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OPTIMAL TAXATION, MARRIAGE, HOME PRODUCTION, AND FAMILY LABOR SUPPLY

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An empirical approach to optimal income taxation design is developed within an equilibrium collective marriage market model with imperfectly transferable utility. Taxes distort time allocation decisions, as well as marriage market outcomes, and the within household decision process. Using data from the American Community Survey and American Time Use Survey, we structurally estimate our model and explore empirical design problems. We allow taxes to depend upon marital status, with the form of tax jointness for married couples unrestricted. We find that the optimal tax system for married couples is characterized by negative jointness, although the welfare gains from jointness are modest. These welfare gains are then shown to be increasing in the gender wage gap, with taxes here, as in the case of gender based taxation, providing an instrument to address within household inequality.

KEYWORDS: Optimal income taxation, marriage, collective household models, intra-household allocation.

1. INTRODUCTION

TAX AND TRANSFER POLICIES often depend on family structure, with the tax treatment of married and single individuals varying significantly both across countries and over time. In the United States, there is a system of joint taxation where the household is taxed based on total family income. Given the progressivity of the tax system, it is not neutral with respect to marriage and both large marriage penalties and marriage bonuses coexist.[1] In contrast, the majority of OECD countries tax individuals separately based on each individual's income. In such a system, married couples are treated as two separate indi-

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[1]A marriage penalty is said to exist when the tax liability for a married couple exceeds the total tax liability of unmarried individuals with the same total income. The reverse is true for a marriage bonus. While married couples in the United States have the option of "Married Filing Jointly" or "Married Filing Separately," the latter is very different from the tax schedule that unmarried individuals face.

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viduals, and hence there is no subsidy or tax on marriage.[2] But what is the appropriate choice of tax unit and how *should* individuals and couples be taxed? A large and active literature concerns the optimal design of tax and transfer policies. In an environment where taxes affect the economic benefits from marriage, such a design problem has to balance redistributive objectives with efficiency considerations while recognizing that the structure of taxes may affect who gets married, and to whom they get married, as well as the intra-household allocation of resources.

Following the seminal contribution of Mirrlees (1971), a large theoretical literature has emerged that studies the optimal design of tax schedules for single individuals.[3] This literature casts the problem as a one-dimensional screening problem, recognizing the asymmetry of information that exists between agents and the tax authorities. The analysis of the optimal taxation of couples has largely been conducted in environments where the form of the tax schedule is restricted to be linearly separable, but with potentially distinct tax rates on spouses (see Boskin and Sheshinski (1983), Apps and Rees (1988, 1999, 2011), and Alesina, Ichino, and Karabarbounis (2011), for papers in this tradition).[4] A much smaller literature has extended the Mirrleesian approach to study the optimal taxation of couples as a two-dimensional screening problem. Most prominently, Kleven, Kreiner, and Saez (2009) consider a unitary model of the household, in which the primary earner makes a continuous labor supply decision (intensive only margin) while the secondary worker makes a participation decision (extensive margin), and characterize the optimal form of tax jointness. When the participation of the secondary earner provides a signal of the couple being better off, the tax rate on secondary earnings is shown to be *decreasing* with primary earnings.[5] Importantly, all of these studies take the married unit as given and ignore the distortionary effect of taxation on who gets married and to whom they get married, and the intra-household allocation of resources.

The theoretical optimal income taxation literature provides many important insights that are relevant when considering the design of a tax system. However, the *quantitative* empirical applicability of optimal tax theory is dependent upon a precise measurement of the key behavioral margins: How do taxes affect time allocation decisions, and the patterns of specialization within the household? How do taxes influence the allocation of resources within the household? What is the effect of taxes on the decision to marry and to whom? In order to examine both the optimal degree of progressivity and jointness of the tax schedule, and to empirically quantify the importance of the marriage market

[2]This is a oversimplification of actual tax systems. Even though many countries have individual income tax filing, there are often other ways in which tax jointness may emerge. For example, transfer systems often depend on family income and certain allowances may be transferable across spouses. See Immervoll, Kleven, Kreiner, and Verdelin (2009) for an evaluation of the tax-transfer treatment of married couples in Europe. Our estimation incorporates the combined influence of taxes and transfers on marriage and time allocation outcomes.

[3]See Brewer, Saez, and Shephard (2010) and Piketty and Saez (2013) for recent surveys.

[4]A quantitative macroeconomic literature compares joint and independent taxation in a nonoptimal taxation setting; see, for example, Chade and Ventura (2002) and Guner, Kaygusuz, and Ventura (2012).

[5]Negative jointness results from a redistributive concern. Intuitively, as the presence of a secondary earner has a greater impact on household welfare the lower are primary earnings, there will exist a greater value in redistributing from two-earner couples to one-earner couples when primary earnings are low. This means that the tax rate on the secondary earner must be decreasing in primary earnings. Kleven, Kreiner, and Saez (2007) also presented a doubly intensive model, where both the primary and secondary earner make continuous (intensive only) labor supply choices. Immervoll, Kleven, Kreiner, and Verdelin (2011) presented a double-extensive model of labor supply, and showed how tax rates vary under unitary and collective models with fixed decision weights. See also Brett (2007), Cremer, Lozachmeur, and Pestieau (2012), and Frankel (2014).

in shaping these, we follow Blundell and Shephard (2012) by developing an empirical structural approach to nonlinear income taxation design that centers the entire analysis around a rich microeconometric model.

Our key point of departure from the previous literature is to introduce a marriage market equilibrium into the optimal design problem. To this end, our model integrates the collective model of Apps and Rees (1988) and Chiappori (1988, 1992) with the empirical marriage-matching model developed in Choo and Siow (2006).[6] Individuals make marital decisions that comprise extensive (to marry or not) and intensive (marital sorting) margins based on utilities that comprise both an economic benefit and an idiosyncratic noneconomic benefit. The economic utilities are microfounded and are derived from the household decision problem. We consider an environment that allows for general nonlinear income taxes, includes both public and private good consumption, and distinguishes between the intensive and extensive labor supply margins. As an important economic benefit of marriage, we incorporate home production activities, which also helps us to replicate empirical marriage matching patterns. We do not introduce an exogenous primary/secondary earner distinction.[7]

Within the household, both explicit and implicit transfers are important. The leading paradigm for modeling matching in a marriage market involves transferable utility. The assumption of transferable utility implies that all transfers within the household take place at a constant rate of exchange, and hence the utility possibility frontier is linear. In this world, time allocation decisions would not depend upon the conditions of the marriage market, and taxation would not affect the relative decision weight of household members. As in the general framework presented in Galichon, Kominers, and Weber (2014, 2018), we therefore allow for utilities to be imperfectly transferable across spouses, thus generating a nonlinear utility possibility frontier. In this environment, we provide sufficient conditions for the existence and uniqueness of equilibrium in terms of the model primitives, demonstrate semiparametric identification, and describe a computationally efficient way to estimate the model using an equilibrium constraints approach.

Using data from the American Community Survey (ACS) and the American Time Use Survey (ATUS), we structurally estimate our equilibrium model, exploiting variation across markets in terms of both tax and transfer policies and population vectors. Given estimated differences in wage offers, we obtain decision weights in the household that typically favor the husband. We show that the model is able to jointly explain labor supply, home time, and marriage market patterns. Moreover, it is able to successfully explain the variation in these outcomes across markets, with the behavioral implications of the model shown to be consistent with the existing empirical evidence. We use our estimated model to examine problems related to the optimal design of the tax system by developing an extended Mirrlees framework. Our taxation design problem is based on an *individualistic* social-welfare function, with inequality both within and across households adversely affecting social welfare. Here, taxes distort labor supply and time allocation decisions, as

[6]Other papers have integrated collective and empirical marriage-matching models. Chiappori, Costa Dias, and Meghir (2017) considered a model of education and marriage with life-cycle labor supply and consumption in a transferable utility setting; Choo and Seitz (2013) estimated a semiparametric version of their static family labor supply model; Galichon, Kominers, and Weber (2018) provided an empirical application where they estimated a matching model with consumption, allowing for imperfectly transferable utility (as we consider here). None of these papers address optimal taxation questions.

[7]The large growth in female labor force participation has made the traditional distinction between primary and secondary earners much less clear. Women now make up around half of the U.S. workforce, with an increasing fraction of households in which the female is the primary earner (Blau and Kahn (2007)).

well as marriage market outcomes, and the within-household decision weight. We allow for a general specification of the tax schedule for both singles and married couples, that nests both individual and fully joint taxation, but also allows for arbitrary forms of tax jointness. We find empirical support for negative jointness in the tax schedule for couples, but find that the welfare gains that this offers relative to a system of individual income taxation are relatively modest. More generally, we show that the gains from introducing jointness in the tax system are increasing in the size of the gender wage gap, with taxes also providing an instrument to lessen the impact of an increased wage gap on household decision weights. The relationship between taxes and within household inequality, which arises due to marriage market considerations, is made even starker when we assess the potential role for gender-based taxes. We also consider the importance of the marriage market more generally, and quantify the cost of neglecting marriage market considerations. When the tax schedule exhibits a strong nonneutrality with respect to marriage, these costs are shown to be sizeable.

The remainder of the paper proceeds as follows. In Section 2, we present our equilibrium model of marriage, consumption, and time allocation, while in Section 3 we introduce the analytical framework that we use to study taxation design. In Section 4, we describe our data and empirical specification, discuss the semiparametric identification of our model, and present our estimation procedure and results. In Section 5, we then consider the normative implications of our estimated model, both when allowing for a very general form of jointness in the tax schedule and when it is restricted. Here, we also present extensions that allow for gender based taxation, and consider the importance of the gender wage gap. Finally, Section 6 concludes.

2. A MODEL OF MARRIAGE AND TIME ALLOCATION

We present an empirical model of marriage-matching and intra-household allocations by considering a static equilibrium model of marriage with imperfectly transferable utility, labor supply, home production, and potentially joint and nonlinear taxation. The economy comprises K separate markets.[8] Given that there are no interactions across markets, we suppress explicit conditioning on a market unless such a distinction is important and proceed to describe the problem for that market. In such a market, there are I types of men and J types of women. The population vector of men is given by $\boldsymbol{\mathcal{M}}$, whose element $m_i > 0$ denotes the measure of type-i males. Similarly, the population vector of women is given by $\boldsymbol{\mathcal{F}}$, whose element $f_j > 0$ denotes the measure of type-j females. Associated with each male and female type is a utility function, a distribution of wage offers, a productivity of home time, a distribution of preference shocks, a value of nonlabor income, and a demographic transition function (which is defined for all possible spousal types). While we are more restrictive in our empirical application, in principle all these objects may vary across markets. Moreover, these markets may differ in their tax system T and the economic/policy environment more generally.

We make the timing assumption that the *realizations* of wage offers, preference shocks, and demographic transitions only occur following the clearing of the marriage market. There are therefore two (interconnected) stages to our analysis. First, there is the characterization of a *marriage matching function*, which is an $I \times J$ matrix $\boldsymbol{\mu}(T)$ whose $\langle i, j\rangle$ element $\mu_{ij}(T)$ describes the measure of type-i males married to type-j females, and which

[8]We do not allow for migration across these markets. Allowing migration due to labor market and marriage market opportunities is an interesting extension for future work. See Eeckhout and Guner (2017) for an examination of nonlinear income taxation in a model with migration and housing.

we write as a function of the tax system T.[9] Note that we do not allow for a cohabitation state.[10] The second stage of our analysis, which follows marriage decisions, is then concerned with the joint time allocation and resource sharing problem for households. These two stages are linked through the decision weight in the household problem: these affect the second stage problem and so the expected value of an individual from any given marriage market pairing. Given our timing assumption, these household decision (or Pareto) weights only vary with marriage-type pairings, and adjust to clear the marriage market such that there is neither excess demand nor supply of any given type.

2.1. *Time Allocation Problem*

We now describe the problem of singles individuals and married couples once the marriage market has cleared. At this stage, all uncertainty (wage offers, preference shocks, and demographic transitions) has been resolved and time and resource allocation decisions are made. Individuals have preferences defined over leisure, consumption of a market private good (whose price we normalize to 1), and a nonmarketable public good produced with home time.

2.1.1. *Time Allocation Problem: Single Individuals*

Consider a single type-i male with wage rate w^i, nonlabor income y^i, and demographic characteristics $\mathbf{X}^i$. His total time endowment is L_0, and he chooses the time allocation vector $\mathbf{a}^i = [\ell^i, h_w^i, h_Q^i]$ comprising hours of leisure ℓ^i, market work time h_w^i, and home production time h_Q^i, to maximize his utility. Market work time determines the consumption level of the market private good q^i through the budget constraint, while home time determines the consumption of the nonmarketable public good Q^i. Time allocation decisions are discrete,[11] with all feasible time allocation vectors described by the set $\mathbf{A}^i$. All allocations that belong to this set satisfy the time constraint $L_0 = \ell^i + h_w^i + h_Q^i$. Associated with each possible discrete allocation is the additive state specific error $\epsilon_{\mathbf{a}^i}$. Excluding any additive idiosyncratic payoff from remaining single, the individual decision problem may formally be described by the following utility maximization problem:

$$\max_{\mathbf{a}^i \in \mathbf{A}^i} u^i\big(\ell^i, q^i, Q^i; \mathbf{X}^i\big) + \epsilon_{\mathbf{a}^i} \tag{1a}$$

$$\text{subject to } q^i = y^i + w^i h_w^i - T\big(w^i h_w^i, y^i; \mathbf{X}^i\big) - FC\big(h_w^i; \mathbf{X}^i\big), \tag{1b}$$

$$Q^i = \zeta_{i0}\big(\mathbf{X}^i\big) \cdot h_Q^i. \tag{1c}$$

[9]Individuals may also choose to remain unmarried, and we use $\mu_{i0}(T)$ and $\mu_{0j}(T)$ to denote the respective measures of single males and females. The marriage matching function must satisfy the usual feasibility constraints. Suppressing the dependence on T, we require that $\mu_{i0} + \sum_j \mu_{ij} = m_i$ for all i, $\mu_{0j} + \sum_i \mu_{ij} = f_j$ for all j, and $\mu_{i0}, \mu_{0j}, \mu_{ij} \geq 0$ for all i and j.

[10]Not allowing for cohabitation is a common assumption in the empirical marriage matching literature. See Mourifié and Siow (2014) for an exception. We use the United States as our empirical environment, where cohabitation only accounts for around 7% of households from our estimation sample. Furthermore, cohabitation in the U.S. is much more of a transitional household state (see Lundberg and Pollak (2014)) and arguably may be more suitably modeled in a dynamic environment.

[11]The presence of taxes and transfers implies nonlinear and potential nonconvex budget sets. The discrete choice framework, by formulating the problem as the choice from a finite set of alternatives, provides a particularly convenient and popular way of avoiding the computational and analytical difficulties associated with utility maximization in a continuous choice setting; see, for example, van Soest (1995), Hoynes (1996), Keane and Moffitt (1998), and Blundell and Shephard (2012).

Equation (1b) states that consumption of the private good is simply equal to net family income (the sum of earnings and nonlabor income, minus net taxes) and less any possible fixed costs of market work, $FC(h_w^i; \mathbf{X}^i) \geq 0$. These fixed costs, as in Cogan (1981), are nonnegative for positive values of working time, and zero otherwise. Equation (1c) says that total production/consumption of the home good is equal to the efficiency units of home time, where the efficiency scale $\zeta_{i0}(\mathbf{X}^i)$ may depend upon both own type (type-i) and demographic characteristics $\mathbf{X}^i$.

The solution to this constrained utility maximization problem is described by the incentive compatible time allocation vector $\mathbf{a}_{i0}^{i\star}(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T)$, which upon substitution into equation (1a), including the state-specific preference term associated with this allocation, yields the indirect utility function for type-i males that we denote as $v_{i0}^i(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T)$. The decision problem for type-j single women is described similarly and yields the indirect utility function $v_{0j}^j(w^j, y^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j; T)$.

2.1.2. *Time and Resource Allocation Problem: Married Individuals*

Married individuals are egoistic, and we consider a collective model that assumes an efficient allocation of intra-household resources (Chiappori (1988, 1992)).[12] An important economic benefit of marriage is given by the publicness of some consumption. The home-produced good (that is produced by combining male and female home time) is public within the household, and so both members consume it equally.

Consider an $\langle i, j\rangle$ couple and let $\lambda_{ij} \in [0, 1]$ denote the Pareto weight on female utility in such a union. The weight on male utility is $1 - \lambda_{ij}$. The household chooses a time allocation vector for each adult and determines how total private consumption is divided between the spouses. Note that the state-specific errors $\epsilon_{\mathbf{a}^i}$ and $\epsilon_{\mathbf{a}^j}$ for any individual depend only on his/her own time allocation and not on the time allocation of his/her spouse. Moreover, the distributions of these preference terms, as well as the form of the utility function, do not change with marriage. Letting $\mathbf{w} = [w^i, w^j]$, $\mathbf{y} = [y^i, y^j]$, $\mathbf{X} = [\mathbf{X}^i, \mathbf{X}^j]$, $\mathbf{h}_w = [h_w^i, h_w^j]$, and $\mathbf{h}_Q = [h_Q^i, h_Q^j]$, the household problem is

$$\begin{aligned} \max_{\mathbf{a}^i \in \mathbf{A}^i, \mathbf{a}^j \in \mathbf{A}^j, s_{ij} \in [0,1]} & (1 - \lambda_{ij}) \cdot \left[u^i\left(\ell^i, q^i, Q; \mathbf{X}^i\right) + \epsilon_{\mathbf{a}^i}\right] \\ & + \lambda_{ij} \cdot \left[u^j\left(\ell^j, q^j, Q; \mathbf{X}^j\right) + \epsilon_{\mathbf{a}^j}\right] \end{aligned} \tag{2a}$$

$$\begin{aligned} \text{subject to } q &= q^i + q^j \\ &= y^i + y^j + \mathbf{w}^\intercal \mathbf{h}_w - T\left(w^i h_w^i, w^j h_w^j, \mathbf{y}; \mathbf{X}\right) - FC(\mathbf{h}_w; \mathbf{X}), \end{aligned} \tag{2b}$$

$$q^j = s_{ij} \cdot q, \tag{2c}$$

$$Q = \widetilde{Q}_{ij}(\mathbf{h}_Q; \mathbf{X}). \tag{2d}$$

In turn, this set of equality constraints describe (i) that *total* family consumption of the private good equals family net income (with the tax schedule here allowed to depend very generally on the labor market earnings of both spouses) less any fixed work-related costs; (ii) the wife consumes the endogenous share $0 \leq s_{ij} \leq 1$ of the private good; and (iii) the

[12] There are two principal ways of modeling the household in a nonunitary setting. First, there are collective (cooperative) models as we consider here, where allocations are assumed to be Pareto efficient. Second, there are strategic (noncooperative) models based on Cournot–Nash equilibrium (e.g., Del Boca and Flinn (1995)). Donni and Chiappori (2011) provided a recent survey of nonunitary models.

public good is produced using home time with the production function $\widetilde{Q}_{ij}(\mathbf{h}_Q; \mathbf{X})$, which may also depend upon demographic characteristics.

Letting $\boldsymbol{\epsilon} = [\boldsymbol{\epsilon}^i, \boldsymbol{\epsilon}^j]$, the solution to the household problem is described by the incentive compatible time allocation vectors $\mathbf{a}_{ij}^{i\star}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})$ and $\mathbf{a}_{ij}^{j\star}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})$, together with the private consumption share $s_{ij}^{\star}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})$. Upon substitution into the individual utility functions (and including the state-specific error associated with the individual's own time allocation decision), we obtain the respective male and female indirect utility functions $v_{ij}^i(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})$ and $v_{ij}^j(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})$.

2.2. *Marriage Market*

We embed our time allocation model in a frictionless empirical marriage-matching model. As noted above, an important timing assumption is that marriage market decisions are made prior to the realization of wage offers, preference shocks, and demographic transitions. Thus, decisions are made based upon the expected value of being in a given marital pairing, together with an idiosyncratic component that we describe below.

2.2.1. *Expected Values*

Anticipating our later application, we write the expected values from remaining single for a type-i male and type-j female (excluding any additive idiosyncratic payoff that we describe below) as explicit functions of the tax system T. These are given by

$$U_{i0}^i(T) = \mathbb{E}\big[v_{i0}^i\big(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T\big)\big],$$
$$U_{0j}^j(T) = \mathbb{E}\big[v_{0j}^j\big(w^j, y^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j; T\big)\big],$$

where the expectation is taken over wage offers, demographics, and the preference shocks. For married individuals, their expected values (again excluding any additive idiosyncratic utility payoffs) may similarly be written as a function of the both the tax system T and a candidate Pareto weight λ_{ij} associated with a type $\langle i, j\rangle$ match

$$U_{ij}^i(T, \lambda_{ij}) = \mathbb{E}\big[v_{ij}^i(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})\big],$$
$$U_{ij}^j(T, \lambda_{ij}) = \mathbb{E}\big[v_{ij}^j(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij})\big].$$

Note that the Pareto weight within a match does not depend upon the realization of uncertainty. This implies full commitment and efficient risk sharing within the household.[13] The expected value of a type-i man when married to a type-j woman is strictly decreasing in the wife's Pareto weight λ_{ij}, while the expected value of the wife is strictly increasing in λ_{ij}. Moreover, we also obtain a condition that relates the change in male and female expected utilities as we vary the wife's Pareto weight

$$\frac{\partial U_{ij}^i(T, \lambda_{ij})}{\partial \lambda} = -\frac{\lambda_{ij}}{1-\lambda_{ij}} \times \frac{\partial U_{ij}^j(T, \lambda_{ij})}{\partial \lambda} < 0. \tag{3}$$

We use this relationship later when demonstrating identification of the Pareto weight.

[13]Other papers have considered nonequilibrium environments with limited commitment, where couples cooperate but are unable to commit to future allocations of resources; see, for example, Mazzocco (2007).

2.2.2. *Marriage Decision*

As in Choo and Siow (2006), we assume that in addition to the systematic component of utility (as given by the expected values above) a given male g receives an idiosyncratic payoff that is specific to him and the type of spouse j that he marries but not her specific identity. These idiosyncratic payoffs are denoted $\theta_{ij}^{i,g}$ and are observed prior to the marriage decision. Additionally, each male also receives an idiosyncratic payoff from remaining unmarried that depends on his specific identity and is similarly denoted as $\theta_{i0}^{i,g}$. The marriage decision problem of a given male g is therefore to choose to marry one of the J possible types of spouses or to remain single. His decision problem is therefore

$$\max_j\{U_{i0}^i(T)+\theta_{i0}^{i,g}, U_{i1}^i(T,\lambda_{i1})+\theta_{i1}^{i,g},\dots,U_{iJ}^i(T,\lambda_{iJ})+\theta_{iJ}^{i,g}\}, \tag{4}$$

where the choice $j=0$ corresponds to the single state.

We assume that the idiosyncratic payoffs follow the Type-I extreme value distribution with a zero location parameter and the scale parameter σ_θ. This assumption implies that the proportion of type-i males who would like to marry a type-j female (or remain unmarried) are given by the conditional choice probabilities

$$\begin{aligned} p_{ij}^i(T,\boldsymbol{\lambda}^i) &= \Pr\left[U_{ij}^i(T,\lambda_{ij})+\theta_{ij}^{i,g} > \max\{U_{ih}^i(T,\lambda_{ih})+\theta_{ih}^{i,g}, U_{i0}^i(T)+\theta_{i0}^{i,g}\}\ \forall h\neq j\right] \\ &= \frac{\mu_{ij}^d(T,\boldsymbol{\lambda}^i)}{m_i} = \frac{\exp\left[U_{ij}^i(T,\lambda_{ij})/\sigma_\theta\right]}{\exp\left[U_{i0}^i(T)/\sigma_\theta\right]+\sum_{h=1}^J\exp\left[U_{ih}^i(T,\lambda_{ih})/\sigma_\theta\right]}, \end{aligned} \tag{5}$$

where $\boldsymbol{\lambda}^i=[\lambda_{i1},\dots,\lambda_{iJ}]^\intercal$ is the $J\times 1$ vector of Pareto weights associated with different spousal options for a type-i male, and $\mu_{ij}^d(T,\boldsymbol{\lambda}^i)$ is the measure of type-i males who "demand" type-j females (the conditional choice probabilities $p_{ij}^i(T,\boldsymbol{\lambda}^i)$ multiplied by the measure of type-i men). Women also receive idiosyncratic payoffs associated with the different marital states (including singlehood) and their marriage decision problem is symmetrically defined. With identical distributional assumptions, the proportion of type-j females who would like to marry a type-i male is given by

$$p_{ij}^j(T,\boldsymbol{\lambda}^j)=\frac{\mu_{ij}^s(T,\boldsymbol{\lambda}^j)}{f_j}=\frac{\exp\left[U_{ij}^j(T,\lambda_{ij})/\sigma_\theta\right]}{\exp\left[U_{0j}^j(T)/\sigma_\theta\right]+\sum_{g=1}^I\exp\left[U_{gj}^j(T,\lambda_{gj})/\sigma_\theta\right]}, \tag{6}$$

where $\boldsymbol{\lambda}^j=[\lambda_{1j},\dots,\lambda_{Ij}]^\intercal$ is the $I\times 1$ vector of Pareto weights for a type-j female, and $\mu_{ij}^s(T,\boldsymbol{\lambda}^j)$ is the measure of type-j females who would choose type-i males. We also refer to this measure as the "supply" of type-j females to the $\langle i,j\rangle$ sub-marriage market.

2.2.3. *Marriage Market Equilibrium*

An equilibrium of the marriage market is characterized by an $I\times J$ matrix of Pareto weights $\boldsymbol{\lambda}=[\boldsymbol{\lambda}^1,\boldsymbol{\lambda}^2,\dots,\boldsymbol{\lambda}^J]$ such that for all $\langle i,j\rangle$ the measure of type-j females demanded by type-i men is equal to the measure of type-j females supplied to type-i males. That is,

$$\mu_{ij}(T,\boldsymbol{\lambda})=\mu_{ij}^d(T,\boldsymbol{\lambda}^i)=\mu_{ij}^s(T,\boldsymbol{\lambda}^j)\quad \forall i=1,\dots,I, j=1,\dots,J, \tag{7}$$

where we note that the equilibrium weights will depend on the distribution of economic gains from alternative marriage market pairings, the distribution of idiosyncratic marital payoffs, and the relative scarcity of spouses of different types. Along with the usual regularity conditions, which are formally stated in Online Appendix A of the Supplemental Material (Gayle and Shephard (2019)), a sufficient condition for the existence and uniqueness of a marriage market equilibrium is provided in Proposition 1. This states that the limit of individual utility is negative infinity as his/her private consumption approaches zero. Essentially, this condition allows us to make utility for any individual arbitrarily low through suitable choice of Pareto weight. We now state our formal existence and uniqueness proposition.

PROPOSITION 1: *If the idiosyncratic marriage market payoffs follow the Type-I extreme value distribution, the regularity conditions stated in Online Appendix* A *hold and the utility function satisfies*

$$\lim_{q^i \to 0} u^i(\ell^i, q^i, Q; \mathbf{X}^i) = \lim_{q^j \to 0} u^j(\ell^j, q^j, Q; \mathbf{X}^j) = -\infty, \tag{8}$$

then an equilibrium of the marriage market exists and is unique.

PROOF: See Online Appendix A. *Q.E.D.*

Our proof is based on constructing excess demand functions and then showing that a unique Walrasian equilibrium exists. This is the same approach used by Galichon, Kominers, and Weber (2018) under a more general heterogeneity structure. In Online Appendix B, we describe the algorithm and approximation methods that we apply when solving for the equilibrium of the marriage market given any tax and transfer system T. In that Appendix, we also note important properties regarding how the algorithm scales as the number of markets is increased.

3. OPTIMAL TAXATION FRAMEWORK

In this section, we present the analytical framework that we use to study tax reforms that are optimal under a social-welfare function. The social planners problem is to choose a tax system T to maximize a social-welfare function subject to a revenue requirement, the individual/household incentive compatibility constraints, and the marriage market equilibrium conditions. The welfare function is taken to be *individualistic*, and is based on individual maximized (incentive compatible) utilities following both the clearing of the marriage market, and the realizations of all uncertainty. Note that inequality both within and across households will adversely affect social welfare.

In what follows, $G^i_{i0}(w^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i)$ and $G^j_{0j}(w^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j)$, respectively, denote the single type-i male and single type-j female joint cumulative distribution functions for wage offers, state-specific errors, and demographic transitions.[14] The joint cumulative distribution function within an $\langle i, j\rangle$ match is similarly denoted $G_{ij}(\mathbf{w}, \mathbf{X}, \boldsymbol{\epsilon})$. As individuals nonrandomly select into different marital pairings given their idiosyncratic marital payoffs, the distribution of these within a match will differ from the unconditional extreme value

[14]Our analysis assumes wage offers and nonlabor income are invariant with respect to the tax system. A model with an endogenous human capital stage, as in Chiappori, Costa Dias, and Meghir (2017), for example, would have more complex implications for the optimal design problem.

distribution for the population as a whole. They are therefore also a function of tax policy. We let $H^i_{i0}(\theta^i; T)$ denote the cumulative distribution function among single type-i males, and similarly define $H^j_{0j}(\theta^j; T)$ for single type-j females. Among married men and women in an $\langle i, j\rangle$ match, these are given by $H^i_{ij}(\theta^i; T)$ and $H^j_{ij}(\theta^j; T)$, respectively. We provide a theoretical characterization of these distributions in Online Appendix F.

Our simulations will consider the implications of alternative redistributive preferences for the planner, which we will capture through the utility transformation function $\Upsilon(\cdot)$.[15] The social-welfare function is defined as the sum of these transformed utilities

$$\begin{aligned}
&\mathcal{W}(T) \\
&\quad = \underbrace{\sum_i \mu_{i0}(T) \int \Upsilon\big[v^i_{i0}\big(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T\big) + \theta^i\big] \,\mathrm{d}G^i_{i0}\big(w^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i\big) \,\mathrm{d}H^i_{i0}\big(\theta^i; T\big)}_{\text{single men}} \\
&\qquad + \underbrace{\sum_j \mu_{0j}(T) \int \Upsilon\big[v^j_{0j}\big(w^j, y^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j; T\big) + \theta^j\big] \,\mathrm{d}G^j_{0j}\big(w^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j\big) \,\mathrm{d}H^j_{0j}\big(\theta^j; T\big)}_{\text{single women}} \\
&\qquad + \underbrace{\sum_{i,j} \mu_{ij}(T) \int \Upsilon\big[v^i_{ij}\big(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij}(T)\big) + \theta^i\big] \,\mathrm{d}G_{ij}(\mathbf{w}, \mathbf{X}, \boldsymbol{\epsilon}) \,\mathrm{d}H^i_{ij}\big(\theta^i; T\big)}_{\text{married men}} \\
&\qquad + \underbrace{\sum_{i,j} \mu_{ij}(T) \int \Upsilon\big[v^j_{ij}\big(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij}(T)\big) + \theta^j\big] \,\mathrm{d}G_{ij}(\mathbf{w}, \mathbf{X}, \boldsymbol{\epsilon}) \,\mathrm{d}H^j_{ij}\big(\theta^j; T\big)}_{\text{married women}}.
\end{aligned} \tag{9}$$

The maximization of $\mathcal{W}(T)$ is subject to a number of constraints. First, there are the usual incentive compatibility constraints that require that time allocation and consumption decisions are optimal given T. We embed this requirement in equation (9) through the inclusion of indirect utility functions. Second, individuals optimally select into different marital pairings based upon expected values and realized idiosyncratic payoffs (equation (4)). Third, we obtain a marriage market equilibrium so there is neither an excess demand nor supply of spouses in each sub-marriage market (equation (7)). Fourth, an exogenously determined revenue amount $\overline{T}$ is raised, as given by the revenue constraint

$$\begin{aligned}
\mathcal{R}(T) = {}& \underbrace{\sum_i \mu_{i0}(T) \int R^i_{i0}\big(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T\big) \,\mathrm{d}G^i_{i0}\big(w^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i\big)}_{\text{revenue from single men}} \\
& + \underbrace{\sum_j \mu_{0j}(T) \int R^j_{0j}\big(w^j, y^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j; T\big) \,\mathrm{d}G^j_{0j}\big(w^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j\big)}_{\text{revenue from single women}}
\end{aligned} \tag{10}$$

[15]Note that in general, this formulation implies that the planner is weighting individual utilities differently relative to the household (as determined by the market clearing vector of Pareto weights).

$$+\underbrace{\sum_{i,j}\mu_{ij}(T)\int R_{ij}\big(\mathbf{w},\mathbf{y},\mathbf{X},\boldsymbol{\epsilon};T,\lambda_{ij}(T)\big)\,\mathrm{d}G_{ij}(\mathbf{w},\mathbf{X},\boldsymbol{\epsilon})}_{\text{revenue from married couples}}\geq\overline{T},$$

where $R^i_{i0}(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T)$ describes the tax revenue raised from an optimizing type-i single male given w^i, y^i, $\mathbf{X}^i$, $\boldsymbol{\epsilon}^i$, and the tax system T. We similarly define $R^j_{0j}(w^j, y^j, \boldsymbol{\epsilon}^j, \mathbf{X}^j; T)$ for single type-j women, and $R_{ij}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij}(T))$ for married $\langle i, j\rangle$ couples. While we are agnostic regarding what the government does with this revenue, we are assuming that it does not interact with either marriage market or time allocation decisions.

Taxes affect the problem in the following ways. First, they have a direct effect on welfare and revenue holding behavior and the marriage market fixed. Second, there is a behavioral effect such that time allocations within a match change and affect both welfare and revenue. Third, there is a marriage market effect that changes who marries whom, the allocation of resources within the household (through adjustments in the Pareto weights), and the distribution of the idiosyncratic payoffs within any given match.

4. DATA, IDENTIFICATION AND ESTIMATION

4.1. *Data*

We use two data sources for our estimation. First, we use data from the 2006 ACS which provides us with information on education, marital patterns, demographics, incomes, and labor supply. We supplement this with pooled ATUS data, which we use to construct a broad measure of home time for individuals sampled in the pre-recession period (2002–2007).[16] Following Aguiar and Hurst (2007) and Aguiar, Hurst, and Karabarbounis (2012), we segment the total endowment of time into three broad mutually exclusive time-use categories: work activities, home production activities, and leisure activities. Home production contains core home production, activities related to home ownership, obtaining goods and services, care of other adults, and child care hours that measure all time spent by an individual caring for, educating, or playing with his/her child(ren).[17]

For both men and women, we define three broad education groups for our analysis: high school and below, some college (less than four years of college), and college and above (a four-year or advanced degree). These constitute the individual *types* for the purposes of marriage market matching. Our sample is restricted to single individuals ages 25–45 (inclusive). For married couples, we include all individuals where the reference householder (as defined by the Census Bureau) belongs to this same age band.[18]

[16]The ATUS is a nationally representative cross-sectional time-use survey launched in 2003 by the U.S. Bureau of Labor Statistics. The ATUS interviews randomly selected individuals age 15 and older from a subset of the households that have completed their eighth and final interview for the Current Population Survey, the U.S. monthly labor force survey. See Aguiar, Hurst, and Karabarbounis (2012) for a full list of the time-use categories contained in the ATUS data.

[17]We use sample weights when constructing empirical moments from each data source. Measures of home time from ATUS are constructed based on a 24-hour time diary completed by survey respondents. We adjust the sample weights so we continue to have a uniform distribution of weekdays following our sample selection. This is a common adjustment; see, for example, Frazis and Stewart (2007).

[18]Similar age selections and educational categorizations are common in the marriage market literature. Papers that have used similar categories include Choo and Siow (2006), Choo and Seitz (2013), Goussé, Jacquemet, and Robin (2017), Chiappori, Iyigun, and Weiss (2009), and Chiappori, Salanié, and Weiss (2017). We have also estimated our model with four groups (less than high school, high school, some college, college and above) and find both our estimation results and our tax design experiments to be quantitatively robust.

Our estimation allows for market variation in the population vectors and the economic environment (taxes and transfers). We define a market at the level of the Census Bureau-designated division, with each division comprising a small number of states.[19] Within these markets, we calculate accurate tax schedules (defined as piecewise linear functions of family earnings) prior to estimation using the National Bureau of Economic Research TAXSIM calculator (see Feenberg and Coutts (1993)). These tax schedules include both federal and state tax rates (including the Earned Income Tax Credit) supplemented with detailed program rules for major welfare programs. The inclusion of welfare benefits is important as it allows us to better capture the financial incentives for lower-income households. We describe our implementation of these welfare rules and the calculation of the combined tax and transfer schedules in Online Appendix C.

4.2. *Empirical Specification*

In Section 4.5, we will see that there are important differences between men and women in the labor supply and the time spent on home production activities. Moreover, there are large differences between those who are single and those who are married (and to whom married). Our aim is to construct a credible and parsimonious model of time allocation decisions that can well describe these facts.

All the estimation and simulation results presented here assume individual preferences that are separable in the private consumption good, leisure, and the public good consumption. Preferences are unchanged by the marriage, and similarly do not vary with worker type (education), gender, or other demographic characteristics. Specifically,

$$u(\ell, q, Q; \mathbf{X}) = \frac{q^{1-\sigma_q} - 1}{1 - \sigma_q} + \beta_\ell \frac{\ell^{1-\sigma_\ell} - 1}{1 - \sigma_\ell} + \beta_Q \frac{Q^{1-\sigma_Q} - 1}{1 - \sigma_Q}. \tag{11}$$

This preference specification allows us to derive an analytical expression for the private good consumption share s_{ij} for any joint time allocation in the household (i.e., the solution to equation (2a)). Given our parametrization, s_{ij} is independent of the total household private good consumption and is tightly connected to the Pareto weight. We have

$$s_{ij}(\lambda_{ij}) = \left[1 + \left(\frac{\lambda_{ij}}{1 - \lambda_{ij}}\right)^{-1/\sigma_q}\right]^{-1},$$

which is clearly increasing in the female weight λ_{ij}. In the case that $\sigma_q = 1$ this expression reduces to $s_{ij}(\lambda_{ij}) = \lambda_{ij}$. To ensure that the sufficient conditions required for the existence and uniqueness of a marriage market equilibrium are satisfied (as described in Proposition 1), we require that $\sigma_q \geq 1$.

In our empirical application, the demographic characteristics $\mathbf{X}$ will correspond to the presence of dependent children in the household.[20] For singles, the demographic transition process depends on gender and own type. For married couples they depend on both

[19] There are nine U.S. Census Bureau divisions. We do not use a finer level of market disaggregation due to sample size and computational considerations. An alternative feasible approach (but at the loss of sample size, and with migration across markets becoming more of a concern) which we considered was to estimate the model on the most populous state from each of these Census divisions. This resulted in slightly lower marginal tax rates in our subsequent tax simulations, but the overall shape of the schedule including the degree of tax jointness was found to be robust.

[20] The model presented does not have a cohabitation state. For individuals with children who were observed to be cohabiting, we treat them as both a single man and a single women with children. Consistent with the

own type and spousal type. Thus individuals are essentially making joint marriage and fertility decisions. These transition processes are estimated nonparametrically by market. Demographics (children) enter the model in the follow ways. First, children directly enter the empirical tax schedule, T. Second, children may affect the fixed work related costs (see equations (1b) and (2b)) with fixed costs restricted to be zero for individuals without children. Third, as we now describe, the presence of children may affect home time productivity.

The home time productivity of singles without children is restricted to be the same for both men and women. It may vary with education type. We allow this productivity to vary by gender for individuals with children. For married couples, we assume a Cobb–Douglas home production technology that depends on the time inputs of both spouses, h_Q^i and h_Q^j, as well as a match specific term $\zeta_{ij}(\mathbf{X})$ that determines the overall efficiency of production within an $\langle i, j\rangle$ match and with demographics characteristics $\mathbf{X}$. That is,

$$\widetilde{Q}_{ij}\big(h_Q^i, h_Q^j; \mathbf{X}\big) = \zeta_{ij}(\mathbf{X}) \times \big(h_Q^i\big)^{\alpha}\big(h_Q^j\big)^{1-\alpha}. \tag{12}$$

In our application, we restrict the specification of the match specific component. For all married households without children, we set $\zeta_{ij}(\mathbf{X}) = 1$. For married households with children, we restrict the match specific component in an $\langle i, j\rangle$ match to be of the form $\widetilde{\zeta}_j \times \vartheta_j^{\mathbb{1}[i=j]}$. The parameter ϑ_j captures potential complementarity in the home production technology in educationally homogamous marriages.[21]

In addition to the home technology, individual heterogeneity also enters our empirical specification through market work productivity. Log-wage offers are normally distributed, with the parameters of the distribution an unrestricted function of both gender and the level of education.[22]

We define the time allocation sets $\mathbf{A}^i$ and $\mathbf{A}^j$ symmetrically for all individuals. The total time endowment L_0 is set equal to 112 hours per week.[23] To construct these sets, we assume that both leisure and home time have a nondiscretionary component (4 hours and 12 hours, respectively), and then define the residual discrete grid comprising 9 equispaced values. A unit of time is therefore given by $(112 - 12 - 4)/(9 - 1) = 12$ hours. Restricting market work and (discretionary) home time to be no more than 60 hours per week, there are a total of 30 discrete time allocation alternatives for individuals and $30^2 = 900$ discrete alternatives for married couples.

The state-specific errors $\boldsymbol{\epsilon}_{\mathbf{a}^i}$ and $\boldsymbol{\epsilon}_{\mathbf{a}^j}$ associated with the individual time allocation decisions are Type-I extreme value with the scale parameter σ_ϵ. The marriage decision depends upon the expected value of a match. For couples, the maximization problem of the household is not the same as the utility maximization problem of an individual. As a

arguments made in Lundberg and Pollak (2014), this means that individuals in such unions are treated as if they are not able to enjoy the public good quality of home time. When calculating tax liabilities, we only allow women to claim children as a dependent.

[21]These restrictions were informed by first estimating a more general specification. Note also that absent a measurement system for home produced output, preferences for the home produced good are indistinct from the production technology. For example, the parameter σ_Q may reflect curvature in the utility or returns to scale in the production process.

[22]The realizations of wage offers within the household are independent conditional on male and female type. We have experimented with introducing a covariance structure which mimics the empirical correlation in accepted wages, and find that it only has a small quantitative impact in our optimality simulations.

[23]We assume that the equivalent of eight hours a day are allocated to sleep and personal care. Our measure of leisure therefore corresponds to "Leisure Measure 1" from Aguiar and Hurst (2007).

result, the well-known convenient results for expected utility and conditional choice probabilities in the presence of extreme value errors (see, e.g., McFadden (1978)) do not apply for married individuals. We therefore evaluate these objects numerically.[24]

4.3. *Identification*

The estimation will be of a fully specified parametric model. It is still important to explore non/semiparametric identification of the model because it indicates the source of variation in the data that is filtered through the economic model that gives rise to the parameter estimates, versus which parameter estimates arise from the functional form imposed in estimation. Here, we explore semiparametric identification. Using the marriage market equilibrium conditions and variation in the population vectors across markets, we prove identification of the wife's Pareto weight. Then using observations on the time allocation decisions of single and married individuals, we prove identification of the primitives of the model, that is, the utility function, home production technology, and parameters of the distributions of state-specific errors.

4.3.1. *Identifying the Wife's Pareto Weight From Marriage*

The literature on the identification of collective models largely focuses on the identification and estimation of the sharing rule. While knowledge of the sharing rule is useful in answering a large set of empirical questions, for the purposes of our empirical taxation design exercise, it is the set of model primitives and the household decision weights that are important. In the context of a collective model with both public and private goods, Blundell, Chiappori, and Meghir (2005) and Browning, Chiappori, and Lewbel (2013) show that if there exists a distribution factor, then both the model primitives and the household decision weights are identified. With such a model embed in an equilibrium marriage market setting, the existence of a distribution factor becomes synonymous with variation across marriage markets. Below we show how the marriage market equilibrium conditions, together with market variation, allow us to identify the household decision weight under very mild conditions.

PROPOSITION 2: *Under the conditions stated in Proposition* 1, *and with sufficient market variation in population vectors*, *the wife's Pareto weight is identified*.

PROOF: See Online Appendix D.1. *Q.E.D.*

The strongest assumption for the identification of the wife's Pareto weights is that the idiosyncratic marital payoffs are distributed Type-I extreme value with an unknown scale parameter.[25] This distributional assumption, is however, used at every stage of our analysis. In particular, it was used when establishing the existence and uniqueness of equilibrium (see Section 2.2) and in the computation of equilibrium. It is also used later when

[24]We approximate the integral over these preference shocks through simulation. To preserve smoothness of our distance metric (in estimation), as well as the welfare and revenue functions (in our design simulations), we employ a Logistic smoothing kernel. Conditional on $(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon})$ and the match $\langle i, j\rangle$, this assigns a *probability* of any given joint allocation being chosen by the household. We implement this by adding an extreme value error with scale parameter $\tau_\epsilon > 0$ that varies with all possible joint discrete time alternatives. The probability of a given joint time allocation is given by the usual conditional Logit form. As the smoothing parameter $\tau_\epsilon \to 0$, we get the unsmoothed simulated frequency.

[25]See Galichon and Salanié (2015) for semiparametric identification results in transferable utility matching models with more general heterogeneity structures.

theoretically characterizing the contribution of these marital payoffs to the social-welfare function in our optimal taxation application (see Section 5).

4.3.2. *Identifying the Other Primitives*

The identification of the utility function, the home production technology, and the scale of the state-specific error distribution follows directly from standard semiparametric identification results for discrete choice models (see Matzkin (1992, 1993)), here modified to reflect the joint-household decision problem.

PROPOSITION 3: *Given identification of the wife's Pareto weight, and under Assumptions* ID-1–ID-8 *from Online Appendix* D.2, *all other model primitives are identified*.

PROOF: See Online Appendix D.2. *Q.E.D.*

In our formal proof, we demonstrate how the observed time allocation decisions of single individuals is first used to identify the utility function, the scale of the state-specific errors, and the efficiency of single individual's home production time. Then, under the maintained assumption that while the budget set and home technology may differ by marital status but individual preferences do not, we use our knowledge of the Pareto weight (whose identification is discussed above) together with information on the time allocation behavior of married couples to identify the home production technology for couples.[26] The wage offer distributions are identified as several exclusion restrictions needed for identification arise naturally in our framework (e.g., children and spouse characteristics affect labor force participation but not wages).[27] These objects imply identification of the expected values in any given marriage market pairing. The observed population vectors and marriage market matching function then imply identification of the scale of the idiosyncratic marital payoff.

4.4. *Estimation*

We estimate our model with a moment based procedure, constructing a rich set of moments that are pertinent to household time allocation decisions and marital sorting patterns. A description of all the moments used is provided in Online Appendix E.

We employ an equilibrium constraints (or MPEC) approach to our estimation (Su and Judd (2012)). This requires that we augment the estimation parameter vector to include the complete vector of Pareto weights for each market. Estimation is then performed with $I \times J \times K$ nonlinear equality constraints that require that there is neither excess demand nor supply for individuals in any marriage market pairing and in each market. That is, equation (7) holds. In practice, this MPEC approach is much quicker than a nested fixed-point approach (which would require that we solve the equilibrium for every candidate model parameter vector in each market) and is also more accurate as it does not involve the solution approximation step that we describe in Online Appendix B. Letting $\boldsymbol{\beta}$ denote

[26]The assumption that preferences are unchanged by marriage is used extensively in the literature; see Browning, Chiappori, and Lewbel (2013), and Lewbel and Pendakur (2008), among others.

[27]See Das, Newey, and Vella (2003).

the $B \times 1$ parameter vector, our estimation problem may be formally described as

$$\big[\widehat{\boldsymbol{\beta}}, \boldsymbol{\lambda}(\widehat{\boldsymbol{\beta}})\big] = \underset{\boldsymbol{\beta},\boldsymbol{\lambda}}{\arg\min}\big[\mathbf{m}_{\mathbf{sim}}(\boldsymbol{\beta}, \boldsymbol{\lambda}) - \mathbf{m}_{\mathbf{data}}\big]^{\intercal}\mathbf{W}\big[\mathbf{m}_{\mathbf{sim}}(\boldsymbol{\beta}, \boldsymbol{\lambda}) - \mathbf{m}_{\mathbf{data}}\big]$$

$$\text{s.t. } \mu^{d}_{ijk}\big(\boldsymbol{\beta}, \boldsymbol{\lambda}^{i}_{k}\big) = \mu^{s}_{ijk}\big(\boldsymbol{\beta}, \boldsymbol{\lambda}^{j}_{k}\big) \quad \forall i = 1, \dots, I, j = 1, \dots, J, k = 1, \dots, K,$$

where $\boldsymbol{\lambda}$ defines the stacked $(I \times J \times K)$ vector of Pareto weights in all markets, $\mathbf{m}_{\mathbf{data}}$ is the $M \times 1$ vector of empirical moments, $\mathbf{m}_{\mathbf{sim}}(\boldsymbol{\beta}, \boldsymbol{\lambda})$ is the model moment vector given $\boldsymbol{\beta}$ and an arbitrary (i.e., potentially nonequilibrium) vector of Pareto weights $\boldsymbol{\lambda}$.[28] Finally, $\mathbf{W}$ defines a $M \times M$ positive definite weighting matrix. Given the well-known problems associated with the use of the optimal weighting matrix (Altonji and Segal (1996)), we choose $\mathbf{W}$ to be a diagonal matrix, whose element is proportional to the inverse of the diagonal variance-covariance matrix of the empirical moments.[29] The solution to this estimation problem is such that $\widehat{\boldsymbol{\lambda}} = \boldsymbol{\lambda}(\widehat{\boldsymbol{\beta}})$.[30]

4.5. *Estimation Results*

We present parameter estimates in Online Appendix H.1. The results show considerable heterogeneity in both market and home productivity by gender and education. More highly educated individuals receive higher wage offers, with higher average offers for men than for women. Similarly, home productivity is broadly increasing in education and with female home time more important than male time within marriage. Educational homogamy is also important. Households where the husband and wife have the same education level have greater home productivity. As we show below, these differences have implications for both within household specialization and marriage patterns.

Given the estimation moments are not strict sample analogues of the populations moments from our formal identification proof, and because there may exist alternative constructive identification proofs giving rise to overidentifying restrictions, we conduct a sensitivity analysis of the estimates to the data moments as in Andrews, Gentzkow, and Shapiro (2017). Details are provided in Online Appendix H.1. Categorizing the complete set of moments into broad groups, we list those which have an important influence on each parameter alongside our estimates. For example, we show that moments related to accepted wages and earnings have an important influence on the market productivity parameters. Additionally, the market productivity parameters for women and less-educated men are influenced by labor supply and home time moments. This accords with the intuition from the formal identification analysis, as time allocation moments are informative about the degree of selection into work. The table also shows that marriage market moments are not only influencing the scale parameter of the marital shock, but also the educational homogamy parameters. The latter helps the model to explain the degree of assortative mating that we see in the data and which we describe below.

[28]In our estimation, we have $3 \times 3 \times 9 = 81$ Pareto weights. We use 600 integration nodes for the state-specific errors, and 30 nodes (each) for male and female wage offers. Given the demographic realisations, multiple markets, and different marital pairings, this requires us to solve the household time allocation problem over 87 million times to evaluate the objective function and constraints for a given $(\boldsymbol{\beta}, \boldsymbol{\lambda})$.

[29]We calculate our empirical moments using ACS and ATUS data. Given the very different sample sizes, the empirical moments from ACS are estimated with much greater precision than are those from ATUS. We therefore increase the weight on any moments calculated from ATUS by a fixed factor $r \gg 1$.

[30]The variance matrix of our estimator is given by $[\mathbf{D}^{\intercal}_{\mathbf{m}}\mathbf{W}\mathbf{D}_{\mathbf{m}}]^{-1}\mathbf{D}^{\intercal}_{\mathbf{m}}\mathbf{W}\boldsymbol{\Sigma}\mathbf{W}^{\intercal}\mathbf{D}_{\mathbf{m}}[\mathbf{D}^{\intercal}_{\mathbf{m}}\mathbf{W}\mathbf{D}_{\mathbf{m}}]^{-1}$, where $\boldsymbol{\Sigma}$ is the $M \times M$ covariance matrix of the empirical moments, and $\mathbf{D}_{\mathbf{m}} = \partial \mathbf{m}_{\mathbf{sim}}(\boldsymbol{\beta}, \boldsymbol{\lambda}(\boldsymbol{\beta}))/\partial \boldsymbol{\beta}$ is the $M \times B$ derivative matrix of the moment conditions with respect to the model parameters at $\boldsymbol{\beta} = \widehat{\boldsymbol{\beta}}$.

TABLE I

EMPIRICAL AND PREDICTED MARITAL SORTING PATTERNS[a]

			Women		
			High school and below	Some college	College and above
Men		–	0.127	0.113	0.099
			[0.121]	[0.095]	[0.064]
	High school and below	0.144	0.150	0.068	0.029
		[0.133]	[0.157]	[0.059]	[0.042]
	Some college	0.097	0.043	0.089	0.051
		[0.098]	[0.033]	[0.103]	[0.046]
	College and above	0.097	0.019	0.046	0.167
		[0.050]	[0.027]	[0.058]	[0.194]

[a]The table shows the empirical and simulated marriage market matching function, aggregated over all marriage markets. Simulated values from the model are presented in brackets.

We now present the fit of the model to some of the most salient features of the data. In Table I, we show the fit to marital sorting patterns across all markets and can see that the while we slightly under predict the incidence of singlehood for college educated individuals, in general the model does well in replicating empirical sorting patterns. Consistent with the data, we obtain strong assortative mating on education. Recall that we do not have any match-level parameter that can be varied to fit marital patterns independently of the time allocation behavior. In Figure 1, we present the marginal distributions of market and home time for both men and women in different marriage market pairings, and by the presence of children (here aggregated over types and markets). The model is able to reproduce key features of the data: relative to single women, married women work less and have higher home time, with the differences most pronounced for mothers. There are much smaller differences in both labor supply and home time between single and married men. Men with children have higher home time than men without children, although the difference is much smaller than observed for women.

Our estimation targets a number of moments conditional on market, with our semiparametric identification result reliant upon the presence of market variation. In Figure 2, we show how well the model can explain market variation in marital sorting patterns. Each data point represents an element of the marriage market matching function in a given market, and we observe a strong concentration of the points around the diagonal, indicating a good model fit. In Figure 3, we illustrate the fit to cross-market unconditional work hours for men and women by type and in different marriage market pairings. Again, we observe a strong clustering of points around the diagonal.

Important objects of interest are the Pareto weights and how they vary at the level of the match and across markets. The Pareto weights implied by our model estimates are presented in Table II and we note several features. First, the female weight is increasing when a woman is more educated relative to her spouse. For example, a college educated woman receives (on average) a share of 0.44 if she is married to a man with the same level of education. If she were instead to marry a high school educated male, her share increases to 0.61. Second, there is an asymmetric gender impact of education differences: we always have that $\lambda_{ij} + \lambda_{ji} < 1$. Third, there is dispersion in these weights across markets, reflecting the joint impact of variation in taxes and population vectors.

There are both economic and noneconomic gains from marriage. In Figure 4, we present an empirical expected utility possibility frontier in marriages where the male has a

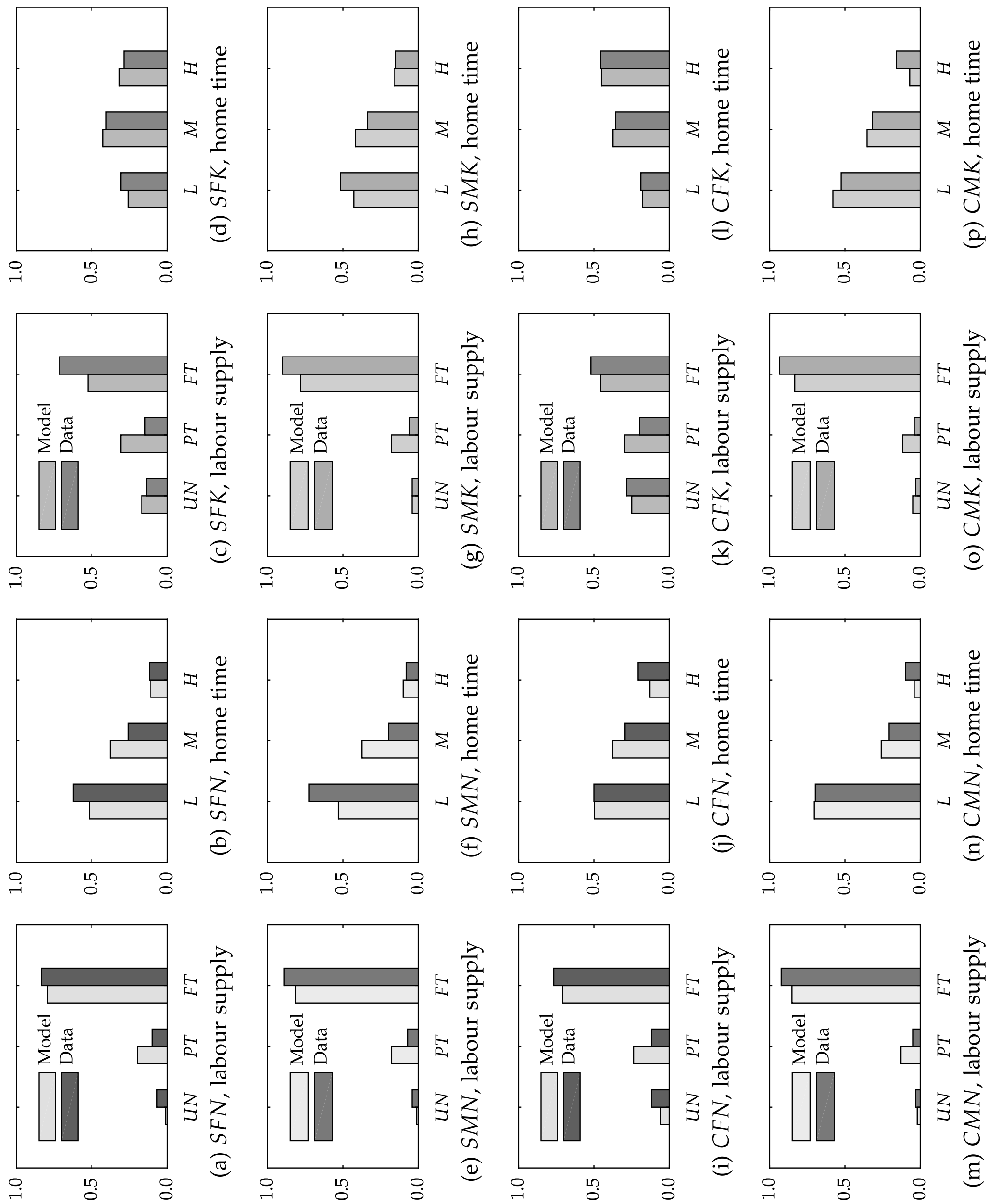


FIGURE 1.—Figure shows empirical and predicted frequencies of work and home time, aggregated over types and conditional on marital status, gender, and children. S (C) identifies singles (couples); F (M) identifies women (men); N (K) identifies childless (children). UN is nonemployment; PT is part-time (12, 24 hours); FT is full-time (36, 48, 60 hours). L is low home time (4, 16 hours); M is medium home time (28, 40 hours); H is high home time (52, 64 hours).

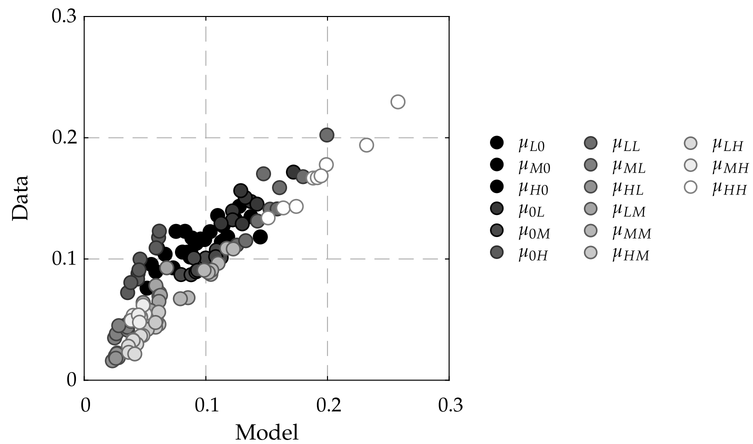


FIGURE 2.—The figure shows elements of the empirical and predicted marriage market matching function. A market corresponds to a Census Bureau-designated division.

college degree or higher and the education level of the female is varied. The patterns for other matches are similar. The expected utility possibility frontier, which is highly nonlinear, shifts out as we increase the schooling level of the woman, and only in the joint "college and above" matches does the expected value of marriage exceed that of singlehood. Heterogamous marriages are therefore primarily explained by the noneconomic gains.[31]

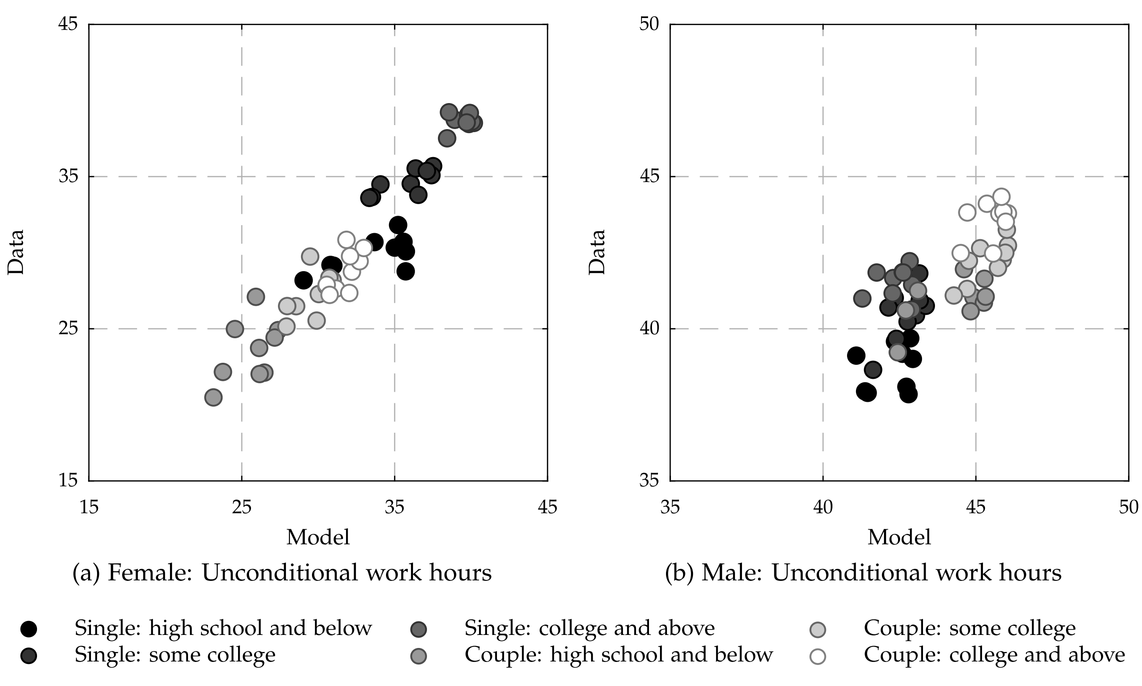


FIGURE 3.—The figure shows empirical and predicted mean unconditional work hours of men and women by education and market. A market corresponds to a Census Bureau-designated division.

[31]Home production activities constitute a key economic benefit of marriage, and complementarity in the technology is a crucial determinant of the degree of assortative mating. In Online Appendix H.7, we describe some of the key arguments for how home production affects the taxation design problem, and we present simulations where the efficiency of home time is reduced.

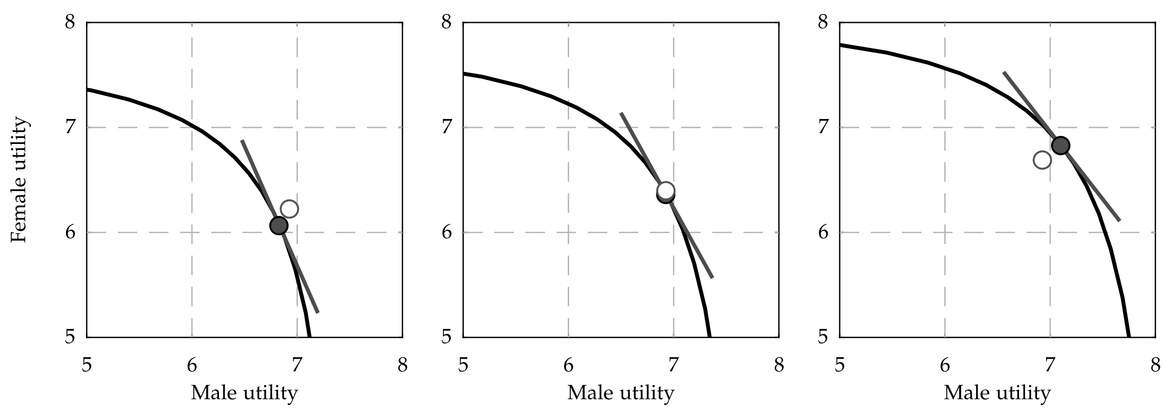
TABLE II

PARETO WEIGHT DISTRIBUTION[a]

		Women		
		High school and below	Some college	College and above
Men	High school and below	0.477 [0.461–0.503]	0.522 [0.512–0.535]	0.611 [0.596–0.619]
	Some college	0.399 [0.381–0.422]	0.465 [0.455–0.481]	0.549 [0.539–0.555]
	College and above	0.287 [0.268–0.308]	0.343 [0.332–0.359]	0.436 [0.429–0.442]

[a]The table shows the distribution of Pareto weights from our estimated model. The unbracketed numbers correspond to the average weight across markets (weighted by market size) within an $\langle i, j\rangle$ match. The range in brackets provides the range of values that we estimate across markets.

While the following optimal design exercise directly uses the behavioral model developed in Section 2, to help understand the implications of our parameter estimates for time allocation decisions, we simulate elasticities under the actual 2006 tax systems for different family types. All elasticities are calculated by increasing the net wage rate while holding the marriage market fixed and correspond to uncompensated changes. In the presence of a nonseparable tax schedule, increasing the net wage of a given married adult means that we are perturbing the tax schedule as we move in a single dimension.[32] The results of this exercise are shown in Table III. For single individuals, we report employment, conditional work hours, and home time elasticities in response to changes in their own wage. For married individuals, we additionally report *cross-wage* elasticities that describe



(a) High school and below (b) Some college (c) College and above

FIGURE 4.—The figure shows the expected utility possibility frontier in marriages where the male has a college degree or higher and the education level of the female is varied. The figure is obtained from the estimated model and is calculated under the New England market. The shaded point in each panel indicates the expected utilities in the sub-marriage market given the market clearing Pareto weights. The unshaded point indicates the expected utilities in the single state.

[32]Starting from a fully joint system (as is true in our estimation exercise) and for any given joint time allocation decision, this perturbation is equivalent to first taxing the spouse whose net wage is not varied on the original joint tax schedule and then reducing marginal tax rates for subsequent earnings (as then applied to the earnings of their spouse, whose net wage we are varying).

TABLE III

SIMULATED ELASTICITIES[a]

	Married		Single	
	Men	Women	Men	Women
Work hours				
Own-wage elasticity	0.13	0.23	0.04	0.08
Cross-wage elasticity	−0.08	−0.17	–	–
Participation				
Own-wage elasticity	0.09	0.31	0.02	0.17
Cross-wage elasticity	−0.05	−0.15	–	–
Home hours				
Own-wage elasticity	−0.20	−0.23	−0.06	−0.17
Cross-wage elasticity	0.10	0.14	–	–

[a]All elasticities are simulated under 2006 federal and state tax/transfer systems, aggregated over markets, and hold the marriage market fixed. Elasticities are calculated by increasing an individual's net wage rate by 1% (own-wage elasticity) or the net wage of his/her spouse by 1% (cross-wage elasticity). *Participation* elasticities measure the percentage increase in the employment rate; *work hours* elasticities measure the percentage increase in hours of work among workers; and *home hours* elasticities measure the percentage increase in total home time.

how employment, work hours, and home time respond as the wage of his/her spouse is varied.[33]

Our labor supply elasticities suggest that women are more responsive to changes in their own wage (both on the intensive and extensive margins) than are men. The same pattern is true with respect to changes in the wage of their partner. However, own-wage elasticities are always larger (in absolute terms) than are cross-wage elasticities. The own-wage hours and participation elasticities that we find are very much consistent with the range of estimates in the labor supply literature (see, e.g., Meghir and Phillips (2010)). The evidence on cross-wage labor supply effects is more limited, although the results here are consistent with existing estimates (e.g., Blau and Kahn (2007)). Also in Table III we report home hours elasticities, which suggest that individuals substitute away from home time for a given uncompensated change in their wage and substitute toward home time when their spouse's wage is increased. The same tax-induced home time pattern was reported in Gelber and Mitchell (2011).

We also simulate elasticities related to the impact of taxes on the marriage market. We consider a perturbation whereby we increase the marriage penalty/decrease the marriage bonus by 1% and then resolve for the equilibrium. This comparative static exercise implies a marriage market elasticity of −0.10. This result falls into the range of estimates in the literature that has examined the impact of taxation on marriage decisions, which often find what are considered modest (but statistically significant) effects; see, for example, Alm and Whittington (1999) and Eissa and Hoynes (2000).

5. OPTIMAL TAXATION OF THE FAMILY

In this section, we consider the normative implications when we adopt a social-welfare function with a set of subjective social-welfare weights. There are several stages to our

[33]Own-wage work-hours elasticities condition on being employed in the base system. As we increase the net wage of an individual (holding that of any spouse fixed), their employment is nondecreasing. Cross-wage work-hours elasticities condition on being employed both before and after the net wage increase.

analysis. First, we consider the case where we do not restrict the form of jointness in our choice of tax schedule for married couples. Under alternative assumptions on the degree of inequality aversion, we empirically characterize the optimal tax system. Second, we consider the choice of tax schedules when the form of tax jointness is exogenously restricted and quantify the welfare loss relative to our more general benchmark specification. Third, we consider the potential role for gender based taxation. Fourth, we describe and quantify the importance of the marriage market on the design problem. Fifth, we consider the impact that the gender wage gap has on the optimal design problem.

The results presented in this section assume a single marriage market, with the population vectors for men and women defined as those corresponding to the aggregate. We consider the following form for the utility transformation function in our social-welfare function:

$$Y(v;\delta)=\frac{e^{\delta v}-1}{\delta}, \tag{13}$$

which is the same form as considered in the applications in, for example, Mirrlees (1971) and Blundell and Shephard (2012). Under this specification, $-\delta=-Y''(v;\delta)/Y'(v;\delta)$ is the coefficient of absolute inequality aversion, and with $\delta=0$ corresponding to the linear case (by L'Hôpital's rule).

This utility transformation function has useful properties, and in conjunction with the additivity of the idiosyncratic marital payoffs permits us to obtain the following result.

PROPOSITION 4: *Consider type-i married men in an $\langle i,j\rangle$ marriage pairing. The contribution of such individuals to $\mathcal{W}(T)$ in equation (9) for $\delta<0$ is given by*

$$\begin{aligned}\mathcal{W}^i_{ij}(T) &= \int_{\theta^i}\int_{\mathbf{w},\mathbf{X},\boldsymbol{\epsilon}} Y\big[v^i_{ij}\big(\mathbf{w},\mathbf{y},\mathbf{X},\boldsymbol{\epsilon};T,\lambda_{ij}(T)\big)+\theta^i\big]\,\mathrm{d}G_{ij}(\mathbf{w},\mathbf{X},\boldsymbol{\epsilon})\,\mathrm{d}H^i_{ij}\big(\theta^i\big)\\ &= p^i_{ij}\big(T,\boldsymbol{\lambda}^i(T)\big)^{-\delta\sigma_\theta}\Gamma(1-\delta\sigma_\theta)\\ &\quad\times\int_{\mathbf{w},\mathbf{X},\boldsymbol{\epsilon}}\frac{\exp\big[\delta v^i_{ij}\big(\mathbf{w},\mathbf{y},\mathbf{X},\boldsymbol{\epsilon};T,\lambda_{ij}(T)\big)\big]}{\delta}\,\mathrm{d}G_{ij}(\mathbf{w},\mathbf{X},\boldsymbol{\epsilon})-\frac{1}{\delta},\end{aligned}$$

where $\Gamma(\cdot)$ is the gamma function and $p^i_{ij}(T,\boldsymbol{\lambda}^i(T))$ is the conditional choice probability (equation (5)) for type-i males. For $\delta=0$, this integral evaluates to

$$\mathcal{W}^i_{ij}(T)=\sigma_\theta\gamma-\sigma_\theta\log p^i_{ij}\big(T,\boldsymbol{\lambda}^i(T)\big)+U^i_{ij}\big(T,\lambda_{ij}(T)\big),$$

where $\gamma=-\Gamma'(1)\approx 0.5772$ is the Euler–Mascheroni constant. The form of the welfare function contribution is symmetrically defined in alternative marriage market pairings and for married women, single men and single women.

PROOF: See Online Appendix F. *Q.E.D.*

As part of our proof of Proposition 4, we characterize the distribution of the marital idiosyncratic payoffs for individuals who select into a given marriage market pairing. This result allows us to decompose the welfare function contributions into parts that reflect the distribution of idiosyncratic utility payoffs from marriage and singlehood, and that which reflects the welfare from individual consumption and time allocation decisions. It is also obviously very convenient from a computational perspective as the integral over these idiosyncratic marital payoffs does not require simulating.[34]

5.1. *Specification of the Tax Schedule*

Before presenting the results from our design simulations, we first describe the parametric specification of the tax system used in our illustrations. Consider the most general case. The tax system comprises a schedule for singles (varying with earnings) and a schedule for married couples (varying with the earnings of both spouses). We define a set $\mathcal{Z}$ of N ordered (and exogenously determined) tax brackets $0 = n_1 < n_2 < \cdots < n_N < \infty$ that apply to the earnings of a given individual. We assume, but do not require, that these brackets are the same for each individual, married or single. Associated with each bracket point for singles is the tax level parameter vector $\mathbf{t}_{N\times 1}$. For married couples, we have the tax level parameter matrix $\mathbf{T}_{N\times N}$. For now, we abstract from the possibility of gender based taxation, and hence impose symmetry of the tax matrix. Together, our tax system is characterized by $N + N \times (N + 1)/2$ tax parameters defined by the vector $\boldsymbol{\beta}_T$.

The tax parameter vector $\mathbf{t}_{N\times 1}$ and tax matrix $\mathbf{T}_{N\times N}$ define tax liabilities at earnings that coincide with the exogenously chosen tax brackets (or nodes). The tax liability for other earnings levels is obtained by fitting an interpolating function. For singles, this is achieved through familiar linear interpolation, so that the tax schedule is of a piecewise linear form. We extend this for married couples by a procedure of polygon triangulation. This procedure, which allows us to approximate the fully nonparametric schedule, divides the surface of the tax schedule into a nonoverlapping set of triangles. Within each of these triangles, marginal tax rates for both spouses, while potentially different, are constant by construction. Given this interpolating function, we write the tax schedule at arbitrary earnings for married couples as $T(z_1, z_2)$, where z_1 and z_2 are henceforth used to denote the labor earnings of the two spouses, respectively. For a single individual with earnings z, and with some abuse of notation, we denote this tax schedule as $T(z)$. Note that we do not condition upon demographics in these illustrations.

In our application, we set $N = 10$ with the earnings nodes (expressed in dollars per year in average 2006 prices) as $\mathcal{Z} = \{0, 12{,}500, 25{,}000, 37{,}500, 60{,}000, 85{,}000, 110{,}000, 150{,}000, 190{,}000, 250{,}000\}$. Thus, we have a tax system that is characterized by 65 parameters.[35] Using our estimated model, the exogenous revenue requirement $\overline{T}$ is set equal to the expected state and federal income tax revenue (including Earned Income Tax Credit payments) and net of welfare transfers. We solve the optimal design problem numerically. Given our parameterization of the tax schedule, we solve for the optimal tax parameter vector $\boldsymbol{\beta}_T$ using an equilibrium constraints approach that is similar to that described in Section 4.4 in the context of estimation. This approach involves augmenting the tax parameter vector to include the $I \times J$ vector of Pareto weights as additional parameters and imposing the $I \times J$ equilibrium constraints $\mu^d_{ij}(T, \boldsymbol{\lambda}^i) = \mu^s_{ij}(T, \boldsymbol{\lambda}^j)$ in addition to the usual

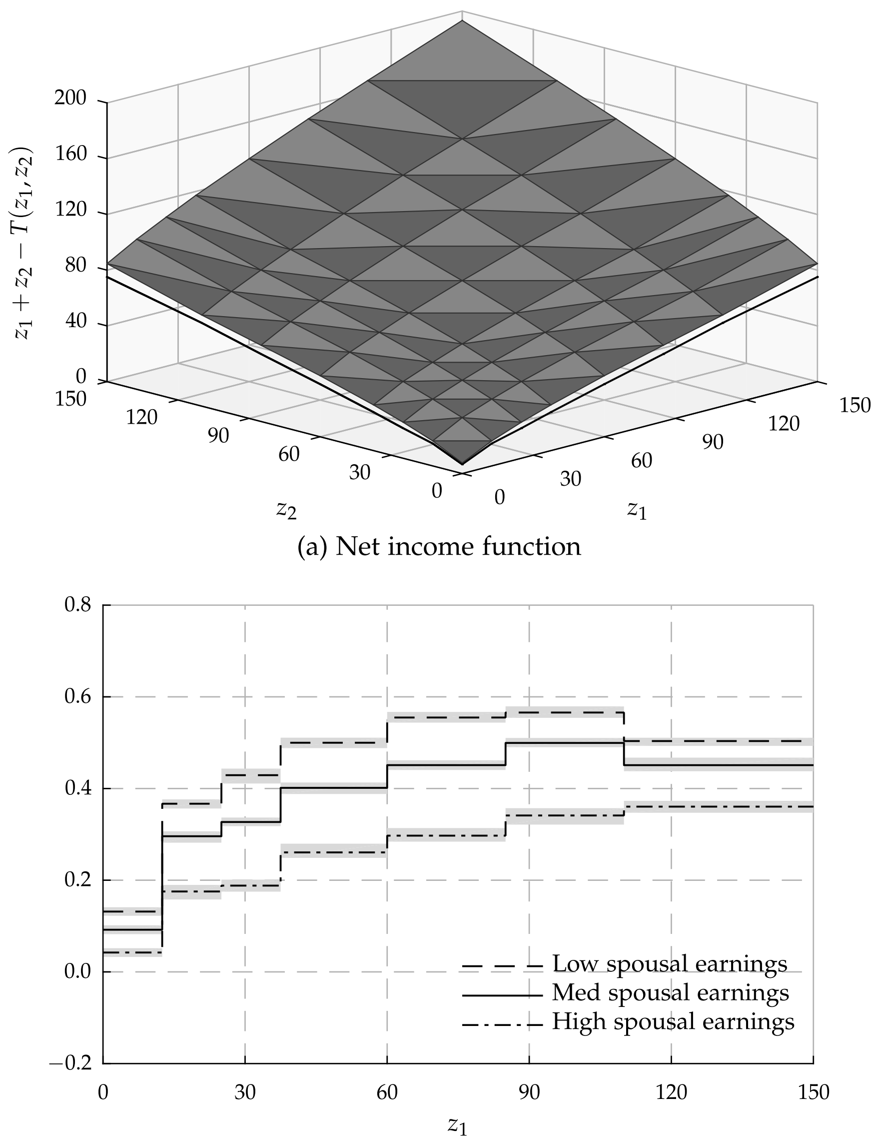
[34] This is a related, but distinct, result compared with Proposition 1 in Blundell and Shephard (2012). That proposition, which characterizes the influence of the state specific errors $\boldsymbol{\epsilon}$, does not apply to the welfare contribution conditional on a given marital state as (for individuals in couples) the maximization problem of the household is not synonymous with the maximization of the individual utility function.

[35] The use of exogenous node positions is not restrictive as there could be arbitrarily many and the distance between them could be made arbitrarily small. We also considered different numbers of nodes, but found that this choice well illustrated the main features of the schedule. In Online Appendix H.6, we present results where we greatly increase the polygon density by increasing the number of nodes, and show it to have little impact on the structure of taxes, including the implied tax jointness. In that Appendix, we also describe the potential difficulty with endogenously determining the node positions.

incentive compatibility and revenue constraints. This approach only involves calculating the marriage market equilibrium associated with the optimal tax parameter vector $\boldsymbol{\beta}_T^*$ rather than any candidate $\boldsymbol{\beta}_T$, as would be true in a nested fixed-point procedure.

5.2. *Implications for Design*

We now describe our main results. In Figure 5(a), we present the joint (net income) budget constraint for both singles and married couples, calculated under the government



(a) Net income function

(b) Marginal tax rates conditional on spousal earnings

FIGURE 5.—Optimal tax schedule with $\delta = 0$. In panel (a), we show net income as a function of labor earnings for both single individuals (solid line) and couples (three-dimensional surface). In panel (b), we show marginal tax rates conditional on alternative values of spousal earnings. At earnings exceeding \$150,000, marginal tax rates conditional on spousal earnings remain approximately unchanged: for *low* spousal earnings (resp., *medium* and *high*) marginal tax rates average 47% (resp., 43% and 34%). The shaded areas indicate the 99% pointwise confidence bands. All incomes are in thousands of dollars per year, expressed in average 2006 prices. See Footnote 36 for a definition of *low*, *medium*, and *high* spousal earnings levels.

preference parameterization $\delta = 0$. For clarity of presentation, the figure has been truncated at individual earnings greater than \$150,000 a year. The implied schedule for singles is shown by the solid line. The general flattening of this line as earnings increase indicates a broadly progressive structure for singles. In the same figure, the optimal schedule for married couples is shown by the three-dimensional surface, which is symmetric by construction (i.e., gender neutrality). Recall that within each of the shaded triangles, the marginal tax rates of both spouses are constant but potentially different. As the earnings of either spouse changes in any direction and enters a new triangle, marginal tax rates may change. Holding constant the earnings of a given spouse, we can clearly see a broadly progressive structure, while comparing these implied schedules at different levels of spousal earnings is informative about the degree of tax jointness.

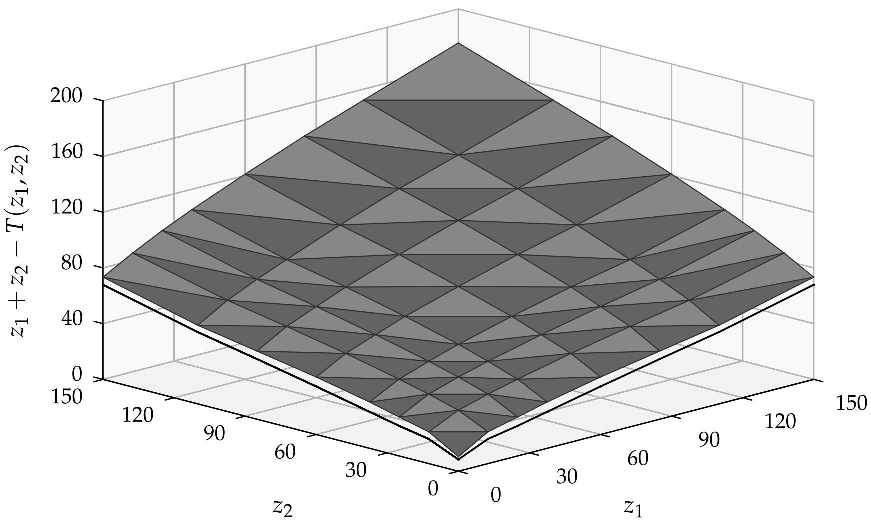
To better illustrate the implied degree of tax jointness, in Figure 5(b) we show the associated marginal tax rate of a given individual as the earnings of his/her spouse is fixed at different levels.[36] Here, we also present pointwise confidence bands that are obtained by sampling 200 times from the distribution of parameter estimates and resolving for the optimal schedule. Guided by the insights of optimal tax theory, we note a number of important features. First, conditional on spousal earnings, marginal tax rates are broadly increasing in an individual's own earnings and only decline slightly at very high earnings. Second, consistent with the empirical differences in labor supply responsiveness at the intensive and extensive margin, and the analysis of Saez (2002), marginal tax rates are close to zero at low earnings. Third, marginal tax rates tend to be lower the higher the are spousal earnings. That is, the schedule is characterized by negative tax jointness.[37] We now comment further on this property.

The desirability of negative jointness in Kleven, Kreiner, and Saez (2007, 2009) [henceforth, KKS] arises because of redistributive concerns. Consider a simplified version of their environment where earnings can be high or low. Starting with an independent tax system, the benefit of a transfer from a low-high couple to a low-low couple will exceed the cost of an equal sized transfer from a high-low to high-high couple. KKS show that there is no first-order revenue cost associated with this perturbation, such that introducing a small amount of negative jointness increases social welfare. Our framework departs from their setting in important ways. In particular, they assume a unitary model of the household, while we consider a collective model. However, as KKS (2007) note, their analysis would proceed identically with a collective model should the planner respect the within household decision weights. While a general theoretical characterisation of the problem, including when the planner and household weights differ, is an extremely complex problem, our quantitative analysis does suggest that the negative jointness property is somewhat more general.

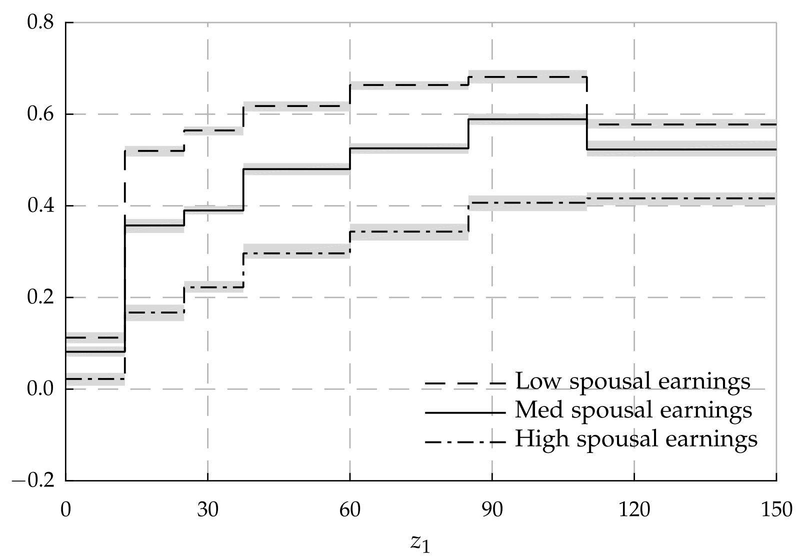
To understand how the redistributive preference of the planner impacts the design problem, we repeat our analysis under an alternative parametrization for government

[36]We present the (average) marginal tax rate for low, medium, and high spousal earnings. *Low* is the arithmetic average of the marginal tax rate for spousal earnings $\{z_2 | z_2 \in \mathcal{Z}, z_2 \leq \$25{,}000\}$. Similarly, *medium* and *high*, respectively, correspond to spousal earnings $\{z_2 | z_2 \in \mathcal{Z}, \$25{,}000 < z_2 \leq \$85{,}000\}$ and $\{z_2 | z_2 \in \mathcal{Z}, \$85{,}000 < z_2 < \$250{,}000\}$.

[37]The negative jointness property contrasts with that of the actual U.S. tax system, which exhibits positive jointness (see Online Appendix H.2). That we obtain marginal tax rates that eventually slightly decline is consistent with the well-known zero top marginal tax rate logic from the Mirrlees (1971) model; see Diamond and Saez (2011) and Mankiw, Weinzierl, and Yagan (2009). Imposing that marginal tax rates are nondecreasing in earnings (conditional on spousal earnings) has little impact on the overall shape of the schedule.



(a) Net income function



(b) Marginal tax rates conditional on spousal earnings

FIGURE 6.—Optimal tax schedule with $\delta = -1$. In panel (a), we show net income as a function of labor earnings for both single individuals (solid line) and couples (three-dimensional surface). In panel (b), we show marginal tax rates conditional on alternative values of spousal earnings. At earnings exceeding \$150,000, marginal tax rates conditional on spousal earnings remain approximately unchanged: for *low* spousal earnings (resp., *medium* and *high*) marginal tax rates average 55% (resp., 49% and 38%). The shaded areas indicate the 99% pointwise confidence bands. All incomes are in thousands of dollars per year, expressed in average 2006 prices. See Footnote 36 for a definition of *low*, *medium*, and *high* spousal earnings levels.

preferences ($\delta = -1$). As we later show, this parametrization is associated with a considerably greater redistributive preference. Results are presented in Figure 6, and relative to the schedule obtained with $\delta = 0$, we have (i) higher transfers when not working; (ii) slightly lower marginal tax rates at low earnings; and (iii) generally higher marginal tax rates with a greater degree of negative jointness (i.e., a larger difference in marginal tax rates as we increase the earnings of a spouse). As the parameter δ is difficult to interpret, in Online Appendix H.3 we present the underlying average social-welfare weights for these alternative values. They tell us the relative value that the government places on increasing consumption at different joint earnings levels. These weights are monotonically declining in earnings as we move in either direction, and given the estimated curvature of the utility function, there is a considerable redistributive motive even in the $\delta = 0$ case. When $\delta = -1$, these weights decline more rapidly, implying a stronger redistributive motive, and generating the higher marginal tax rates and increased tax jointness.

The choice of tax schedule has implications for time allocation decisions, marriage market outcomes, and the distribution of resources within the household. We briefly comment on these effects when $\delta = 0$. Relative to our estimated baseline model, the most pronounced difference in labor supply behavior is for married women: the employment rate is 87%, relative to 79% in the estimated model, while conditional work hours are approximately unchanged and home hours are one hour per week lower. In contrast, the employment rate for married men is a percentage point higher, while work hours are two hours per week lower and home time is essentially unchanged. In terms of marriage market outcomes, we still obtain welfare weights/private consumption shares that typically favor the husband (see Table V), and compared to the estimated model we have slightly lower (higher) weights for less (more highly) educated women, and a higher overall marriage rate (a 5-percentage-point increase).

5.3. *Restrictions on the Form of Tax Schedule Jointness*

Our previous analysis allowed for a general form of jointness in the tax schedule. We now consider the design implications when the form of the jointness is restricted. There are two stages to our analysis. First, we characterize the tax schedule with a given revenue requirement by solving the same constrained welfare maximization problem as before. Second, in order to quantify the cost of these restricted forms, we consider the dual problem. That is, we now maximize the revenue raised from our tax system, subject to the incentive and marriage market equilibrium constraints *and* the requirement that the level of social welfare achieved is at least that which was obtained from our unrestricted specification from Section 5.2. If the tax schedule which solves the dual problem is given by T_r, then the welfare cost may be constructed as $\Delta_{\text{unrestricted}} = \mathcal{R}(T_r)/\overline{T} - 1$. In what follows, we consider the following forms for the tax schedule:

1. **Individual taxation**. In many countries, there is a system of individual filing in the tax system. Under such a system, the total tax liability for a couple with earnings z_1 and z_2 is given by $T(z_1, z_2) = \widehat{T}(z_1) + \widehat{T}(z_2)$, where the function $\widehat{T}(\cdot)$ is the tax schedule that is applied to both married and single individuals.
2. **Joint taxation with income splitting**. Under joint taxation with income splitting, an individual is taxed upon an income measure that attributes the income of one spouse to the other. We consider equal splitting, so each household member is taxed based upon average earned income. Thus, $T(z_1, z_2) = 2 \times \widetilde{T}(z_1/2 + z_2/2)$, with the same tax schedule $\widetilde{T}(\cdot)$ applied to singles and married couples.
3. **Joint taxation with income aggregation**. With income aggregation, we maintain a common tax schedule $\check{T}(\cdot)$ for singles and couples, but allow the tax liability of couples to depend upon total household earned income: $T(z_1, z_2) = \check{T}(z_1 + z_2)$.

We present results from this exercise when $\delta = 0$ in Table IV. Here, we show the marginal rate structure for these alternative sets of tax instrument as we vary the earning of one adult, conditional on alternative spousal earnings levels. In the case of independent taxation, taxes do not, by definition, vary with spousal earnings. While the shape of the schedule is broadly similar (relative to the unrestricted schedule) when spousal earnings are low, given our empirical finding of negative tax jointness, it does imply higher tax

TABLE IV

MARGINAL TAX RATES WITH RESTRICTED TAX INSTRUMENTS AND CONDITIONAL ON SPOUSAL EARNINGS[a]

	Unrestricted			Independent			Income splitting			Income aggregation		
z_1	*Low*	*Med.*	*High*	*Low*	*Med.*	*High*	*Low*	*Med.*	*High*	*Low*	*Med.*	*High*
0.0	13	9	4	13	13	13	16	44	48	33	36	38
12.5	37	30	18	43	43	43	28	46	48	34	36	38
25.0	43	33	19	44	44	44	42	47	48	28	40	38
37.5	50	40	26	49	49	49	43	48	49	31	40	36
60.0	55	45	30	52	52	52	46	48	48	39	41	35
85.0	57	50	34	55	55	55	48	48	49	41	40	33
110.0	50	45	36	51	51	51	48	47	57	41	38	33
150.0	49	43	35	47	47	47	48	49	64	39	33	33

[a]The table shows marginal tax rates (rounded to the nearest percentage point) as a function of earnings z_1 under alternative tax schedule specifications and conditional on alternative values of spousal earnings. All incomes are in thousands of dollars per year, expressed in average 2006 prices. See Footnote 36 for a definition of *low*, *medium*, and *high* spousal earnings levels.

rates when spousal earnings are higher. Joint taxation with income splitting is typically associated with lower marginal tax rates (again, relative to the unrestricted schedule) when spousal earnings are low. At medium levels of spousal earnings, they are higher or at roughly the same level. At high levels of spousal earnings, marginal tax rates are everywhere higher. Finally, in the case of joint taxation with income aggregation, we have marginal tax rates that are higher at low earnings and lower at high earnings. This is true for the alternative spousal earnings levels. In Online Appendix H.4, we present the marriage market matching functions that are associated with these alternative tax policies. Relative to the unrestricted specification, the changes are most pronounced when we consider joint taxation with income aggregation: the marriage rate is lower, while the diagonal of the matrix is less dominant (i.e., less assortative mating).

These restricted tax schedules are revenue equivalent to our most general specification but imply a reduction in social welfare. We now quantify this welfare loss by considering the dual problem of the planner as described above. The differences in revenue raised with the same social-welfare target can be interpreted as the cost of the more restrictive tax instruments. Individual taxation implies a welfare loss that is equivalent to around 1.5% of revenue; joint taxation with income splitting implies a 3.8% loss, while income aggregation implies an 8.7% loss. See also Table VI. All welfare losses are larger when there is greater redistributive concern ($\delta = -1$) but the respective ranking remains the same. Thus, while we our most general specification did imply that the optimal system was characterized by negative jointness, the actual welfare gains from introducing this jointness (relative to a system of independent taxation) appear somewhat modest.

5.4. *Gender Based Taxation*

In Section 5.2, we presented results where the tax schedule for married couples was constrained to be a symmetric function of male and female earnings, and similarly where the tax schedule for single individuals did not depend upon gender. It has long been recognized that gender may constitute a useful tagging device (Akerlof (1978)) such that there may be efficiency gains from conditioning taxes on gender (e.g., Rosen (1977), Boskin and Sheshinski (1983), Alesina, Ichino, and Karabarbounis (2011)). This follows as women are often estimated to have higher labor supply elasticities than men (see also the reduced form elasticities presented in Table III). Thus, by imposing distinct tax rates a given level of redistribution may be achieved at a lower efficiency cost.

In our equilibrium framework, gender based taxation also provides an instrument for addressing *within* household inequality.[38] This can be seen more formally by considering the impact of a marginal change in some tax parameter τ. This perturbation has revenue and welfare consequences. While the revenue consequences are largely standard, the impact on social welfare is more interesting, as the following proposition demonstrates.

PROPOSITION 5: *Let τ denote a parameter of the tax schedule T. Suppressing the dependence of λ_{ij} on T, the impact of a marginal change in τ on social welfare when $\delta = 0$ is given by*

$$\begin{aligned}\frac{\partial SWF(T)}{\partial \tau} &= \sum_i \mu_{i0}(T, \boldsymbol{\lambda}^i)\frac{\partial U^i_{i0}(T)}{\partial \tau} + \sum_j \mu_{0j}(T, \boldsymbol{\lambda}^j)\frac{\partial U^j_{0j}(T)}{\partial \tau} \\ &\quad + \sum_{i,j} \mu_{ij}(T, \boldsymbol{\lambda})\Bigg[\frac{\partial U^i_{ij}(T, \lambda_{ij})}{\partial \tau} + \frac{\partial U^j_{ij}(T, \lambda_{ij})}{\partial \tau} \\ &\quad + \frac{\partial U^i_{ij}(T, \lambda_{ij})}{\partial \lambda_{ij}} \frac{(2\lambda_{ij} - 1)}{\lambda_{ij}} \frac{\partial \lambda_{ij}}{\partial \tau}\Bigg].\end{aligned} \tag{14}$$

PROOF: See Online Appendix G. *Q.E.D.*

This proposition decomposes the effect of a marginal change of a tax parameter τ into two components. The first line in equation (14) captures the change in social welfare arising from the combined mechanical and behavioral effects for single men and women. The same terms are present in an environment that does not consider marriage market responses. The second line in this equation captures the same mechanical and behavioral effects for men and women in couples, together with an additional term that does not arise when marriage market considerations are neglected. This additional term is nonzero because of differences in the weights of the social planner relative to the household. It says that whenever there exists within household inequality, a tax perturbation can improve social welfare when the wife has a lower (higher) weight compared to her husband, if the tax reform increases (decreases) the wife's weight. There is no first-order welfare effect associated with changes in marriage market pairings.

To understand the mechanism through which gender based taxation may affect within household inequality, recall that in our baseline (gender neutral) simulations we obtain Pareto weights that typically favor the husband. Now consider a small tax increase for single men. This results in a reduction in the expected economic value for single men $U^i_{i0}(T)$, which with a fixed vector of Pareto weights $\boldsymbol{\lambda}$, would create an excess demand for women in the marriage market, that is, $\mu^d_{ij}(T, \boldsymbol{\lambda}^i) > \mu^s_{ij}(T, \boldsymbol{\lambda}^j)$. An increase in the wife's Pareto weight is therefore required for equilibrium to be restored, reducing within household inequality and, therefore, offering a potential welfare gain.

Repeating our analysis of Section 5.2, but allowing distinct tax rates for men and women (both married and single), results in significant changes in the structure of taxes. We now

[38]The potential for taxes to affect within household inequality was conjectured by Alesina, Ichino, and Karabarbounis (2011), and analyzed in a linear tax setting by Bastani (2013). While marriage is exogenous in Bastani (2013), utility when single provides the threat point in the household bargaining game.

TABLE V

MARRIAGE MATCHING FUNCTION AND PARETO WEIGHTS WITH GENDERED TAXATION[a]

			Women		
			High school and below	Some college	College and above
			(a) Gender neutral taxation		
Men		–	0.117	0.090	0.077
		–	–	–	–
	High school and below	0.136	0.156	0.061	0.039
		–	(0.448)	(0.497)	(0.583)
	Some college	0.094	0.036	0.106	0.044
		–	(0.387)	(0.456)	(0.536)
	College and above	0.055	0.028	0.059	0.187
		–	(0.295)	(0.354)	(0.448)
			(b) Gendered taxation		
		–	0.112	0.095	0.091
Men		–	–	–	–
	High school and below	0.141	0.156	0.058	0.036
		–	(0.540)	(0.585)	(0.660)
	Some college	0.099	0.038	0.101	0.041
		–	(0.476)	(0.535)	(0.609)
	College and above	0.058	0.032	0.061	0.178
		–	(0.364)	(0.420)	(0.508)

[a]The table shows marriage matching function under alternative tax schedule specifications. *Gender neutral taxation* corresponds to the *Unrestricted* schedule described in Section 5.1. *Gendered taxation* allows the tax schedule for single individuals and couples to vary by gender.

describe these changes, and present full results in Online Appendix H.5. First, for married couples we find that marginal tax rates are lower for married women than for married men (conditional on spousal earnings, the average difference is around five percentage points). Second, for single individuals we obtain both higher out-of-work income for single women compared to men and lower marginal tax rates (typically between around 5 and 10 percentage points lower). As shown in Table V, these changes have important consequences for the marriage market, with a higher marriage rate and an improvement in the woman's decision weight in all marriage pairings. These combined changes impact time allocation behavior. In particular, among married couples labor supply increases for men on both the intensive and extensive margin, while the reverse is true for married women. Home time for married men is approximately unchanged, while it decreases for married women. Relative to the optimal gender neutral tax schedule, we obtain welfare gains that are equivalent to 5.6% of government revenue.[39]

[39]The impact of the changing decision weights is nontrivial. Restricting the tax schedule for single individuals to be gender neutral, while continuing to allow the gendered taxation of married couples, results in the same broad pattern of marginal tax rates for married couples. However, relative to the completely gender neutral results presented in Section 5.2, the changes in marriage market pairings, the household decision weights, and the associated welfare gain, are all much smaller than described above. All our results here are subject to the caveat that conditioning on certain tags (such as gender) may violate horizontal equity concerns that are not well captured by the traditional utilitarian optimal taxation framework, as we adopt here; see Mankiw, Weinzierl, and Yagan (2009) and Diamond and Saez (2011).

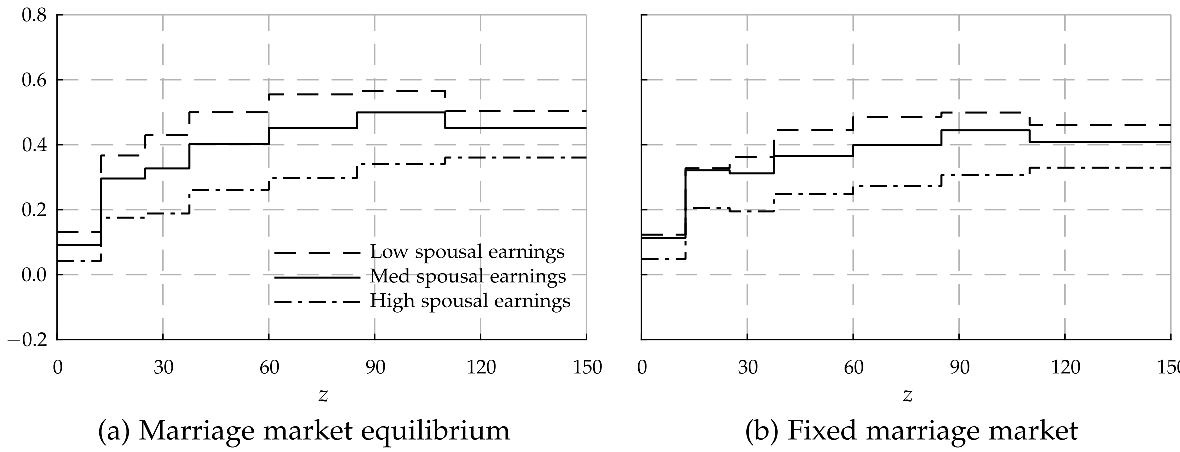


FIGURE 7.—Optimal tax schedule with fixed and equilibrium marriage market under $\delta = 0$. The figure shows marginal tax rates for married couples conditional on spousal earnings. Panel (a) shows the marginal tax rates obtained with an equilibrium marriage market; Panel (b) shows the marginal tax rates obtained with a fixed marriage market. See Footnote 36 for a definition of *low*, *medium*, and *high* spousal earnings.

5.5. *The Importance of the Marriage Market*

In our theoretical framework, a complex set of interactions exist between taxes and the marriage market. In particular, taxes affect the decision to marry and who marries with whom, the distribution of resources within the household, and the distribution of the idiosyncratic noneconomic benefits. Indeed, the role of the marriage market was seen clearly in Section 5.4, where taxes affected within household inequality solely through marriage market considerations.

We now consider how the marriage market affects the design problem more generally. First, we repeat our (gender-neutral) analysis from Section 5.2, but now relax our optimal design problem by removing the $I \times J$ constraints that require zero excess demand in all marriage submarkets. We then resolve for the optimal tax structure for couples holding the entire vector of Pareto weights, marriage market pairings, and distributions of idiosyncratic payoffs fixed at their values from the estimated model of Section 4.4. In Figure 7, we show the results from this exercise when $\delta = 0$. This figure reproduces the marginal rate schedule from Figure 5(b), and additionally displays the optimal marginal rate structure with a fixed marriage market. With the marriage market held fixed, we obtain lower marginal tax rates for married couples together with a lower level of income in the joint nonemployment state.

In the above experiment, the tax schedule (which we denote T_p) is chosen such that, absent marriage market considerations, social welfare is maximized subject to a fixed revenue target. Of course, with a nonzero marriage market elasticity, once the marriage market clears both tax revenue $\mathcal{R}(T_p)$ and social-welfare $\mathcal{W}(T_p)$ will, in general, differ compared to the solution of the initial relaxed maximization problem. To measure the importance of the marriage market, we now consider how much better the government can do if it recognizes the equilibrium of the marriage market in the design problem. We do this by maximizing the revenue raised from our tax system subject to the requirement that the level of social welfare achieved is at least $\mathcal{W}(T_p)$. Letting the solution to this problem be denoted T_e, we construct $\Delta_{\text{eq-welfare}} = [\mathcal{R}(T_e) - \mathcal{R}(T_p)]/\overline{T}$. Since this metric does not attribute a cost to not satisfying the initial target revenue constraint, we consider this as a lower bound on the cost, and also report $\Delta_{\text{eq-revenue}} = [\mathcal{R}(T_e) - \overline{T}]/\overline{T}$.

TABLE VI

WELFARE COST AND MARRIAGE MARKET IMPORTANCE WITH ALTERNATIVE TAX INSTRUMENTS[a]

	Unrestricted	Independent	Income splitting	Income aggregation
$\Delta_{\text{unrestricted}}$	–	1.5	3.8	8.7
$\Delta_{\text{eq-welfare}}$	0.5	0.4	6.8	3.4
$\Delta_{\text{eq-revenue}}$	0.2	−0.0	−9.8	−17.8

[a]The table shows (i) the welfare cost ($\Delta_{\text{unrestricted}}$) of alternative tax specifications relative to the *Unrestricted* specification, and (ii) the importance of the marriage market ($\Delta_{\text{eq-welfare}}$ and $\Delta_{\text{eq-revenue}}$) in the design exercise.

We report results from this exercise when $\delta = 0$ in Table VI. Here, we again consider both our general tax specification, together with the tax schedule specifications from Section 5.3 where the form of tax jointness is exogenously restricted. The table shows that while the welfare cost associated with neglecting marriage market considerations is relatively modest when we consider either the general unrestricted tax specification or independent taxation ($\Delta_{\text{eq-welfare}} \approx 0.5\%$), they are very sizeable when the tax schedule exhibits a strong nonneutrality with respect to marriage. In the case of joint taxation with income aggregation (income splitting), we obtain $\Delta_{\text{eq-welfare}} = 3.4\%$ ($\Delta_{\text{eq-welfare}} = 6.8\%$), together with large tax revenue discrepancies.

5.6. *The Role of the Gender Wage Gap*

While still pervasive, the gender wage gap has narrowed considerably over the past few decades (Blau and Kahn, 2017). Such changes have strong implications for the design problem. We now show how, by accentuating the difference between spouses (increasing the gender wage gap), the degree of tax jointness and the associated welfare gains may increase. Intuitively, the more dissimilar are spouses, the more dissimilar one would want the independent tax schedules to be, and if this is not possible, the greater the potential role from introducing jointness in the tax system.

We illustrate the importance of the gender wage gap by reducing female log-wage offers. In Online Appendix H.7, we present results where we set $\Delta\mathbb{E}[\ln w_j] = -0.5$ for all female types $j = 1, \dots, J$, and then resolve for the optimal tax schedules. For couples, we obtain increased negative tax jointness at the new optimum, while for single individuals we obtain a more progressive tax schedule with marginal tax rates increasing by around 10 percentage points. The marriage market, with its intricate connection to within household inequality, exerts an important influence on the shape of these schedules. With a fixed tax schedule, reducing wage offers for women unambiguously decreases their economic value in singlehood $U_{0j}^{j}(T)$, while leaving that of single men, $U_{i0}^{i}(T)$, unchanged. As such, and by arguments similar to those laid out in Section 5.4, this perturbation adversely effects women's position within marriage (the wife's Pareto weight). Increasing taxes on single individuals, through marriage market effects, provides an instrument to partially offset this.[40] Relative to a system of independent taxation, we now obtain a welfare gain that is equivalent to almost 4% of tax revenue. When the gender wage gap is increased further

[40]The changing wage distribution in the single pool also provides a force for increased progressivity. In the new equilibrium, the wife's Pareto weight is everywhere lower. For example, in educationally homogamous marriages the wife's weight ($\text{diag}(\boldsymbol{\lambda})$) is reduced from [0.448, 0.456, 0.448] to [0.427, 0.430, 0.400].

still, there are larger increases in tax jointness, higher taxes on singles, and even larger welfare gains relative to independent taxation.[41]

6. SUMMARY AND CONCLUSION

We have presented a microeconometric equilibrium marriage matching model with labor supply, public home production, and private consumption. Household decisions are made cooperatively and, as in the general framework presented in Galichon, Kominers, and Weber (2014, 2018), utility is imperfectly transferable across spouses. We provide sufficient conditions on the primitives of the model in order to obtain existence and uniqueness of equilibrium. Semiparametric identification results are presented, and we show how the marriage market equilibrium conditions, together with market variation, allow us to identify the household decision weight.

Using an equilibrium constraints approach, we then estimate our model using American Community Survey and American Time Use Survey data, while incorporating detailed representations of the U.S. tax and transfer systems. We show that the model is able to jointly explain labor supply, home time, and marriage market patterns. Moreover, it is able to successfully explain the variation in these outcomes across markets, with the behavioral implications of the model shown to be consistent with the existing empirical evidence.

Our estimated model is then embed within an extended Mirrlees framework. The empirical design exercise concerns the simultaneous choice of a tax schedule for singles and for married couples, recognizing that taxes may affect outcomes including who marries with whom and the allocation of resources within the household. For married couples, we allow for a general form of the tax schedule and find empirical support for negative tax jointness (Kleven, Kreiner, and Saez (2009)). Importantly, the welfare gain that such a system offers relative to fully independent taxation is modest. These welfare gains are then shown to be increasing in the size of the gender wage gap, with taxes here, as in the case of gender based taxation, providing an important instrument to address within household inequality through marriage market considerations.

We believe that this paper represents an important step in placing both the family, and the marriage market, at the heart of the taxation design problem. Common with much of the empirical marriage matching literature, we do not consider cohabitation. But cohabitation is increasing in prevalence. If tax authorities do not recognize cohabitation, the ability for couples to cohabit introduces a form of tax avoidance. Our environment is static, with an irrevocable marriage decision. Marriage has an important life-cycle component and introduces many complex dynamic considerations related to the insurance that marriage may provide and the risk that different marriages may be exposed to. Taxes also affect other outcomes, such as education, that are relevant for the marriage decision. The exploration of such considerations is left for future work.

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[41] Reevaluating the role for gender based taxation, we obtain even starker differences in the schedules by gender as the gender wage gap increases. In Online Appendix H.7, we also consider increasing the differences between spouses by endogenously reducing the degree of assortative mating.

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