in any divorce law regime. Finally, I conduct a welfare comparison of different legal regimes, and find that both *unilateral divorce* and *equitable division* laws lead to a substantial loss in economic efficiency.

The model sheds light on key mechanisms through which the changes in divorce and property division laws affect marriage decisions on the intensive and extensive margins. For instance, a high income earner would be less willing to marry a low-income earner in an *unilateral divorce, equitable* division regime than in a *mutual consent, title-based* regime. This is on account of the fact that in a *unilateral divorce, equitable division* regime, the high income earner knows that if the marriage does not work out, the low-earning spouse can *unilaterally* quit the marriage with half the marital property, to which the high-earning spouse would have principally contributed. This channel tends to increase assortative matching. However, equitable division distorts the high-income earner's incentives to save within marriage, thereby reducing the gains from marriage. This channel tends to cause high income earners, typically men, not to marry. With fewer men willing to marry, the splits of marital surplus accruing to men rise, causing some women to remain single, in turn affecting the splits of marital surplus negotiated in the marriage market and marital sorting. Given the complex general equilibrium effects at play, the effects on marital sorting are ambiguous. My simulations indicate that the introduction of *equitable division* changes behaviors at the extensive (marriage) margin, but leaves the intensive (marriage) margin unaffected. Moreover, the divorce and property division laws alter the splits of marital surplus negotiated in the marriage market, causing marriages to behave differently in different legal regimes.

This paper is closely related to a large strand of literature that investigates the effects of change in divorce and property division laws, on family formation, decisions within marriage, and divorce, both in the U.S. and European contexts. The behaviors studied by previous literature include divorce rates (see Allen (1992), Peters (1992), Friedberg (1998), Wolfers (2006), González & Viitanen (2009)), rates of marriage formation (see Rasul (2003), Matouschek & Rasul (2008)), asset accumulation (see Stevenson (2007)), female labor supply (see Gray (1998), Chiappori *et al.* (2002) and Voena (2015)), rates of violent crime (see Cáceres-Delpiano & Giolito (2012)), spousal homicide and suicide rates (see Stevenson & Wolfers (2006)), the welfare of children (see Gruber (2004)) and college educational attainment (see Blair & Neilson (2018)). Further, Voena (2015) studies the effects of changes in divorce and property division laws on couples who married before the legal changes, and finds that female labor force participation decreased and asset accumulation increased after the introduction of *unilateral* divorce and *equitable* division. In a recent paper, Fernández & Wong (2017) conduct a welfare analysis of divorce law regimes, assuming equal property division in the event of divorce. Finally, in a paper related very closely to the research in this paper, Reynoso (2019) extends the literature by studying the effect of change in divorce laws on marriage decisions and behavior within marriage.

This paper contributes to the literature by enhancing the understanding of the long-term consequences of changes in divorce and property division laws in the following three ways. First, this paper quantifies the effect of changes in divorce and property division laws on marriage and divorce rates in the long-run. I find that *equitable* division laws can account for 18% of the long-term decline in the rate of marriage. Second, this paper allows for endogenous marital choice, and finds that the introduction of *equitable division* leads to a reduction in the rate of asset accumulation. This stands in contrast to the findings in the existing literature (see Voena (2015)), which suggests that *equitable division* laws increase the rate of accumulation, if the marriage decisions are not allowed to endogenously respond to changes in property division laws. Third, this paper quantifies how changes in divorce and property division laws affect welfare.

The remaining part of this paper is structured as follows: Section 1.2 describes the institutional background of changes in divorce and property division laws. Section 1.3 details the model. Section 1.4 describes the dataset and the estimation methodology. Section 1.5 presents results of simulating the model with estimated parameter values for different legal regimes, and their welfare implications. Section 1.6 concludes.

1.2 Institutional Background of Legal Changes

Traditional family law in the United States, drawing upon the British legal tradition that was heavily influenced by Christian religious principles, treated marriage as a sacrament consisting in a commitment between a man and a woman to join one another for life.[1] However, by 1900 all states in the United States permitted divorce on "*fault-based*" grounds. Amongst

[1]The actual marital vow was a promise "to take each other to love and to cherish, in sickness and in health, for better, for worse, until death do us part" (see Weitzman (1985), page 1).

the commonly accepted grounds for divorce were instances of marital fault such as adultery, cruelty (physical or mental) and desertion. Starting in the 1920s different states in the United States changed their divorce laws to include a "*no-fault*" ground for divorce. In most cases this new ground was termed "*irretrievable breakdown*" of marriage. Thus, under the *no-fault* statutes, the law expressly permitted divorce by *mutual consent* even though there was no claim or evidence of wrongdoing on either side. Beginning in the late 1960s and through the 1980s, many states in the United States enacted further changes to their divorce laws, instituting divorce statutes that came to be known as "*unilateral*" divorce. In such a legal regime, any one spouse, acting on her/his own and without the consent of her/his partner, could obtain a divorce. Further, in a *unilateral* divorce regime, a spouse did not need to establish "marital fault" on part of her/his partner as a pre-condition for divorce. Figure 1.3 shows how the proportion of states with *unilateral* divorce statutes changed between 1965 and 1992. Note that the fraction of states with *unilateral* divorce increased rapidly in the early 1970s. Adoption of *unilateral* divorce continued through the late 1970s and 1980s, albeit at a slower pace.

In this paper, I follow the existing economic literature (see Gruber (2004), Voena (2015), Reynoso (2019)) and classify divorce law regimes into two broad categories, namely, *mutual consent* and *unilateral* divorce regimes. Thus, the *mutual consent* regime encompasses legal regimes that allowed divorce only on grounds of *marital fault* and those that allowed divorce on grounds of either marital fault or irretrievable breakdown of marriage, subject to the condition that both spouses agreed that there had been an "irretrievable breakdown" of marriage. The rationale for classifying these two legal regimes as *mutual consent* is that even in a *fault-based* regime, a divorce by *mutual consent* was possible. If both spouses wanted divorce, one spouse could falsely accuse the other of having committed some "fault" and the spouse accused could simply choose not to contest the allegations during divorce proceedings.[2] In fact, such acts of perjury were so common that their prevention appears to have been a major motivation for the enactment of *no-fault* statutes.

[2]This seems to have been fairly common under *fault-based* statutes. Weitzman (1985)(pg. 8) writes, "Over time, in actual practice, many divorcing couples privately agreed to an uncontested divorce whereby one party, usually the wife, would take the *pro forma* role of the innocent plaintiff. Supported by witnesses, she would attest to her husband's cruel conduct and he would not challenge her allegations." In such cases, a divorce would be granted under the law.

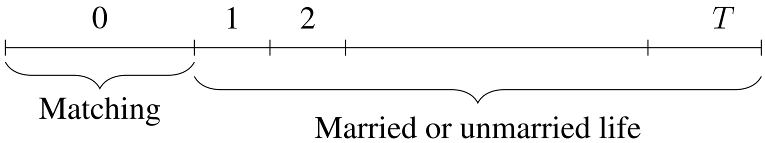
The laws regarding division of marital property in the event of divorce varied across states. By the middle of the twentieth century, there were three distinct property division regimes, namely, *title-based*, *equitable division* and *community property*. As of 1967, thirty states followed a *title-based* property division regime which mandated that in the event of divorce, marital property be divided in accordance with the property titles held by each spouse. In contrast, eight states, mostly with a Spanish or French historical legacy, followed the *community property* regime, under which marital assets were equally divided between the ex-spouses. The remaining thirteen states followed an *equitable division* regime, in which the judge adjudicating divorce decided on the fair share of marital property between the ex-spouses. Through the 1970s and the 1980s, a large number of states that had *title-based* property division changed their laws to institute *equitable division* property regimes. In contrast, states that already had *equitable division* or *community property* did not change their property division laws. Figure 1.3 shows how the fraction of states that had *equitable division* laws increased over time. Further, Table A1 provides the dates of change in both divorce and property division laws.

1.3 The Model

1.3.1 An Outline

Every individual in the economy is either female or male and has either high education or low education. The highly(low) educated individuals are potential high(low) income earners, ie, they earn a higher(lower) wage if they work over their life cycle. The number of individuals in each education category and gender and their wages over the life cycle are exogenously given and are common knowledge. Each individual knows the current divorce and property division laws, and expects the same laws to persist through her/his lifetime.

The life of any individual consists of two stages. In the first stage, each individual must decide whether to marry or to remain unmarried. Individuals who marry must also decide the type of partner to marry. While making marital choices individuals factor in both economic and non-economic considerations. The economic gains from marriage consist in consumption economies of scale available exclusively to married couples. The non-economic gains from marriage, or “love” is modeled as a taste-for-partner shock. Each person draws a taste shock for each type partner of the opposite sex. They then match with members of the opposite sex in a frictionless marriage market. Matches are made and some individuals could remain single. In each type of marital pairing[3], a contract regarding the split of the marital surplus is negotiated on the marriage market. Once the matches have been made, the marriage market closes. No further matches can be made thereafter. Married couples and unmarried individuals start living their lives. Over the course of their lives, couples may divorce, but divorcees are not allowed to remarry. This sequence of events is succinctly depicted in the timeline drawn below:



Individuals enter their adult lives either as an unmarried person or as a spouse in a married couple. The behavior of married couples is modeled using a dynamic extension of the collective model of the household (*à* la Voena (2015))[4]. This stage lasts for T periods. At the beginning of each period except the last, each spouse in a marriage draws a “distaste-for-work” shock. Having observed the values of the shock, the couple makes labor supply, savings and consumption allocation decisions.

At the end of each period except the last, each spouse draws a “taste-for-partner” shock, which evolves as a random walk stochastic process. Based on the realizations of this shock, the couple decides whether to enter the next period married or to divorce. The legal regime, which agents take as given and expect to persist through their lives,[5] enters into the problem of married individuals in two ways. The *divorce law* regime affects conditions under which divorce may be obtained while the *property division* regime affects the division of property in the event of divorce.

In a *mutual consent* regime, divorce requires the consent of both spouses. So, if there is

[3]There are four types of marital pairing, namely, $\{HighMan, HighWoman\}$, $\{HighMan, LowWoman\}$, $\{LowMan, HighWoman\}$ and $\{LowMan, LowWoman\}$

[4]The original static versions of the collective model can be found in Chiappori (1988) and Chiappori (1992).

[5]While pre-nuptial agreements might allow a couple to contract out of the existing legal regime, they were not consistently enforced until the Uniform Prenuptial Agreements Act 1983 (see Voena (2015)). Moreover, prenuptial agreements remain rare even today (see Mahar (2003)).

a disagreement between the husband and the wife regarding whether to divorce or to remain married, the spouse who wants to divorce could attempt to transfer a share of her marital assets to the spouse who wants to stay married so as to make her indifferent between getting divorced and staying married. By contrast, in a *unilateral* divorce regime, marriage, rather than divorce, requires the consent of both spouses. Hence, if there is a disagreement between the husband and the wife regarding whether to divorce or to remain married, the split of marital surplus contracted in the previous period might be re-negotiated so as to make the spouse requesting divorce indifferent between remaining married and getting divorced. It bears emphasis that in a *mutual consent* regime, the model, under no circumstances, allows re-negotiation of the contract relating to the split of marital surplus that was agreed to at the start of marriage. Thus, in the language of Pollak (2019), the *mutual consent* regime is modeled as being characterized by Binding Agreements in the Marriage Market (BAMM) while the *unilateral* divorce regime is modeled as being characterized by a very specific form of Bargaining In Marriage (BIM). To be precise, the specific form of BIM that I impose is known as *limited commitment* (for instance, see Voena (2015) and Kocherlakota (1996)) in the literature.

If a couple divorces, each partner must remain unmarried thereafter, and her/his problem is identical to that of an unmarried woman/man with the same state variables. The problem for unmarried individuals is analogous to that of married couples except for the fact that they do not receive any "taste-for-partner" shock at the end of any period and do not need to make a decision about whether to divorce or not. Further, the legal regime does not enter into the problem of unmarried individuals in any way.

The last period of life is different from all other periods in two respects. First, all individuals are retired, and do not work in this period. Thus, consumption in the final period of life is entirely out of savings. Second, for married couples, no "taste-for-partner" shock realizes in the final period of life. Hence, there is no divorce at the end of period T. At the end of the final period of life both spouses die without leaving any bequest.

I describe the model formally below, beginning with the life cycle.

1.3.2 The Life Cycle

I first describe the problem of an unmarried individual.

The Problem of an Unmarried Individual

The instantaneous utility of an unmarried individual i at time t is given by:

$$u_{it}(C_{it}, l_{it}, h_{it}, \boldsymbol{\eta}) = \frac{C_{it}^{1-\gamma}}{1-\gamma} + l_{it} * \phi(X) - \mathbf{1}(h_{it})\eta_{it}^{h} \tag{1.1}$$

where C denotes consumption, l denotes leisure, h denotes hours of work, $h \in \{0, \frac{1}{2}, 1\}$, which corresponds to the alternatives of not working, working part time and working full-time. $\mathbf{1}(.)$ denotes the indicator function and X denotes demographic characteristics. ϕ denotes the systematic utility from leisure. Associated with each discrete alternative labor supply choice is an alternative-specific taste shock denoted by $\eta_{it}^{h} \overset{iid}{\sim} N(0, \sigma_{\eta}^{2}(X))$. Conditional upon X, η_{it}^{h} is assumed to be independently distributed across individuals and over time. Each individual is endowed with a unit of time in each period and faces the following time budget constraint.

$$h_{it} + l_{it} = 1, \qquad h_{it} \in \{0, 1/2, 1\} \quad \forall t < T \tag{1.2}$$

and

$$h_{iT} = 0$$

An unmarried individual i with education level e faces the following per-period budget constraint:

$$\begin{gathered} C_{it} = w_{it}^{e,g} h_{it} + K_{i,t} - \frac{K_{i,t+1}}{R}, \qquad g \in \{m, f\} \\ \text{and } K_{it} \geq 0 \quad \forall t \in \{1, 2, .., T\} \end{gathered} \tag{1.3}$$

where $w_{it}^{e,g}$ denotes the wage earned by individual i with education level e and of gender g at time t, K_t denotes assets at the beginning of period t, and R is the gross rate of interest. The budget constraint requires that total consumption equal the sum of income and assets minus savings.

For an unmarried person i, define the choice vector $\mathbf{q}_t^s = \{C_{it}, h_{it}, l_{it}, K_{i,t+1}\}$ and the state vector $\omega_t^s = \{K_{it}, \eta_{it}\}$.

The value of an unmarried person who enters T with state vector ω_{iT} is defined as follows:

$$V_{jT}(\omega_{iT}) = \frac{K_{iT}^{1-\gamma}}{1-\gamma}$$

Having defined V_{iT}, recursively define $V_{it}(\omega_t)\ \forall t < T$ as follows:

$$V_{it}^s(\omega_t^s) = \max_{\mathbf{q}_t^s} \quad u(C_{it}, h_{it}, l_{it}, \eta) + \beta \mathbf{E}\big[V_{i,t+1}^s(\omega_{t+1}^s | \omega_t^s)\big] \tag{1.4}$$

subject to

the time budget constraint (1.2)

the budget constraint for singles (1.3)

Finally, note that the legal regime does not enter into the problem of the unmarried person in any way.

The Couple's Problem

I describe the problem beginning from the last period, i.e., period T. The state vector of a couple that enters T married is defined as $\omega_T = \{K_T, \mu_T\}$, where K_T denotes total marital assets at period T and μ_T denotes the husband's Pareto weights applicable in period T. As couples are retired in the last period, the value to the couple at the beginning of period T is given by:

$$V_T(\omega_T) = \max_{C_{mT}, C_{fT}} \quad \mu_T \frac{C_{mT}^{1-\gamma}}{1-\gamma} + (1-\mu_T)\frac{C_{fT}^{1-\gamma}}{1-\gamma} \tag{1.5}$$

subject to

$$C_{mT} + C_{fT} = \rho K_T, \qquad \rho > 1$$

Here, C_{mT} and C_{fT} denote consumptions of the husband and wife at period T respectively,[6] and ρ denotes the consumption economies of scale parameter. Note that these economies of scale in consumption are available only in marriage but not in a state of singlehood. Denote the policy functions from solving the above problem as $C^*_{jT}(\omega_T)$, $j \in \{m, f\}$. Then the value to spouse j in period T given state vector ω_T is defined as

$$V_{jT}(\omega_T) = \frac{\left(C^*_{jT}(\omega_T)\right)^{1-\gamma}}{1-\gamma}$$

In any period t prior to the last, the vector of states and controls at the beginning of period t depend on the property division regime. In a *title-based* property division regime, the state vector at t is given by $\omega_t = \{K_t, \kappa_t, \mu_t, \boldsymbol{\eta}_t, \boldsymbol{\xi}_{t-1}\}$, where K_t denotes total marital assets at the beginning of period t, κ_t ($\in [0, 1]$) denotes the share of marital assets held under the husband's name, μ_t denotes husband's Pareto weight applicable to the marriage at period t, $\boldsymbol{\eta}_t$ is the vector of "distaste-for-work" shocks that realize at the beginning of period t, and $\boldsymbol{\xi}_{t-1}$ is the vector of "taste-for-partner" shocks that realized at $t-1$. The choice-vector in a *title-based* property division regime is given by $\mathbf{q}_t = \{C_{mt}, C_{ft}, h_{mt}, h_{ft}, l_{mt}, l_{ft}, K_{t+1}, \kappa_{t+1}\}$. In words, couples observe ω_t and decide how much to work, how much to consume, how to split consumption between the two spouses, how much assets to accumulate, and how to split property titles to those assets between the two spouses. In an *equitable* or a *community property* regime, who has the title to marital property is irrelevant, and all that matters is the total value of assets held jointly by the couple. So, the state space in an *equitable* or a *community property* regime is given by $\omega_t = \{K_t, \mu_t, \boldsymbol{\eta}_t, \boldsymbol{\xi}_{t-1}\}$, and the vector of controls is given by $\mathbf{q}_t = \{C_{mt}, C_{ft}, h_{mt}, h_{ft}, l_{mt}, l_{ft}, K_{t+1}\}$. Notice that κ_t does *not* feature in either the state or the control space in these legal regimes.

At the end of period t (where $t < T$), each spouse draws a "taste-for-partner" shock which

[6] Note the the Pareto weight of the husband and the wife have been normalized to sum to 1.

I denote as ξ_{jt}, $j \in \{m, f\}$. ξ_{jt} follows a random walk stochastic process as under[7].

$$\xi_{jt} = \xi_{j,t-1} + \zeta_{jt}, \quad \zeta_{jt} \overset{iid}{\sim} N(0, \sigma_\zeta^2), \quad \xi_{j0} = 0 \tag{1.6}$$

Given the vector of marital choices $\mathbf{q}_t^*$, and having observed the realized vector of "taste-for-spouse" shock $\boldsymbol{\xi}_t$, each spouse j computes her present discounted value from staying married as follows:

$$\widetilde{V}_{jt}^{marr}(\mathbf{q}_t^*, \boldsymbol{\xi_t}) = \beta \mathbf{E}\big[V_{j,t+1}(\omega_{t+1})|\mathbf{q}_t^*, \mu_t, \boldsymbol{\xi_t}\big] + \xi_{jt} \tag{1.7}$$

The present-discounted value (at the end of period t) to the couple from staying married is computed as under

$$\widetilde{V}_t^{marr}(\mathbf{q}_t^*, \boldsymbol{\xi_t}) = \mu_t \widetilde{V}_{mt}^{marr} + (1 - \mu_t)\widetilde{V}_{ft}^{marr} \tag{1.8}$$

The present discounted value to spouse j of divorcing in period t with the default allocation of marital property as specified by the property division regime $\mathcal{P}$ is given by

$$V_{jt}^d(\mathbf{q}_t^*, \boldsymbol{\xi_t}) = \beta \mathbf{E}\big[V_{j,t+1}^s(\omega_{j,t+1}^s)|\omega_{jt}^d(\mathbf{q}_t^*, \mathcal{P})\big] \tag{1.9}$$

Here $\omega_{jt}^d(\mathbf{q}_t^*, \mathcal{P})$ is the default allocation of marital property (in the event of divorce) to spouse j under the property division regime $\mathcal{P}$ for a couple that has made choice $\mathbf{q}_t$ at period t. For a *title-based* property division regime,

$$\omega_{mt}^d(\mathbf{q}_t^*) = \kappa_t.(K_{t+1}^*/R)$$

and

$$\omega_{ft}^d(\mathbf{q}_t^*) = (1 - \kappa_t).(K_{t+1}^*/R)$$

In a *community property* regime, the default division of marital property is fixed at half by law. So,

$$\omega_{jt}^d(\mathbf{q}_t^*) = \frac{1}{2}(K_{t+1}^*/R), \quad j \in \{m, j\}$$

[7] For the purpose of numerical solution, I discretized the random walk as a Markov process (see Tauchen (1986) and Adda *et al.* (2003))

In an *equitable division* regime, the default division of marital property is up to judge. Ex-ante, the division of marital property is a random variable from the couple's point of view. So, in an *equitable division* regime,

$$\omega_{mt}^{d}(\mathbf{q}_t^*) = \kappa_t^J K_{t+1}^*/R$$

and

$$\omega_{ft}^{d}(\mathbf{q}_t^*) = (1-\kappa_t^J) K_{t+1}^*/R$$

where κ_t^J is a random variable denoting the share of marital assets accruing to the husband. Thus, in an *equitable division* regime, $\omega_{jt}^{d}(\mathbf{q}_t^*)$ is a random variable, and the expectation in equation (1.9) is taken both over ω_{jt}^{d} and shocks that will realize in period $t+1$.[8] By contrast, in a *title-based* property division regime and a *community property* regime, ω_{jt}^{d} is deterministic, and the expectation in equation (1.9) is taken only over shocks that will realize in period $t+1$.

A couple that has made a given vector $\mathbf{q}_t^*$ of first-stage choices at t and has drawn a given vector of shocks $\boldsymbol{\xi}_t$ at the end of t is faced with exactly one of the following four situations.

1. $\widetilde{V}_{jt}^{marr} \geq V_{jt}^{d} \quad \forall j \in \{m, f\}$
2. $\widetilde{V}_{jt}^{marr} < V_{jt}^{d} \quad \forall j \in \{m, f\}$
3. $\widetilde{V}_{mt}^{marr} < V_{mt}^{d}$ and $\widetilde{V}_{ft}^{marr} \geq V_{ft}^{d}$
4. $\widetilde{V}_{mt}^{marr} \geq V_{mt}^{d}$ and $\widetilde{V}_{ft}^{marr} < V_{ft}^{d}$

In words, (1) and (2) correspond to situations where the couple agrees to stay married or to get divorced. In these cases the unanimously decided outcome of the couple occurs regardless of the divorce law regime. On the other hand, cases (3) and (4) correspond to situations where the couple are divided over whether to remain married or to divorce. In situation (3), the man wants to divorce while the woman wants to remain married while in situation (4), the intentions of the spouses are the reverse.

The conditions under which the marriage can be dissolved depends on the divorce law regime. In a *mutual consent* regime, divorce requires the consent of both spouses. So, if spouse

[8] Technically, in an *equitable* division regime, $V_{jt}^{d}(\mathbf{q}_t^*, \boldsymbol{\xi_t}) = \beta \mathbf{E}_{\omega_{jt}^d}\left[\mathbf{E}_{\boldsymbol{\eta}_{t+1}}\left[V_{j,t+1}^{s}(\omega_{j,t+1}^{s}) | \omega_{jt}^{d}(\mathbf{q}_t^*, \mathcal{P})\right]\right]$

j wants divorce and spouse j' wants to remain married, the allocation of marital assets in the event of divorce may be re-negotiated (in favor of spouse j') to make her indifferent between marriage and divorce. In such a situation, spouse j solves for λ^* such that

$$\begin{aligned} \lambda^* = \min \quad & \lambda \\ \text{s.t. } & \lambda \in [0,1] \\ \text{s.t. } & \widetilde{V}^{marr}_{j',t} = \beta \mathbf{E}_{\eta_{j',t+1}} \big[V^s_{j',t+1}(\lambda K^*_{t+1}, \eta_{j',t+1}) \big] \\ \text{s.t. } & \widetilde{V}^{marr}_{jt} \leq \beta \mathbf{E}_{\eta_{j,t+1}} \big[V^s_{j,t+1}((1-\lambda) K^*_{t+1}, \eta_{j,t+1}) \big] \end{aligned} \tag{1.10}$$

If λ^* does not exist, the marriage continues. On the other hand, if a solution to (1.10) exists, divorce occurs, and the division of marital property is as per λ^* and the values to spouses j and j' are $\widetilde{V}^{reneg,d}_{j,t}$ and $\widetilde{V}^{marr}_{j',t}$ respectively, where $\widetilde{V}^{reneg,d}_{j,t} = \beta \mathbf{E}_{\eta_{j,t+1}} \big[V^s_{j,t+1}((1-\lambda^*) K^*_{t+1}, \eta_{j,t+1}) \big]$. Note that in a *mutual consent* regime, the husband's Pareto weight in marriage (denoted by μ) is not re-negotiated under any circumstance. So, in a *mutual consent* regime we have $\mu_t = \mu \; \forall t \in \{1, 2, ..., T\}$, where μ is determined in the marriage market as described in Section 1.3.3. Let D^*_t denote the indicator for divorce at the end of period t.[9] Given $\mathbf{q}^*_t$ and $\boldsymbol{\xi}_t$, the present value to the couple at the end of t is:

$$\begin{aligned} \widetilde{V}_t(\mathbf{q}^*_t, \boldsymbol{\xi}_t) = & \mathbf{1}(\widetilde{V}^{marr}_{jt} \geq V^d_{jt}, \; j \in \{m, f\}) * (\mu \widetilde{V}^{marr}_{mt} + (1-\mu) \widetilde{V}^{marr}_{ft}) \\ & + \mathbf{1}(\widetilde{V}^{marr}_{jt} < V^d_{jt}, \; j \in \{m, f\}) * (\mu V^d_{mt} + (1-\mu) V^d_{ft}) \\ & + \mathbf{1}(\widetilde{V}^{marr}_{mt} < V^d_{mt}, \widetilde{V}^{marr}_{ft} \geq V^d_{ft}) * \big[D^*_t \big(\mu \widetilde{V}^{reneg,d}_{mt} + (1-\mu) \widetilde{V}^{marr}_{ft} \big) + \\ & (1-D^*_t)(\mu \widetilde{V}^{marr}_{mt} + (1-\mu) \widetilde{V}^{marr}_{ft}) \big] \\ & + \mathbf{1}(\widetilde{V}^{marr}_{mt} \geq V^d_{mt}, \widetilde{V}^{marr}_{ft} < V^d_{ft}) * \big[D^*_t \big(\mu \widetilde{V}^{marr}_{mt} + (1-\mu) \widetilde{V}^{reneg,d}_{ft} \big) + \\ & (1-D^*_t)(\mu \widetilde{V}^{marr}_{mt} + (1-\mu) \widetilde{V}^{marr}_{ft}) \big] \end{aligned} \tag{1.11}$$

The values to the man and woman, denoted by $\widetilde{V}_{mt}$ and $\widetilde{V}_{ft}$ respectively, are defined as

[9] $D^*_t = 1$ if divorce occurs at the end of period t, and $D^*_t = 0$ otherwise.

follows:

$$
\begin{aligned}
\widetilde{V}_{mt}(\mathbf{q}_t^*, \boldsymbol{\xi}_t) &= \mathbf{1}(\widetilde{V}_{jt}^{marr} \geq V_{jt}^d,\ j \in \{m, f\}) * \widetilde{V}_{mt}^{marr} + \mathbf{1}(\widetilde{V}_{jt}^{marr} < V_{jt}^d,\ j \in \{m, f\}) * V_{mt}^d \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} < V_{mt}^d, \widetilde{V}_{ft}^{marr} \geq V_{ft}^d) * \left[D_t^* \, \widetilde{V}_{mt}^{reneg,d} + (1 - D_t^*) \, \widetilde{V}_{mt}^{marr}\right] \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} \geq V_{mt}^d, \widetilde{V}_{ft}^{marr} < V_{ft}^d) * \widetilde{V}_{mt}^{marr} \\
\widetilde{V}_{ft}(\mathbf{q}_t^*, \boldsymbol{\xi}_t) &= \mathbf{1}(\widetilde{V}_{jt}^{marr} \geq V_{jt}^d,\ j \in \{m, f\}) * \widetilde{V}_{ft}^{marr} + \mathbf{1}(\widetilde{V}_{jt}^{marr} < V_{jt}^d,\ j \in \{m, f\}) * V_{ft}^d \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} < V_{mt}^d, \widetilde{V}_{ft}^{marr} \geq V_{ft}^d) * \widetilde{V}_{ft}^{marr} \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} \geq V_{mt}^d, \widetilde{V}_{ft}^{marr} < V_{ft}^d) * \left[D_t^* \, \widetilde{V}_{ft}^{reneg,d} + (1 - D_t^*) \, \widetilde{V}_{ft}^{marr}\right]
\end{aligned}
\tag{1.12}
$$

By contrast, in a *unilateral divorce* regime, marriage, rather than divorce requires the consent of both spouses. So, if the husband wants to divorce and the wife wants to stay married, the husband's Pareto weight in marriage applicable in the next period, ie μ_{t+1} might be renegotiated so that the husband may be made indifferent between marriage and divorce. In such a situation, the wife solves for μ_{t+1}^* such that

$$
\begin{aligned}
\mu_{t+1}^* = \min \quad & \mu_{t+1} \\
\text{s.t. } & \mu_{t+1} \in [0, 1] \\
\text{s.t. } & \beta \mathbf{E}\left[V_{m,t+1}(\omega_{t+1}) | \mathbf{q}_t^*, \boldsymbol{\xi}_t, \mu_{t+1}\right] = V_{mt}^d \\
\text{s.t. } & \beta \mathbf{E}\left[V_{f,t+1}(\omega_{t+1}) | \mathbf{q}_t^*, \boldsymbol{\xi}_t, \mu_{t+1}\right] \geq V_{ft}^d
\end{aligned}
\tag{1.13}
$$

If a solution to the above problem exists, the marriage continues into the next period with husband's Pareto weight μ_{t+1}^* and $D_t^* = 0$ and the value to spouse $j, j \in \{m, f\}$ is given by

$$
\widetilde{V}_{jt}^{reneg,uni} = \beta \mathbf{E}\left[V_{j,t+1}(\omega_{t+1}) | \mathbf{q}_t^*, \boldsymbol{\xi}_t, \mu_{t+1}^*\right]
$$

Otherwise, divorce occurs with the division of marital property as specified by the default property division regime and $D_t^* = 1$. Here, D_t^* is an indicator for divorce. Note that in a *unilateral* divorce regime, if a divorce occurs, the division of marital property follows the default under the property division regime in question, and is not re-negotiated upon in any circumstance.

Conversely, if the wife wants to divorce and the husband wants to stay married for some vector $\mathbf{q}_t^*$ of first-stage choices at t and and a given realization of shocks $\boldsymbol{\xi}_t$ at the end of t, the husband's Pareto weight in marriage applicable in the next period, ie μ_{t+1} might be re-negotiated so that the wife may be made indifferent between marriage and divorce. In such a situation, the husband solves for μ_{t+1}^* such that

$$\begin{aligned}\mu_{t+1}^* = \max \quad & \mu_{t+1} \\ \text{s.t. } & \mu_{t+1} \in [0,1] \\ \text{s.t. } & \beta \mathbf{E}\big[V_{f,t+1}(\omega_{t+1})|\mathbf{q}_t^*, \boldsymbol{\xi}_t, \mu_{t+1}\big] = V_{ft}^d \\ \text{s.t. } & \beta \mathbf{E}\big[V_{m,t+1}(\omega_{t+1})|\mathbf{q}_t^*, \boldsymbol{\xi}_t, \mu_{t+1}\big] \geq V_{mt}^d\end{aligned} \tag{1.14}$$

If a solution to the above problem exists, the marriage continues into the next period with husband's Pareto weight μ_{t+1}^* and the value to spouse $j, j \in \{m, f\}$ is given by

$$\widetilde{V}_{jt}^{reneg,uni} = \beta \mathbf{E}\big[V_{j,t+1}(\omega_{t+1})|\mathbf{q}_t^*, \boldsymbol{\xi}_t, \mu_{t+1}^*\big]$$

Otherwise, divorce occurs with the division of marital property as specified by the default property division regime and $D_t^* = 1$. Hence, given $\mathbf{q}_t^*$ and $\boldsymbol{\xi}_t$, the present value to the couple at the end of t is

$$\begin{aligned}\widetilde{V}_t(\mathbf{q}_t^*, \boldsymbol{\xi}_t) = {} & \mathbf{1}(\widetilde{V}_{jt}^{marr} \geq V_{jt}^d,\ j \in \{m, f\}) * (\mu_t \widetilde{V}_{mt}^{marr} + (1-\mu_t)\widetilde{V}_{ft}^{marr}) \\ & + \mathbf{1}(\widetilde{V}_{jt}^{marr} < V_{jt}^d,\ j \in \{m, f\}) * (\mu_t \widetilde{V}_{mt}^{d} + (1-\mu_t)\widetilde{V}_{ft}^{d}) \\ & + \mathbf{1}(\widetilde{V}_{mt}^{marr} < V_{mt}^d, \widetilde{V}_{ft}^{marr} \geq V_{ft}^d) * \big[D_t^*\big(\mu_t \widetilde{V}_{mt}^{d} + (1-\mu_t)\widetilde{V}_{ft}^{d}\big) + \\ & (1-D_t^*)(\mu_t \widetilde{V}_{mt}^{reneg,uni} + (1-\mu_t)\widetilde{V}_{ft}^{reneg,uni})\big] \\ & + \mathbf{1}(\widetilde{V}_{mt}^{marr} \geq V_{mt}^d, \widetilde{V}_{ft}^{marr} < V_{ft}^d) * \big[D_t^*\big(\mu_t \widetilde{V}_{mt}^{d} + (1-\mu_t)\widetilde{V}_{ft}^{d}\big) + \\ & (1-D_t^*)(\mu_t \widetilde{V}_{mt}^{reneg,uni} + (1-\mu_t)\widetilde{V}_{ft}^{reneg,uni})\big]\end{aligned} \tag{1.15}$$

The values to the man and woman, denoted $\widetilde{V}_{mt}$ and $\widetilde{V}_{ft}$ respectively are defined as follows

$$\begin{aligned}
\widetilde{V}_{mt}(\mathbf{q}_t^*, \boldsymbol{\xi}_t) = &\mathbf{1}(\widetilde{V}_{jt}^{marr} \geq V_{jt}^d,\ j \in \{m, f\}) * \widetilde{V}_{mt}^{marr} + \mathbf{1}(\widetilde{V}_{jt}^{marr} < V_{jt}^d,\ j \in \{m, f\}) * V_{mt}^d \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} < V_{mt}^d, \widetilde{V}_{ft}^{marr} \geq V_{ft}^d) * V_{mt}^d \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} \geq V_{mt}^d, \widetilde{V}_{ft}^{marr} < V_{ft}^d) * (D_t^* V_{mt}^d + (1 - D_t^*) \widetilde{V}_{mt}^{reneg,uni}) \\
\widetilde{V}_{ft}(\mathbf{q}_t^*, \boldsymbol{\xi}_t) = &\mathbf{1}(\widetilde{V}_{jt}^{marr} \geq V_{jt}^d,\ j \in \{m, f\}) * \widetilde{V}_{ft}^{marr} + \mathbf{1}(\widetilde{V}_{jt}^{marr} < V_{jt}^d,\ j \in \{m, f\}) * V_{ft}^d \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} < V_{mt}^d, \widetilde{V}_{ft}^{marr} \geq V_{ft}^d) * (D_t^* V_{ft}^d + (1 - D_t^* V_{ft}^{reneg,uni})) \\
&+ \mathbf{1}(\widetilde{V}_{mt}^{marr} \geq V_{mt}^d, \widetilde{V}_{ft}^{marr} < V_{ft}^d) * V_{ft}^d
\end{aligned} \tag{1.16}$$

By allowing the Pareto weight to be subject to re-negotiation period-by-period in a *unilateral* divorce regime, the model implies that the marital contract in a *unilateral* divorce regime is characterized by limited commitment rather than by full commitment. Limited commitment implies that some splits of the marital surplus are not possible to credibly commit to ex-ante (see Kocherlakota (1996), Ligon *et al.* (2000), Ligon *et al.* (2002), Mazzocco *et al.* (2013)). On the other hand, the marriage contract in a *mutual consent* regime is characterized by full commitment. Couples' decisions to divorce or to stay married coincide with the efficient outcome in a *mutual consent* regime.

I now describe the problem of a couple that enters period t married with state vector ω_t. First, note that the instantaneous utility to spouse j at time t is given by:

$$u_{jt}(C_{jt}, l_{jt}, h_{jt}, \boldsymbol{\eta}) = \frac{C_{jt}^{1-\gamma}}{1-\gamma} + \mathbf{1}_{jt}(\text{NW}) * \phi(X) + \mathbf{1}_{jt}(\text{PT}) * 0.5 * \phi(X) - \mathbf{1}(h_{jt})\eta_{jt}^h \tag{1.17}$$

where C denotes consumption, l denotes leisure, h denotes hours of work, which is constrained to be one of the three discrete alternatives, namely, full time, part time or non-participation in the workforce. Associated with each discrete alternative labor supply choice is an alternative-specific taste shock denoted by $\eta_{jt}^h \overset{iid}{\sim} N(0, \sigma_\eta^2)$. η_{jt}^h is assumed to be independently distributed across individuals and over time. Note that the distribution of the vector $\boldsymbol{\eta}_{jt}$ is independent of marital status.

I assume that wages are exogenously given and vary by education and gender. Given gender, more educated individuals have higher wages and given education, women may earn less than men on account of the gender pay gap. Thus, $w_f^e = \phi w_m^e \quad \forall e \in \{High, Low\}$, $\phi \leq 1$. For a married couple $(m^e, f^{e'})$ with husband's and wife's education levels e and e' respectively, the per-period budget constraint is

$$\begin{gathered} C_{mt} + C_{ft} = \rho.(w_{mt}^e h_{mt} + w_{ft}^{e'} h_{ft} + K_t - \frac{K_{t+1}}{R}) \\ \text{and } K_t \geq 0 \quad \forall t \in \{1, 2, ..., T\} \end{gathered} \tag{1.18}$$

with $K_t = K_{mt} + K_{ft}$, where K_t denotes assets in period t and $\rho > 1$. The budget constraint requires that total household consumption equal the sum of total household income and assets minus savings, inflated by the economies of scale (in marriage) parameter ρ.

The couple solves

$$\begin{aligned} V_t(\omega_t) = \max\nolimits_{\mathbf{q}_t} \quad & \mu_t \, u_{mt} + (1 - \mu_t) \, u_{ft} + \mathbf{E}_{\boldsymbol{\xi}_t} \left[\widetilde{V}_t(\mathbf{q}_t, \boldsymbol{\xi}_t) | \omega_t \right] \\ & \text{s.t. the per-period budget constraint (1.18)} \\ & \text{s.t. the time budget constraint (1.2)} \end{aligned} \tag{1.19}$$

Let $\mathbf{q}_t^*(\omega_t) = \{C_{mt}^*, C_{ft}^*, h_{mt}^*, h_{ft}^*, l_{mt}^*, l_{ft}^*, K_{t+1}^*, \kappa_{t+1}^*\}$[10] be a solution to (1.19). Then the present values to an individual spouse j, $j \in \{m, f\}$, at the beginning of period t is given by

$$\begin{aligned} V_{jt}(\omega_t) = & \frac{(C_{jt}^*)^{1-\gamma}}{1 - \gamma} + \mathbf{1}_{it}(\text{NW}) * \phi(X) + \mathbf{1}_{it}(\text{PT}) * 0.5 * \phi(X) - \mathbf{1}(h_{it}) \eta_{it}^h \\ & + \mathbf{E}_{\boldsymbol{\xi}_t} \left[\widetilde{V}_{jt}(\mathbf{q}_t, \boldsymbol{\xi}_t) | \omega_t \right] \end{aligned} \tag{1.20}$$

To initialize the problem, I assume that across property division regimes, marriage starts with zero marital assets, i.e., $K_1 = 0$, and $\kappa_1 = \frac{1}{2}$.

Solving the lifecycle problem in any given *divorce* and *property division* regime yields, for each gender g and education level e, the expected values of singlehood (denoted by $\mathbf{E}V_{ge}^s$) and marriage to each education category e' (denoted by $\mathbf{E}V_{ge}^{e'}(\mu_{e,e'})$, $e, e' \in \{High, Low\}$) for that legal regime. Here, the expectation is taken prior to the start of the life cycle. Note

[10] Technically, this is the choice vector in a *title-based* property division regime. In a *community* property regime, the corresponding choice vector is $\mathbf{q}_t^*(\omega_t) = \{C_{mt}^*, C_{ft}^*, h_{mt}^*, h_{ft}^*, l_{mt}^*, l_{ft}^*, K_{t+1}^*\}$.

that the expected value to a person with a given gender and a given level of education of marrying a partner with a given level of education depends on the Pareto weight applicable in that marital pairing at the time of entering the marriage. These Pareto weights are determined in the marriage market which I describe below.

1.3.3 The Marriage Market

Following Choo & Siow (2006) (also see Gayle & Shephard (2019) and Chiappori *et al.* (2018)), I assume that an individual i of any gender with any education level receives, over and above the systematic component of utility, an idiosyncratic payoff from marrying each type of individual of the opposite sex. Let θ_i^e denote this idiosyncratic payoff received by individual i for any member of the opposite sex with education level e. Notice that θ_i^e depends only on the type of the individual of the opposite sex but not on her/his specific identity. Thus, the problem of a given individual i of gender g with education level $e \in \{H, L\}$, is

$$\max_{\{H,L,s\}} \{\mathbf{E}V_{ge}^H(\mu_{e,H}) + \theta_i^H, \mathbf{E}V_{ge}^L(\mu_{e,L}) + \theta_i^L, \mathbf{E}V_{ge}^s + \theta_i^s\} \tag{1.21}$$

Here, superscripts H, L and s refer to the alternatives of marrying a high type, low type and staying single respectively and $\mu_{ee'}$ denotes the husband's Pareto weight in a marriage of a man with education level e to a woman with education level e'. I assume that the idiosyncratic payoffs θ_i^e follow Type-I extreme value distribution with a zero location parameter and the scale parameter σ_θ. Hence, the proportion of type e males that would be willing to marry type e' females, which is denoted by $p_{me}^{e'}$, is given by

$$\begin{aligned} p_{me}^{e'}(\mu_{ee}, \mu_{ee'}) &= \Pr\big[\mathbf{E}V_{me}^{e'}(\mu_{e,e'}) + \theta_i^{e'} > \max\{\mathbf{E}V_{me}^{e}(\mu_{e,e}) + \theta_i^{e}, \mathbf{E}V_{me}^{s} + \theta_i^{s}\}\big] \\ &= \frac{D_{me}^{e'}(\mu_{ee}, \mu_{ee'})}{N_{me}} = \frac{\exp[\mathbf{E}V_{me}^{e'}(\mu_{e,e'})/\sigma_\theta]}{\exp[\mathbf{E}V_{me}^{e'}(\mu_{e,e'})/\sigma_\theta] + \exp[\mathbf{E}V_{me}^{e}(\mu_{e,e})/\sigma_\theta] + \exp[\mathbf{E}V_{me}^{s}/\sigma_\theta]} \end{aligned} \tag{1.22}$$

where $D_{me}^{e'}$ denotes "demand" for type e' females by type e males and N_{me} denotes the measure of males with education level e in the population. Similarly, the proportion of type e' females that would be willing to marry type e males, which is denoted by $p^e_{fe'}$, is given by

$$\begin{aligned} p^e_{fe'}(\mu_{ee'},\mu_{e'e'}) &= \Pr\left[\mathbf{E}V^e_{fe'}(\mu_{e,e'}) + \theta^e_i > \max\{\mathbf{E}V^{e'}_{fe'}(\mu_{e',e'}) + \theta^{e'}_i, \mathbf{E}V^s_{fe'} + \theta^s_i\}\right] \\ &= \frac{S^e_{fe'}(\mu_{ee'},\mu_{e'e'})}{N_{fe'}} = \frac{\exp[\mathbf{E}V^e_{fe'}(\mu_{e,e'})/\sigma_\theta]}{\exp[\mathbf{E}V^e_{fe'}(\mu_{e,e'})/\sigma_\theta] + \exp[\mathbf{E}V^{e'}_{fe'}(\mu_{e',e'})/\sigma_\theta] + \exp[\mathbf{E}V^s_{fe'}/\sigma_\theta]} \end{aligned} \tag{1.23}$$

where $S^e_{fe'}$ denotes "supply" of type e' females to type e males.

Given the expected value functions $\mathbf{E}V^s_{ge}$ and $\mathbf{E}V^{e'}_{ge}$, $g \in \{m.f\}$; $e, e' \in \{H, L\}$, the equilibrium in the marriage market consists of the following objects satisfying CONDITION A below:

1. A vector of husband's Pareto weights $\boldsymbol{\mu}^* = (\mu^*_{HH}, \mu^*_{HL}, \mu^*_{LH}, \mu^*_{LL})$

2. $D^{e'}_{me}(\mu^*_{e,e'})$, $e, e' \in \{H, L\}$ which denotes the number of men with education e who marry women with education e', given husband's Pareto weight $\mu^*_{e,e'}$.

3. $S^e_{fe'}(\mu^*_{e,e'})$, $e', e \in \{H, L\}$ which denotes the number of women with education e' who marry women with education e, given husband's Pareto weight $\mu^*_{e,e'}$.

CONDITION A: $D^{e'}_{me}\mu^*_{e,e'} = S^e_{fe'}\mu^*_{e,e'}$ $\forall e, e' \in \{H, L\}$.

Proposition 1 in Gayle & Shephard (2019) demonstrates that the equilibrium in such a model exists and is unique. As all relevant regularity conditions hold, it follows the equilibrium in the current model exists and is unique.

1.4 Data, Identification and Estimation

I estimate the model using data from the Panel Study of Income Dynamics(PSID). The PSID is a long panel of a representative sample of American households. Households in the study were interviewed annually from 1968 to 1997, and bi-annually thereafter. It contains rich information on education and employment history of the household head and and his/her spouse. Crucial for the current analysis, it contains information on marital histories of the head and his/her spouse. Table 1.1 provides descriptive statistics on key variables. Something that stands out is that about 22% of all marriages end in a divorce.

I estimate parameters of the model using data on marriages that were solemnized in a *mutual consent, equitable* division regime, and remained in that regime for at least 10 years. For the purpose of estimation, I pre-set the values of a few parameters. These are presented in Table 1.2. Also, each period in the model corresponds to 5 years in the data. In the model, I have distinguished between two types of individuals on the marriage market, namely, those with high and low education. For the purpose of estimation, I define individuals with thirteen or more completed years of schooling as "high" and the rest as "low". Thus, the high type consists of some college and above, whereas everybody else is classified as "low" type.

The parameters to be estimated are as follows:

1. The scale of taste shocks σ_θ. Recall that these shocks are drawn in the marriage market.

2. The standard deviation of alternative-specific "distaste-for-work" shock σ_η, allowed to vary by education group and gender.

3. The systematic utility form leisure ϕ, allowed to vary by education group and gender.

4. The standard deviation of the "taste-for-partner" shock σ_ς.

Identification of these parameters is achieved in the following way: The rate of non-marriage (or singlehood) identifies σ_θ. Labor supply decisions of married individuals identify σ_η and ϕ .Divorce rates identify σ_ς. Finally, the Pareto weights are identified by population vectors of the different education groups by gender. Assuming an even sex ratio, the population vector used is obtained from the CPS and is presented in Table 1.3.

I estimate the model using the simulated method of moments (see McFadden (1989), Pakes & Pollard (1989)). In order to speed up the estimation, I use an equilibrium constraints (or MPEC) approach (Su & Judd (2012)). In practice, this translates into the following estimation routine: Given an initial guess of the vector of structural parameters, denoted as $\widehat{\Theta}_{guess}$, and associated marriage-market clearing vector of Pareto weights $\boldsymbol{\mu}^*(\widehat{\Theta}_{guess})$, the model generates moments to which data counterparts exist. The estimation routine iterates on the guess for structural parameters until moments simulated from the model are "close" enough, as measured by a standard criterion function, to the moments in the data. Formally, let any vector of structural parameters be denoted by $\widehat{\Theta}$, and associated moments obtained by simulating the model be $\text{mom}_{sim}(\widehat{\Theta})$. Further, let the data counterparts to which data counterparts exist. I denote the data counterpart as mom_{data}. I choose that vector $\widehat{\Theta}^*$ and associated market-clearing Pareto weights , $\boldsymbol{\mu}^*(\widehat{\Theta}^*)$ such that:

$$
\begin{aligned}
[\widehat{\Theta}^*, \boldsymbol{\mu}^*(\widehat{\Theta}^*)] = \underset{\Theta,\boldsymbol{\mu}}{arg\min}\big[\text{mom}_{sim}(\Theta, \boldsymbol{\mu}) - \text{mom}_{data}\big]'\mathcal{W}\big[\text{mom}_{sim}(\Theta, \boldsymbol{\mu}) - \text{mom}_{data}\big] \\
\text{s.t. } D^{e'}_{me}(\mu^*_{e,e}, \mu^*_{e,e'}) = S^{e}_{fe'}(\mu^*_{e,e'}, \mu^*_{e',e'}) \quad \forall e, e' \in \{H, L\}
\end{aligned}
\tag{1.24}
$$

where $\mathcal{W}$ is a diagonal matrix, whose element is proportional to the inverse of the diagonal variance-covariance of the moments in the data.

Parameter estimates are presented in Table 1.4. The model moments and data moments are presented in Table 1.6. We notice that for the estimated parameter values, the model is able to replicate several moments of the data, which include male and female labor supply, rates of non-marriage (or singlehood) and the rate of divorce.

1.5 Results

1.5.1 Simulation Results

I use the parameter estimates obtained by targeting moments from marriages under *mutual consent, equitable* division regime to simulate behavior in the other legal regimes. Simulation results are presented in Table 1.7. In what follows, I describe the a few key patterns observed in the simulations.

First, according to the simulations, introduction of *equitable division* in any divorce law regime leads to a decrease in the proportion of the population that marries. Moreover, the change in divorce and property division laws from *mutual consent, title-based* to of *unilateral, equitable* leads to roughly a 6% reduction in the proportion of the population that marries. Given that the reduction in the proportion of the population that had married at least once (see Figure 1.1) was about 33%, my findings indicate that *equitable* division laws account for about 18% of the long-term retreat from marriage. To put the number into perspective, the findings in

Reynoso (2019) imply that *unilateral* divorce laws account for only about 3% of the long-term decline in the rate of marriage.[11]

My finding that there are more marriages in a *title-based* property division regime than in an *equitable* division regime is intuitively reasonable. In a *title-based* regime each individual knows that she/he can retain her/his own property in the event of divorce. So, an individual is more open to entering into a marriage. On the other hand, in an *equitable division* regime the prospect of the partner taking away half the property in the event of divorce deters individuals from entering into a marriage. Further, this pattern is starker in a *unilateral* divorce regime. This is reasonable because a *title-based* property division law in a unilateral divorce regime entails maximum flexibility in terms of retaining one's own assets, and in quitting the marriage with it if she/he does not like it at some point. While one's spouse can also exercise this option, ex-ante it makes sense to enter into marriage in the hope of benefiting from economies of scale. On the other hand, *equitable division* in a *unilateral* divorce regime provides the maximum disincentives against marriage. Entering into marriage is a risky proposition because a spouse can quit with half the property unilaterally.

Second, the simulations indicate that the legal regime had only a minor effect on assortative matching as measured by the proportion of couples with the same level of education. The proportion of assortatively matched individuals is around 0.52 in each legal regime. Thus, my simulations indicate that while changes in divorce and property division laws affect decisions on the extensive marriage margin, they leave decisions on the intensive marriage margin relatively unaffected. The explanation for this finding is as follows: In the model, the changes in divorce and property division laws exert two opposing forces on marital sorting patterns. The highest income earners, i.e., highly educated men, are less willing to marry a less educated woman in a *unilateral divorce, equitable division* regime than in a *mutual consent, title-based* regime. The reason for this is that in a *unilateral divorce, equitable division*, the high income earner is concerned that the low income earner may quit the marriage *unilaterally*, and with half the marital property, to which the high income earner would have principally contributed. This force causes some high income earners not to marry. Those who marry prefer equally educated

[11]The magnitude of decline in the proportion of the population that marries in Reynoso (2019) are based on my calculations from Tables 2, 3 and 6 in Reynoso (2019).

women if they marry, and this tends to make marital sorting more assortative in a *unilateral divorce, equitable division* regime. However, given that fewer high income earners marry, the high earning males willing to marry are scarcer in the marriage market, and command a higher share of the marital surplus in a *unilateral divorce, equitable division* regime (see Table 1.5). This discourages highly educated women from marrying highly educated men, and tends to reduce assortative matching. Given that there are two opposing forces at play, the direction of change in assortative matching is determined by which force dominates. My simulations indicate that the two forces roughly cancel out one another, so that assortative matching remains unchanged.

Third, Figure 1.4 reveals that in any divorce law regime, accumulation of marital assets is higher in a *title-based* property division regime as compared to an *equitable* division regime. Interestingly, these results stand in contrast to those in Voena (2015) who studies behavior of couples who married in a *mutual consent, title-based* regime and experienced a change in legal regime while they were married. Restricting her analysis to such couples, she finds that the introduction of *unilateral divorce, equitable* division laws increase rates of asset accumulation.

The introduction of *equitable* division acts as a tax on asset accumulation for the high-income earner, typically the man, and reduces his incentive to save. On the other hand, *equitable* division laws increase the low-income earner's incentive to save, because she is entitled to a higher share of the marital property in the event of divorce as compared to what *title-based* property settlements would entail. Since the low income earner's consumption in divorce is lower than the high income earner's consumption in divorce, concavity of the utility function implies that the low income earner's incentives to increase asset accumulation is stronger than the high income earner's incentive to reduce asset accumulation in an *equitable* division regime. Given that the household maximizes a weighted sum of individual utilities of the husband and the wife, the effect of the introduction of *equitable* division on household asset accumulation is ambiguous, and depends on the relative bargaining weights of the husband and the wife. Thus, the finding in Voena (2015) that the introduction of *equitable* division increases asset accumulation reflects the fact that if one assumes that the household bargaining weights remain unchanged in the newly-introduced *unilateral divorce, equitable division* regime,[12] the incentive of the low income earner (to increase asset accumulation) dominates the incentives of the high income earner (to decrease asset accumulation) in the household decision problem. This is reflected in higher rates of asset accumulation in an *equitable* division regime as compared to that in a *title-based* property division regime.

My analysis differs from the analysis in Voena (2015) in that I allow the marriage market to equilibrate separately in each legal regime. As mentioned before, I find that the introduction of *equitable* division laws increase the rate of non-marriage. As discussed above, men, typically the high income earner on account of the gender-pay gap, have lower incentives to marry in an *equitable* division regime. Those men who marry obtain a higher share of the marital surplus in the new equilibrium (see Table 1.5). Given that the husband's utility has a higher weight in the equilibrium under an *equitable* division regime, the incentives of the husband to reduce asset accumulation gains priority over the wife's incentives to increase asset accumulation. This is reflected in a lower rate of asset accumulation in the household in an *equitable* division regime as compared to the rate of asset accumulation in a *title-based* property division regime.

Fourth, the model predicts that the probability of a marriage ending in a divorce varies by legal regime. Regardless of the divorce law regime, the introduction of *equitable* division reduces the rate of divorce. For instance, the proportion of marriages that end in a divorce in the first ten years is about 31% lower in a *mutual consent, equitable division* than in a *mutual consent, title-based* regime. In contrast to *equitable* division, the introduction of *unilateral* divorce increases the rate of divorce in any property division regime. Overall, the change in divorce and property division laws from *mutual consent, title-based* to *unilateral, equitable division* increases the rate of divorce by 3 percentage points, and accounts for only about 11% of the long-term increase in the rate of divorce as seen in Figure 1.2. These findings are consistent with Wolfers (2006) who found that the introduction of *unilateral* divorce did not lead to a significant persistent increase in the rate of divorce.

[12] This is a perfectly valid assumption for the research question in Voena (2015), who studies how changes in divorce and property division laws affect the behavior of couples who married before these legal changes. However, I do not make that assumption in this paper because I tackle a different question: How does the change in divorce and property division laws affect marriage decisions, i.e., whether to marry and whom to marry, and how the marriages that form in the new legal regime behave differently as compared to marriages that formed in the old legal regime.

My finding that the divorce rate in a *mutual consent, equitable division* regime is lower than in any other legal regime makes intuitive sense. In a *mutual consent, equitable division* regime, the conditions for divorce are the most stringent. First, *mutual consent* implies that the consent of both spouses is necessary for divorce. Moreover, if a partner wants to quit the marriage while the other wants to continue with the marriage, it is extremely hard for a partner desiring divorce to convince the dissenting partner to agree to the divorce. This is because the default divorce allocation is a half-half share to begin with, so in order to convince the dissenting spouse to divorce a lot of compensation needs to be provided, which might make divorce unprofitable for the partner desiring divorce in the first place. By contrast, in a *mutual consent, title-based* regime, if the richer spouse wants to quit the marriage and the poorer spouse wants to stay married, the richer spouse, by virtue of being the richer person, has more resources to transfer to the poorer spouse in the event of divorce. Hence, the richer spouse has a better prospect of convincing the poorer spouse to divorce in this legal regime. Further, note that the *unilateral, equitable division* has a high divorce rate as well. This is because *equitable division* implies the outside option of each spouse is rather high. When hit by a bad "taste-for-partner" shock, the *unilateral* divorce entails that any spouse can quit the marriage on her own volition.

Fifth, I find that divorce and property division laws have negligible effect on the labor force participation of men. The labor force participation of women is more sensitive to changes in divorce and property division laws. The change in divorce and property division laws from *mutual consent, title-based* to *unilateral, equitable* division reduces female labor force participation. In the model the introduction of *equitable* division exerts two opposing forces on female labor force participation. First, it reduces women's incentives to work because they are entitled to a greater share of marital assets in the event of divorce. On the other hand, the bargaining weight of men is higher in the new regime. That causes the household to place less weight on women's leisure, and tends to increase labor supply of women. My simulations indicate that the former effect dominates the latter, and is consistent with the findings of Chiappori *et al.* (2002).

In summary, the simulations indicate that change in divorce and property division laws affect selection into marriage but do not affect patterns of marital sorting. Moreover, behavior within marriage is affected substantially by changes in divorce and property division laws. Marriages in *equitable division* regime accumulate less assets as compared to marriages in a *title-based* property division regime. Further, the stability of marriage is affected by the prevalent divorce and property division laws. Marriages in *mutual consent, equitable division* regime appear to be more stable than marriages in any other legal regime.

1.5.2 Empirical Validation

As mentioned above, I have estimated parameters of the model by targeting data from marriages that took place and remained in *mutual consent, equitable* division regime. Thus, while the parameter values are chosen to replicate the data under *mutual consent, equitable* division, the model is not disciplined by the data under any other legal regime. Hence, the simulated behavior of agents in the model may or may not align with the behavior of agents in the actual data obtained from any other legal regime. So, the extent to which the model is able to replicate the data in any legal regime other than *mutual consent, equitable* division serves as a test for external validity of the predictions of the model.

Fortunately, the PSID data contain empirical counterparts to quite a few important model moments like marital sorting patterns and marital histories. However, testing the extent to which predictions of the model find support in the data is not straightforward. This is on account of the fact that the legal regimes were changing quickly through the 1970s and 1980s. Hence, for some legal regimes, for example *unilateral* divorce and *title-based* property division, there are not enough marriages in the data that were solemnized in that particular legal regime and remained in it for a reasonable period of time (say, 10 years). Nonetheless, I try to test the predictions of the model in the data to the extent feasible.

First, I test the prediction that divorce and property division laws did not change patterns of assortative matching. To that end, I run the following regression[13] to test if the correlation between the years of schooling of the husband and the wife has been affected by divorce and property division laws:

[13] This regression specification has been used in the prior literature (see Greenwood *et al.* (2014), Reynoso (2019)).

$$
\begin{aligned}
\text{Yrs of Edu}^{\text{hus}}_{jst} =& \beta_0 + \beta_1 \text{Yrs of Edu}^{\text{wife}}_{jst} + \beta_2 \mathbf{1}(\text{Unilateral})_{st} * \text{Yrs of Edu}^{\text{wife}}_{jst} \\
& + \beta_3 \mathbf{1}(\text{Equitable})_{st} * \text{Yrs of Edu}^{\text{wife}}_{jst} \\
& + \beta_4 \mathbf{1}(\text{Unilateral})_{st} * \mathbf{1}(\text{Equitable})_{st} * \text{Yrs of Edu}^{\text{wife}}_{jst} \\
& + \beta_5 \mathbf{1}(\text{Unilateral}) + \beta_5 \mathbf{1}(\text{Equitable}) + \boldsymbol{\beta_6 X_{jst}} \\
& + \beta_7 t + \Lambda_s + \Lambda_s * t + \epsilon_{jst}
\end{aligned} \tag{1.25}
$$

where j indexes a married couple, s indexes a state and t indexes the year of marriage. The coefficient β_1 measures correlation between the husband's and wife's years of education, controlling for spousal characteristics ($\boldsymbol{X}$), state fixed effects(Λ_s), a linear time trend t, and the interaction of the linear time trend with state fixed effects. $\beta_2(\beta_3)$ measures how the introduction of *unilateral*(*equitable*) divorce into the baseline *mutual consent, title-based* regime affected the correlation between spousal educational attainment. Finally, β_4 measures the extent to which introduction of *equitable* division in an *unilateral* regime affects the spousal correlation between educational attainment over and above the effect on the variable induced by the introduction of *unilateral* divorce. Table 1.9 provides OLS estimates of equation (1.25). We notice that estimates of β_2, β_3 and β_4 are all statistically indistinguishable from zero. This suggests that change in legal regime did not affect spousal correlation in educational attainment,[14] thereby providing empirical support for the predictions of the model.

Second, I test if the there is any empirical support for the prediction that the rate of non-marriage was affected by the property division regime. Consistent with the model, I find that regardless of the divorce law regime, the proportion of individuals who had never married by age 30 was higher in *equitable division* than in a *title-based* regime. For instance, amongst individuals who lived in a *mutual consent* divorce regime until age 30, the proportion of never-married individuals who lived in a *title-based* state until age 30 was only 4.38%. Amongst those whose states witnessed a change in property division regime to *equitable*, the proportion of never-married (by age 30) was 9.14%. A similar and more dramatic pattern is observed

[14] How to measure assortative matching is a contentious issue. While the method used above has been used earlier (see Greenwood *et al.* (2014)), its appropriateness has been questioned by Eika *et al.* (2014) and Gihleb & Lang (2016).

amongst individuals living in a *unilateral* divorce regime. In what follows, I restrict attention to individuals whose states had unilateral divorce by the time they were 30. For individuals who lived in *title-based* states until they were 30, the proportion of never-married was 9.12%. By contrast, for individuals whose states had witnessed a transition to *equitable* division regime, the proportion of never-married was was 29.72%.

Third, I test the prediction of the model in respect of asset accumulation. Recall that the model predicts that in any divorce law regime the rate of asset accumulation is lower in an *equitable* division regime than in a *title-based* property division regime. If that is true, we must find the following pattern in the data: Observationally equivalent households that formed and remained in *equitable* division regime accumulated lower assets than their counterparts that formed and remained in *title-based* property division regime. The PSID collects detailed information on assets only in selected years. In order to test the prediction of the model, we must use information from those years where there are sufficiently many households satisfying the aforesaid sample restriction. I find that the asset data in 1989 satisfies this criterion. To test if the rate of asset accumulation was lower in an *equitable* division regime as compared to a *title-based* property division regime, I specify the following regression:

$$\text{Asset}_i = \beta_0 + \beta_1 \mathbf{1}(\text{Equitable}) + X_i + \epsilon_i \tag{1.26}$$

Here, Asset_i is the dollar value of assets accumulated by couple i in 1989. I restrict the sample to those couples that satisfy one of the following two criteria:

1. The couple married in a *title-based* regime and remained in a *title-based* regime up to 1989.

2. The couple married in an *equitable* division regime and remained in an *equitable* division regime up to 1989.

Notice that the coefficient β_1 measures the difference in assets accumulated by a couple in an *equitable* division regime and assets accumulated by a couple in a *title-based* property division regime, conditioning on background characteristics of the couple given by the vector X. Here, The vector X includes age of the household head, years of schooling of the husband and the wife and year of marriage. Table 1.10 presents estimates of equation (1.26). In line with the predictions of the model, the coefficient estimate of β_1 is negative and statistically significant at the 10% level.

Fourth, I test the prediction of the model in respect to divorce rates. Recall that the model A challenge in doing this is that since the laws changed very quickly over the 1970s, we do not observe sufficient number of marriages to make inferences about life cycle behaviors for all legal regimes. The legal regimes where the sample sizes support such analysis include *mutual consent, equitable division*; *mutual consent, title-based*; and *unilateral divorce, community property*. In all cases, I restrict my analysis to such marriages that would have been in the same legal regime if it had survived for at least 10 years. Figure 1.5 shows that the cumulative rate of divorce (after the passage of the same amount of time) is lower in a *mutual consent, equitable division* regime as compared to *mutual consent, title-based* or *unilateral divorce, community property* regime. Table 1.11 shows that this pattern is robust to the introduction of controls for husband's age at marriage and year of marriage fixed effects.

1.5.3 Welfare Analysis

The changes in divorce and property division laws have implications for welfare, both from the viewpoints of efficiency and distribution. Divorce and property division laws distort marriage decisions, particularly on the extensive margin. *Unilateral* divorce introduces limited commitment into the marital contract, and makes certain splits of marital surplus not possible to credibly commit to ex-ante. *Equitable* division laws erode the gains from marriage by distorting incentives to accumulate assets within marriage. These distortions imply welfare losses, and I use the estimated model to quantify the magnitude of these losses.

Formally, the utilitarian welfare function is specified as follows:

$$\mathcal{W}(\mathcal{L}) = \sum_{g\in\{m,f\},e\in\{H,L\}} N^{s}_{ge}(\mathcal{L}).\mathbf{E}V^{s}_{ge} + \sum_{g\in\{m,f\};e,e'\in\{H,L\}} N^{e'}_{ge}(\mathcal{L}).\mathbf{E}V^{e'}_{ge}(\mathcal{L}) \tag{1.27}$$

where $\mathcal{L}$ denotes the vector of divorce and property division laws, $\mathbf{E}V^{s}_{ge}$ denotes the expected utility of an individual of gender g and education level e who remains unmarried, $N^{s}_{ge}(\mathcal{L})$

denotes the measure of individuals of gender g and education level e who remain unmarried under the legal regime $\mathcal{L}$, $\mathbf{E}V_{ge}^{e'}(\mathcal{L})$ denotes the expected utility of an individual of gender g and education level e who marries an individual with education level e' under the legal regime $\mathcal{L}$, and $N_{ge}^{e'}(\mathcal{L})$ denotes the measure of individuals of gender g and education level e that marry individuals with education level e' under the legal regime $\mathcal{L}$.

I first welfare-rank the legal regimes using from the viewpoint of a utilitarian social planner in each legal regime. I find that a utilitarian social planner ranks the legal regimes in the following order:

1. Mutual consent, title-based
2. Mutual consent, equitable division
3. Unilateral, title-based
4. Unilateral, equitable division

To quantify the effect of welfare losses implied by a legal regime relative to a *mutual consent, title-based* regime. Results are presented in Table 1.8. I find that the long-term change in legal regime from *mutual consent, title-based*to a *unilateral divorce, equitable division* results in about 20% welfare loss as measured in utility units. However, this loss is welfare is unequally shared between the two sexes. Both men and women are worse off, but men shoulder a greater share of the burden. About 65% of the burden falls on men, while the remaining 35% is borne by women.

1.6 Conclusion

In this paper, I study how changes in divorce and property division laws affected marital decisions and behaviors within marriage such as asset accumulation and divorce. To that end, I formulate a rich structural microeconometric model featuring collective households making labor supply, asset accumulation and divorce decisions. I embed the model of the collective household in an empirical marriage-matching model. To quantify the effect of these legal changes, I estimate parameters of the model using data from marriages under a *mutual consent, equitable division* regime and simulate behavior under other legal regimes, namely, *mutual consent, title-based*; *unilateral, title-based*; and *unilateral, equitable*. I find that equitable division laws reduce the rate of marriage, and account for 18% of the long-term decline in the rate of marriage in the United States. Moreover, consistent with the data, equitable division laws reduce the rates of asset accumulation and divorce. Further, both unilateral divorce and equitable division laws lead to substantial losses in economic efficiency.

While this paper represents the first step in the direction of understanding the longer-term consequences of changes in divorce and property division laws, there are several limitations of the exercise. For instance, I have assumed changes in divorce laws do not affect pre-investment in education. Such an assumption may be reasonable for individuals who were too old to adjust educational attainments in response to changes in these laws. However, a complete understanding of the long-term consequences of these legal changes should factor in endogenous pre-investment in education. Similarly, my framework does not consider cohabitation, which has become more common as a living arrangement over time. To what extent changes in divorce and property division laws changed incentives to cohabit is an interesting question. The exploration of such open questions is left for future research.

1.7 Figures

Figure 1.1: Proportion Ever-Married by Year of Birth (PSID Data)

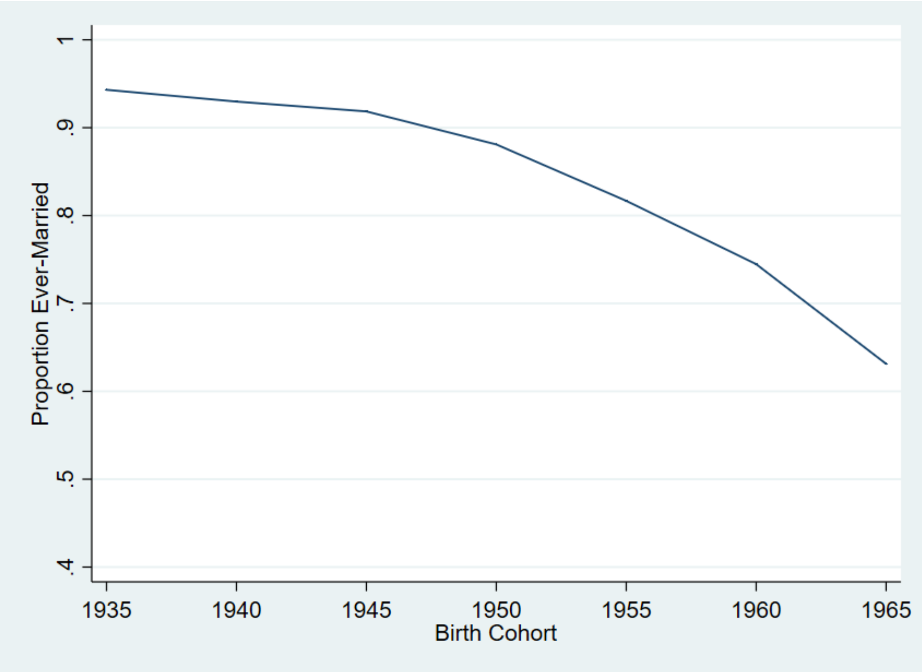


Figure 1.2: Proportion Ever-Divorced/Separated by Year of Marriage (PSID Data)

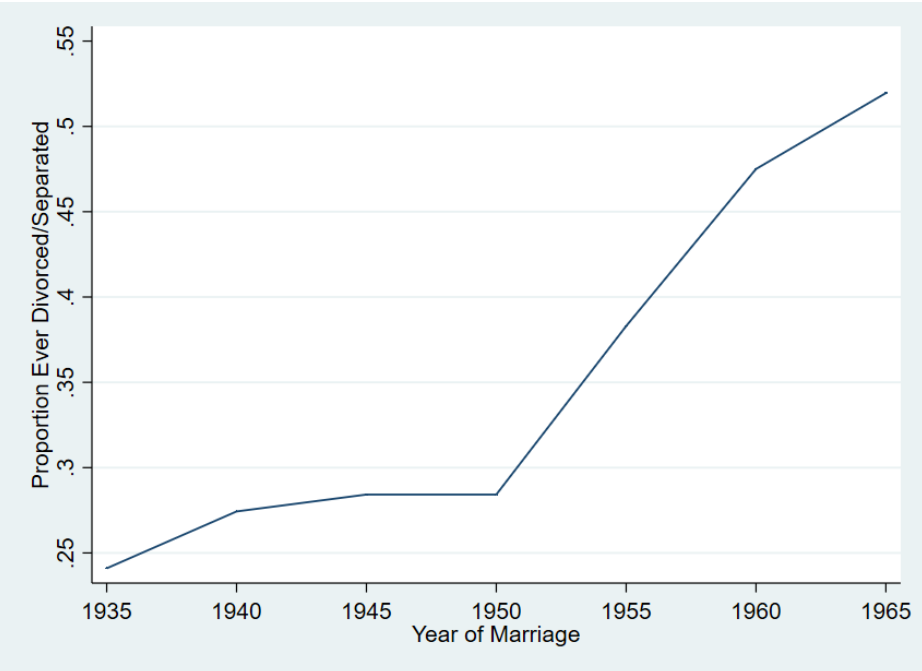


Figure 1.3: Fraction of States in a Legal Regime over Time

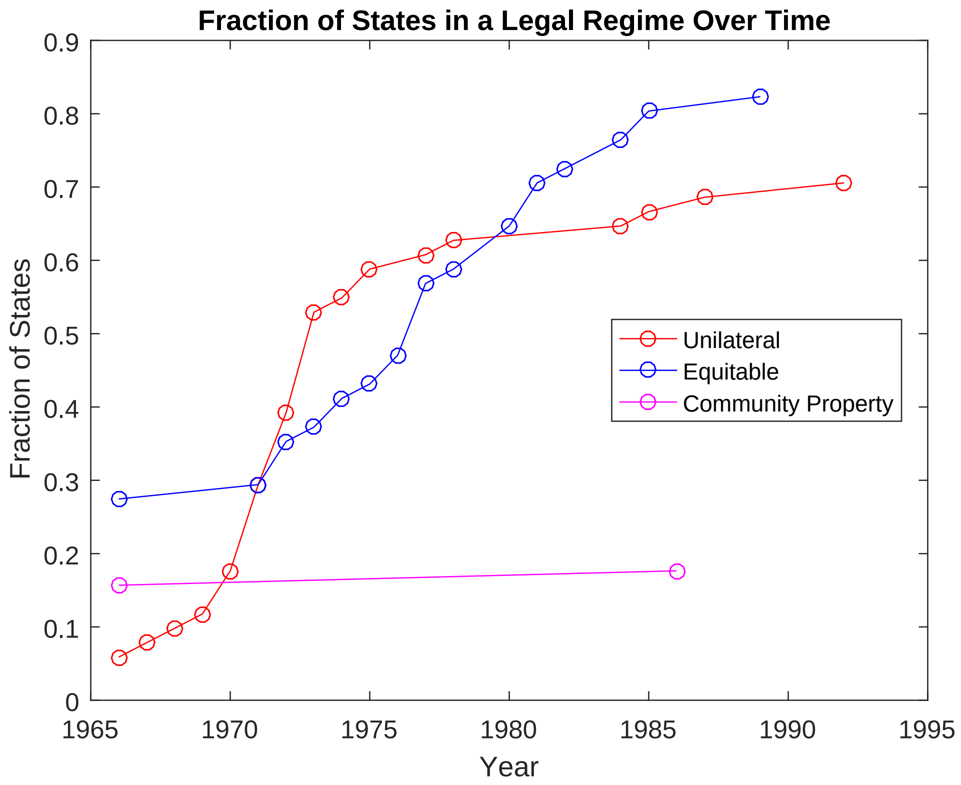


Figure 1.4: Simulated Asset Accumulation Profile by Legal Regime

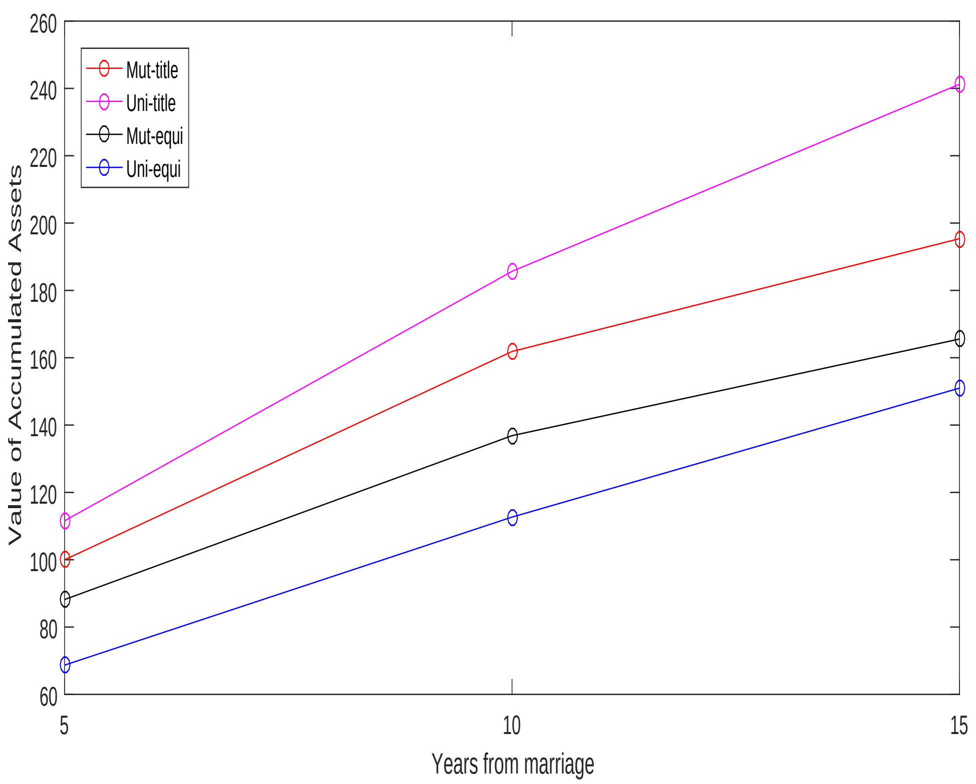
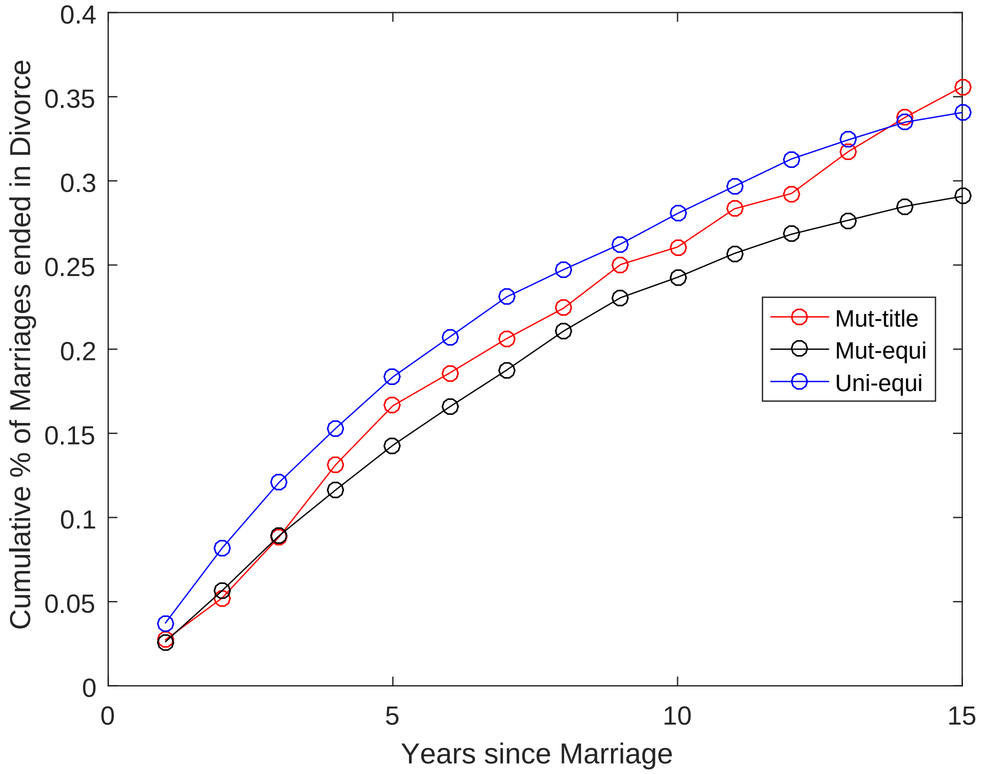


Figure 1.5: Cumulative Divorce Rates by Legal Regime (PSID Data)



1.8 Tables

Table 1.1: Summary statistics

Variable	Observations	Mean	Standard Deviation
Yrs of school$_{\text{Husb}}$ − Yrs of school$_{\text{Wife}}$	10228	-.121	2.245
Husband's years of schooling	11029	12.568	2.629
1(Community Property)	12969	.26	.439
1(Equitable)	12969	.556	.497
1(Unilateral)	12969	.511	.5
Order of marriage	12886	1.341	.628
Age at marriage	12890	29.133	10.06
1(Marriage ended in Divorce)	28682	.218	.413
Year of marriage	12969	1987.911	12.1
Labor Force Participation (Male)	124,052	.860	.347
Labor Force Participation (Female)	132,878	.628	.483
Hours of Work Yearly (Male)	106,652	2061.682	696.128
Hours of Work Yearly (Female)	82,942	1670.893	577.447
Annual Household Income	56,792	13194.55	13507.28

Source: My calculations from PSID Data (Family, Individual and Marriage History Files)

Table 1.2: Pre-set Parameters

Parameter	Value
T(Total time periods in the model)	4
γ (Relative Risk-Aversion Parameter)	1.5 (Attanasio *et al.* (2008))
Some College Male Wage (full-time work)	100(normalization)
High School or less Male Wage(full-time work)	70 (wage gap from CPS data)
Some College Female Wage (full-time work)	71 (gender-wage gap, Blau & Kahn (2017))
High School or less Female Wage(full-time work)	49.7 (gender-wage gap, Blau & Kahn (2017))
Part-time wage	Half of full time wage for corresponding gender and education
ρ (Consumption Economies of Scale)	1.7
β (Discount Factor)	0.98
R (Gross Interest Rate)	1.03

Table 1.3: Population Vector (CPS Data)

	High Men	Low Men	High Women	Low Women
Numbers	0.48	0.52	0.36	0.64

Table 1.4: Parameter Estimates

Parameter	Estimates	Standard Error
σ_η(Some college Man)	0.72	0.17
σ_η(HS Man)	1.53	0.81
σ_η(Some college Woman)	1.98	0.07
σ_η(HS Woman)	2.34	0.06
ϕ(Some college Man)	-1.56	0.17
ϕ(HS Man)	-1.21	0.13
ϕ(Some college Woman)	-1.03	0.12
ϕ(HS Woman)	0.23	0.50
σ_θ	0.72	0.03
σ_ζ	0.96	0.07

Table 1.5: Husband's Pareto Weights in Marriage Market Equilibrium

Legal Regime	High Man, High Woman	High Man, Low Woman	Low Man, High Woman	Low Man Low Woman
Mutual Consent, Title-based	0.23	0.72	0.18	0.76
Mutual Consent, Equitable	0.41	0.79	0.32	0.81
Unilateral, Title-based	0.36	0.85	0.57	0.84
Unilateral, Equitable	0.45	0.88	0.25	0.89

Table 1.6: Model Fit

Variable	Data Moments	Model Moments
Proportion full-time Some College Men	0.85	0.82
Proportion part-time Some College Men	0.11	0.15
Proportion full-time HS Men	0.78	0.78
Proportion part-time HS Men	0.16	0.19
Proportion full-time Some College Women	0.47	0.43
Proportion part-time Some College Women	0.31	0.30
Proportion full-time HS Women	0.37	0.43
Proportion part-time HS Women	0.29	0.31
Proportion divorced in 10 years from Marriage	0.24	0.20
Proportion single	0.11	0.11

Table 1.7: Simulation of Different Legal Regimes

Variable	Mutual, Title	Mutual, Equitable	Unilateral, Title	Unilateral, Equitable
Porportion Married	0.95	0.89	0.99	0.89
Proportion assortatively matched	0.52	0.51	0.51	0.52
Proportion divorced in 10 yrs	0.28	0.20	0.36	0.31
Labor force Participation (Male)	0.97	0.95	0.96	0.96
Labor force Participation (Female)	0.78	0.77	0.79	0.69

Table 1.8: Welfare Loss by Legal Regime

Legal Regime	Utility Loss Relative to Mutual, Title
Mutual, Equitable	15%
Unilateral, Title	16.8%
Unilateral, Equitable	19.5%

Table 1.9: Change in Correlation between Husband's and Wife's Completed Years of Schooling due to Change in Legal Regime (from PSID Data)

	Husband's Years of Schooling
Wife's Years of Schooling	0.617***
	(0.04859)
$\mathbf{1}$(Unilateral) $*$ $\mathbf{1}$(Equitable) *Wife's Years of Schooling	-0.0275 (0.01796)
$\mathbf{1}$(Unilateral) *Wife's Years of Schooling	0.0591
	(0.03700)
$\mathbf{1}$(Equitable) *Wife's Years of Schooling	-0.0624
	(0.05016)
$\mathbf{1}$(Unilateral)	-0.685
	(0.4975)
$\mathbf{1}$(Equitable)	0.866
	(0.6626)
N	3323
R^2	0.383

Note: Model controls for order of marriage, year of marriage, sex ratio in each education category in year of marriage, state fixed effects and a linear time trend interacted with state fixed effects. The sample has been restricted to third or lower order marriages in White-headed households in non-community property states. The omitted category is marriages formed in a *mutual consent, title-based* regime. Standard errors (clustered at state level) in parentheses

Source: PSID, multiple waves

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

Table 1.10: Property Division Laws and Asset Accumulation

	Accumulated Asset in 1989
$\mathbf{1}$(Equitable)	-3642.9*
	(20081.2)
Head's Age in 1989	128.8
	(117.64)
N	1919
R^2	0.467

Note: Model controls for years of schooling of husband and wife, years elapsed since marriage, year of marriage. The omitted category is title-based property division regime. Standard errors (clustered at the state level are in parentheses.

Source: PSID, multiple waves

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

Table 1.11: Laws and Divorce Probability within 10 years from Marriage (from PSID Data)

	$\mathbf{1}$(Divorce in 10 years)
$\mathbf{1}$(Mutual Consent, Equitable or Community)	-.0268**
	(0.0112)
Age at Marriage	-0.0117***
	(0.0009)
Order of Marriage	.0112
	(0.0086)
Yrs. of Schooling (Husband)	-.0180***
	(.0027)
Yrs. of Schooling (Wife)	-.0087***
	(.0021)
N	7751
R^2	0.0482
Dep. Var. Mean	0.2240

Note: Model controls for race and year of marriage fixed effects. The omitted category is marriages formed in mutual consent title-based and marriages formed in unilateral and title-based, equitable or community property regimes. Sample restricted to such marriages that would have been in the same divorce and property division regime 10 years from formation.

Chapter 2

Saving for Marriage Expenses and Early Childhood Nutrition: Evidence from India

2.1 Introduction

Marriage is near-universal amongst adults in India. For instance, more than 97% of women aged 25 years or more in the year 2005 had married at least once[1]. Most women marry at a relatively young age. The average age at marriage for ever-married women born in 1980 was around 18 years.

Indian marriages are typically very expensive, and the widespread prevalence of the practice of dowry[2] makes daughters' weddings especially expensive. These weddings could cost a household more than six times its annual income (see Bloch *et al.* (2004)) or up to 68% of the value of its total assets (see Rao (1993)). Sons' weddings can be financed, at least partially, by the dowry received from the bride, and hence are much less costly as compared to daughters' weddings.

In this socio-economic environment, where most daughters marry, a majority of them at a young age, it is natural for parents to consider the birth of a daughter to be a greater negative shock to their lifetime income than the birth of a son. Further, poor households are known to

[1]This number is based on my calculations from the IHDS data.

[2] Dowry is a transfer at marriage from the bride or her family to the groom or his family. The opposite of this, bride price, is rare in India (see Anderson (2007)).

have limited access to credit markets. Hence, households could start saving early, long before their daughter is of marriageable age. In very poor households, such savings could potentially crowd out resources for the purchase of food and adversely affect nutritional outcomes of children in the family.

In this paper, I use data from the two waves of the India Human Development Survey to provide evidence that supports the above hypothesis. I find that the reduction in household consumption expenditure per capita, both on all consumption goods and on foods, associated with the presence of an additional daughter is greater than the corresponding reduction associated with the presence of an additional son. This is suggestive of households with more daughters saving more. Further, I find that the customary amount of expenses on a daughter's wedding is higher amongst "higher/forward caste" households than amongst "lower caste" households at comparable levels of income and assets. This gap in the obligatory amount of a daughter's wedding expenses across the two caste categories is mirrored in the nutritional outcomes of children, as measured by height-for-age z-scores, in the following way: The presence of an additional unmarried daughter aged 18 years or less is associated with a *greater* deterioration in the nutritional outcomes of children aged 5 years or less in "higher" caste households as compared to the corresponding amount amongst their counterparts in "lower" caste households.

The differential worsening in nutritional outcomes across caste categories that I find is fairly large in size. In absolute value, the presence of each additional daughter is associated with a 0.33 standard deviation differential reduction in height-for-age z-scores across the caste categories. To put the absolute value in perspective, it corresponds to about 135% of the height-for-age differential between second-born Indian children and second-born African children, and about 77% of the corresponding differential between third born children (see Jayachandran & Pande (2017)).

The differential worsening of children's nutritional outcomes across the caste categories demonstrates two interesting patterns. First, the differential worsening is observed only amongst children aged 5 years or less, and the association is weak or non-existent amongst older children. Second, the differential worsening of nutritional outcome is *independent* of the child's gender. These patterns are informative about the distribution of the financial burden to save for a daughter's wedding amongst children in the family, and constitute the central contribution of this paper. They indicate that the incidence of this burden on children depends on their age and not on their gender. In view of the well-established link between height in early childhood and future earnings potential (for instance, see Hoddinott *et al.* (2013), Case & Paxson (2008)), these patterns suggest that *all* children, regardless of their *gender*, who grow up in poor families that anticipate incurring high obligatory marriage expenses could have worse outcomes in later life.

The remainder of this paper is structured as follows: Section 2.2 discusses the background, the related literature and the contribution of this paper. Section 2.3 describes the dataset used in the analysis. Section 2.4 presents the empirical strategy. Section 2.5 presents the results of the empirical analysis. Section 2.6 discusses potential policy implications of the results. Section 2.7 concludes.

2.2 Background, Related Literature and Contribution

Transfers at marriage, which form an important component of expenses at marriage, have been studied by a strand in the economic literature that goes back at least to the seminal contribution of Becker (2009), who conceptualized marital transfers as prices that equilibrate the marriage market. More recently, Botticini & Siow (2003) suggest an alternative explanation for dowries, namely, that they are a form of pre-mortem bequest rather than a price. In the Indian context, Arunachalam & Logan (2016) provide evidence suggestive of dowries playing the role of both prices and pre-mortem bequests.

Ethnographhic evidence (see Anderson (2007) for a survey) documents variation in the direction and magnitude of marital transfers across societies and over time. This literature documents the widespread prevalence of dowries—transfers from the bride to the groom at marriage—in the Indian context. In the Indian subcontinent, dowries arose amongst Hindus (see Gupta (2002), Botticini & Siow (2003)) but the practice has spread amongst Muslims and other religious minorities over time (see Srinivas (1984), Ambrus *et al.* (2010), Waheed (2009)).

Some studies (for example, Rao (1993)) claim that dowry amounts in India have been rising over time, and Anderson (2003) provides a theory that suggests the hierarchical nature of the caste system as an explanation. However, in the absence of reliable data on dowries, possibly on account of illegality of the practice, claims of dowry inflation have been subject to skepticism (see Logan & Arunachalam (2014)). Paucity of representative data and reliable instruments also constrain empirical research on the effects of dowry in India. Nonetheless, (plausible) claims that dowry motivates son-preferring behaviors (like sex-selective abortion, infanticide and gender-differentiated investments in children) abound in the sociological and economic literature (see Arnold *et al.* (1998), Miller (1981), Harris (1993), Das Gupta *et al.* (2003)). The extraction of dowry[3] has also been recognized as a motive behind crimes against women, ranging from domestic violence to murder, both in the news media (for example, see Gyan (2013), Singh (2019)) and in the scholarly literature (see Bloch & Rao (2002), Sekhri & Storeygard (2014)).

A few papers in economics attempt to establish a causal connection between marital transfers and outcomes. For example, Brown (2009) finds evidence in China that a higher dowry improves the bargaining power of the newlywed woman at her in-laws' place.[4] Ashraf *et al.* (2016) find that the sensitivity of female enrollment to the INPRES school construction program in Indonesia varied by bride price traditions of ethnic groups. Similarly, Corno *et al.* (2016) find evidence in Tanzania that the sensitivity of the probability of girls' early marriage and fertility to adverse rainfall shocks (during teenage years) varies by bride price traditions of their ethnic group. In the Indian context, Bhalotra *et al.* (2016) find that an unexpected increase in anticipated dowry payments due to a sudden and sharp rise in the price of gold (in 1980) is reflected in increased girl relative to boy mortality amongst neonates and infants, and shorter adult stature amongst surviving women. Interestingly, their results in respect of the adult stature of surviving men are unstable across different specifications.

While Bhalotra *et al.* (2016) is the first study that establishes a plausible causal link between anticipated future marriage expenses and outcomes like mortality and adult stature, it

[3]Anecdotally, a woman's in-laws might continue to ask the woman and her family to pay additional amounts as dowry, even after marriage.

[4]Most societies that practise dowry are patrilocal (see Anderson (2007)).

leaves open several important questions with potentially serious implications for the design and targeting of policy. For example, at what age do we first see a reduction in children's height that eventually culminates in a shorter adult stature? Does a boy growing up in a family with unmarried sister(s) fare any worse than a boy growing up in a family with no unmarried sisters? Does a boy growing up with an unmarried sister fare any better than his unmarried sister herself, whose future marriage is the very cause for strain on the family's resources? In other words, how is the burden of a daughter's wedding distributed among children in the family?

This paper contributes by filling in some of these gaps. First, I provide evidence that anticipated marriage expenses lead to the deterioration of nutritional outcomes of children in early childhood, ie, the first five years of life. Second, my findings shed light on how the financial burden to save for a daughter's wedding is shared amongst children in the household. They suggest that the incidence of this burden on children depends on their age and not on their gender. *All* children under five years of age, *regardless* of their *gender*, are adversely affected by the anticipated marriage expenses of girls. By contrast, there are no effects on children who are older than five years of age.

A striking feature of my findings is their gender-neutrality — the fact that both young boys and girls are equally affected by the obligation to save for daughters' marriages. This stands in contrast to the findings of a large body of literature that has documented various son-preferring behaviors in the Indian context (see Behrman & Deolalikar (1990), Rose (1999) and Sekhri & Storeygard (2014) for gender-differentiated responses in intrahousehold allocation of resources to negative income shocks; Clark (2000) and Jensen (2002) for differential fertility stopping behavior; Oster (2009), Chakravarty *et al.* (2010), Jayachandran & Kuziemko (2011), Bharadwaj & Lakdawala (2013) and Barcellos *et al.* (2014) for gender differentiated investments in children).

The findings of the current paper are important for the following two reasons: First, in view of the well-established link between height and health in early childhood and future earnings potential (Glewwe & Miguel (2007), Guven & Lee (2015), Strauss & Thomas (1998), Case & Paxson (2008), Hoddinott *et al.* (2013)), these findings suggest that *all* children, regardless of their *gender*, who grow up in poor families that anticipate incurring high obligatory marriage expenses could have worse economic outcomes (like wages, for example) in later life. Second, my findings point out which demographic should be targeted by governmental welfare schemes, like nutritional supplemental programs. They indicate that such programs should be targeted at children, regardless of their gender, who happen to be below five years of age and are growing up in families that, on account of social custom, anticipate incurring high marriage expenses and have a large number of unmarried daughters.

2.3 The Data and Descriptive Statistics

I use data from the two waves of the India Human Development Survey (see Desai *et al.* (2005) and Desai *et al.* (2015)). The India Human Development Survey (IHDS hereafter) is a two-wave panel of a representative sample of Indian households. Data for the first wave, ie, IHDS-1, were collected in 2004-05, and data for the second wave, ie, IHDS-II, were collected in 2011-12. IHDS-I surveyed a nationally representative sample of 41,554 households. IHDS-II reinterviewed 83% of these households, and had a replacement sample of 2,134 households.

The IHDS contains detailed information on individual-level characteristics (such as age, education, marital status, labor supply, labor and non-labor income, etc.) of all members in the the household. It also contains rich information about socio-economic attributes of the household like assets possessed, monthly consumption expenditure and demographic characteristics of the household like religion and caste. In particular, IHDS-II allows the head of the household to self-identify as belonging to one of the following six broad caste categories: Brahmin, other forward but not Brahmin, Scheduled Caste (SC), Scheduled Tribe (ST), Other Backward Castes (OBC) and Others. For my analysis, I use this six-fold categorization to create a two-fold categorization of caste, namely, the upper/forward castes and the lower castes. In this categorization, the "upper/forward" caste category comprises the Brahmins and other forward castes. All other caste categories are lumped into the "lower castes". Thus, the lower castes are comprised primarily of SCs, STs and OBCs, which are caste groups that are officially recognized as backward castes by the Indian government and are entitled to benefits under affirmative action policies enshrined in the Indian Constitution.

The IHDS contains two further pieces of information that make it uniquely suited for the current analysis. First, it contains information on usual marriage expenses in the social group that the household belongs to. To be precise, the interviewed woman in each household was asked the following question: "In your community (jati)[5] for a family like yours, at the time of the marriage, how much money is usually spent by the girl's (boy's) family?" The interviewer was asked to probe for a single number in each case but was allowed to accept a range provided by the respondent. While the responses to this question are indicative of social norms relating to marriage expenses as perceived by the household, they are presumably noisy indicators of the incidence of the financial burden (on account of marriage expenses) on the household. This is because a household possibly has some flexibility to deviate from the social norm. On the other hand, differences in average usual marriage expenses at a more aggregate level (like caste category) are plausibly driven by differences in social norms across these broader groups, and hence, this difference is likely to be mirrored in group differences in outcomes. Based on this logic, I use variation in average usual expenses across broad caste categories to identify the effects of marriage expenses on nutritional outcomes.

The second crucial piece of information provided by the IHDS consist of height measurements of children. IHDS-I provides height measurements for children aged 0-5 and 8-11 years while IHDS-II provides height measurements for all children up to 18 years of age at the time of the survey. I use the information on children's heights to compute their height-for-age z-scores, which is the measure of nutritional outcome recommended by the World Health Organization (WHO) to monitor child development in any population. The height-for-age z-score of a child is calculated with respect to an international reference population[6] in the following way:

$$\text{Height-for-age z-score} = (\text{Height of child} - M)/SD$$

where M and SD denote the median and standard deviation of height among children of

[5] *Jati* is usually understood to refer to the sub-caste, which is an endogamous social group.

[6] The international reference population consists of a sample of healthy children drawn from six different countries, namely, the United States of America, Norway, Oman, India, Ghana and Brazil.

the same gender and age (measured in months) in the reference population. Thus, if a child has a z-score of -1, it implies that its height is 1 standard deviation below the height of the median child (of the same gender) in the reference population.

Table 2.1 provides descriptive statistics. We note that the average child aged 5 years or less is close to stunted. (Stunting is defined as a height-for-age z-score less than -2.). Consistent with women marrying at a relatively young age, the average age at marriage for women is around 17 years. Marriage expenses are high relative to income, especially for the bottom 25 percentiles of the income distribution (see Table 2.2). Note also that the "Forward Castes" have costlier marriages at similar levels of income. Around 25% of the sample households are Forward Caste (see Table 2.3) and there is some variation in the number of unmarried daughters aged 18 or less across households (see Table 2.4). These variations in the data are crucial for identification of the model presented in Section 2.4 below.

2.4 The Methodology

As mentioned before, the upper caste households customarily spend more money on their daughters' weddings as compared to their lower caste counterparts. In order to check if this is robust to the introduction of controls for demographic characteristics, I specify the following model:

$$Y_{it} = \beta_0 + \beta_1 \mathbf{1}(\text{Forward Caste})_i + \beta_2 X_{it} + \epsilon_{it} \tag{2.1}$$

where i and t index a household and time period respectively, and Y_{it} is the customary amount of money that is spent marrying off a daughter in a household of the relevant social class and caste as declared by the interviewed woman and X is a vector of controls that includes household income, assets index and the wave of the panel.

If my hypothesis that parents save money for their daughters' wedding is true we must observe that all else equal, within the set of families that have the same number of children, families with more unmarried daughters of marriageable age spend less on consumption. This can be tested by running the following regression:

$$\begin{aligned} C_{it} = \gamma_0 + \gamma_1 \text{Income}_{it} + \gamma_2 \text{No. of children}_{it} \\ + \gamma_3 \text{No. of daughters}_{it} + \gamma_4 X_{it} + \epsilon_{it} \end{aligned} \tag{2.2}$$

where C_{it} denotes monthly consumption expenditure per capita.

Finally, I must tease out the causal effect of dowry on the nutritional outcome of children. I use a difference-in-differences model for the purpose. Consider potential outcomes given by the following two equations.

$$N_{i,UC(n_i \geq 0)} = n_i \alpha_{UC} + \gamma_{UC} + \delta_{n_i} + X_i \beta + \epsilon_{i,UC(n_i)} \tag{2.3}$$

$$N_{i,LC(n_i \geq 0)} = n_i \alpha_{LC} + \gamma_{LC} + \delta_{n_i} + X_i \beta + \epsilon_{i,LC(n_i)} \tag{2.4}$$

where $N_{i,UC(n_i \geq 0)}$ denotes the nutritional outcome of child i if (s)he lives in an upper/forward caste (UC) household which has a total of n_i unmarried females aged 18 years or less while $N_{i,LC(n_i \geq 0)}$ denotes the nutritional outcome of the same child if (s)he lives in a lower caste (LC) household with the same number of unmarried females aged 18 or less. The potential nutritional outcome is allowed to depend on the following:

1. If i lives in an upper (lower) caste household, (s)he is potentially "treated" with high (low) marriage expenses. The effect of living in an upper (lower) caste household with a total of one unmarried female aged 18 or less is denoted by α_{UC} (α_{LC}). The intensity of "treatment" depends on the total number of unmarried females aged 18 or less, hence the effect of treatment for a child living in an upper (lower) caste household is $n_i \alpha_{UC}$ ($n_i \alpha_{LC}$).

2. A caste-fixed effect (denoted by γ_j, $j \in \{UC, LC\}$). This term accounts for unobservables unrelated to marriage expenses that could affect nutrition and could potentially vary by caste. Plausible examples include dietary patterns, sanitary practices, the disease environment, etc.

3. A "number of daughters" effect (denoted by δ_{n_i}) that *does not* vary across the two caste

categories. This accounts for the fact that families that have different numbers of unmarried daughters of marriageable age may have different "preferences" that might be consequential for nutrition of a child in the family.

4. An idiosyncratic component ϵ.

My objective is to identify α_{UC}. A lower bound for $|\alpha_{UC}|$ is identified in the following manner. Taking a single difference as below eliminates all the *marriage-expense-neutral* channels through which caste and omitted variables correlated with caste affect nutrition.

$$\mathbf{E}\big[N_{i,UC(n_i=k+1)} - N_{i,UC(n_i=k)}\big] = \alpha_{UC} + [\delta_{k+1} - \delta_k] \tag{2.5}$$

$$\mathbf{E}\big[N_{i,LC(n_i=k+1)} - N_{i,LC(n_i=k)}\big] = \alpha_{LC} + [\delta_{k+1} - \delta_k] \tag{2.6}$$

(2.5) – (2.6) yields

$$\mathbf{E}\Big[\big[N_{i,UC(n_i=k+1)} - N_{i,UC(n_i=k)}\big] - \big[N_{i,LC(n_i=k+1)} - N_{i,LC(n_i=k)}\big]\Big] = \alpha_{UC} - \alpha_{LC} \tag{2.7}$$

Since the intensity of treatment for the upper castes is greater than the intensity of treatment for the lower castes, I assume that $|\alpha_{UC}| > |\alpha_{LC}|$. Under this assumption, $|\alpha_{UC} - \alpha_{LC}|$ is lower bound for $|\alpha_{UC}|$. The crucial assumption here that facilitates identification is that the part of the effect of the number of unmarried females (aged 18 or less) that is independent of marriage expenses does not vary by caste. In other words, δ_{n_i} does not have a caste subscript in equations (2.3) and (2.4). Empirically, I identify the coefficient of interest by running the following regression.

$$\begin{aligned} N_{ij} = \alpha_0 + \alpha_1 Umf_j + \mathbf{1}(\text{Forward Caste})_j + \alpha_2 Umf_j * \mathbf{1}(\text{Forward Caste})_j \\ + \alpha_3 \mathbf{1}(\text{Female})_{ij} + \alpha_4 X_{ij} + \epsilon_{ij} \end{aligned} \tag{2.8}$$

where N_{ij} refers to the nutritional outcome (as measured by the height-for-age Z-score) of child i living in household j, Umf_j denotes the number of unmarried girls aged 18 or less in household j and $\mathbf{1}(.)$ denotes the indicator function. Notice that caste is a household-level characteristic.

Next, I check if the differential worsening of nutritional outcomes (consequent upon the presence of an additional daughter) across castes differs by the gender of the child. To that end, I use the following triple difference specification:

$$\begin{aligned} N_{ij} = {} & \alpha_1 Umf_j + \alpha_2 Umf_j * \mathbf{1}(\text{Forward Caste})_j \\ & + \alpha_3 Umf_j * \mathbf{1}(\text{Forward Caste})_j * \mathbf{1}(\text{Female})_{ij} \\ & + \alpha_4 \mathbf{1}(\text{Forward Caste})_j * \mathbf{1}(\text{Female})_{ij} + \alpha_5 \mathbf{1}(\text{Forward Caste})_j \\ & + \alpha_6 \mathbf{1}(\text{Female})_{ij} + \alpha_7 \mathbf{1}(\text{Female})_{ij} * Umf_j \\ & + \alpha_8 X_j + \epsilon_{ij} \end{aligned} \tag{2.9}$$

Here, the coefficient of interest is α_3. A negative estimate of α_3 would indicate discrimination against girls.

There is, however, an endogeneity concern with the above specifications. It is possible that household-specific unobservables associated with the presence of a certain number of daughters vary systematically across the caste categories. In other words, it could be that δ_{n_i} has a caste subscript. If that is the case, $\widehat{\alpha}_2$ obtained by estimating equation (2.8) may produce a biased estimate of α_{UC}. In an attempt to address this concern, I specify the following household fixed-effects model.

$$N_{ijt} = \alpha_j + \alpha_2 Umf_{jt} * \mathbf{1}(\text{Forward Caste})_j + \alpha_3 Umf_{jt} + \alpha_4 \mathbf{1}(\text{Female})_i + \alpha_5 X_{ijt} + \epsilon_{ijt} \tag{2.10}$$

Here, t indexes time and α_j denotes household fixed effects. In equation (2.10), α_2 is identified off "within-household" variation in the number of daughters, and hence, estimates thereof are not subject to the endogeneity concern mentioned above.

2.5 Results

I present estimates of equation (2.1) in Table 2.5. The dependent variable here is the usual lower or upper limit of expenses on a daughter's marriage (as reported by the interviewee).

We notice that controlling for assets, the wave of survey, location and state fixed effects, girls' marriage expenses are higher amongst the so-called upper/forward castes at comparable levels of income. This holds both for the entire income distribution (see columns 1 and 2) as well as for households belonging to the bottom 25% of the income distribution (see columns 3 and 4).

Table 2.6 presents estimates of equation (2.2). A comparison of columns (1) and (2) indicate that holding the number of persons in the household fixed, the presence of an additional unmarried female aged 18 or less is associated with a 8% decrease in monthly consumption expenditure per capita while the corresponding decline associated with the presence of an additional male aged 18 or less is only 5%. Column (3) controls for both the number of unmarried females aged 18 or less and the number of males aged 18 or less. We notice that all else equal, one more unmarried girl aged 18 or less is associated with a 9.43% decline in consumption per capita while the corresponding decline associated with a male aged 18 or less is only 6.55%. These results are consistent with households with more daughters saving up for their daughters' marriages and the presence of an additional son imposing no such burden on the household. Further, Table 2.7 shows that food consumption expenditures show a similar pattern for the bottom 25% of the income distribution.

Table 2.8 presents estimates of equation (2.8). In column 1, the sample is restricted to children who are five years of age or younger. Notice that the estimate of the coefficient on the interaction of the number of unmarried daughters aged 18 years or younger and the indicator for forward caste is negative and statistically significant at the 1 % level. The estimated coefficient is interpreted as follows: The presence of an additional unmarried girl aged 18 or less in the household is associated with a 0.33 standard deviation higher reduction in height-for-age z-scores in Forward Caste households as compared to the corresponding reduction amongst lower caste households. However, this does not hold for children over 5 years of age (see columns 2 and 3 of Table 2.8).

In terms of magnitude, the 0.33 standard deviation differential reduction in height-for-age z-scores across the caste categories for each additional girl child, is fairly large. To put the absolute value in perspective, it corresponds to about 135% of the height-for-age differential between second-born Indian children and second-born African children, and about 77% of the corresponding differential between third born children (see Column 5, Table 2 in Jayachandran & Pande (2017)).

Next, I check if the differential worsening of nutritional outcomes across the two caste categories varies by gender of the child. Table 2.9 presents estimates of equation (2.9). If the differential worsening is more (less) acute for girls than boys, the coefficient of the triple interaction term would be negative (positive) and statistically significant. We notice that for each age group, this coefficient is statistically indistinguishable from zero. This suggests that the differential worsening of nutritional outcomes across the two caste categories does not vary by gender of the child.

With regard to the results presented in Tables 2.8 and 2.9, two comments are in order. First, the sample, in each case, restricted to households belonging to roughly the bottom 25 percentiles of the income distribution. It is only amongst these very poor households that the differential worsening described above is observed. For richer household, this is not the case. This is consistent with Engel's Law[7]. Second, all specifications control for a rich set of covariates that include the age of the child (measured in months), the total number of persons in the household, annual household income, an index of asset possession, rural or urban location, religion, and state fixed effects. Importantly, they also control for two other variables, namely, the order of birth of the child and the type of sanitation facility in the household, that have been shown to affect nutritional outcomes in early childhood (see Jayachandran & Pande (2017), Geruso & Spears (2018)). Thus, the coefficients estimated are contaminated neither by birth order effects nor by sanitation effects.

Nonetheless, the results described above are subject to potential endogeneity concerns. First, it is possible that the two caste groups respond differently (in terms of intrahousehold allocation of food) to increases in the number of children. If that were true, the effects identified above are driven not by variation in marriage expenses across the caste categories but by their differential response to increases in the number of children. However, in that case, we should observe a differential worsening of nutritional outcomes across caste groups associated with the presence of additional boys aged 18 years or less, similar to the differential worsening

[7]Engel's Law states that the expenditure share of food goes down at higher levels of income. Thus, at higher levels of income, income elasticity of food demand is expected to be low.

across caste groups associated with the presence of additional girls aged 18 years or less. Table 2.10 shows that this is not true in the data. In each column, the coefficient on the interaction between the number of males below 18 years of age and the indicator for forward/upper caste is statistically indistinguishable from zero.

Second, there is the concern that household-specific unobservables associated with the presence of a certain number of daughters varies systematically across the caste categories. In other words, it is possible δ_{n_i}'s in equations (2.3) and (2.4) have caste subscripts. If that is the case, the estimates reported above could be biased. To address this concern, I estimate the household fixed-effects model specified by equation (2.10). Here, identification (of the coefficient on the interaction of the number of daughters with the indicator for forward caste) is achieved by using "within-household" variation in the number of daughters in the household across the two waves of the panel. Estimates are presented in Table 2.11. Notice that in column 1, the coefficient on the stated interaction term is negative and statistically significant. Column 2 implements the robustness check described in the previous paragraph, adapted for the current specification. Here, the following change is made to the set of explanatory variables: The number of unmarried females below the age of 18 (used in column 1) is replaced by the number of males below 18 years of age in the household. Consistent with the results presented in Table 2.10, we notice from column 2 of Table 2.11 that the coefficient on the interaction term is statistically indistinguishable from zero. These robustness checks increase confidence in the main results of this paper.

2.6 Policy Implications

The findings of this paper have potentially interesting implications for the design and targeting of governmental welfare schemes. For example, consider the policy debate (in India) on whether the government should retain its current system of making direct food transfers to the poor or replace it with cash transfers (see Dreze & Khera (2015), Kotwal *et al.* (2011)). My findings suggest that if the government were to replace food transfers with cash transfers, families that have a large number of daughters and that belong to caste groups that (by custom) have to spend more money on daughters' weddings could end up saving the transferred cash. In such families, nutritional outcomes of young children could deteriorate further if food transfers were to be replaced with cash transfers.

Second, in respect of designing nutritional supplementation programs for children, my findings indicate that such programs should be targeted at young children (aged 5 years or less) who grow up in families that are customarily required to incur high (daughter's) marriage expenses and live with a lot of siblings of marriageable age. However, there is no merit in prioritizing girls over boys since children of both genders suffer equally in terms of nutritional outcomes.

2.7 Conclusion and Future Directions

Using data from the two rounds of the India Human Development Survey, a rich nationally representative panel from India, I document that daughters' marriages are more expensive than sons' marriages. Moreover, at comparable levels of income and wealth, daughters' marriages in upper/forward Caste households are more expensive as compared to daughters' marriages in lower caste households. The gap in the obligatory amount of a daughter's wedding expenses across the two caste groups is mirrored in the nutritional outcomes of children, as measured by height-for-age z-scores, in the following way: The presence of an additional unmarried daughter aged 18 years or less is associated with a greater deterioration in the nutritional outcomes of children aged 5 years or less in "higher" caste households as compared to the corresponding amount amongst their counterparts in "lower" caste households. Further, the differential worsening of nutritional outcomes across caste groups does not vary by sex of the child but does vary by age. Children appear most susceptible to the reduction in height in early childhood. As one would expect the result holds only for households with incomes below the 25th percentile of the income distribution. These findings, to the best of my knowledge, are the first to suggest that marriage expenses might lead to a deterioration in nutritional outcomes in early childhood, and that all children exposed to the shock in the early years of their lives are vulnerable to it regardless of their sex. In view of the well-established fact that early childhood height predicts later life outcomes, high marriage expenses could be a cause for lower earnings in later life.

The findings of this paper raise a few interesting questions with implications for the design of policy. For instance, why is the effect on nutritional outcomes different for younger children as compared to that for older children? Is it a consequence of younger children being discriminated against by parents in the event of a negative shock to lifetime income, or is it because younger children are more sensitive to small variations in food intake or nutritional content thereof? What are the parental beliefs in respect of the connection between childhood height and later life outcomes? The exploration of such questions is left for future research.

Table 2.1: Summary statistics (IHDS-1 & 2)

	Mean	Standard Error	Observations
Height-for-age z-score (children $\leq$ 60 months)	-1.933	2.075	16224
$\mathbf{1}$(Female)	0.4897	0.499	386635
Order of birth	2.559	1.662	140816
Woman's age at marriage for women $\leq$ 30	17.367	3.335	114496
Monthly consumption per capita	997.310	754.479	75229
No. of persons	5.24	2.455	79275
No. unmarried females aged 0-18	0.958	1.125	80034
No. of males aged 0-18	1.115	.0139	52537
Asset Index	12.799	6.107	80013
$\mathbf{1}$(Forward Caste)	0.278	0.448	79878
Max. amt. spent in a girl's wedding (2004 Rupees)	124867.008	106402.885	78117
Min. amt. spent in a girl's wedding (2004 Rupees)	94711.046	81742.514	78129
Max. amt. spent in a son's wedding (2004 Rupees)	80783.035	69000.351	78141
Min. amt. spent in a son's wedding (2004 Rupees)	60468.411	51364.868	78159

Table 2.2: Customary Marriage Expenses (2004 Rupees) for a Daughter by Caste Category (1st quartile of Income distribution)

Caste category	Upper bound Mean (se)	Lower bound Mean (se)
Forward Castes	105222	83295
	(3406.48)	(2836.12)
Other Castes	74541	56747
	(1450.38)	(926.2953)

Source: IHDS 1 & 2, household weights used

Table 2.3: Caste Categories (IHDS-1 households): Weighted Percentage

Item	Per cent
Brahmin	4.56
Forward/General (except Brahmin)	20.77
Other Backward Castes (OBC)	42.20
Scheduled Castes (SC)	22.89
Scheduled Tribes (ST)	8.05
Others	1.53
Total	100

Source: Sample restricted to panel households

Table 2.4: Number of Unmarried Females aged 0-18 in a household: Weighted Percentage

Number	Per cent
0	42.43
1	32.12
2	15.66
3	6.43
4	2.26
≥ 5	1.1
Total	100

Note: Sample restricted to panel households
Panel household weights used

Table 2.5: Determinants of Girls' Marriage Expenses (Customary Minimum and Maximum in 2004 Rupees)

	(1) Min. Expenses	(2) Max. Expenses	(3) Min. Expenses	(4) Max. Expenses
$\mathbf{1}$(Forward Caste)	21421.5***	28476.6***	17527.0***	24178.0***
	(1855.6)	(2386.6)	(2296.4)	(2910.3)
$\mathbf{1}$(Wave 2)	13556.7***	26000.9***	13336.8***	24029.8***
	(1193.7)	(1723.1)	(1355.3)	(2322.9)
$\mathbf{1}$(Forward Caste)* $\mathbf{1}$(Wave 2)	-1975.0	-5071.5*	965.1	-2722.7
	(2429.4)	(3077.8)	(4285.6)	(5080.5)
Annual hhd. Income	0.155***	0.205***	-0.391***	-0.345**
	(0.01074)	(0.01398)	(0.1263)	(0.1501)
Assets Index	4586.2***	6006.1***	3938.8***	5420.4***
	(115.38)	(153.35)	(165.66)	(245.41)
$\mathbf{1}$(Urban)	-2490.9	-4181.9*	-868.4	-2862.0
	(1684.0)	(2218.3)	(1951.9)	(2917.0)
N	75732	75731	18956	18938
R^2	0.342	0.361	0.270	0.291
Sample:				
Income distribution	All	All	1-25th %ile	1-25th%ile

Standard errors in parentheses

Source: IHDS-1 & 2

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

All regressions control for state fixed effects and have a constant

Table 2.6: Variation of Log Monthly Per Capita Consumption Expenditure with Number of Unmarried Daughters aged 0-18, Household Fixed Effects Model

	(1)	(2)	(3)
	ln(COPC)	ln(COPC)	ln(COPC)
No. unmarried females 0-18	-0.0807***		-0.0943***
	(0.009707)		(0.009764)
No. of males 0-18		-0.0472***	-0.0655***
		(0.01088)	(0.01103)
Annual hhd. income	0.00000347***	0.00000372***	0.00000309***
	(7.313e-07)	(7.491e-07)	(7.475e-07)
No. of Persons	-0.0560***	-0.0636***	-0.0343***
	(0.005063)	(0.005008)	(0.006145)
Wave of Survey	0.232***	0.231***	0.229***
	(0.01073)	(0.01072)	(0.01072)
N	35273	35273	35273
F	291.3	260.2	237.1
R^2	0.297	0.291	0.304
Sample:			
Income distribution:	1-50th %ile	1-50th %ile	1-50th %ile

Standard errors in parentheses

Source: IHDS-1 & 2

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

Note: All regressions are estimated using household fixed effects. In column 3, the coefficients on the first two rows are statistically different from one another at the 5% level.

Table 2.7: Variation of Log Monthly Per Capita Food Consumption Expenditure with Number of Unmarried Daughters aged 0-18

	(1)	(2)	(3)
	ln(FCOPC)	ln(FCOPC)	ln(FCOPC)
No. unmarried girls 0-18	-0.0467***		-0.0693***
	(0.003687)		(0.004238)
No. males 0-18		-0.0286***	-0.0579***
		(0.004395)	(0.004789)
No. of persons	-0.0708***	-0.0767***	-0.0464***
	(0.002656)	(0.002573)	(0.003415)
Hhd. Income	0.000000638	0.000000779	0.000000627
	(7.045e-07)	(7.132e-07)	(7.006e-07)
Wave of Survey	0.117***	0.115***	0.113***
	(0.008267)	(0.008305)	(0.008232)
N	18012	18012	18012
R^2	0.386	0.381	0.394
Sample:			
Income distribution:	1-25th %ile	1-25th %ile	1-25th %ile

Standard errors in parentheses

Source: IHDS-1 & 2

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

All regressions control for religion and caste category fixed effects. In column 3, the coefficients on the first two rows are statistically different from one another at the 5% level.

Table 2.8: Variation of Height-for-age Z scores of children with Number of Unmarried Daughters aged 0-18, Sample restricted to very poor households

	(1) Height-for-age Z Score	(2) Height-for-age Z Score	(3) Height-for-age Z Score
No. of unmarried girls 0-18	0.0784	0.0456	-0.0406
	(0.06745)	(0.06479)	(0.04429)
1(Forward Caste)	0.597***	0.217	0.222
	(0.1817)	(0.1934)	(0.1366)
No. of unmarried girls 0-18***1**(Forward Caste)	-0.329***	-0.0756	-0.0666
	(0.09336)	(0.1000)	(0.08295)
1(Female)	-0.0545	-0.0181	-0.0461
	(0.1122)	(0.1006)	(0.06646)
N	3289	2458	2749
R^2	0.0457	0.0911	0.0934
Sample:			
Age in months	≤ 60	$61 - 110$	$111 - 228$

Standard errors in parentheses

Source: IHDS-1 & 2

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

Note: All regressions are weighted using panel household weights. All regressions control for order of birth, age in months, no. of persons in the household, household income, asset index, rural or urban location, religion, type of toilet dummies, dummy for having a bank account, education of highest educated male and female aged 21 or more and state fixed effects. All regressions have a constant. Standard errors are clustered at the PSU level. In all cases sample restricted to households with annual income between 3500 and 18500 (2004) Indian Rupees, which roughly corresponds to the bottom 25% of the income distribution.

Table 2.9: Checking for discrimination against girls (DDD Model)

	(1) Height-for-age Z Score	(2) Height-for-age Z Score	(3) Height-for-age Z Score
No. of unmarried girls 0-18	0.0764	0.0223	0.0443
	(0.08609)	(0.08242)	(0.06410)
$\mathbf{1}$(Forward Caste)	0.588***	0.217	0.264*
	(0.2198)	(0.2060)	(0.1439)
$\mathbf{1}$(Female)	-0.0397	0.0611	0.251**
	(0.1936)	(0.1753)	(0.1245)
No. of unmarried girls 0-18*$\mathbf{1}$(Forward Caste)	-0.278**	0.0921	0.00191
	(0.1373)	(0.1487)	(0.1204)
$\mathbf{1}$(Forward Caste)*$\mathbf{1}$(Female)	-0.00194	-0.203	-0.275
	(0.4146)	(0.3301)	(0.2544)
No. of unmarried girls 0-18*$\mathbf{1}$(Female)	0.000509	0.0119	-0.173**
	(0.1072)	(0.09247)	(0.08049)
No. of unmarried girls 0-18*$\mathbf{1}$(Female)	-0.0717	-0.188	-0.00505
*$\mathbf{1}$(Forward Caste)	(0.2123)	(0.1975)	(0.1628)
N	3289	2458	2763
R^2	0.0458	0.0945	0.0984
Sample:			
Age in months	≤ 60	$61 - 110$	$111 - 228$

Standard errors in parentheses

Source: IHDS-1 & 2

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

Note: All regressions are weighted using panel household weights. All regressions control for order of birth, age in months, no. of persons in the household, household income, asset index, rural or urban location, religion, type of toilet dummies, dummy for having a bank account, education of highest educated male and female aged 21 or more and state fixed effects. All regressions have a constant. Standard errors are clustered at the PSU level. In all cases sample restricted to households with annual income between 3500 and 18500 (2004) Indian Rupees, which roughly corresponds to the bottom 25% of the income distribution.

Table 2.10: Placebo Specification: Variation of Height-for-age Z scores of children with Number of Males aged 0-18

	(1) Height-for-age Z Score	(2) Height-for-age Z Score	(3) Height-for-age Z Score
No. of males aged 0-18	0.0152	-0.0686	-0.0713
	(0.06779)	(0.07046)	(0.05632)
$\mathbf{1}$(Forward Caste)	-0.0607	-0.119	0.0393
	(0.2095)	(0.2093)	(0.1567)
No. of males aged 0-18 *$\mathbf{1}$(Forward Caste)	0.144	0.130	0.0632
	(0.1209)	(0.1157)	(0.08562)
$\mathbf{1}$(Female)	0.0158	-0.0222	-0.147**
	(0.1069)	(0.09925)	(0.07323)
N	3289	2458	2749
R^2	0.0425	0.0918	0.0935

Standard errors in parentheses

Source: IHDS-1 & 2

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

Note: All regressions are weighted using panel household weights. All regressions control for order of birth, age in months, no. of persons in the household, household income, asset index, rural or urban location, religion, type of toilet dummies, dummy for having a bank account, education of highest educated male and female aged 21 or more and state fixed effects. All regressions have a constant. Standard errors are clustered at the PSU level. In all cases sample restricted to households with annual income between 3500 and 18500 (2004) Indian Rupees.

Table 2.11: Variation of Height-for-age Z scores (of children 10 years or less) with Number of Unmarried Daughters aged 0-18 (Household Fixed Effects), Sample restricted to very poor households

	(1) Height-for-age Z-score	(2) Height-for-age Z-score
No. of Unmarried Females 0-18	0.490	
	(0.3243)	
No. of Males 0-18		-0.902***
		(0.2303)
No. of Unmarried Females 0-18 *$\mathbf{1}$(Forward Caste)	-1.023*	
	(0.5904)	
No. of Males 0-18 *$\mathbf{1}$(Forward Caste)		1.035
		(0.9110)
Hhd. Fixed Effects	Yes	Yes
N	5074	5074
F	5.152	6.529
R^2	0.0703	0.0768

Standard errors in parentheses

Source: IHDS-1 & 2

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

Both regressions control for gender, order of birth, age in months, no. of persons in the household, household income, asset index, dummy for having a bank account, education of highest educated male and female aged 21 or more. In both cases sample is restricted to households with annual income between 6000 and 18000 (2004) Indian Rupees. Standard errors clustered at the PSU level. Both regressions are weighted using household weights.

Chapter 3

Commitment and Matching in the Marriage Market

(with Marcus Berliant)

3.1 Introduction

The dominant paradigm in the marriage-matching literature considers marriage market equilibrium under **B**inding **A**greements in the **M**arriage **M**arket(**BAMM**). In the typical model of the marriage market (for instance, see Chiappori *et al.* (2018), Chiappori *et al.* (2017), Gayle & Shephard (2019)), the division of the marital surplus is negotiated at the time of marriage. It is assumed that the contract reached in the marriage market is binding upon the couple, i.e., it cannot be breached or re-negotiated under any state of the world that may occur in future. In other words, there is full commitment within marriage.

An empirically testable implication of BAMM is that unanticipated changes in laws governing exit from marriage, i.e., divorce, have no impact on behavior within marriage. However, this does not hold in the data. For example, Voena (2015) finds that change in divorce and property division laws in the United States reduced female labor force participation and increased rates of asset accumulation in marriages that had formed before the change in laws. Similarly, empirical evidence suggests that policy-induced changes in spousal incomes change household expenditure patterns (for example, see Lundberg *et al.* (1997)) — a finding that is at odds with couples having reached binding agreements in the marriage market.

While the empirical evidence is not consistent with BAMM, it can be rationalized using the **B**argaining **I**n **M**arriage(**BIM**) hypothesis. According to BIM, married couples play a co-operative game in each period. Given the threat points (whether internal as in Lundberg & Pollak (1993) or exit threats as in Voena (2015)) of this game, married couples attain efficient outcomes in each period of marriage, which can change if threat points are affected by exogenous changes in policy, examples of which include legal changes and government-administered welfare programs that affect relative spousal incomes.

The BAMM and BIM assumptions also entail potentially different marriage market equilibria, and have potentially different welfare implications. For instance, with transferable utility, any stable matching under BAMM yields the highest total utility (to all players) amongst all possible matchings. In other words, a stable matching under BAMM and transferable utility is *utilitarian efficient*. However, this does not necessarily hold under BIM. As Pollak (2019) demonstrates, the set of stable matchings under BIM do not necessarily coincide with the set of stable matchings under BAMM. In particular, he illustrates that the BAMM and BIM equilibria can be distinct.

If the notion of marriage market equilibrium in a BIM setting is stability, the appropriate algorithm to find the equilibrium/equilibria is the Gale-Shapley algorithm. This is the route taken by Pollak (2019). However, the few empirical papers that have tried to predict real world matches using the Gale-Shapley algorithm (see Hitsch *et al.* (2010), Banerjee *et al.* (2013), Lee (2009)) have failed to replicate patterns of assortative matching on several important dimensions. These results cast doubt on whether Gale-Shapley is the appropriate algorithm to use in order to find marriage market equilibria. Further, they leave open the possibility that the marriage market equilibrium under BIM is identical to the marriage market equilibrium under BAMM — a possibility, which, in our opinion, should be a subject of theoretical and empirical research.

In this paper, we explore the theoretical aspect of the problem. To be precise, we pose the following question: Using a matching algorithm different from the Gale-Shapley algorithm, can we implement the stable matching under BAMM (with transferable utility) even under BIM?

An obvious candidate for implementing the BAMM assignment in the BIM world is the *top trading cycles* algorithm, which, in contrast to the Gale-Shapley algorithm, produces a Pareto efficient matching. We show that if agents on one side of the market are sufficiently sensitive to matches relative to the other side, if the more sensitive side can be ranked by sensitivity, and if preferences over members of the opposite sex are hierarchical, the top trading cycles algorithm results in a utilitarian efficient matching. As is obvious, utilitarian efficiency is achieved at the cost of stability — a tension that has been well-recognized in the literature (see Lee & Yariv (2018) for a recent example).

The exercise in the current paper is, in spirit, similar to the familiar second welfare theorem in general equilibrium theory (see Mas-Colell *et al.* (1995)), which provides conditions under which a Pareto optimal allocation can be supported as a competitive equilibrium (with taxes and transfers). In our setting, the counterpart to a Pareto optimal allocation is a stable matching under BAMM, which happens to be belong to the core of the assignment game; while the counterpart to decentralization using prices (as in the second welfare theorem) is the "decentralization" using the top trading cycles algorithm.

The remainder of this paper is structured as follows: Section 3.2 describes the economic environment. Section 3.3 presents alternative desirable properties of a marriage market equilibrium. Section 3.4 discusses implementation of the utilitarian efficient assignment under BIM. Section 3.5 concludes with a brief discussion. All proofs are placed in the appendix.

3.2 The Economic Environment

There are a finite and equal number of men and women in the market. Formally, let $\mathcal{M}$ and $\mathcal{W}$ denote the set of men and women respectively and let $|\mathcal{M}| = |\mathcal{W}| = N$, where $|X|$ denotes the cardinality of the set X. Men and women play the following two-stage game: In the first stage, men and women match with one another. We assume that the matching is simultaneous, not sequential. In the second stage, matched couples play a cooperative game. In particular, each married couple decides on public and private consumption within marriage.

We assume that individual preferences over private and public consumption goods within marriage are such that utility is transferable within any couple. Formally, let $\{\succ_m\}_{m\in\mathcal{M}}, \{\succ_w\}_{w\in\mathcal{W}}$ denote individual preference orderings over bundles of private and public consumption goods. We assume that these orderings are such that for any $m \in \mathcal{M}$, $w \in \mathcal{W}$, there exist cardinalizations, denoted by U_m and U_w, that represent $\succ_m$ and $\succ_w$ such that the utility possibility set is given by:

$$\mathbf{U} = \{(U_m, U_w) \in \mathbb{R}^2 : U_m + U_w \leq s_{m,w}\}. \tag{3.1}$$

where $s_{m,w}$ denotes the utility surplus produced if man m were to marry woman w. We assume that $s_{m,w} > 0 \; \forall m \in \mathcal{M}$, $w \in \mathcal{W}$. Thus, utility is transferable within each household.

While we shall not specify the household game that gives rise to the Pareto frontiers described here, we point out two important facts. First, it is well-known that (generalized) quasi-linear preference orderings satisfy the transferable utility property (see Bergstrom (1989), Chiappori (2017)). Second, transferability of utility does not require the Pareto frontier to be a hyperplane for every cardinalization of preferences. However, transferability of utility requires that there exist a cardinalization of preferences such that the Pareto frontier is a hyperplane as described above (see Bergstrom & Varian (1985), Chiappori (2017)). In our context, U_m and U_w are such well-chosen cardinalizations.

The primitives of the economic environment depend on whether we assume BIM or BAMM. Under BAMM, the primitives of the two-stage problem are given by the objects $< \mathcal{M}, \mathcal{W}, S >$, where S is a NXN utility-surplus matrix, whose m, w -th element, denoted by $s_{m,w}$, is the utility surplus if the couple (m, w) were to be formed. Further, we normalize the utility surplus from non-marriage to zero for each individual. By contrast, the primitives of the problem under BIM are given by the following objects: $< \mathcal{M}, \mathcal{W}, U^{\mathcal{M}}_{BIM}, U^{\mathcal{W}}_{BIM} >$, where $U^{\mathcal{M}}_{BIM}$ ($U^{\mathcal{W}}_{BIM}$) is an NXN matrix whose m, w-th element, denoted by $u^{\mathcal{M}}_{m,w}$ ($u^{\mathcal{W}}_{m,w}$), gives the payoff in marriage that will accrue to man m (woman w) if he (she) were to marry woman w (man m). These payoffs are the outcome of bargaining that would happen in marriage, were couple (m, w) to be formed. Moreover, the outcome of the bargaining game is correctly foreseen by all participants in the marriage market. Further, we assume that the anticipated outcome of the bargaining game induces a strict preference ordering over the set of men. Formally, for any w, $u^{\mathcal{W}}_{m,w} \neq u^{\mathcal{W}}_{m',w}$ whenever $m \neq m'$. Finally, in order to ensure comparability with BAMM, we set $U^{\mathcal{M}}_{BIM} + U^{\mathcal{W}}_{BIM} = S$.

The solution under BAMM consists of the following two objects: an assignment/matching of women to men[1] and a utility imputation vector for all possible couples that determine how the marital surplus will be split. Formally, the solution under BAMM consists of A_{BAMM} and I_{BAMM} where A_{BAMM} is a one-to-one onto mapping such that $A_{BAMM} : \mathcal{W} \mapsto \mathcal{M}$ and and a NXN matrix I_{BAMM}, whose $(m, w) - th$ element, denoted by $I_{BAMM}(m, w)$ is an ordered pair in$\{(U_m, U_w) \in \mathbb{R}^2 : m \in \mathcal{M}, w \in \mathcal{W}$ and $U_m + U_w \leq s_{m,w}\}$, $m \in \mathcal{M}$, $w \in \mathcal{W}$. By contrast, under BIM the solution to the matching game consists of only one object, namely, the assignment $A_{BIM} : \mathcal{W} \mapsto \mathcal{M}$ where A_{BIM} is one-to-one and onto. For any couple that may form, the utility to the man and the woman are as dictated by the primitives of the problem.

Notice that under BAMM, the splits of the marital surplus are decided in the marriage market. These contracts are inviolable, ie, they cannot be reneged in marriage. By contrast, under BIM, each individual, in the marriage market, correctly foresees his/her payoff in each possible match. As mentioned before, the potential payoffs result from bargaining in marriage, should the corresponding man-woman pair match. Most importantly, no contracts regarding the split of marital surplus can be made in the marriage market.

If we are in a BIM environment, it is convenient to develop some further notation to denote the utility to an individual from an assignment. For any i, $i \in \mathcal{M} \cup \mathcal{W}$, we intend to have a function that provides the utility received by i under any given assignment A. This is accomplished by defining $\widetilde{U}_i : \mathcal{A} \mapsto \mathbb{R}_+$, where
$\mathcal{A} = \{A | A : \mathcal{W} \mapsto \mathcal{M}\}$ and $\widetilde{U}_i$ satisfies the following property:

1. For any $A \in \mathcal{A}$, $m \in \mathcal{M}$ and the ordered pair $(w, m) \in A$, $\widetilde{U_m}(A) = u^{\mathcal{M}}_{m,w;BIM}$
2. For any $A \in \mathcal{A}$, $w \in \mathcal{W}$ and the ordered pair $(w, m) \in A$, $\widetilde{U_w}(A) = u^{\mathcal{W}}_{m,w;BIM}$.

Notice that $\widetilde{U}_i(A)$ is the utility of individual i under assignment A. As is standard, in this basic framework, there are no externalities between matched couples.

It is worth emphasizing that under our set-up, both the matching and the split of the surplus accruing to each spouse in the second stage are determined in the first stage. Nonetheless, the

[1]Since we have normalized the utility surplus from non-marriage to zero and assumed that each marriage produces a positive surplus, all individuals would marry under any reasonable solution concept in our setting. Also, we exclude polygamy by assumption.

second stage of the game is not superfluous. In other words, we cannot reduce the game we have described to a one-shot game, like the prisoners' dilemma, for example. The difference between a one-shot game, like the prisoners' dilemma and the current set-up is as follows: In a prisoners' dilemma, the prisoners are matched. By contrast, under the current set-up, the payoff matrix in the second stage is sensitive to the matching that occurs in the first stage.

Finally, we note that while the Gale-Shapley algorithm is usually used in a non-transferable utility framework, it can easily be adapted for use in a transferable utility setting in a Bargaining in Marriage (BIM) set-up. In doing so, we follow Pollak (2019), who points out that the anticipated outcome of bargaining provides the utility that agents foresee arising from different marriages. These numbers can be used to derive a ranking of potential partners, which are the primitives required to run the Gale-Shapley algorithm.

3.3 Marriage Market Equilibrium: Alternative Criteria and Welfare Implications

With a view to exploring the nature of the marriage market equilibrium under Binding Agreements in the Marriage Market(BAMM) and Bargaining in Marriage(BIM), we first introduce a few possible characteristics of an equilibrium assignment:

1. **Stability:** In a BIM setting, an assignment A_{BIM} is said to be stable if there does not exist a pair (w, m), $w \in \mathcal{W}$, $m \in \mathcal{M}$ such that $A_{BIM}(w) \neq m$, $u^{\mathcal{W}}_{m,w} > u^{\mathcal{W}}_{A_{BIM}(w),w}$ and $u^{\mathcal{M}}_{m,w} > u^{\mathcal{M}}_{m,A^{-1}_{BIM}(m)}$. Analogously, in a BAMM setting, an assignment A_{BAMM} and associated imputations of utility $I_{BAMM}(m, w) = (u^*_m(m, w), u^*_w(m, w))$, $m \in \mathcal{M}$, $w \in \mathcal{W}$, is said to be stable if there does not exist a pair (w', m'), $w' \in \mathcal{W}$, $m' \in \mathcal{M}$ such that $A_{BAMM}(w') \neq m'$, $u^*_{w'}(m', w') > u^*_{w'}(A_{BAMM}(w'), w')$ and $u^*_{m'}(m', w') > u^*_{m'}(m', A^{-1}_{BAMM}(m'))$.

2. **Woman-Pareto Optimality:** In a BIM setting, an assignment A is said to be *woman Pareto optimal* if there does not exist another assignment $A' \in \mathcal{A}$ such that $\widetilde{U}_w(A') \geq \widetilde{U}_w(A)\ \forall w \in \mathcal{W}$ and there is at least one $w' \in \mathcal{W}$ such that $\widetilde{U}_{w'}(A') > \widetilde{U}_{w'}(A)$. Similarly,

one can define a *man Pareto optimal* assignment[2].

3. **Utilitarian Optimality**: In a BIM setting, an assignment A_{BIM} is said to satisfy *utilitarian optimality* if it is an assignment that a utilitarian social planner would choose, ie, $A_{BIM} \in \underset{A' \in \mathcal{A}}{\arg\max} \left[\sum_{m \in \mathcal{M}} \widetilde{U}_m(A') + \sum_{w \in \mathcal{W}} \widetilde{U}_w(A') \right]$. Analogously, in a BAMM setting, an assignment A_{BAMM} is said to satisfy *utilitarian optimality* if $A_{BAMM} \in \underset{A' \in \mathcal{A}}{\arg\max} \left[\sum_{\{(w,m):A'(w)=m\}} s_{m,w} \right]$.

It is well-known that with transferable utility and BAMM, stability is equivalent to *utilitarian optimality* (see Koopmans & Beckmann (1957), Shapley & Shubik (1971)). On the other hand, a stable assignment under BIM, which may be found by using the Gale-Shapley algorithm, is not utilitarian optimal in general (see Pollak (2019)). As mentioned before, we will implement the utilitarian efficient assignment in a BIM setting using the top trading cycles algorithm. To ensure comparability, we will restrict our attention to the *woman-proposing* Gale-Shapley algorithm and the *" woman-choosing" top trading cycles* algorithm. The two alternative matching algorithms are described below.

The *woman-proposing* Gale-Shapley algorithm proceeds as follows: In the first round, each woman proposes to her favorite man. Each man tentatively accepts (ie, "dates") the woman that he prefers most amongst the women who have proposed to him. He rejects all other proposals. In any subsequent round, each woman who is not currently "dating" a man proposes to her most preferred man from amongst the set of men have not rejected her at any previous round. If a man prefers his current partner to all the proposals he receives in the current round, he rejects all proposals and continues "dating" his existing partner. On the other hand, if a woman who has proposed to a man is more attractive to him than his current partner, he ends his "engagement" with his current partner and starts "dating" the most preferred woman who proposed to him in the current round. He rejects all other proposals. The algorithm stops when there are no more rejections by men.

The *" woman-choosing" top trading cycles* algorithm proceeds as follows. In the first step, each man points to his favorite woman and each woman points to her favorite man. If $(m_1, w_1, m_2, w_2, ..., m_k, w_k)$ form a cycle, each woman pairs with the man she points to.

[2] We do not need to define Pareto optimality for a BAMM setting.

Matched men and women are removed and the algorithm proceeds until everyone is matched.

As originally shown by Gale & Shapley (1962), the Gale-Shapley algorithm produces a stable match. On the other hand, the *top trading cycles* algorithm produces a *woman-Pareto optimal* assignment, ie, an assignment of men to women such that by changing the assignment, no woman can be made better off without making at least one other woman worse off. The Gale-Shapley assignment is not necessarily *woman-Pareto optimal* while the *top trading cycles* assignment is not necessarily stable (see Abdulkadiroğlu & Sönmez (2003) for an illustration).

A matching mechanism is said to be strategy proof if it is a dominant strategy for all agents to reveal their true preferences under that mechanism. Since the woman-proposing Gale-Shapley mechanism is woman-optimal, it is a dominant strategy for each woman to state her true preferences (see Roth & Sotomayor (1990), Theorem 4.7, page 90). However, with strict preferences, whenever more than one stable assignment exists, there will always be an incentive for some man to misrepresent his preferences under the woman-proposing Gale-Shapley algorithm (see Roth & Sotomayor (1990), Corollary 4.12, page 96). A similar result applies to the top trading cycles algorithm. Abdulkadiroğlu & Sönmez (2003)[3] prove that the top trading cycles mechanism is strategy proof for women while the example in our Appendix B shows that it is not strategy proof for men.

3.4 Implementing the BAMM Assignment in a BIM Framework

Proposition 1 below provides a sufficient condition under which the **BAMM** assignment may coincide with the assignment under **BIM** with *top-trading cycles*. In order to state Proposition 1, we must first introduce some notation and establish a lemma.

For $\mathcal{J} = \mathcal{M}, \mathcal{W}$, define $U_{\mathcal{J}} = \{u \in \mathbb{R} : \exists\, A \in \mathcal{A} \text{ s.t. } u = \sum_{i \in \mathcal{J}} \widetilde{U}_i(A)\}$ $U^*_{\mathcal{J}} := \max\limits_{A \in \mathcal{A}} \sum_{i \in \mathcal{J}} \widetilde{U}_i(A)$ and $A^*_{\mathcal{J}} = \arg\max\limits_{A \in \mathcal{A}} \sum_{i \in \mathcal{J}} \widetilde{U}_i(A), .$

In words, $A^*_{\mathcal{J}}$ is the set of assignments, each element of which maximizes the sum of utilities of all individuals belonging to set $\mathcal{J}$.

[3] See their Proposition 4, pg. 738

$U_{\mathcal{J}}^{*,(-1)} := \max_{A \in \mathcal{A} \setminus A_{\mathcal{J}}^*} \sum_{i \in \mathcal{J}} \widetilde{U}_i(A), \qquad \mathcal{J} = \mathcal{M}, \mathcal{W}$

In words, if the unique values of the sum of utilities (over all possible assignments) of individuals in set $\mathcal{J}$ (to members of the opposite sex) were to be ranked in descending order, $U_{\mathcal{J}}^{*,(-1)}$ would be the second element.

Further, define **CONDITION A** as follows:

CONDITION A: $U_{\mathcal{W}}^* - U_{\mathcal{W}}^{*,(-1)} > U_{\mathcal{M}}^*$, and $A_{\mathcal{W}}^*$ is a singleton.

With a view toward understanding the condition intuitively, let us define the first-best assignment for any gender as the assignment that maximizes the sum of utilities of all members of that gender across all possible assignments. Then, **CONDITION A** translates into the requirement that the first-best assignment for men entail a lower total utility (to men) than the difference in utility (to women) between the first-best and the second-best assignment for women. Since we have normalized the utility of non-marriage to zero, **CONDITION A** implies that men, as a group, are less sensitive to marriage than women. Also, note that **CONDITION A** is a cardinal property, ie, whether it holds depends on the choice or cardinalization of the utility function representing preferences. Given underlying preference orderings over private and public consumption goods in marriage, it has to hold for a well-chosen cardinalization of utility such that the Pareto frontier is a hyperplane as in (3.1).

As an illustration of **CONDITION A**, consider the following example.

Example 1

An economy consists of three men and three women with the following preferences[4] Suppose the utilities from different assignments are given by

Table 3.1: Example Illustrating Condition A

	Woman 1	Woman 2	Woman 3
Man 1	(1,5)	(0,10)	(0.5,1)
Man 2	(0.5,10)	(1,5)	(0,0.5)
Man 3	(0.5,2)	(1,2)	(0,0)

[4]The preference ordering in this example is a slight alteration of Example 1 in Abdulkadiroğlu & Sönmez (2003), pg. 736. Cardinal utility values consistent with the ordering have been added by us.

In Table 3.1 above, the entry in the cell with index (i, j) is the ordered pair (U_i^j, U_j^i) where U_i^j denotes the utility of man i if he were to marry woman j and U_j^i denotes the utility of woman j if she were to marry man i.

It is easy to check that **CONDITION A** holds in the example above (see Appendix C).

As stated earlier, **CONDITION A** requires that the loss in total utility to women by moving from the assignment that is first-best for women to the assignment that is second-best for women exceed the total utility (to men) of the first-best assignment for men. Thus, it seems intuitive that this requirement implies that the assignment that is first-best for women also maximizes the total utility of all individuals (of both sexes). This is formally demonstrated in the lemma below.

Lemma 1

*If **CONDITION A** holds,* $A^* \in A^*_{\mathcal{W}} \implies A^* \in \underset{A \in \mathcal{A}}{\arg\max} \left[\sum_{m \in \mathcal{M}} \widetilde{U}_m(A) + \sum_{w \in \mathcal{W}} \widetilde{U}_w(A)\right]$

Proof: See Appendix D.

Proposition 1

*If the top-trading cycles algorithm produces an assignment $A^* \in A^*_{\mathcal{W}}$ and **CONDITION A** holds, then the assignment under top-trading cycles coincides with an equilibrium **BAMM** assignment.*

Proof: See Appendix E.

As an illustration of the proposition above, note that in Example 1 the *man-pointing, woman-choosing top trading cycles* algorithm converges to the following assignment.

$$M_1 \to W_2, \quad M_2 \to W_1, \quad M_3 \to W_3 \tag{3.2}$$

By part 1 of Proposition 1, (3.2) is also the equilibrium assignment under **BAMM**.

The *woman-proposing* variant of the Gale-Shapley algorithm converges to the unique stable assignment, which is the following:

$$M_1 \to W_1, \quad M_2 \to W_2, \quad M_3 \to W_3 \tag{3.3}$$

Notice that assignments (3.2) and (3.3) are distinct. Thus, A^* is not stable in general.

Note that Proposition 1 requires that the top trading cycles assignment coincide with an element in $A^*_{\mathcal{W}}$. While that may be the case, it is not guaranteed to happen. In particular, the top trading cycles algorithm can converge to an assignment that is Pareto optimal but does not belong to $A^*_{\mathcal{W}}$. As an illustration of this consider the following simple example.

Example 2

Suppose there are two individuals of each gender in the economy and their utilities from alternative assignments are as shown in Table 3.2 below:

Table 3.2: Example Illustrating that the TTC algorithm is not Utilitarian Efficient in general

	Woman 1	Woman 2
Man 1	(0,10)	(1,5)
Man 2	(0,0)	(1,0)

If we run the top trading cycles, in the first step both women point at man 1. Both men point at woman 2. Man 1 and woman 2 form the only cycle, so they match. In the next step man 2 matches with woman 1. Thus the top trading cycles algorithm produces the following assignment.

$$W_1 \to M_2, \quad W_2 \to M_1 \tag{3.4}$$

Notice that assignment (3.4) yields a total utility of 6, which is lower than the total utility of 11 yielded by assignment (3.5) below

$$W_1 \to M_1, \quad W_2 \to M_2 \tag{3.5}$$

Hence, assignment (3.5) is the unique BAMM assignment in this economy, and the top trading cycles algorithm reaches a different assignment.

Since our interest lies in implementing the BAMM assignment, that leaves open the issue as to whether there are conditions on preferences under which the top trading cycles algorithm or some variant thereof can implement the BAMM assignment.

Example 2 above illustrates why the top trading cycles algorithm may fail to converge to the **BAMM** assignment. If the preferences of men are such that they prefer women who lose lower amounts of utility when they are matched with a lower ranked partner as opposed to women who lose higher amounts of utility when forced to make the corresponding change in respect to their partner, the assignment resulting from the top trading cycles is different from the **BAMM** assignment. In order to ensure that the top trading cycles implements the BAMM assignment, we need to make more assumptions on preferences. To that end, we first introduce a definition.

Definition:

Woman i is more sensitive than woman i' if and only if the following holds:

$\widetilde{\mathcal{U}}_i^{(j+1)} - \widetilde{\mathcal{U}}_i^{(j)} > N.\big(\widetilde{\mathcal{U}}_{i'}^{(N)} - \widetilde{\mathcal{U}}_{i'}^{(1)}\big) \quad \forall j \in \{1, 2, .., N-1\}$

where $\widetilde{\mathcal{U}}_i := \{u \in \mathbb{R}_+ | \exists A \in \mathcal{A} \text{ s.t.} u = \widetilde{U}_i(A)\}$ and $\widetilde{\mathcal{U}}_i^{(j)}$ denotes the j-th order statistic of $\widetilde{\mathcal{U}}_i$.

In words, if a more "sensitive" woman were to be matched with a partner one rank below rather than with a partner of the rank (according to her ordering) under consideration, she would lose more utility than all "less" sensitive woman could gain by switching from her worst partner to her best partner.

We assume that women can be ranked by order of sensitivity. We state this formally in **Assumption 1**[5] below.

Assumption 1: Sensitivity

The following statements hold:

1. $\min \widetilde{\mathcal{U}}_i = C, \quad C \in \mathbb{R}_+ \quad \forall i \in \mathcal{W}$

2. i *is more sensitive than* $i+1$ $\forall i \in \{1, ..., N-1\},\ i \in \mathcal{W}$

[5]These are not the weakest possible assumptions that implement the utilitarian efficient assignment, but weaker assumptions are more complicated.

Assumption 2: Hierarchy

1. There exist a finite number of groups labeled $1, 2, .., K$, where $K \leq N$, ranked hierarchically; group 1 being the highest and group K being the lowest. Formally, let the family of sets $P_1, P_2, ..., P_K$ be a partition of the set of all agents in the game, i.e., $\mathcal{M} \cup \mathcal{W}$.

2. There are an equal number of men and women in each set P_k, $k = 1, 2, ..., K$.

3. Given $w_1, w_2 \in \mathcal{W}$, if w_1 is more sensitive than w_2, w_1 is in the same level as w_2 or at a higher level than w_2.

4. For men and women in a group k, $k < K$, the following holds: For each woman(man), there is a distinct man(woman) in her(his) level whom she(he) strictly prefers to all other men(women) in her(his) level or below her(his) level. For men and women in a group $k > 1$, the following holds: Each woman(man) strictly prefers any man(woman) above her(his) level to any man(woman) in her(his) level.

One can think of at least two real-world scenarios in which it is plausible that Assumption 2 holds. The first is a school assignment context where a school may have a priority for students who live in the attendance area of the school, or has siblings attending the same school (see Abdulkadiroğlu & Sönmez (2003)). The second example, and the one that is more closely related to the current context, is the Indian marriage market, where there are quite a few castes ranked hierarchically (see Anderson (2003)). Interestingly, Anderson (2003) uses a quality-of-groom (as perceived by the bride) function which is such that a bride prefers grooms of a higher caste to those of a lower caste. Such a quality-of-groom function is consistent with Assumption 2.

We are now in a position to state the central proposition in this paper.

Proposition 2

If Condition A, Assumption 1 and Assumption 2 hold, the top trading cycles algorithm produces the BAMM assignment.

Proof: See Appendix F.

As an illustration of Proposition 2, consider the following example[6]:

Example 3

There are three women and three men with preference orderings given below.

$m_1 : w_1 \succ w_3 \succ w_2$

$m_2 : w_2 \succ w_1 \succ w_3$

$m_3 : w_2 \succ w_1 \succ w_3$

$w_1 : m_2 \succ m_1 \succ m_3$

$w_2 : m_1 \succ m_2 \succ m_3$

$w_3 : m_1 \succ m_2 \succ m_3$

There are two levels in society, ie $K = 2$. Level 1 consists of $\{m_1, m_2, w_1, w_2\}$ and level two consists of $\{m_3, w_3\}$. Notice that this preference ordering satisfies Assumption 2 if we further assume w_1 is more sensitive than w_2, who is more sensitive than w_3. To see this, observe that the most preferred woman for m_1 and m_2 are both from level 1. The same holds for w_1 and w_2. Further, w_3 is m_3's worst choice. Similarly, m_3 is w_3's worst choice.

The top trading cycles algorithm on this particular preference ordering proceeds as follows: At Step 1, there is exactly one cycle, which is the following: (w_1, m_2, w_2, m_1). Notice that this cycle is nested within level 1. Further, all members from level 2, ie m_3 and w_3 point to some member in level 1, but neither m_3 nor w_3 is part of any cycle. At Step 1, w_1 is matched with m_2 and w_2 is matched with m_1. At Step 2 of the algorithm the only cycle is (m_3, w_3). Thus, m_3 and w_3 are paired at Step 2 of the algorithm, and the algorithm terminates.

While the matching produced by the top trading cycles algorithm is woman Pareto optimal, it is not stable. For example, m_1 prefers w_3 over his current match and w_3 prefers m_1 over her current match. Two aspects of the matching produced by the top trading cycles algorithm are worth emphasizing. First, all matches are nested within levels. This is consistent with caste

[6]The example is adapted from Abdulkadiroğlu & Sönmez (2003), Example 1, Pg. 736

endogamy observed in the Indian marriage market. Second, given the assignment produced by the top trading cycles, the profitable bilateral deviation is between the two levels, not within a given level. This is a result that holds generally. The proposition below states this formally.

Proposition 3

If Assumption 2 holds, all bilaterally profitable deviations from the matching produced by the top trading cycles are across levels.

Proof: See Appendix G.

The fact that bilaterally profitable deviations are across levels has the following interpretation in the Indian marriage context: If the marriage matching process in society produces a utilitarian efficient matching, individuals may have an incentive to deviate from the efficient matching. To prevent those one would need strict social norms, for example, brutal punishments to couples who bilaterally deviate. However, these punishments would not be necessary if the matching produced were stable. Thus, the existence of costly-to-implement social sanctions against inter-caste marriages is consistent with our framework, but cannot be rationalized if the marriage matching in the Indian market were to be thought of as being produced by the Gale-Shapley algorithm.

We now provide a partial converse to Proposition 1. To that end, define **CONDITION B** as follows:

CONDITION B: $U^*_{\mathcal{W}} - \sum_{w\in\mathcal{W}} \widetilde{U}_w(A^*_{\mathcal{M}}) > U^*_{\mathcal{M}}$, $A^*_{\mathcal{W}}$ is a singleton, and $A^*_{\mathcal{M}} \cap A^*_{\mathcal{W}} = \emptyset$.

In words, **CONDITION B** requires that the total loss in utility to women by moving from the assignment that is first-best for women to the assignment that is first-best for men exceed the total utility to all men from the assignment that is first-best for men. If we assume $A^*_{\mathcal{M}} \cap A^*_{\mathcal{W}} = \emptyset$, CONDITION A $\implies$ CONDITION B To see why this is true, assume that $A^*_{\mathcal{M}} \cap A^*_{\mathcal{W}} = \emptyset$ and CONDITION A holds. So, $U^{*,(-1)}_{\mathcal{W}} \geq \sum_{w\in\mathcal{W}} \widetilde{U}_w(A^*_{\mathcal{M}})$. Hence,

$U^*_{\mathcal{W}} - U^{*,(-1)}_{\mathcal{W}} > U^*_{\mathcal{M}} \implies U^*_{\mathcal{W}} - \sum_{w\in\mathcal{W}} \widetilde{U}_w(A^*_{\mathcal{M}}) > U^*_{\mathcal{M}}$

Hence, $A^*_{\mathcal{M}} \cap A^*_{\mathcal{W}} = \emptyset$ and **CONDITION A** $\implies$ **CONDITION B**. Before we introduce the next proposition, we need to develop some notation. Denote by A^*_{TTC} the assignment that the *top trading cycles algorithm* produces.

Proposition 4

If $\mathcal{A}^*_{BAMM} = A^*_{TTC} = A^*_{\mathcal{W}}$*,* $A^*_{\mathcal{M}} \cap \mathcal{A}^*_{BAMM} = \emptyset$ *and* $\mathcal{A}^*_{BAMM}$ *is a singleton, then* ***CONDITION B*** *holds.*

Proof: See Appendix H

Next, we illustrate through an example that Assumption 2 is necessary for implementing the utilitarian efficient matching through the top trading cycles algorithm. Consider the example below:

Example 4

Table 3.3: Example that Assumption 2 is necessary for implementing the utilitarian efficient matching through the TTC algorithm

	Woman 1	Woman 2	Woman 3
Man 1	(5,500)	(0.1,25)	(1,6)
Man 2	(1,1000)	(5,50)	(0.1,5)
Man 3	(1,0.1)	(5,0.1)	(0.1,0.1)

In Table 3.3 above, the entry in the cell with index (i, j) is the ordered pair (U_i^j, U_j^i) where U_i^j denotes the utility of man i if he were to marry woman j and U_j^i denotes the utility of woman j if she were to marry man i. Note that in the example above, the preference ordering satisfies CONDITION A and Assumption 1, but fails to satisfy Assumption 2 (see Appendix I for details). Further, as we show in Appendix I, the top trading cycles algorithm produces the following assignment:

$$W_1 \rightarrow M_1, \quad W_2 \rightarrow M_2, \quad W_3 \rightarrow M_3$$

The assignment above results in a total utility of 560.2 to all agents, which is lower than 1026.3 produced by the following assignment:

$$W_1 \rightarrow M_2, \quad W_2 \rightarrow M_1, \quad W_3 \rightarrow M_3$$

Hence, in the example above, the top trading cycles algorithm does not result in a utilitarian efficient assignment/matching.

Finally, note that in the "unusual" case where a stable assignment is also Pareto optimal, the equilibrium under **BIM** with the Gale-Shapley algorithm could coincide with the equilibrium with the top-trading cycles algorithm. This equilibrium could be distinct from the equilibrium under **BAMM**. As an illustration, consider the following example[7].

Example 5

Suppose the economy consists of two men and two women whose preferences can be represented by the cardinal utility shown in Table 3.4 below.

Table 3.4: Example illustrating that the stable matching may be Pareto optimal

	Woman 1	Woman 2
Man 1	(11,1)	(2,2)
Man 2	(2,2)	(0,0)

The equilibrium **BAMM** assignment is the following:

$$M_1 \rightarrow W_1, \quad M_2 \rightarrow W_2 \tag{3.6}$$

Irrespective of whether one uses the *top trading cycles* algorithm or the Gale-Shapley algorithm, the **BIM** assignment is the following:

$$M_1 \rightarrow W_2, \quad M_2 \rightarrow W_1 \tag{3.7}$$

Note that assignments (3.6) and (3.7) are distinct.

[7]The example is a slight modification of the example in Pollak (2019), pg 23.

3.5 Conclusion

The set of stable marriage matches, and their welfare implications, are different depending on whether allocation within marriage is determined by binding agreements in the marriage market (BAMM) or by bargaining in marriage (BIM) with no commitment. With transferable utility, any stable matching is utilitarian efficient under BAMM. This, however, does not hold under BIM, which appears to be a more (empirically) plausible assumption than BAMM. In this paper we showed that it is possible to implement the utilitarian efficient matching even in a BIM setting. If agents on one side of the market are sufficiently sensitive to matches relative to the other side, the more sensitive side can be ranked by sensitivity, and preferences over members of the opposite sex are hierarchical, the top trading cycles algorithm results in a utilitarian efficient matching.

Given that the assignments produced by using the alternative algorithms of Gale-Shapley and top trading cycles under BIM could be different, it is of great interest to examine the empirical evidence on which algorithm better represents the real world marriage market. After all, these algorithms are not meant to serve as literal descriptions of the matching process, but rather as constructive proofs of the existence of a matching with desirable properties — stability in the case of the Gale-Shapley algorithm and Pareto efficiency in the case of the top trading cycles algorithm. Thus, the choice of one matching algorithm over the other should not be based on the consideration as to whether one provides a better literal description of marriage matching but on whether one algorithm is better able to rationalize the data as compared to the other. However, this question has hardly been addressed in the literature.

There are only a few empirical papers dealing with marriage-matching in a *non-transferable* utility setting that use the Gale-Shapley algorithm. For instance, Hitsch *et al.* (2010) estimate mate preferences from matches observed on a dating site. Then they use the Gale-Shapley algorithm to predict matches on the dating site and do fairly well. They also attempt to use the estimated preferences to predict matches in the real world, again using the Gale-Shapley algorithm. In the real world, the Gale-Shapley algorithm underpredicts assortative matching on several dimensions. Lee (2009) performs a similar exercise using data from an online match-making platform in South Korea. In her exercise, she estimates preferences with matchmaker data, and the Gale-Shapley algorithm does a fair job of predicting matches amongst users of online services. Gale-Shapley predictions, however, are somewhat off in terms of predicting matches in the real world. Banerjee *et al.* (2013) use data on matches in the marriage market from India to estimate preferences for partner attributes, most notably for caste of the partner. They use their estimated preferences to simulate matches using the Gale-Shapley algorithm to clear the marriage market. While moments from their simulated data match data fit real world matches on several dimensions, their simulations overpredict (by a substantial margin) caste homogamy relative to that in the data.

In summary, the Gale-Shapley algorithm does not do a stellar job in predicting matches in the real world. Further, while there is sufficient evidence to suggest that BIM, rather than BAMM, is an appropriate framework to model ongoing marriages, there are, to the best of our knowledge, no empirical studies that investigate whether the marriage market equilibrium in the real world is substantially different from the BAMM equilibrium. Moreover, social norms governing marriage and courtship vary widely across the world, and there may exist social norms that violate stability. For example, in Kyrgyzstan, men routinely kidnap women, often without their consent, for marriage (see Kleinbach *et al.* (2005), Handrahan (2004) and Nedoluzhko & Agadjanian (2015)). In India, caste endogamy and clan exogamy are widely prevalent. It is possible that social norms relating to endogamy and exogamy serve to facilitate efficient matches even though these matches may not be stable. Further, the fact that they are often enforced by brutal social punishments to couples that deviate could be on account of the fact that the utilitarian efficient matching is not robust to bilateral deviation. In all these cases, the *top trading cycles* algorithm, which results in an assignment that is Pareto optimal, could be a better predictor of matches in the real world than the *Gale-Shapley* algorithm, which results in an assignment that is stable. In future research, we intend to estimate models using the *top trading cycles* algorithm instead of the Gale-Shapley algorithm, for example, with the data in the studies cited above.

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Appendix

A Divorce and Property Division Law Reforms in the sample period

Table A1: Divorce and Property Division Law Reforms in the sample period

State	Unilateral divorce	Equitable division	State	Unilateral divorce	Equitable division
Alabama	1971	1984	Montana	1973	1976
Alaska	pre-1967	pre-1967	Nebraska	1972	1972
Arizona	1973	community	Nevada	1967	community
Arkansas	no	1977	New Hampshire	1971	1977
California	1970	community	New Jersey	no	1974
Colorado	1972	1972	New Mexico	pre-1967	community
Connecticut	1973	1973	New York	no	1980
Delaware	1968	pre-1967	North Carolina	no	1981
District of Columbia	no	1977	North Dakota	1971	pre-1967
Florida	1971	1980	Ohio	1992	1981
Georgia	1973	1984	Oklahoma	pre-1967	1975
Hawaii	1972	pre-1967	Oregon	1971	1971
Idaho	1971	community	Pennsylvania	no	1980
Illinois	no	1977	Rhode Island	1975	1981
Indiana	1973	pre-1967	South Carolina	no	1985
Iowa	1970	pre-1967	South Dakota	1985	pre-1967
Kansas	1969	pre-1967	Tennessee	no	pre-1967
Kentucky	1972	1976	Texas	1970	community
Louisiana	no	community	Utah	1987	pre-1967
Maine	1973	1972	Vermont	no	pre-1967
Maryland	no	1978	Virginia	no	1982
Massachusetts	1975	1974	Washington	1973	community
Michigan	1972	pre-1967	West Virginia	1984	1985
Minnesota	1974	pre-1967	Wisconsin	1978	community(1986)
Mississippi	no	1989	Wyoming	1977	pre-1967
Missouri	no	1977			

Note: Data from Voena (2015), Online Appendix, Table F.1

B Example: Top Trading Cycles is not strategy-proof for men

The example below illustrates that *top trading cycles* algorithm is not strategy proof for men. Suppose there are three men and three women and that their true preferences are as follows:

$m_1 : w_1 \succ w_3 \succ w_2$

$m_2 : w_2 \succ w_1 \succ w_3$

$m_3 : w_2 \succ w_1 \succ w_3$

$w_1 : m_2 \succ m_1 \succ m_3$

$w_2 : m_1 \succ m_2 \succ m_3$

$w_3 : m_1 \succ m_2 \succ m_3$

If everyone reveals her/his true preference, the *top trading cycles* mechanism converges to the following assignment:

$m_1 \rightarrow w_2, \quad m_2 \rightarrow w_1, \quad m_3 \rightarrow w_3$

Notice that man 1 is matched with the woman ranked lowest according to his preference ordering.

Suppose man 1, instead of revealing his true preferences, reveals the following: m_1^{false} : $w_3 \succ w_1 \succ w_2$.

Suppose further that all other individuals in the economy state their true preferences. In this case the top trading cysles mechanism converges to the following assignment.

$m_1 \rightarrow w_3, \quad m_2 \rightarrow w_2, \quad m_3 \rightarrow w_1$

Notice that man 1 is now matched with the woman ranked second according to his true preference ordering. Thus, truth-telling is not a dominant strategy for man 1.

C Example 1 satisfies CONDITION A

Here, $U^*_{\mathcal{M}} = 2$, $U^*_{\mathcal{W}} = 20$, $U^{*,(-1)}_{\mathcal{W}} = 13$

$\therefore U^*_{\mathcal{W}} - U^{*,(-1)}_{\mathcal{W}} = 7 > 2 = U^*_{\mathcal{M}}$.

Table C1: Tabulation of sum of Utilities from all Possible Assignments

(m,w) pairs	$\sum_{m\in\mathcal{M}} U_m$	$\sum_{w\in\mathcal{W}} U_w$
(1,1), (2,2), (3,3)	2	10
(1,2), (2,3), (3,1)	0.5	12.5
(1,3), (2,1), (3,2)	2	13
(1,1), (2,3), (3,2)	2	7.5
(1,2), (2,1), (3,3)	0.5	20
(1,3), (2,2), (3,1)	2	8
Maximum	2	20

Hence, CONDITION A holds.

D Proof of Lemma 1

Suppose **CONDITION A** holds, $A^* \in A^*_{\mathcal{W}}$ but $A^* \notin \underset{A\in\mathcal{A}}{\arg\max}\,\left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A)+\sum_{w\in\mathcal{W}} \widetilde{U}_w(A)\right]$. Then, $\exists\, A' \in \mathcal{A}$, $A' \neq A^*$ such that

$$\left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A') + \sum_{w\in\mathcal{W}} \widetilde{U}_w(A')\right] > \left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A^*) + \sum_{w\in\mathcal{W}} \widetilde{U}_w(A^*)\right]$$

$$\implies \left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A') + \sum_{w\in\mathcal{W}} \widetilde{U}_w(A')\right] > \left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A^*) + U^*_{\mathcal{W}}\right] \quad \left[\because A^* \in A^*_{\mathcal{W}}\right]$$

Rearranging the above inequality and applying **CONDITION A**, we have

$$\left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A') - \sum_{m\in\mathcal{M}} \widetilde{U}_m(A^*)\right] > \left[U^*_{\mathcal{W}} - \sum_{w\in\mathcal{W}} \widetilde{U}_w(A')\right] \geq U^*_{\mathcal{W}} - U^{*,(-1)}_{\mathcal{W}} > U^*_{\mathcal{M}} \tag{D1}$$

$$\text{But} \quad U^*_{\mathcal{M}} \geq \sum_{m\in\mathcal{M}} \widetilde{U}_m(A') \geq \left[\sum_{m\in\mathcal{M}} \widetilde{U}_m(A') - \sum_{m\in\mathcal{M}} \widetilde{U}_m(A^*)\right] \quad \forall A' \in \mathcal{A} \tag{D2}$$

From (D1) and (D2), $U^*_{\mathcal{M}} > U^*_{\mathcal{M}}$ which is a contradiction.■

E Proof of Proposition 1

Suppose the top-trading cycles algorithm produces an element $A^* \in A^*_{\mathcal{W}}$ and **CONDITION A** holds. With transferable utility, the set of equilibrium assignments under **BAMM** is given by $\mathcal{A}^*_{BAMM} = \{A \in \mathcal{A} : A \in \underset{A \in \mathcal{A}}{\arg\max} \left[\sum_{m \in \mathcal{M}} \widetilde{U}_m(A) + \sum_{w \in \mathcal{W}} \widetilde{U}_w(A)\right]\}$. Thus, if **CONDITION A** is true, from **Lemma 1** we conclude that $A^* \in \mathcal{A}^*_{BAMM}$. ■

F Proof of Proposition 2

Step 1

Definition: Nested Cycle

A cycle $C = (m_1, w_1, ..., m_n, w_n)$ is nested within level k, $k \leq K$ if and only if for any j, $j = 1, 2, ..., n$, such that $m_j, w_j \in C$, m_j and w_j are both in level k.

Claim: *At Step 1 of the TTC, all cycles are nested within the top level, ie, level 1.*

Proof:

Suppose not. Then there is at least one cycle not nested within level 1. First, notice that all individuals below level 1 are pointing at someone in level 1. So any cycle has to include at least one person from level 1. Suppose such a cycle is not nested within level 1. Then there is at least one man or woman in level 1 who is pointing at a woman or man at level k, $k > 1$. But that implies she or he prefers a partner below her or his level to all partners at her/his level, which violates Assumption 2.■

Step 2

Claim: *Each man and woman in level 1 is part of some cycle at Step 1 of the top trading cycles (TTC).*

Proof:

Suppose there are some women and men in level 1 who are not part of any cycle at Step 1. Note that there is at least one cycle. Since each man and woman has a unique and distinct most preferred mate, no individual who does not belong to any cycle is pointing to any individual who is part of a cycle. Further, there are as many men as women who do not belong to any cycle. Let each man point to his most preferred woman and each woman point to her most preferred man. Let such men and women form the following ordered list: $(m_1^c, w_1^c, ..., m_l^c, w_l^c)$. Then, w_l^c must be pointing back at some man in the ordered list, thus forming a cycle, and contradicting the initial claim that no man or woman in $(m_1^c, w_1^c, ..., m_l^c, w_l^c)$ belongs to a cycle.■

Step 3

Claim: *Each man and woman in level 1 is matched at Step 1 of the TTC.*

Proof:

From Step 2 of this proof, each man and each woman at level 1 is part of some cycle. By construction of the TTC, each woman is matched with the man she points to at *Step 1* of the TTC. Hence, each man and woman in level 1 is matched at *Step 1* of the TTC.■

Step 4

Claim: *At any subsequent Step k of the TTC, all cycles are nested within level k. All individuals at level k are matched in Step k.*

Proof:

By induction on k.

Suppose the statement is true for some $k = m$, $m \leq K - 1$. We will show that the statement is true for $k = m + 1$. Note that by Step $m + 1$ of the TTC, all individuals at or above level m are already matched. (This holds by the induction hypothesis.) By the same argument as in Step 1 of this proof, all cycles at Step $m + 1$ of the TTC are nested within level $m + 1$. By the same argument as in Step 2 of this proof, each man and woman at level $m + 1$ is part of some cycle at Step $m + 1$ of the TTC, and are, therefore, matched at Step $m + 1$ of the TTC.■

Step 5

Claim: *The top trading cycles algorithm produces a matching A^* where A^* is given by:*

$A^*(w_1) = m_j$ s.t. $U_{w_1}(m_j) = max\{U_{w_1}(m_1), U_{w_1}(m_2), ..., U_{w_1}(m_N)\}$

For $j = \{2, 3, ..., N\}$, $A^*(w_j) = m_l$

s.t. $U_{w_j}(m_l) = max\Big\{\{U_{w_j}(m_1), U_{w_j}(m_2), ..., U_{w_j}(m_N)\}\backslash \underset{i=1,..,j-1}{\cup} A(w_i)\Big\}$

Proof:

Consider women at level 1, ie $w_1, .., w_{K_1}$. Each woman at level 1 has a unique and distinct most preferred man. Thus, $m_l^* \neq m_{l'}^*\ \forall\ l \neq l'$, $w_l, w_{l'} \in$ level 1, where

$m_l^* := argmax\{U_{w_l}(m_1), U_{w_l}(m_2), ..., U_{w_l}(m_N)\}$

Hence, for all women at level 1, A^* satisfies the following property:

$A^*(w_1) = m_j$ s.t. $U_{w_1}(m_j) = max\{U_{w_1}(m_1), U_{w_1}(m_2), ..., U_{w_1}(m_N)\}$, and

for $j = \{2, 3, ..., K_1\}$, $A^*(w_j) = m_l^*$

s.t. $U_{w_j}(m_l^*) = max\Big\{\{U_{w_j}(m_1), U_{w_j}(m_2), ..., U_{w_j}(m_N)\}\backslash \underset{i=1,..,j-1}{\cup} A(w_i)\Big\}$

All men and women at level 1 are matched in Step 1 of the TTC. Thus, when the TTC proceeds to Step 2, the most preferred men of all women at level 2 have already been eliminated at Step 1 of the TTC. Thus, each woman at level 2 has a unique and distinct most preferred man from amongst the set of unmatched men. Hence, the argument in the above paragraph can be applied repeatedly to establish the claim. ■

Step 6

Claim: *A^* is woman-Pareto optimal.*

Proof:

Suppose A^* is not woman-Pareto optimal. Then $\exists$ an assignment $A' \neq A^*$ such that $\widetilde{U}_{w_i}(A') \geq \widetilde{U}_{w_i}(A^*)\ \forall w_i \in \mathcal{W}$ and $\exists\ w_{i'} \in \mathcal{W}$ such that $\widetilde{U}_{w_{i'}}(A') > \widetilde{U}_{w_{i'}}(A^*)$. Define $i'_{\text{min}} := \min\Big\{i' \in \{1, 2, ..., N\} | \widetilde{U}_{w_{i'}}(A') > \widetilde{U}_{w_{i'}}(A^*)\Big\}$. By definition, A^* assigns w_1 to her most preferred man. Hence, $i'_{\text{min}} \neq 1$. Further, by construction of A^*, the following holds: If the preference of $w_{i'_{min}}$ clashes with the preference of a woman with a higher index, $w_{i'_{min}}$'s preferences are given priority. Since preferences over men are strict, it follows that if assignment A' matches $w_{i'_{min}}$ with the partner that some woman with a higher index had under assignment A^*, $w_{i'_{min}}$ would be worse off under assignment A' than under assignment A^*. But that cannot be the case since that would violate the definition of i'_{min}. Formally, $\nexists\, i,\ i \geq i'_{\text{min}}$, such that $A'(w_{i'_{\text{min}}}) = A^*(w_i)$. So, $w_{i'_{min}}$'s partner under A' must have been the partner of a woman with a lower index under A^*. Formally, $\exists\, w_i \in \mathcal{W}, i \in \{2, ..., i'_{\text{min}} - 1\}$ such that $A'(w_{i'_{\text{min}}}) = A^*(w_i)$. But then A' must match w_i with a man who, under A^*, was the partner of a woman with an index (weakly) higher than i'_{min}. So it must be the case that $A'(w_i) = A^*(w_{\widetilde{i}})$ where $\widetilde{i} \in \{i'_{\text{min}}, ..., N\}$. However, by construction of A^*, $U_{w_i}(A^*(w_i)) > U_{w_i}(A^*(w_{\widetilde{i}})) = U_{w_i}(A'(w_i))$ $\implies \widetilde{U}_{w_i}(A') < \widetilde{U}_{w_i}(A^*)$ which contradicts the definition of A'. ■

Step 7

$A \in A^*_{\mathcal{W}} \implies$ *A is woman-Pareto optimal*

Proof:

Suppose A is not woman Pareto optimal. Then there is an assignment $A' \neq A$ such that $\widetilde{U}_{w_i}(A') \geq \widetilde{U}_{w_i}(A)\ \forall w_i \in \mathcal{W}$ and $\exists\, w_{i'} \in \mathcal{W}$ such that $\widetilde{U}_{w_{i'}}(A') > \widetilde{U}_{w_{i'}}(A)$.

Let $\mathcal{W}_b := \{w \in \mathcal{W} | \widetilde{U}_w(A') > \widetilde{U}_w(A)\}$.

$\sum_{w\in\mathcal{W}} \widetilde{U}_w(A') = \sum_{w\in\mathcal{W}_b} \widetilde{U}_w(A') + \sum_{w\in\mathcal{W}\setminus\mathcal{W}_b} \widetilde{U}_w(A') > \sum_{w\in\mathcal{W}} \widetilde{U}_w(A)$.

Hence, $A \notin A^*_{\mathcal{W}}$. ■

Step 8

Claim: *If* Assumption 1 *holds*, A^* *is the unique element in* $A^*_{\mathcal{W}}$.

Proof:

From Step 7 above, it suffices to demonstrate that $\sum_{w\in\mathcal{W}} \widetilde{U}_w(A^*) > \sum_{w\in\mathcal{W}} \widetilde{U}_w(A')$ where $A' \neq A^*$ and A' is an arbitrary woman Pareto optimal assignment.

Suppose $A' \neq A^*$ and A' is an arbitrary woman Pareto optimal assignment. Define the set of losers $L := \{w \in \mathcal{W} | \widetilde{U}_w(A') < \widetilde{U}_w(A^*)\}$ and the set of gainers $G := \{w \in \mathcal{W} | \widetilde{U}_w(A') > \widetilde{U}_w(A^*)\}$

For $I = L, G$, define $I_{min} := \min\Big\{i \in \{1, 2, ..., N\} | w_i \in I\Big\}$ and $I_{max} := \max\Big\{i \in \{1, 2, ..., N\} | w_i \in I\Big\}$. Notice, $L_{min} < G_{min}$. To see why this holds, assume, for the sake of contradiction, that $L_{min} > G_{min}$[8]. Note that $G_{min} \neq 1$, because A^* matches w_1 with her most preferred man. Further, by construction of A^*, the following holds: Under assignment A', any woman $w_i \in G$ would have to be matched with a man, who, under A^*, was partnered with a woman $w_{i'}$, where $i' < i$. In particular, this holds for G_{min}. Thus, $\exists\ i \in \{1, .., G_{min} - 1\}$ such that under A', G_{min} gets i's partner under A^*. But then, woman i has a different partner under A' than under A^*. Since preferences are strict, woman i is not indifferent between A' and A^*. She has a lower index than G_{min}, so $w_i \notin G$. Therefore, $w_i \in L$, which contradicts the supposition that $L_{min} > G_{min}$.

Hence, $\exists$ at least one woman, $w_{L_{min}} \in L$, who is more sensitive (or equivalently, has a lower index) than any woman in G.

Now, $\forall\ w \in G$, $\widetilde{U}_w(A') - \widetilde{U}_w(A^*) \leq (\widetilde{\mathcal{U}}_w^{(N)} - \widetilde{\mathcal{U}}_w^{(1)}) \leq (\widetilde{\mathcal{U}}_{w_{G_{min}}}^{(N)} - \widetilde{\mathcal{U}}_{w_{G_{min}}}^{(1)})$
where the second inequality above follows from observing the fact that any $w \in G$ is weakly less sensitive than $w_{G_{min}}$ and by applying Assumption 1[9].

Hence, we have

$$\sum_{w \in G} [\widetilde{U}_w(A') - \widetilde{U}_w(A^*)] \leq |G|.(\widetilde{\mathcal{U}}_{w_{G_{min}}}^{(N)} - \widetilde{\mathcal{U}}_{w_{G_{min}}}^{(1)}) < N.(\widetilde{\mathcal{U}}_{w_{G_{min}}}^{(N)} - \widetilde{\mathcal{U}}_{w_{G_{min}}}^{(1)}) \tag{F1}$$

Since $L_{min} < G_{min}$, by Assumption 1,

$$\begin{aligned} &[\widetilde{U}_{w_{L_{min}}}(A^*) - \widetilde{U}_{w_{L_{min}}}(A')] > N.(\widetilde{\mathcal{U}}_{w_{G_{min}}}^{(N)} - \widetilde{\mathcal{U}}_{w_{G_{min}}}^{(1)}) \\ \implies &\sum_{w \in L} [\widetilde{U}_w(A^*) - \widetilde{U}_w(A')] > N.(\widetilde{\mathcal{U}}_{w_{G_{min}}}^{(N)} - \widetilde{\mathcal{U}}_{w_{G_{min}}}^{(1)}) \end{aligned} \tag{F2}$$

Now, $\sum_{w \in \mathcal{W}} \widetilde{U}_w(A^*) - \sum_{w \in \mathcal{W}} \widetilde{U}_w(A')$
$= \sum_{w \in L} [\widetilde{U}_w(A^*) - \widetilde{U}_w(A')] - \sum_{w \in G} [\widetilde{U}_w(A') - \widetilde{U}_w(A^*)]$.
From (F1) and (F2), $\sum_{w \in \mathcal{W}} \widetilde{U}_w(A^*) - \sum_{w \in \mathcal{W}} \widetilde{U}_w(A') > 0$ ■

[8] $L_{min} = G_{min}$ is not a possibility because the same woman cannot be both a loser and a gainer, i.e., she cannot be in both sets L and G.

[9] From Assumption 1 it follows that for any $i < i'$,
$(\widetilde{\mathcal{U}}_{w_{i'}}^{(N)} - \widetilde{\mathcal{U}}_{w_{i'}}^{(1)}) < \frac{1}{N}(\widetilde{\mathcal{U}}_{w_i}^{(j+1)} - \widetilde{\mathcal{U}}_{w_i}^{(j)}) < \frac{1}{N}(\widetilde{\mathcal{U}}_{w_i}^{(N)} - \widetilde{\mathcal{U}}_{w_i}^{(1)}) < (\widetilde{\mathcal{U}}_{w_i}^{(N)} - \widetilde{\mathcal{U}}_{w_i}^{(1)})$ where $j \in \{1, 2, ..., N-1\}$

Step 9

Claim: *Under* Assumption 1 *and* CONDITION A, $A^* = A^*_{BAMM}$

Proof:

From Step 8 above, A^* is the unique element in $A^*_{\mathcal{W}}$ if Assumption 1 holds. From Proposition 1, if CONDITION A holds, $A^* = A^*_{BAMM}$ ■

G Proof of Proposition 3

For any level k, $k \leq K$, each woman at level k gets her most preferred man within level k. So a woman from level k is not interested in deviating to any man at level k.■

H Proof of Proposition 4

Suppose $\mathcal{A}^*_{BAMM} = A^*_{TTC} = A^*_{\mathcal{W}}$ and $\mathcal{A}^*_{BAMM}$ is a singleton. Then,

$U^*_{\mathcal{W}} + \sum_{m \in \mathcal{M}} \widetilde{U}_m(\mathcal{A}^*_{BAMM}) > \sum_{w \in \mathcal{W}} \widetilde{U}_w(A) + \sum_{m \in \mathcal{M}} \widetilde{U}_m(A) \quad \forall A \neq \mathcal{A}^*_{BAMM}$.

In particular, for $A = A^*_{\mathcal{M}}$, we have

$U^*_{\mathcal{W}} + \sum_{m \in \mathcal{M}} \widetilde{U}_m(\mathcal{A}^*_{BAMM}) > \sum_{w \in \mathcal{W}} \widetilde{U}_w(A^*_{\mathcal{M}}) + U^*_{\mathcal{M}}$

$\implies U^*_{\mathcal{W}} - \sum_{w \in \mathcal{W}} \widetilde{U}_w(A^*_{\mathcal{M}}) > U^*_{\mathcal{M}} - \sum_{m \in \mathcal{M}} \widetilde{U}_m(\mathcal{A}^*_{BAMM}) > U^*_{\mathcal{M}}$

$\implies$ **CONDITION B**.■

I Details relevant to Example 4

I1 Example 4 satisfies CONDITION A

Here, $U^*_{\mathcal{M}} = 10.1$, $U^*_{\mathcal{W}} = 1025.1$, $U^{*,(-1)}_{\mathcal{W}} = 1006.1$

$\therefore U^*_{\mathcal{W}} - U^{*,(-1)}_{\mathcal{W}} = 19 > 10.1 = U^*_{\mathcal{M}}$.

Further, the matching $\{(1,2),(2,1),(3,3)\}$ uniquely maximizes $\sum_{w \in \mathcal{W}} U_w$.

Hence, CONDITION A holds.

Table I1: Tabulation of sum of Utilities from all Possible Assignments

(m, w) pairs	$\sum_{m \in \mathcal{M}} U_m$	$\sum_{w \in \mathcal{W}} U_w$
(1,1), (2,2), (3,3)	10.1	550.1
(1,2), (2,3), (3,1)	1.2	30.1
(1,3), (2,1), (3,2)	7	1006.1
(1,1), (2,3), (3,2)	10.1	505.1
(1,2), (2,1), (3,3)	1.2	1025.1
(1,3), (2,2), (3,1)	7	56.1
Maximum	10.1	1025.1

I2 Example 4 satisfies Assumption 1

First, observe that each woman's utility from her worst possible match is 0.1. Next, notice that w_1 is more sensitive than w_2. By moving from her first-best to her second-best match, w_1 loses 500 utils while she loses 499.9 utils by moving from her second-best to her third-best. Both these number are more than 149.7 utils[10]. Note that w_2's gain by moving from her best to her worst partner equals 49.9. Similarly, w_2 is more sensitive than w_3. By moving from her first to her second-best w_2 loses 25 utils while she loses 24.9 utils. Both these numbers are larger than 17.7 utils, which is what w_3 gains by moving from her worst to her best choice[11].

I3 Example 4 violates Assumption 2

We must show that there is no partition of $\mathcal{M} \cup \mathcal{W}$ such that the conditions of Assumption 2 are satisfied. We can consider all possible partitions of $\mathcal{M} \cup \mathcal{W}$ below. **Case 1**

$K = 1$, $P_1 = \mathcal{M} \cup \mathcal{W}$

$\mathcal{M} \cup \mathcal{W}$ does not satisfy Assumption 2. w_1 and w_2 both have m_2 as their stated preference, which is a violation of Assumption 2.

Case 2

$K = 2$. There are two sub-cases of this case.

1. Consider a partition in which w_1 and w_2 are at the same level and w_3 is at a lower level. Both w_1 and w_2 both have m_2 as their stated preference, which is a violation of Assump-

[10] 49.9 X 3 = 149.7

[11] 5.9 X 3 = 17.7

tion 2. To see why, notice that m_2 can either belong to the same level as w_2 or the lower level. In the first case, Assumption 2 is violated because the most preferred man (in the same level) for two women are not distinct. In the second case, Assumption 2 is violated because the most preferred man of both w_1 and w_2 belong to a lower level.

2. Consider a partition in which w_1 is at the highest level and w_2 and w_3 both belong to the lower level. m_2 can belong to the higher or to the lower level. If m_2 belongs to the lower level, m_1 and m_3 belong to a higher level. But w_1 prefers m_2, who is at a lower level over m_1, who is at a higher level. This is a violation of Assumption 2. Alternatively, if m_2 belongs to the higher level, m_1 and m_3 must belong to the lower level. Then, w_3's preference ordering violates Assumption 2, because she prefers m_1, who is at a lower level, over m_2, who is in a higher level.

Case 3

If $K = 3$, we might have the following sub-cases:

Sub-case 1

$P_1 = \{w_1, m_1\}$, $P_2 = \{w_2, m_2\}$, $P_3 = \{w_3, m_3\}$

Notice, w_1 prefers m_2, who is in a lower level over m_1, who is in a higher level. This is a violation of Assumption 2.

Sub-case 2

$P_1 = \{w_1, m_1\}$, $P_2 = \{w_2, m_3\}$, $P_3 = \{w_3, m_2\}$

Notice, w_1 prefers m_2, who is in a lower level over m_1, who is in a higher level. This is a violation of Assumption 2.

Sub-case 3

$P_1 = \{w_1, m_2\}$, $P_2 = \{w_2, m_1\}$, $P_3 = \{w_3, m_3\}$

Notice, m_1 prefers w_3, in level 3, over w_2, who is in level 2, thereby violating Assumption 2.

Sub-case 4

$P_1 = \{w_1, m_3\}$, $P_2 = \{w_2, m_1\}$, $P_3 = \{w_3, m_2\}$

Notice, w_1 prefers m_2 in level 2 over m_3 in level 1, thereby violating Assumption 2.

Sub-case 5

$P_1 = \{w_1, m_2\}$, $P_2 = \{w_2, m_3\}$, $P_3 = \{w_3, m_1\}$

Notice, w_3 prefers m_1 in level 3 over m_3 in level 1, thus violating Assumption 2.

Sub-case 6

$P_1 = \{w_1, m_3\}$, $P_2 = \{w_2, m_2\}$, $P_3 = \{w_3, m_1\}$

Notice, w_1 prefers m_2 in level 2 over m_3 in level 1, thus violating Assumption 2.

I4 Top Trading Cycles (TTC) on Example 4

In Step 1 of the TTC, M_2 and W_2 are the only two agents that are part of a cycle. They are matched in Step 1. The algorithm proceeds to Step 2. M_1 and W_1 are the only two agents that are part of a cycle. They are matched in Step 2. In Step 3, M_3 and W_3 point to one another, and are matched. Thus, the TTC algorithm produces the following assignment:

$$W_1 \to M_1, \quad W_2 \to M_2, \quad W_3 \to M_3$$