Optimal Taxation, Marriage, Home Production, and Family Labour Supply[*]

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April 27, 2018

Abstract

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.

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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 individuals, 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, 2007, 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,

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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.

[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 et al. (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 non-optimal taxation setting. See, e.g., Chade and Ventura (2002) and Guner, Kaygusuz and Ventura (2012).

Kreiner and Saez (2009) consider a unitary model of the household, in which the primary earner makes a continuous labour 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 behavioural 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 in shaping these, we follow Blundell and Shephard (2012) by developing an empirical structural approach to non-linear income taxation design that centres the entire analysis around a rich micro-econometric 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

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[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 present a doubly intensive model, where both the primary and secondary earner make continuous (intensive only) labour supply choices. Immervoll et al. (2011) present a double-extensive model of labour supply, and show 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).

[6]Other papers have integrated collective and empirical marriage-matching models. Chiappori, Costa Dias and Meghir (2015) consider a model of education and marriage with life-cycle labour supply and consumption in a transferable utility setting; Choo and Seitz (2013) estimate a semi-parametric version of their static family labour supply model; Galichon, Kominers and Weber (2016) provide an empirical application where they estimate a matching model with consumption, allowing for imperfectly transferable utility (as we consider here). None of these papers address optimal taxation questions.

non-economic benefit. The economic utilities are micro-founded and are derived from the household decision problem. We consider an environment that allows for general non-linear income taxes, includes both public and private good consumption, and distinguishes between the intensive and extensive labour 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 modelling 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, 2016), we therefore allow for utilities to be imperfectly transferable across spouses, thus generating a non-linear utility possibility frontier. In this environment we provide sufficient conditions for the existence and uniqueness of equilibrium in terms of the model primitives, demonstrate semi-parametric 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 favour the husband. We show that the model is able to jointly explain labour supply, home time, and marriage market patterns. Moreover, it is able to successfully explain the variation in these outcomes across markets, with the behavioural 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 labour supply and time allocation decisions, as well as marriage market outcomes, and the within-

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[7]The large growth in female labour 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).

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 non-neutrality 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 describes our data and empirical specification, discuss the semi-parametric 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, labour supply, home production, and potentially joint and non-linear 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 $\mathcal{M}$, whose element

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

$m_i > 0$ denotes the measure of type-i males. Similarly, the population vector of women is given by $\mathcal{F}$, 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 non-labour 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 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

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[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 percent 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 modelled in a dynamic environment.

market private good (whose price we normalize to 1), and a non-marketable 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, non-labour income y^i, and demographic characteristics $\mathbf{X}^i$. His total time endowment is L_0, and he chooses the time allocation vector $\mathbf{a}^i = [\ell^i, h^i_w, h^i_Q]$ comprising hours of leisure ℓ^i, market work time h^i_w, and home production time h^i_Q, 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 non-marketable 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 $L_0 = \ell^i + h^i_w + h^i_Q$. 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

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

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

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

Equation (1b) states that consumption of the private good is simply equal to net family income (the sum of earnings and non-labour income, minus net taxes) and less any possible fixed costs of market work, $FC(h^i_w; \mathbf{X}^i) \geq 0$. These fixed costs, as in Cogan (1981), are non-negative 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 $\mathbf{a}^{i\star}_{i0}(w^i, y^i, \mathbf{X}^i, \epsilon^i; T)$, which upon substitution into equation (1a), including the state-specific preference term associated with this allo-

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[11]The presence of taxes and transfers implies non-linear and potential non-convex 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).

cation, yields the indirect utility function for type-i males that we denote as $v_{i0}^i(w^i, y^i, \mathbf{X}^i, \epsilon^i; T)$. The decision problem for type-j single women is described similarly and yields the indirect utility function $v_{0j}^j(w^j, y^j, \mathbf{X}^j, \epsilon^j; T)$.

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

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

$$\text{subject to} \quad q = q^i + q^j = y^i + y^j + \mathbf{w}^\mathsf{T} \mathbf{h}_w - T(w^i h_w^i, w^j h_w^j, \mathbf{y}; \mathbf{X}) - FC(\mathbf{h}_w; \mathbf{X}), \quad \text{(2b)}$$

$$q^j = s_{ij} \cdot q, \quad \text{(2c)}$$

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

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 labour market earnings of both spouses) less any fixed work-related costs; (ii) the wife consumes the endogenous share $0 \le s_{ij} \le 1$ of the private good; and (iii) the 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.

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

Letting $\epsilon = [\epsilon^i, \epsilon^j]$, the solution to the household problem is described by the incentive compatible time allocation vectors $\mathbf{a}_{ij}^{i\star}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij})$ and $\mathbf{a}_{ij}^{j\star}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij})$, together with the private consumption share $s_{ij}^\star(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij})$. 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 $v_{ij}^i(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij})$ and $v_{ij}^j(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij})$.

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

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

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

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

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. The expected value of a type-i man when married to a type-j woman is strictly

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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.

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

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

where $\boldsymbol{\lambda}^i = [\lambda_{i1}, \dots, \lambda_{iJ}]^\mathsf{T}$ 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

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

where $\boldsymbol{\lambda}^j = [\lambda_{1j}, \ldots, \lambda_{Ij}]^\mathsf{T}$ 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 $\boldsymbol{\lambda} = [\boldsymbol{\lambda}^1, \boldsymbol{\lambda}^2, \ldots, \boldsymbol{\lambda}^J]$ 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,

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

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 Appendix A, 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 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 Appendix A. □

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 (2016) under a more general heterogeneity structure. In Online Appendix F 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, $G_{i0}^i(w^i, \mathbf{X}^i, \epsilon^i)$ and $G_{0j}^j(w^j, \mathbf{X}^j, \epsilon^j)$ 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.[13] The joint cumulative distribution function within an $\langle i, j \rangle$ match is similarly denoted $G_{ij}(\mathbf{w}, \mathbf{X}, \epsilon)$. As individuals non-randomly select into different marital pairings on the basis of their idiosyncratic marital payoffs, the distribution of these within a match will differ from the unconditional extreme value distribution for the population as a whole. They are therefore also a function of tax policy. We let $H_{i0}^i(\theta^i; T)$ denote the cumulative distribution function amongst single type-i males and similarly define $H_{0j}^j(\theta^j; T)$ for single type-j females. Among married men and women in an $\langle i, j \rangle$ match, these are given by $H_{ij}^i(\theta^i; T)$ and $H_{ij}^j(\theta^j; T)$, respectively. We provide a theoretical characterization of these distributions in Appendix C.

Our simulations will consider the implications of alternative redistributive preferences for the planner, which we will capture through the utility transformation function

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[13]Our analysis assumes wage offers and non-labour income are invariant with respect to the tax system. A model with an endogenous human capital stage, as in Chiappori, Costa Dias and Meghir (2015), for example, would have more complex implications for the optimal design problem.

$Y(\cdot)$.[14] The social-welfare function is defined as the sum of these transformed utilities

$$\mathcal{W}(T) = \underbrace{\sum_i \mu_{i0}(T) \int \Upsilon\left[v_{i0}^i(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T) + \theta^i\right] \mathrm{d}G_{i0}^i(w^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i)\, \mathrm{d}H_{i0}^i(\theta^i; T)}_{\text{single men}}$$

$$+ \underbrace{\sum_j \mu_{0j}(T) \int \Upsilon\left[v_{0j}^j(w^j, y^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j; T) + \theta^j\right] \mathrm{d}G_{0j}^j(w^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j)\, \mathrm{d}H_{0j}^j(\theta^j; T)}_{\text{single women}}$$

$$+ \underbrace{\sum_{i,j} \mu_{ij}(T) \int \Upsilon\left[v_{ij}^i(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij}(T)) + \theta^i\right] \mathrm{d}G_{ij}(\mathbf{w}, \mathbf{X}, \boldsymbol{\epsilon})\, \mathrm{d}H_{ij}^i(\theta^i; T)}_{\text{married men}}$$

$$+ \underbrace{\sum_{i,j} \mu_{ij}(T) \int \Upsilon\left[v_{ij}^j(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij}(T)) + \theta^j\right] \mathrm{d}G_{ij}(\mathbf{w}, \mathbf{X}, \boldsymbol{\epsilon})\, \mathrm{d}H_{ij}^j(\theta^j; T)}_{\text{married women}}. \quad (9)$$

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

$$\mathcal{R}(T) = \underbrace{\sum_i \mu_{i0}(T) \int R_{i0}^i(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T)\, \mathrm{d}G_{i0}^i(w^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i)}_{\text{revenue from single men}}$$

$$+ \underbrace{\sum_j \mu_{0j}(T) \int R_{0j}^j(w^j, y^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j; T)\, \mathrm{d}G_{0j}^j(w^j, \mathbf{X}^j, \boldsymbol{\epsilon}^j)}_{\text{revenue from single women}}$$

$$+ \underbrace{\sum_{i,j} \mu_{ij}(T) \int R_{ij}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon}; T, \lambda_{ij}(T))\, \mathrm{d}G_{ij}(\mathbf{w}, \mathbf{X}, \boldsymbol{\epsilon}) \geq \overline{T},}_{\text{revenue from married couples}} \quad (10)$$

where $R_{i0}^i(w^i, y^i, \mathbf{X}^i, \boldsymbol{\epsilon}^i; T)$ describes the tax revenue raised from an optimizing type-i sin-

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[14]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).

gle male given $w^i, y^i, \mathbf{X}^i, \epsilon^i$, and the tax system T. We similarly define $R_{0j}^j(w^j, y^j, \epsilon^j, \mathbf{X}^j; T)$ for single type-j women, and $R_{ij}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij}(T))$ 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 behaviour and the marriage market fixed. Second, there is a behavioural 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 labour 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).[15] 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 childcare hours that measure all time spent by an individual caring for, educating, or playing with his/her child(ren).[16]

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 pur-

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[15]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 labour force survey. See Aguiar, Hurst and Karabarbounis (2012) for a full list of the time-use categories contained in the ATUS data.

[16]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, e.g., Frazis and Stewart (2007).

poses 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.[17]

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.[18] 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 E.

4.2 Empirical specification

In Section 4.5 we will see that there are important differences between men and women in labour 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

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[17]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 that both our estimation results and our tax design experiments to be quantitatively robust.

[18]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.

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.[19] For singles, the demographic transition process depends on gender and own type. For married couples they depend on both own type and spousal type. Thus individuals are essentially making joint marriage and fertility decisions. These transition processes are estimated non-parametrically 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

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[19]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 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.

of production within an $\langle i,j \rangle$ match and with demographics characteristics **X**. That is

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

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.[20]

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.[21]

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.[22] To construct these sets, we assume that both leisure and home time have a non-discretionary component (4 hours and 12 hours, respectively), and then define the residual discrete grid comprising 9 equi-spaced 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 $\epsilon_{\mathbf{a}^i}$ and $\epsilon_{\mathbf{a}^j}$ 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 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.[23]

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[20]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.

[21]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.

[22]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).

[23]We approximate the integral over these preference shocks through simulation. To preserve smooth-

4.3 Identification

The estimation will be of a fully specified parametric model. It is still important to explore non-/semi-parametric 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 semi-parametric 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, i.e., 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 Appendix B.1. □

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ness 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 $(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon)$ 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.

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.[24] 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 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 semi-parametric 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 Appendix B.2, all other model primitives are identified.*

Proof. See Appendix B.2. □

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 behaviour of married couples to identify the home production technology for couples.[25] 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 labour force participation but not wages).[26] 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.

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[24]See Galichon and Salanié (2015) for semi-parametric identification results in transferable utility matching models with more general heterogeneity structures.

[25]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.

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

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 G.

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 $I \times J \times K$ non-linear 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 F. Letting β denote the $B \times 1$ parameter vector, our estimation problem may be formally described as

$$[\widehat{\beta}, \lambda(\widehat{\beta})] = \arg\min_{\beta, \lambda} [\mathbf{m_{sim}}(\beta, \lambda) - \mathbf{m_{data}}]^{\mathsf{T}} \mathbf{W} [\mathbf{m_{sim}}(\beta, \lambda) - \mathbf{m_{data}}]$$

$$\text{s.t. } \mu_{ijk}^{d}(\beta, \lambda_k^i) = \mu_{ijk}^{s}(\beta, \lambda_k^j) \quad \forall i = 1, \dots, I, j = 1, \dots, J, k = 1, \dots, K,$$

where λ defines the stacked $(I \times J \times K)$ vector of Pareto weights in all markets, $\mathbf{m_{data}}$ is the $M \times 1$ vector of empirical moments, $\mathbf{m_{sim}}(\beta, \lambda)$ is the model moment vector given β and an arbitrary (i.e., potentially non-equilibrium) vector of Pareto weights λ.[27] Finally, $\mathbf{W}$ defines an $M \times M$ 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.[28] The solution to this estimation problem is such that $\widehat{\lambda} = \lambda(\widehat{\beta})$.[29]

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[27]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 (β, λ).

[28]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 $r \gg 1$.

[29]The variance matrix of our estimator is given by $\left[\mathbf{D_m^{\mathsf{T}} W D_m}\right]^{-1} \mathbf{D_m^{\mathsf{T}} W \Sigma W^{\mathsf{T}} D_m} \left[\mathbf{D_m^{\mathsf{T}} W D_m}\right]^{-1}$, where $\mathbf{\Sigma}$ is the $M \times M$ covariance matrix of the empirical moments, and $\mathbf{D_m} = \partial \mathbf{m_{sim}}(\beta, \lambda(\beta))/\partial \beta$ is the $M \times B$ derivative matrix of the moment conditions with respect to the model parameters at $\beta = \widehat{\beta}$.

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 over-identifying 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 labour 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.

We now present the fit of the model to some of the most salient features of the data. In Table 1 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 behaviour. 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

Table 1: Empirical and predicted marital sorting patterns

		Women		
		High school and below	Some college	College and above
	–	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]

(Row label "Men" spans the four data rows.)

Notes: Table shows the empirical and simulated marriage market matching function, aggregated over all marriage markets. Simulated values from the model are presented in brackets.

work less and have higher home time, with the differences most pronounced for mothers. There are much smaller differences in both labour 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 semi-parametric 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 2 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.
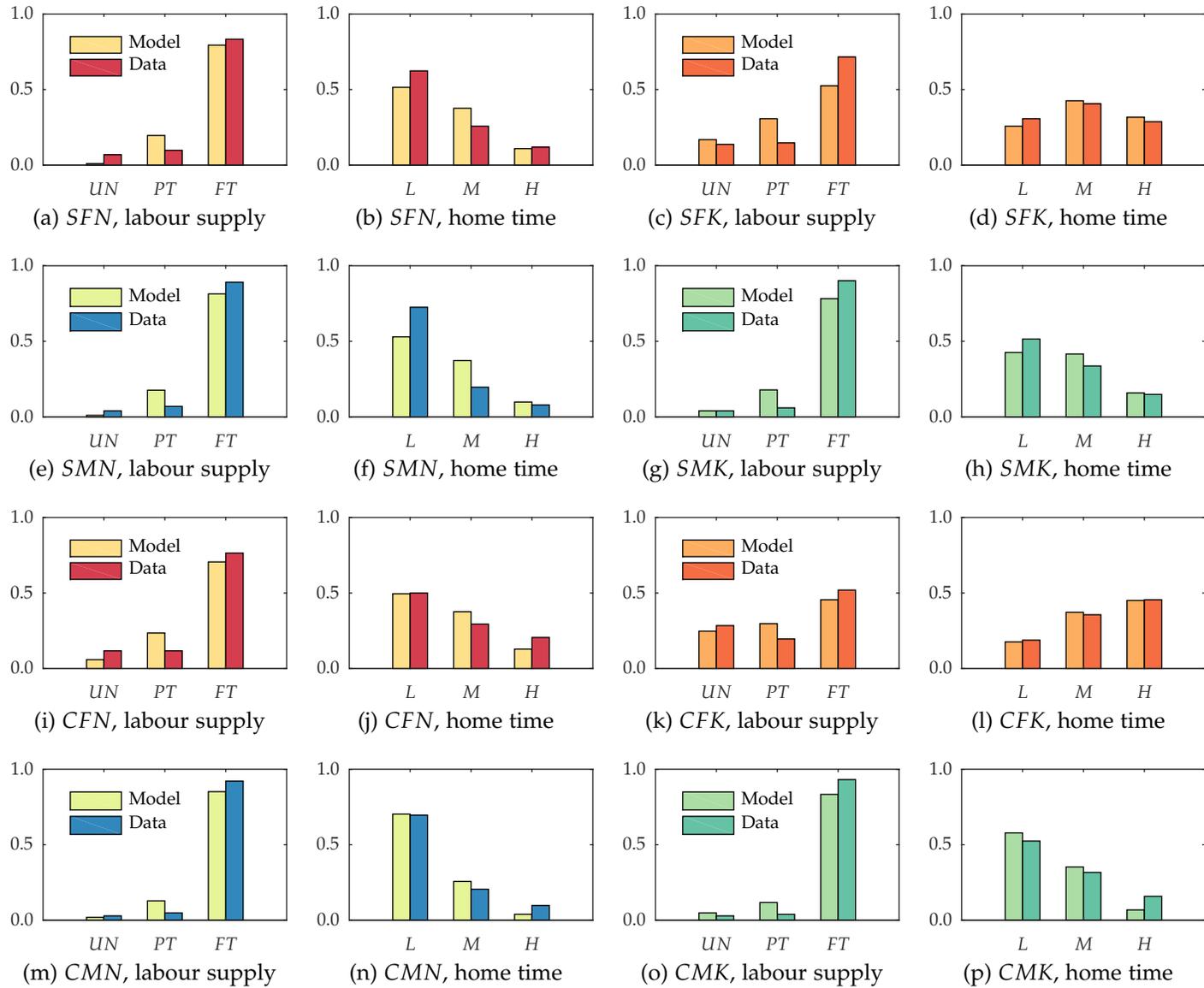
Figure 1: Figure shows empirical and predicted frequencies of work and home time, aggregated over types and conditional on marital status, gender, and children. *S* (*C*) identifies singles (couples); *F* (*M*) identifies women (men); *N* (*K*) identifies childless (children). *UN* is non-employment; *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).
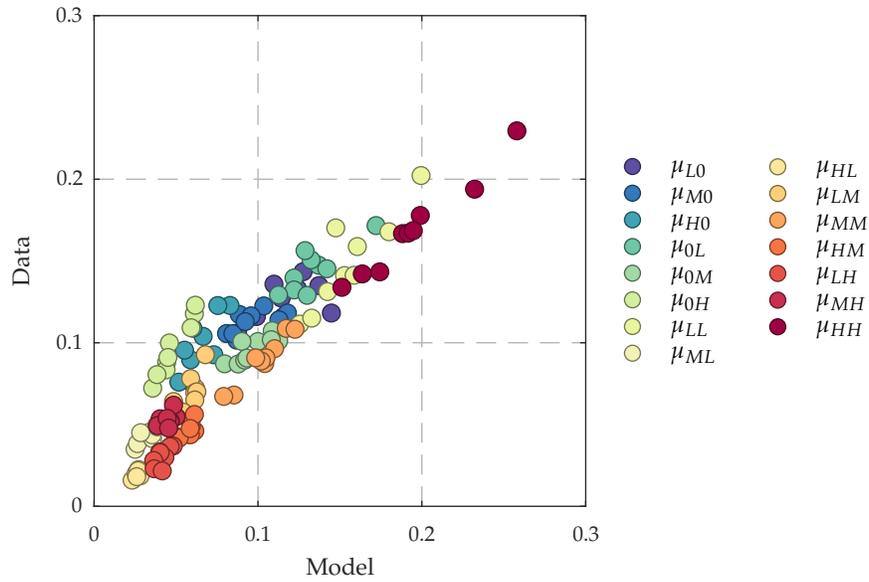
Figure 2: Figure shows elements of the empirical and predicted marriage market matching function. A market corresponds to a Census Bureau-designated division.

(a) Female: Unconditional work hours

(b) Male: Unconditional work hours
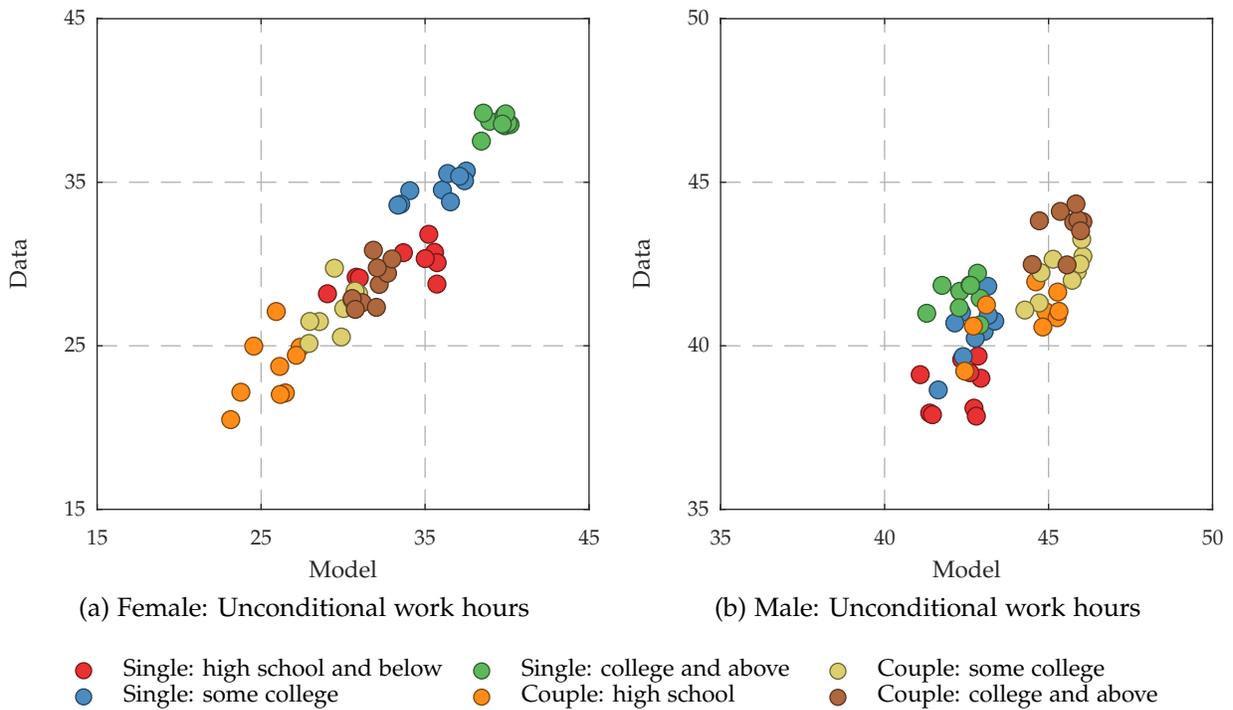
Figure 3: Figure shows empirical and predicted mean unconditional work hours of men and women by education and market. A market corresponds to a Census Bureau-designated division.

Table 2: Pareto weight distribution

|		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]

Notes: Table shows the distribution of Pareto weights from our estimated model. The numbers in black 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.

There are both economic and non-economic gains from marriage. In Figure 4 we present an empirical 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 patterns for other matches are similar. The expected utility possibility frontier, which is highly non-linear, 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 non-economic gains.[30]

While the following optimal design exercise directly uses the behavioural 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 non-separable 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.[31] The results of this exercise are shown in Table 3. For single individuals we report em-

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[30]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.6 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.

[31]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).

| | (a) High school and below | (b) Some college | (c) College and above |
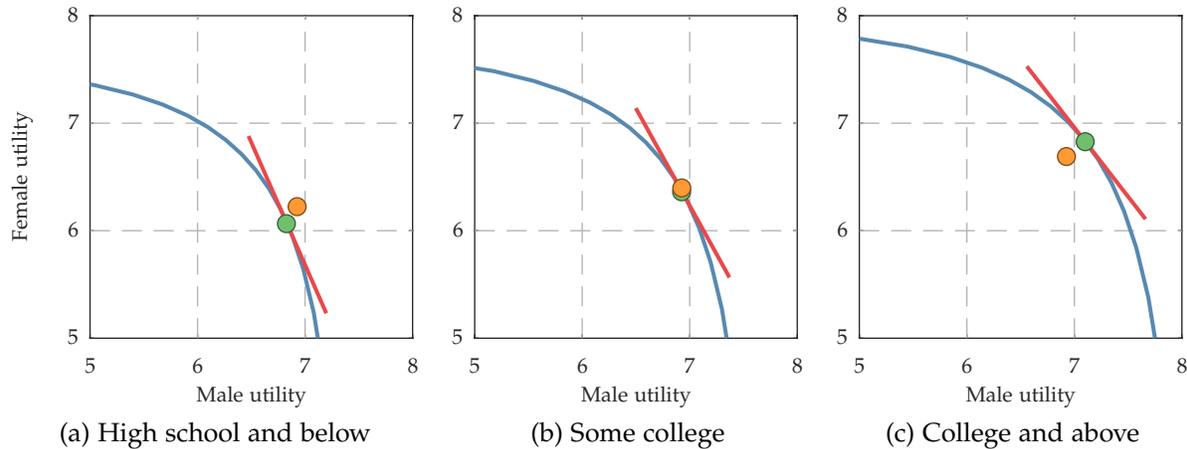
Figure 4: The figure shows the expected utility possibility frontier in marriages where the male has a college degree or higher and the education level of the female is varied. The figure is obtained from the estimated model and is calculated under the New England market. The green point in each panel indicates the expected utilities in the sub-marriage market given the market clearing Pareto weights. The orange point indicates the expected utilities in the single state.

ployment, 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 how employment, work hours, and home time respond as the wage of his/her spouse is varied.[32]

Our labour 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 labour supply literature (see, e.g., Meghir and Phillips, 2010). The evidence on cross-wage labour supply effects is more limited, although the results here are consistent with existing estimates (for example, Blau and Kahn, 2007). Also in Table 3 we report home hours elasticities, which suggest that individuals substitute away from home time for a given uncompensated change in their wage and substitute towards home time when their spouse's wage is increased. The same tax-induced home time pattern was reported in Gelber and Mitchell (2011).

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[32]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 non-decreasing. Cross-wage work-hours elasticities condition on being employed both before and after the net wage increase.

Table 3: Simulated elasticities

	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	–	–

Notes: 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.

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, e.g., 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 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, e.g., 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*

$$\mathcal{W}_{ij}^i(T) = \int_{\theta^i} \int_{\mathbf{w}, \mathbf{X}, \epsilon} Y[v_{ij}^i(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij}(T)) + \theta^i] \, dG_{ij}(\mathbf{w}, \mathbf{y}, \mathbf{X}) \, dH_{ij}^i(\theta^i)$$

$$= p_{ij}^i(T, \boldsymbol{\lambda}^i(T))^{-\delta \sigma_\theta} \Gamma(1 - \delta \sigma_\theta) \int_{\mathbf{w}, \mathbf{X}, \epsilon} \frac{\exp[\delta v_{ij}^i(\mathbf{w}, \mathbf{y}, \mathbf{X}, \epsilon; T, \lambda_{ij}(T))]}{\delta} \, dG_{ij}(\mathbf{w}, \mathbf{X}, \epsilon) - \frac{1}{\delta},$$

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

$$\mathcal{W}_{ij}^i(T) = \sigma_\theta \gamma - \sigma_\theta \log p_{ij}^i(T, \boldsymbol{\lambda}^i(T)) + U_{ij}^i(T, \lambda_{ij}(T)),$$

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 Appendix C. $\qquad\square$

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.[33]

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 $0 = n_1 < n_2 < \ldots < n_N < \infty$ 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 β_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 non-parametric schedule, divides the surface of the tax schedule into a non-overlapping 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 labour 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 $\mathcal{Z} = \{0, 12500, 25000, 37500, 60000, 85000, 110000, 150000,$

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[33]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 ϵ, 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.

190000, 250000}. Thus, we have a tax system that is characterized by 65 parameters.[34] 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 β_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 $\mu_{ij}^d(T, \boldsymbol{\lambda}^i) = \mu_{ij}^s(T, \boldsymbol{\lambda}^j)$ in addition to the usual incentive compatibility and revenue constraints. This approach only involves calculating the marriage market equilibrium associated with the optimal tax parameter vector β_T^* rather than any candidate β_T, as would be true in a nested fixed-point procedure.

5.2 Implications for design

We now describe our main results. In Figure 5a we present the joint (net income) budget constraint for both singles and married couples, calculated under the government 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 blue 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 5b we show the associated marginal tax rate of a given individual as the earnings of his/her spouse

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[34]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.5 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.

(a) Net income function

(b) Marginal tax rate conditional on spousal earnings
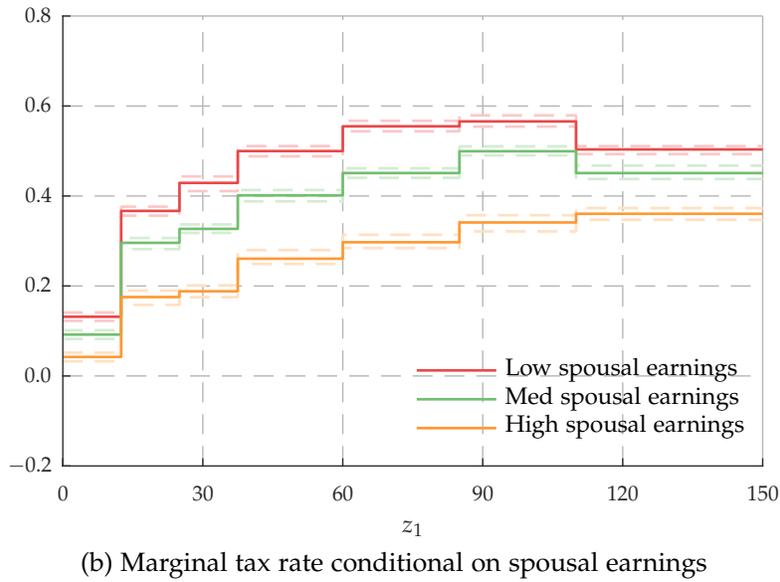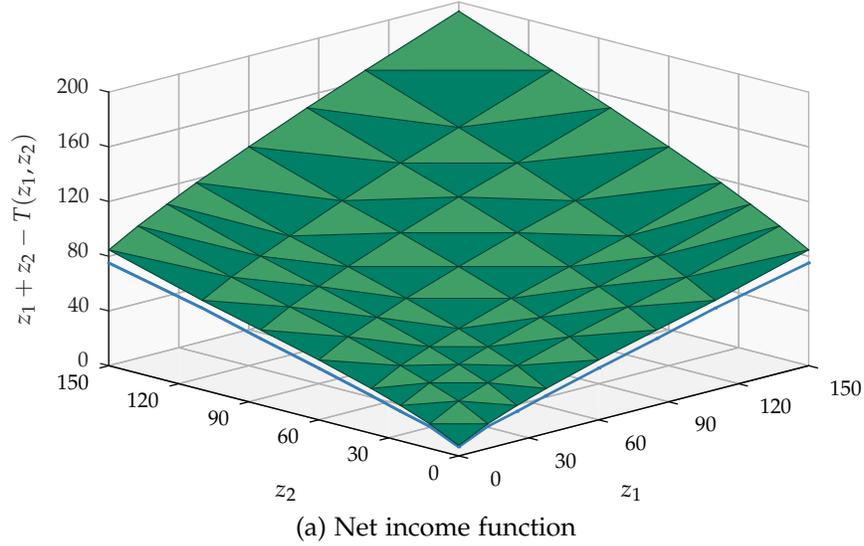
Figure 5: Optimal tax schedule with $\delta = 0$. In panel (a) we show net income as a function of labour earnings for both single individuals (blue line) and couples (three-dimensional surface). In panel (b) we show marginal tax rates conditional on alternative values of spousal earnings. At earnings exceeding \$150,000, marginal tax rates conditional on spousal earnings remain approximately unchanged: for *low* spousal earnings (respectively *medium* and *high*) marginal tax rates average 47% (respectively 43% and 34%). The broken lines indicate the 99% pointwise confidence bands. All incomes are in thousands of dollars per year, expressed in average 2006 prices. See Footnote 35 for a definition of *low*, *medium*, and *high* spousal earnings levels.

is fixed at different levels.[35] 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 labour 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.[36] 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 preferences ($\delta = -1$). As we later show, this parametrization is associated with a consid-

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[35]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 $\{z_2 | z_2 \in \mathcal{Z}, \$85,000 < z_2 < \$250,000\}$.

[36]The negative tax jointness property contrasts with that of the actual U.S. tax system. With a broadly progressive rate structure, and with households taxed based on total family income, the U.S. system exhibits *positive* tax jointness. 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 non-decreasing in earnings (conditional on spousal earnings) has little impact on the overall shape of the schedule.

erably 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.2 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 labour supply behaviour 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 favour the husband (see Table 5 later), 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

(a) Net income function

(b) Marginal tax rate conditional on spousal earnings
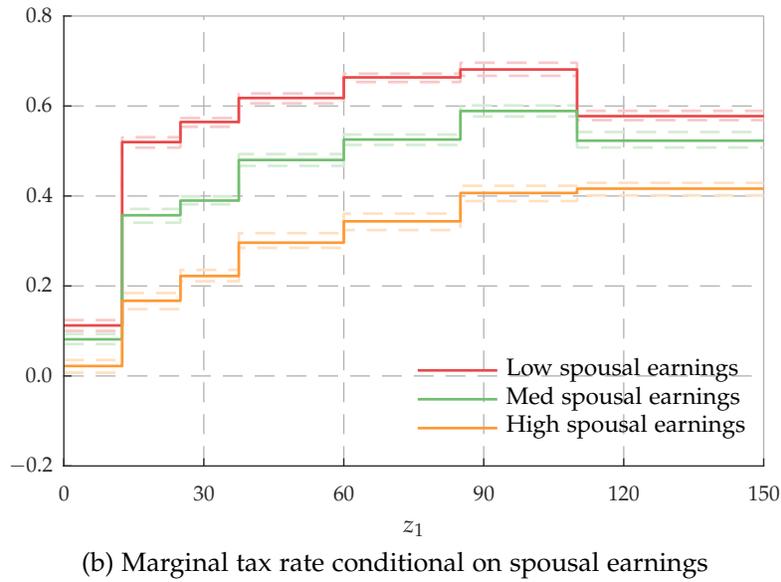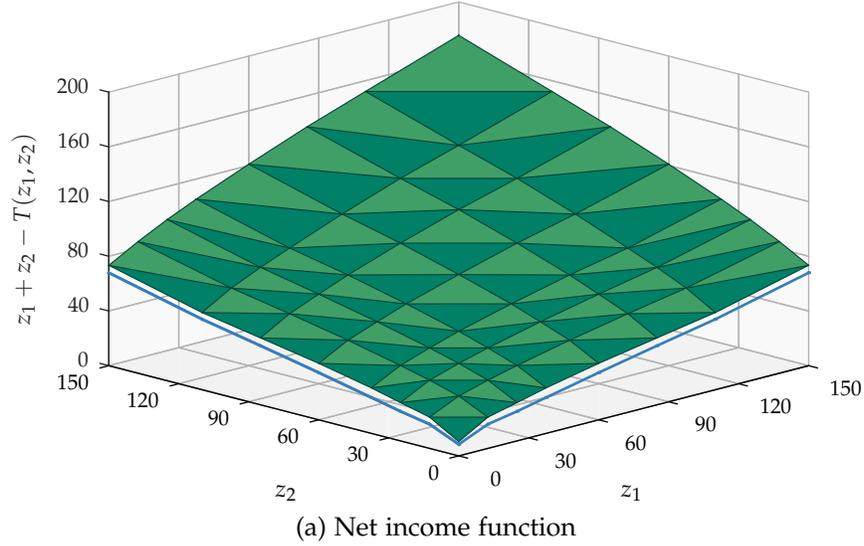
Figure 6: Optimal tax schedule with $\delta = -1$. In panel (a) we show net income as a function of labour earnings for both single individuals (blue line) and couples (three-dimensional surface). In panel (b) we show marginal tax rates conditional on alternative values of spousal earnings. At earnings exceeding \$150,000, marginal tax rates conditional on spousal earnings remain approximately unchanged: for *low* spousal earnings (respectively *medium* and *high*) marginal tax rates average 55% (respectively 49% and 38%). The broken lines indicate the 99% pointwise confidence bands. All incomes are in thousands of dollars per year, expressed in average 2006 prices. See Footnote 35 for a definition of *low*, *medium*, and *high* spousal earnings levels.

Table 4: Marginal tax rates with restricted tax instruments and conditional on spousal earnings

	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

Notes: 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 35 for a definition of *low*, *medium*, and *high* spousal earnings levels.

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 $\breve{T}(\cdot)$ for singles and couples, but allow the tax liability of couples to depend upon total household earned income: $T(z_1, z_2) = \breve{T}(z_1 + z_2)$.

We present results from this exercise when $\delta = 0$ in Table 4. 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 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.3 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 6. 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 labour supply elasticities than men (see also the reduced form elasticities presented in Table 3). 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.[37] 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*

$$\frac{\partial SWF(T)}{\partial \tau} = \sum_i \mu_{i0}(T, \boldsymbol{\lambda}^i) \frac{\partial U_{i0}^i(T)}{\partial \tau} + \sum_j \mu_{0j}(T, \boldsymbol{\lambda}^j) \frac{\partial U_{0j}^j(T)}{\partial \tau} \tag{14}$$

$$+ \sum_{i,j} \mu_{ij}(T, \boldsymbol{\lambda}) \left[\frac{\partial U_{ij}^i(T, \lambda_{ij})}{\partial \tau} + \frac{\partial U_{ij}^j(T, \lambda_{ij})}{\partial \tau} + \frac{\partial U_{ij}^i(T, \lambda_{ij})}{\partial \lambda_{ij}} \frac{(2\lambda_{ij} - 1)}{\lambda_{ij}} \frac{\partial \lambda_{ij}}{\partial \tau} \right].$$

Proof. See Appendix 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 behavioural 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 behavioural 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

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[37]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.

Pareto weights that typically favour the husband. Now consider a small tax increase for single men. This results in a reduction in the expected economic value for single men $U_{i0}^i(T)$, which with a fixed vector of Pareto weights $\boldsymbol{\lambda}$, would create an excess demand for women in the marriage market, i.e., $\mu_{ij}^d(T, \boldsymbol{\lambda}^i) > \mu_{ij}^s(T, \boldsymbol{\lambda}^j)$. 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 describe these changes, and present full results in Online Appendix H.4. Firstly, 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 5, 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 behaviour. In particular, amongst married couples labour 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.[38]

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 non-economic benefits. Indeed, the role of the marriage market was seen

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[38]The impact of the changing decision weights is non-trivial. 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).

Table 5: Marriage matching function and Pareto weights with gendered taxation

			Women		
			High school and below	Some college	College and above
(a). Gender neutral taxation					
		–	0.117	0.090	0.077
		–	–	–	–
Men	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)

Notes: 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.

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 5b (as solid lines), and additionally displays the optimal marginal rate structure with a fixed marriage market (as broken lines). 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 non-employment state.
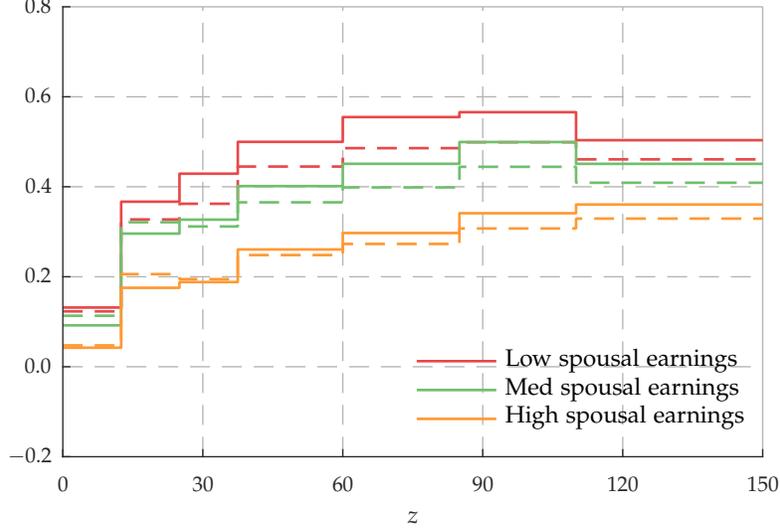
Figure 7: Optimal tax schedule with fixed and equilibrium marriage market under $\delta = 0$. Figure shows marginal tax rates for married couples conditional on spousal earnings. The solid (broken) lines show the marginal tax rates obtained with an equilibrium (fixed) marriage market. See Footnote 35 for a definition of *low, medium*, and *high* spousal earnings.

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 non-zero 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 $\Delta_{\text{eq-revenue}} = [\mathcal{R}(T_e) - \overline{T}]/\overline{T}$.

We report results from this exercise when $\delta = 0$ in Table 6. 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

Table 6: Welfare cost and marriage market importance with alternative tax instruments

	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

Notes: 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.

exhibits a strong non-neutrality 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.6 we present results where we set $\Delta\mathbb{E}[\ln w_j] = -0.5$ for all female types $j = 1, \ldots, J$, 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 it's 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.[39] 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 still, there are larger increases in tax jointness, higher taxes on singles, and even larger welfare gains relative to independent taxation.[40]

6 Summary and conclusion

We have presented a micro-econometric equilibrium marriage matching model with labour 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, 2016), 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. Semi-parametric 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 labour supply, home time, and marriage market patterns. Moreover, it is able to successfully explain the variation in these outcomes across markets, with the behavioural 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,

---

[39]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 $[0.427, 0.430, 0.400]$.

[40]Re-evaluating 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.6 we also consider increasing the differences between spouses by endogenously reducing the degree of assortative mating.

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.

Appendices

A   Proof of Proposition 1

We assume that the distribution $G_{ij}(\mathbf{w}, \mathbf{y}, \mathbf{X}, \boldsymbol{\epsilon})$ is absolutely continuous and twice continuously differentiable. The individual utility functions $u^i(\ell^i, q^i, Q; \mathbf{X}^i)$ and $u^j(\ell^j, q^j, Q; \mathbf{X}^j)$ are assumed increasing and concave in ℓ, q, and Q, and with $\lim_{q^i \to 0} u^i(\ell^i, q^i, Q; \mathbf{X}^i) = \lim_{q^j \to 0} u^j(\ell^j, q^j, Q; \mathbf{X}^j) = -\infty$. To proceed we define the *excess demand function* as

$$ED_{ij}(\boldsymbol{\lambda}) = \mu_{ij}^d(\boldsymbol{\lambda}^i) - \mu_{ij}^s(\boldsymbol{\lambda}^j), \quad \forall i = 1, \dots, I, j = 1, \dots, J.$$

Here and in what follows, we suppress the dependence of the excess demand functions (and other objects) on the tax system T. Equilibrium existence is synonymous with the excess demand for all types being equal to zero at some vector $\boldsymbol{\lambda}^* \in [0,1]^{I \times J}$, i.e., $ED_{ij}(\boldsymbol{\lambda}^*) = 0, \forall i, j$. Equilibrium uniqueness implies that there is a single vector that achieves this.[41] Under our regularity conditions, we have that: (i) $U_{ij}^i(\lambda_{ij})$ and $U_{ij}^j(\lambda_{ij})$ are *continuously differentiable in* λ_{ij}; (ii) $\partial U_{ij}^i(\lambda_{ij})/\partial \lambda = -\lambda_{ij}/(1 - \lambda_{ij}) \cdot \partial U_{ij}^j(\lambda_{ij})/\partial \lambda < 0$; (iii) $\lim_{\lambda_{ij} \to 0} ED_{ij}(\lambda_{ij}, \boldsymbol{\lambda}_{-ij}) > 0$; and (iv) $\lim_{\lambda_{ij} \to 1} ED_{ij}(\lambda_{ij}, \boldsymbol{\lambda}_{-ij}) < 0$.

---

[41]Reformulating their matching model as a demand system, Galichon, Kominers and Weber (2016) also use the properties of the excess demand function to provide a proof of existence and uniqueness with a more general heterogeneity structure. A proof using the marriage matching function and Type-I extreme value errors is presented in Galichon, Kominers and Weber (2014).

A.1 Properties of the excess demand functions

We now state further properties of the excess demand functions. We have

$$\partial ED_{ij}(\boldsymbol{\lambda})/\partial \lambda_{ij} < 0, \tag{A.1a}$$

$$\partial ED_{ik}(\boldsymbol{\lambda})/\partial \lambda_{ij} > 0; \quad \text{if } k \neq j, \tag{A.1b}$$

$$\partial ED_{kj}(\boldsymbol{\lambda})/\partial \lambda_{ij} > 0; \quad \text{if } k \neq i, \tag{A.1c}$$

$$\partial ED_{kl}(\boldsymbol{\lambda})/\partial \lambda_{ij} = 0; \quad \text{if } k \neq i, l \neq j, \tag{A.1d}$$

where equation (A.1d) follows the Type-I extreme value distribution's IIA property.

A.2 Equilibrium existence

We construct a continuous function $\boldsymbol{\Gamma} : [0,1]^{I \times J} \to [0,1]^{I \times J}$ such that any fixed point $\boldsymbol{\lambda}^*$ is an equilibrium of the marriage market. Brouwer's fixed point theorem then implies existence. Letting $\psi > 0$, we define

$$\boldsymbol{\Gamma}(\boldsymbol{\lambda}) = \psi \cdot \mathbf{ED}(\boldsymbol{\lambda}) + \boldsymbol{\lambda}.$$

Notice that $\boldsymbol{\lambda}^*$ is a fixed point, $\boldsymbol{\lambda}^* = \psi \cdot \mathbf{ED}(\boldsymbol{\lambda}^*) + \boldsymbol{\lambda}^*$, if and only excess demand is identically zero, i.e. $\mathbf{ED}(\boldsymbol{\lambda}^*) = 0$. The following Lemma's establish that we can choose ψ small enough so that the range of $\boldsymbol{\Gamma}$ is $[0,1]^{I \times J}$.

Lemma 1. *The excess demand functions are continuously differentiable with* $\mathbf{ED}(\mathbf{0}_{I \times J}) \succcurlyeq \mathbf{0}_{I \times J}$ *and* $\mathbf{ED}(\mathbf{1}_{I \times J}) \preccurlyeq \mathbf{0}_{I \times J}$.

Proof of Lemma 1. The continuous differentiability follows directly from the regularity conditions described above. $\mathbf{ED}(\mathbf{0}_{I \times J}) \succcurlyeq \mathbf{0}_{I \times J}$ and $\mathbf{ED}(\mathbf{1}_{I \times J}) \preccurlyeq \mathbf{0}_{I \times J}$ follow from our regularity conditions along with equations (A.1a)–(A.1d). Intuitively, there is no supply when $\boldsymbol{\lambda} = \mathbf{0}_{I \times J}$, and no demand when $\boldsymbol{\lambda} = \mathbf{1}_{I \times J}$. □

Lemma 2. *Let* $0 < \psi \leq \left(\sup_{i,j,\boldsymbol{\lambda}} \left| \frac{\partial ED_{ij}(\boldsymbol{\lambda})}{\partial \lambda_{ij}} \right| \right)^{-1}$, *then* $\mathbf{0}_{I \times J} \preccurlyeq \boldsymbol{\Gamma}(\boldsymbol{\lambda}) \preccurlyeq \mathbf{1}_{I \times J}$.

Proof of Lemma 2. Such a ψ exists by the extreme value theorem because $\mathbf{ED}(\boldsymbol{\lambda})$ is continuously differentiable on $[0,1]^{I \times J}$. Now, we have that $\psi \cdot \partial ED_{ij}(\boldsymbol{\lambda})/\partial \lambda_{ij} + 1 \geq 0$. This combined with equations (A.1b)–(A.1d) being non-negative implies that $\partial \boldsymbol{\Gamma}(\boldsymbol{\lambda})/\partial \boldsymbol{\lambda} \succcurlyeq \mathbf{0}_{I \times J}$. Consequentially,

$$\boldsymbol{\Gamma}(\mathbf{0}_{I \times J}) \preccurlyeq \boldsymbol{\Gamma}(\boldsymbol{\lambda}) \preccurlyeq \boldsymbol{\Gamma}(\mathbf{1}_{I \times J}).$$

Finally, by Lemma 1, $\mathbf{0}_{I \times J} \preccurlyeq \Gamma(\mathbf{0}_{I \times J})$ and $\Gamma(\mathbf{1}_{I \times J}) \preccurlyeq \mathbf{1}_{I \times J}$. $\qquad\qquad\qquad\qquad\square$

Thus, from Lemma 2, Brouwer's conditions are satisfied and an equilibrium exists.

A.3 Equilibrium uniqueness

Suppose the equilibrium is not unique. Consider any distinct vectors of Pareto weights $\boldsymbol{\lambda}^* \neq \boldsymbol{\lambda}'$ with $\mathbf{ED}(\boldsymbol{\lambda}^*) = \mathbf{ED}(\boldsymbol{\lambda}') = \mathbf{0}$. Then let $B^* = \{\langle i, j \rangle | \lambda^*_{i,j} < \lambda'_{i,j}\}$ denote the pairings where $\boldsymbol{\lambda}^*$ is *strictly* less than $\boldsymbol{\lambda}'$. As the labelling of $\boldsymbol{\lambda}^*$ and $\boldsymbol{\lambda}'$ is arbitrary, without loss of generality, we take B^* to be non-empty. Defining $U^i_{i0}(\lambda_{i0}) = U^i_{i0}$ the following holds

$$
\sum_{\langle i,j \rangle \in B^*} \mu^d_{ij}(\boldsymbol{\lambda}^*) = \sum_i m_i \Pr \left[\max_{\{j \, : \, \langle i,j \rangle \in B^*\}} \{U^i_{ij}(\lambda^*_{ij}) + \theta^i_{ij}\} > \max_{\{j \, : \, \langle i,j \rangle \notin B^* \vee j=0\}} \{U^i_{ij}(\lambda^*_{ij}) + \theta^i_{ij}\} \right]
$$

$$
> \sum_i m_i \Pr \left[\max_{\{j \, : \, \langle i,j \rangle \in B^*\}} \{U^i_{ij}(\lambda'_{ij}) + \theta^i_{ij}\} > \max_{\{j \, : \, \langle i,j \rangle \notin B^* \vee j=0\}} \{U^i_{ij}(\lambda'_{ij}) + \theta^i_{ij}\} \right] = \sum_{\langle i,j \rangle \in B^*} \mu^d_{ij}(\boldsymbol{\lambda}').
$$

The outside inequality is strict because $U^i_{ij}(\lambda_{ij})$ is strictly *decreasing* in λ_{ij}, and because θ^i_{ij} has full support. Thus, the measure of type-i men who would choose type-j women (the demand) from the set B^* is strictly higher under $\boldsymbol{\lambda}^*$ compared to $\boldsymbol{\lambda}'$. By the same arguments, the measure of type-j females who would choose type-i males (the supply) from the set B^* is strictly lower under $\boldsymbol{\lambda}^*$ compared to $\boldsymbol{\lambda}'$. It therefore follows that

$$
\sum_{\langle i,j \rangle \in B^*} ED_{ij}(\boldsymbol{\lambda}^*) > \sum_{\langle i,j \rangle \in B^*} ED_{ij}(\boldsymbol{\lambda}'),
$$

which is a contradiction. Hence, the equilibrium must be unique.

B Identification

B.1 Proof of Proposition 2

Consider a given market $k \leq K$. From the conditional choice probabilities (equations (5) and (6)) and imposing market clearing $\mu^d_{ij}(T, \boldsymbol{\lambda}^i) = \mu^j_{ij}(T, \boldsymbol{\lambda}^j) = \mu_{ij}(T, \boldsymbol{\lambda})$ we have that

$$
\ln \mu_{ij}(T, \boldsymbol{\lambda}) - \ln \mu_{i0}(T, \boldsymbol{\lambda}^i) = [U^i_{ij}(T, \lambda_{ij}) - U^i_{i0}(T)] / \sigma_\theta, \tag{B.1a}
$$

$$
\ln \mu_{ij}(T, \boldsymbol{\lambda}) - \ln \mu_{0j}(T, \boldsymbol{\lambda}^j) = [U^j_{ij}(T, \lambda_{ij}) - U^j_{0j}(T)] / \sigma_\theta. \tag{B.1b}
$$

The left-hand side of equations (B.1a) and (B.1b) are obtained from the empirical marriage matching function and is therefore identified. Now consider variation in this object as we vary population vectors. Importantly, variation in population vectors has no impact on the value of the single state and only affects the value in marriage through its influence on the Pareto weight λ_{ij}. That is, such variation serves as a *distribution factor* (see Bourguignon, Browning and Chiappori, 2009). From a marginal perturbation in, e.g., the male population vector we obtain

$$\sum_{i'} \frac{\partial \left[\ln \mu_{ij}(T, \boldsymbol{\lambda}) - \ln \mu_{i0}(T, \boldsymbol{\lambda}^i)\right]}{\partial m_{i'}} \, \mathrm{d}m_{i'} = \frac{1}{\sigma_\theta} \frac{\partial U^i_{ij}(T, \lambda_{ij})}{\partial \lambda_{ij}} \sum_{i'} \frac{\partial \lambda_{ij}}{\partial m_{i'}} \, \mathrm{d}m_{i'}, \qquad \text{(B.2a)}$$

$$\sum_{i'} \frac{\partial \left[\ln \mu_{ij}(T, \boldsymbol{\lambda}) - \ln \mu_{0j}(T, \boldsymbol{\lambda}^j)\right]}{\partial m_{i'}} \, \mathrm{d}m_{i'} = \frac{1}{\sigma_\theta} \frac{\partial U^j_{ij}(T, \lambda_{ij})}{\partial \lambda_{ij}} \sum_{i'} \frac{\partial \lambda_{ij}}{\partial m_{i'}} \, \mathrm{d}m_{i'}. \qquad \text{(B.2b)}$$

Taking the ratio of the partial derivatives in equations (B.2a) and (B.2b) we define

$$\pi_{ij} = \frac{\partial U^i_{ij}(T, \lambda_{ij})/\partial \lambda_{ij}}{\partial U^j_{ij}(T, \lambda_{ij})/\partial \lambda_{ij}}.$$

We proceed by combining the definition of z_{ij} with equation (3) from the main text which requires that $(1 - \lambda_{ij}) \cdot \partial U^i_{ij}(T, \lambda_{ij})/\partial \lambda_{ij} + \lambda_{ij} \cdot \partial U^j_{ij}(T, \lambda_{ij})/\partial \lambda_{ij} = 0$. It immediately follows that $\lambda_{ij} = \pi_{ij}/(\pi_{ij} - 1)$, which establishes identification.

B.2 Proof of Proposition 3

The identification proof will proceed in two steps. First, we demonstrate identification of the time allocation problem for single individuals. Second, we show how we use the household time allocation patterns to identify the home production technology for married couples. The following assumptions are used in the proof of identification in this section. While some of them are easily relaxed, for reasons of clarity and ease of exposition, and because they relate directly to the empirical and optimal design analysis, these assumptions are maintained here. We also only consider identification of the model without the fixed cost of labour force participation, as it adds nothing to the analysis.

Assumption ID-1**.** *The state-specific errors, $\epsilon_{\mathbf{a}^i}$ are distributed Type-I extreme value with location parameter zero and an unknown scale parameter, σ_ϵ.*

Assumption ID-2. *The systematic utility function is additively separable in leisure, ℓ^i, private consumption, q^i, and home goods, Q^i. That is*

$$u^i(\ell^i, q^i, Q^i, \mathbf{X}^i) = u_q^i(q^i, \mathbf{X}^i) + u_\ell^i(\ell^i, \mathbf{X}^i) + u_Q^i(Q^i, \mathbf{X}^i).$$

Assumption ID-3. *There is a known private consumption level $\widehat{q}$ such that $\partial u_q^i(\widehat{q}, \mathbf{X}^i)/\partial q = 1$.*

Assumption ID-4. *$u_Q^i(Q^i, \mathbf{X}^i)$ is monotonically increasing in Q, i.e. $\partial u_Q^i(Q^i, \mathbf{X}^i)/\partial Q > 0$.*

Assumption ID-5. *There exist an element of $\mathbf{X}^i$, $\mathbf{X}_r^i$, such that $\mathbf{X}_r^i$ affects $\zeta_{i0}(\mathbf{X}^i)$ but not $u_Q^i(Q^i, \mathbf{X})$. Also there exists an $\mathbf{X}_*^i$ such that $\zeta_{i0}(\mathbf{X}_*^i) = 1$.*

Assumption ID-6. *The support of Q is the same for both single individuals and married couples.*

Assumption ID-7. *Conditional on work hours h_w^i, the tax schedule T is differentiable in earnings, with $\partial T(w^i h_w^i, y^i; \mathbf{X}^i)/\partial wh_w \neq 1$.*

Assumption ID-8. *The utility of function of the private good, $u_q^i(q^i, \mathbf{X}^i)$, is monotonically increasing and quasi-concave in q^i.*

B.2.1 Step 1: The identification using the singles problem

Consider the problem of a single type-i male. Let $\mathcal{A}^i = \{1, \ldots, \overline{A}^i\}$ be an index representation set of time allocation alternatives, with $\widehat{u}^i(a)$ denoting the systematic part of utility associated with alternative $a \in \mathcal{A}^i$ (where the dependence on conditioning variables is suppressed for notational compactness). Without loss of generality, let $a = 1$ be the choice where the individual does not work and has the lowest level of home hours. Under Assumption ID-1, well-known results imply that the following holds

$$\log\left[\frac{\mathbb{P}(a)}{\mathbb{P}(1)}\right] = \frac{\widehat{u}^i(a) - \widehat{u}^i(1)}{\sigma_\epsilon}, \tag{B.3}$$

where the conditional choice probabilities $\mathbb{P}(\cdot)$ should be understood as being conditional on $[y^i, w^i, \mathbf{X}^i, T]$. Taking the partial derivative of equation (B.3) with respect to w^i and using Assumption ID-2 yields

$$\frac{\partial \log\left[\mathbb{P}(a)/\mathbb{P}(1)\right]}{\partial w} = \frac{1}{\sigma_\epsilon} \cdot \frac{\partial u_q^i(q^i(a); \mathbf{X}^i)}{\partial q} \cdot \left[1 - \frac{\partial T(w^i h_w^i(a), y^i; \mathbf{X}^i)}{\partial wh_w}\right] \cdot h_w^i(a), \tag{B.4}$$

where $q^i(a)$ and $h_w^i(a)$ are the respective private consumption and market work hours associated with the allocation a. The conditional choice probabilities and the marginal tax rates are known and hence, given Assumptions ID-3 and ID-7, the scale coefficient for the state-specific errors σ_ϵ is identified. Hence, the marginal utility of private consumption is identified. Integrating equation (B.4) and combining with equation (B.3) implies that the sum $u_\ell^i(\ell^i; \mathbf{X}^i) + u_Q^i(Q^i; \mathbf{X}^i)$ is identified up to a normalizing constant. Then for each level of feasible home hours, both $u_\ell^i(\ell^i; \mathbf{X}^i)$ and $u_Q^i(Q^i; \mathbf{X}^i)$ are identified by varying the level of market hours and fixing either home time or leisure. Under Assumption ID-5, the home efficiency parameter $\zeta_{i0}(\mathbf{X}^i)$ is identified by comparing $u_Q^i(Q^i(a); \mathbf{X}^i)$ across different values of $\mathbf{X}^i$.

B.2.2   Step 2: Identification of marriage home production function.

In Step 1 we show that the subutilities are identified up to a normalizing constant. Without loss of generality, we set the location normalization to be zero in what follows. Consider a $\langle i, j \rangle$ household with the time allocation set $\mathcal{A}_{ij} = \{1, \ldots, \overline{A}\}$, $\overline{A} = \overline{A}^i \times \overline{A}^j$, and let $\widehat{u}^{ij}(a) = (1 - \lambda_{ij}) \times \widehat{u}^i(a) + \lambda_{ij} \times \widehat{u}^j(a)$ denote the systematic part of household utility associated with $a \in \mathcal{A}_{ij}$. Let $\varepsilon_a^{ij} = (1 - \lambda_{ij}) \times \epsilon_a^i + \lambda_{ij} \times \epsilon_a^j$, and define $\mathcal{G}_{ij}^a(\cdot)$ to be the joint cumulative distribution function of $[\varepsilon_a^{ij} - \varepsilon_1^{ij}, \ldots, \varepsilon_a^{ij} - \varepsilon_{a-1}^{ij}, \varepsilon_{a+1}^{ij} - \varepsilon_a^{ij}, \ldots, \varepsilon_a^{ij} - \varepsilon_A^{ij}]$. For each $a \in \{1, \ldots, \overline{A} - 1\}$, define

$$\mathbb{P}(a) = \mathcal{Q}_j(\widehat{\mathbf{u}}^{ij}) \equiv \mathcal{G}_{ij}^a(\widehat{u}_a^{ij} - \widehat{u}_1^{ij}, \ldots, \widehat{u}_a^{ij} - \widehat{u}_{a-1}^{ij}, \widehat{u}_a^{ij} - \widehat{u}_{a+1}^{ij}, \ldots, \widehat{u}_a^{ij} - \widehat{u}_A^{ij}),$$

with $\widehat{\mathbf{u}}^{ij} = [\widehat{u}_1^{ij} - \widehat{u}_A^{ij}, \ldots, \widehat{u}_{A-1}^{ij} - \widehat{u}_A^{ij}]^\mathsf{T}$ defining the $(\overline{A} - 1)$ vector of utility differences, and let $\mathcal{Q}(\widehat{\mathbf{u}}^{ij}) = [\mathcal{Q}_1(\widehat{\mathbf{u}}^{ij}), \ldots, \mathcal{Q}_{A-1}(\widehat{\mathbf{u}}^{ij})]^\mathsf{T}$ define a $(\overline{A} - 1)$ dimensional vector function. Then, by Proposition 1 of Hotz and Miller (1993), the inverse of $\mathcal{Q}(\widehat{\mathbf{u}}^{ij})$ exists.[42] Given that the distribution of ϵ is known and λ_{ij} is identified, the inverse of $\mathcal{Q}(\widehat{\mathbf{u}}^{ij})$ is known. Hence, the vector $\widehat{\mathbf{u}}^{ij} = \mathcal{Q}^{-1}(\mathbb{P}(1), \ldots, \mathbb{P}(\overline{A} - 1))$ is identified. Define

$$\Delta_{ij}(a) = \widehat{\mathbf{u}}_{[a]}^{ij} - (1 - \lambda_{ij}) \times [u_\ell^i(\ell^i(a^i); \mathbf{X}^i) + u_q^i((1 - s_{ij}(a; \lambda_{ij})) \cdot q(a); \mathbf{X}^i)]$$
$$- \lambda_{ij} \times [u_\ell^j(\ell^j(a^j); \mathbf{X}^j) + u_q^i(s_{ij}(a; \lambda_{ij}) \cdot q(a); \mathbf{X}^j)].$$

---

[42]Notice that ε_a^{ij} is not i.i.d. However, independence is not required for the Hotz and Miller (1993) proposition.

The arguments from Step 1 imply that $u_q^i(q^i; \mathbf{X}^i)$ and $u_q^j(q^j; \mathbf{X}^j)$ are known. From Proposition 2 we have that λ_{ij} are identified. These, together with Assumption ID-2 and Assumption ID-4, imply that $s_{ij}(a; \lambda_{ij})$ is also known. Thus, identification of $\Delta_{ij}(a)$ follows. Finally, the definition of $\widehat{u}^{ij}(a)$ and Assumption ID-2 imply

$$\Delta_{ij}(a) = (1 - \lambda_{ij}) \times u_Q^i(\widetilde{Q}_{ij}(h_Q^i(a), h_Q^j(a); \mathbf{X}), \mathbf{X}^i) + \lambda_{ij} \times u_Q^j(\widetilde{Q}_{ij}(h_Q^i(a), h_Q^j(a); \mathbf{X}), \mathbf{X}^j).$$

The subutility function of the public good does not depend on $\mathbf{w}$. Therefore, once we observe different values of these two variables, both $u_Q^j(\widetilde{Q}_{ij}(h_Q^i(a), h_Q^j(a); \mathbf{X}), \mathbf{X}^j)$ and $u_Q^i(\widetilde{Q}_{ij}(h_Q^i(a), h_Q^j(a); \mathbf{X}), \mathbf{X}^i)$ are identified. Finally, under Assumption ID-4 the inverse of u_Q^i and u_Q^j exist and hence $\widetilde{Q}_{ij}(h_Q^i(a^i), h_Q^j(a^j); \mathbf{X})$ is identified.

C Proof of Proposition 4

In this Appendix we derive the contribution of the marital shocks within each match to the social-welfare function. We proceed in two steps. First, we characterize the *distribution* of martial preference shocks within a particular match, recognizing the non-random selection into a given pairing. Second, given this distribution, we obtain the adjustment term using our specification of the utility transformation function.

Consider the first step. For brevity of notation, here we let U_j denote the expected utility of a given individual from choice/spousal type j. Associated with each alternative j is an extreme value error θ_j that has scale parameter σ_θ. We now characterize the distribution of θ_j conditional on j being chosen. Letting $p_j = (\sum_k \exp[(U_k - U_j)/\sigma_\theta])^{-1}$ denote the associated conditional choice probability. It follows that

$$\begin{aligned}
\Pr[\theta_j < x | j = \arg\max_k U_k + \theta_k] &= \frac{1}{\sigma_\theta p_j} \int_{-\infty}^x \prod_{k \neq j} \exp\left(-e^{-\frac{\theta_j + U_j - U_k}{\sigma_\theta}}\right) \exp\left(-e^{-\frac{\theta_j}{\sigma_\theta}}\right) e^{-\frac{\theta_j}{\sigma_\theta}} \, \mathrm{d}\theta_j \\
&= \frac{1}{\sigma_\theta p_j} \int_{-\infty}^x \exp\left(-e^{-\frac{\theta_j}{\sigma_\theta}} \sum_k e^{-\frac{U_j - U_k}{\sigma_\theta}}\right) e^{-\frac{\theta_j}{\sigma_\theta}} \, \mathrm{d}\theta_j \\
&= \frac{1}{\sigma_\theta p_j} \int_{-\infty}^x \exp\left(-e^{-\frac{\theta_j}{\sigma_\theta}} p_j^{-1}\right) e^{-\frac{\theta_j}{\sigma_\theta}} \, \mathrm{d}\theta_j \\
&= \exp\left(-e^{-\frac{\theta_j + \sigma_\theta \log p_j}{\sigma_\theta}}\right).
\end{aligned}$$

Hence, the distribution of the idiosyncratic payoff conditional on j being optimal is extreme value with the scale parameter σ_θ and the shifted location parameter $-\sigma_\theta \log p_j$.

Marital payoff adjustment term: $\delta < 0$. Using the utility transformation function (equation (13)) and letting $\mathbf{Z}_j$ denote the entire vector of post-marriage realizations in alternative j (wages, preference shocks, demographics), it follows that the contribution to social-welfare of an individual in this marital pairing may be written in the form

$$\int_{\theta_j} \int_{\mathbf{Z}_j} Y[v_j(\mathbf{Z}_j) + \theta_j]\, dG_j(\mathbf{Z}_j)\, dH_j(\theta_j) = \int_{\theta_j} \exp(\delta\theta_j)\, dH_j(\theta_j) \int_{\mathbf{Z}_j} \frac{\exp[\delta v(\mathbf{Z}_j)]}{\delta}\, dG_j(\mathbf{Z}_j) - \frac{1}{\delta},$$

where we have suppressed the dependence on the tax system T.

We now complete our proof in the $\delta < 0$ case by providing an analytic characterization of the integral term over the idiosyncratic marital payoff. Using the result that $\theta_j|_{j=\arg\max_k U_k + \theta_k} \sim EV(-\sigma_\theta \log p_j, \sigma_\theta)$ from above, we have

$$\int_{\theta_j} \exp(\delta\theta_j)\, dH_j(\theta_j) = \frac{1}{\sigma_\theta} \int_{\theta_j} \exp(\delta\theta_j) \exp(-[\theta_j + \sigma_\theta \log p_j]/\sigma_\theta) e^{-\exp(-[\theta_j + \sigma_\theta \log p_j]/\sigma_\theta)}\, d\theta_j$$

$$= \exp(-\delta\sigma_\theta \log p_j) \int_0^\infty t^{-\delta\sigma_\theta} \exp(-t)\, dt$$

$$= p_j^{-\delta\sigma_\theta} \Gamma(1 - \delta\sigma_\theta).$$

The second equality performs the change of variable $t = \exp(-[\theta_j + \sigma_\theta \log p_j]/\sigma_\theta)$, and the third equality uses the definition of the Gamma function. Since we are considering cases where $\delta < 0$, this integral will converge.

Marital payoff adjustment term: $\delta = 0$. Here the contribution to social-welfare of a given individual in a given marital pairing is simply given by

$$\int_{\theta_j} \int_{\mathbf{Z}_j} Y[v_j(\mathbf{Z}_j) + \theta_j]\, dG_j(\mathbf{Z}_j)\, dH_j(\theta_j) = \int_{\theta_j} \theta_j\, dH_j(\theta_j) + \int_{\mathbf{Z}_j} v(\mathbf{Z}_j)\, dG_j(\mathbf{Z}_j)$$

$$= \sigma_\theta \gamma - \sigma_\theta \log p_j + \int_{\mathbf{Z}_j} v(\mathbf{Z}_j)\, dG_j(\mathbf{Z}_j),$$

with the second equality using the above result for the distribution of marital shocks within a match and then just applying the well-known result for the expected value of the extreme value distribution with a non-zero location parameter.

D Proof of Proposition 5

In Proposition 4 we present an expression for the contribution to social welfare in alternative marriage market positions. Note that in the $\delta = 0$ case we may write $\mathcal{W}_{ij}^i(T)$ in the familiar log-sum form

$$\mathcal{W}_{ij}^i(T, \boldsymbol{\lambda}^i) = \sigma_\theta \gamma + \sigma_\theta \log \left(\exp[U_{i0}^i(T)/\sigma_\theta] + \sum_{h=1}^{J} \exp[U_{ih}^i(T, \lambda_{ih})/\sigma_\theta] \right) = \mathcal{W}^i(T, \boldsymbol{\lambda}^i),$$

which is independent of the match pairing j. Letting $\mathcal{W}^j(T, \boldsymbol{\lambda}^j)$ be defined similarly, it then follows that the overall social-welfare function may be written as

$$\sum_i m_i \cdot \mathcal{W}^i(T, \boldsymbol{\lambda}^i) + \sum_j f_j \cdot \mathcal{W}^j(T, \boldsymbol{\lambda}^j).$$

Thus, relative to the form of the social-welfare function when marriage positions are fixed, we have the *type* specific expected values appearing rather than the *match* specific expected values. Differentiating with respect to τ we obtain

$$\begin{aligned}
\frac{\partial SWF(T)}{\partial \tau} &= \sum_i m_i \left[p_{i0}^i(T, \boldsymbol{\lambda}^i) \frac{\partial U_{i0}^i(T)}{\partial \tau} + \sum_j p_{ij}^i(T, \boldsymbol{\lambda}^i) \frac{\partial U_{ij}^i(T, \lambda_{ij})}{\partial \tau} \right] \\
&+ \sum_j m_j \left[p_{0j}^j(T, \boldsymbol{\lambda}^j) \frac{\partial U_{0j}^j(T)}{\partial \tau} + \sum_i p_{ij}^j(T, \boldsymbol{\lambda}^j) \frac{\partial U_{ij}^j(T, \lambda_{ij})}{\partial \tau} \right] \\
&+ \sum_i m_i \sum_j p_{ij}^i(T, \boldsymbol{\lambda}^i) \frac{\partial U_{ij}^i(T, \lambda_{ij})}{\partial \lambda_{ij}} \frac{\partial \lambda_{ij}}{\partial \tau} + \sum_j m_j \sum_i p_{ij}^j(T, \boldsymbol{\lambda}^j) \frac{\partial U_{ij}^j(T, \lambda_{ij})}{\partial \lambda_{ij}} \frac{\partial \lambda_{ij}}{\partial \tau}.
\end{aligned}$$

Finally, collecting terms and using equations (3), (5), (6), and (7), completes the proof.

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Supplement to "Optimal Taxation, Marriage, Home Production, and Family Labour Supply"

In these online appendices we (i) describe our empirical tax and transfer schedule implementation; (ii) describe the iterative algorithm and solution approximation methods for calculating the marriage market equilibrium; (iii) describe the set of targeted estimation moments; (iv) present additional tables and simulation results.

E Empirical tax and transfer schedule implementation

In this appendix we describe our implementation of the empirical tax and transfer schedules for our estimation exercise. Since some program rules will vary by U.S. state, here we are explicit in indexing the respective parameters by market.[43] Our measure of taxes includes both state and federal Earned Income Tax Credit (EITC) programmes, and we also account for the Food Stamps Program and the Temporary Assistance for Needy Families (TANF) program. It does not include other transfers (e.g. Medicaid) and non-income taxes such as sales and excises taxes.[44]

Consider (a married or single) household ι in market k, with household earnings $E_{\iota k} = \mathbf{h}_w^{\iota k} \cdot \mathbf{w}_{\iota k}$ and demographic characteristics $\mathbf{X}_{\iota k}$. As before, the demographic conditioning vector comprises marital status and children. The total net tax liability for such a household is given by $T_{\iota k} = \widetilde{T}_{\iota k} - Y_{TANF}^{\iota k} - Y_{FSP}^{\iota k}$, where $\widetilde{T}_{\iota k}$ is the (potentially negative) tax liability from income taxes and the EITC, $Y_{TANF}^{\iota k}$ and $Y_{FSP}^{\iota k}$ are the respective (non-negative) amounts of TANF and Food Stamps.

Income taxes and EITC. Our measure of income taxes $\widetilde{T}_{\iota k}$ includes both federal and state income taxes, as well as federal and state EITC. In addition to market, the tax schedules

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[43]Since we define a market as a Census Bureau-designated division, we apply the state tax rules that correspond to the most populous state within a defined market.

[44]While Medicaid is the largest U.S. means-tested program in terms of overall expenditure, the bulk of this expenditure (67% in 2006) goes on the disabled and aged population. Neither of these groups are part of our analysis. Furthermore, very few structural labour supply models actually incorporate in-kind transfers such as Medicaid, as quantifying the value to recipients is much more complicated. See the recent survey by Chan and Moffitt (2018). In the case of Medicaid, there is both a transfer and an insurance component, and we have experimented with incorporating the transfer value in the budget constraint. We construct this value using data from the full-year consolidated Household Component data files of the Medical Expenditure Survey, together with the 2006 state Medicaid rules from Ross, Cox and Marks (2007) to determine eligibility, and find that incorporating this transfer value has very little impact on either the initial estimation results, or our subsequent optimality simulations.

that we calculate may also vary with marital status and with children. These schedules are calculated prior to estimation with the National Bureau of Economic Research TAXSIM calculator, as described in Feenberg and Coutts (1993). We assume joint filing status for married couples. For singles with children, we assume head-of-household filing status.

Food Stamp Program. Food Stamps are available to low-income households both with and without children.[45] For the purposes of determining the entitlement amount, net household earnings are defined as

$$N_{FSP}^{\iota k} = \max\{0, E_{\iota k} + Y_{TANF}^{\iota k} - D_{FSP}[\mathbf{X}_{\iota k}]\},$$

where $Y_{TANF}^{\iota k}$ is the dollar amount of TANF benefit received by this household (see below), and $D_{FSP}[\mathbf{X}_{\iota k}]$ is the standard deduction, which may vary with household type. The dollar amount of Food Stamp entitlement is then given by

$$Y_{FSP}^{\iota k} = \max\{0, Y_{FSP}^{\max}[\mathbf{X}_{\iota k}] - \tau_{FSP} \times N_{FSP}^{\iota k}\},$$

where $Y_{FSP}^{\max}[\mathbf{X}_{\iota k}]$ is the maximum food stamp benefit amount for a household of a given size and $\tau_{FSP} = 0.3$ is the phase-out rate.[46]

TANF. Financial support to families with children is provided by TANF.[47] Given the static framework we are considering, we are not able to incorporate certain features of the TANF program, notably the time limits in benefit eligibility (see Chan, 2013). For the purposes of entitlement calculation, we define net household earnings as

$$N_{TANF}^{\iota k} = \max\{0, (1 - R_{TANF}^{k}) \times (E_{\iota k} - D_{TANF}^{k}[\mathbf{X}_{\iota k}])\},$$

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[45]Food Stamp parameters for 2006 are obtained from U.S. Department of Agriculture, Food and Nutrition Service (Wolkwitz, 2007).

[46]In practice, the Food Stamp Program also has a gross-earnings and net-earnings income test. These require that earnings are below some threshold related to the federal poverty level for eligibility (see, e.g., Chan, 2013). For some families, these rules would mean that there may be a discontinuous fall in entitlement (to zero) as earnings increase. We also assume a zero excess shelter deduction in our calculations and do not consider asset tests. Incorporating asset tests (even in a dynamic model) is challenging as the definition of *countable* assets does not correspond to the usual assets measure in life-cycle models.

[47]We obtain TANF parameters from 2006 from the Urban Institute's Welfare Rules Data Book. See Rowe and Murphy (2006).

where the *dollar* earnings disregard $D_{TANF}^k[\mathbf{X}_{\iota k}]$ varies by market and household characteristics. The market-level *percent* disregard is given by R_{TANF}^k. The dollar amount of TANF entitlement is then given by

$$Y_{TANF}^{\iota k} = \min\{Y_{TANF}^{\max}[\mathbf{X}_{\iota k}], \max\{0, r_{TANF}^k \times (Y_{TANF}^{\widehat{\max}}[\mathbf{X}_{\iota k}] - N_{TANF}^{\iota k})\}\}.$$

Here $Y_{TANF}^{\max}[\mathbf{X}_{\iota k}]$ defines the maximum TANF receipt in market k for a household with characteristics $\mathbf{X}_{\iota k}$, while $Y_{TANF}^{\widehat{\max}}[\mathbf{X}_{\iota k}]$ defines what is typically referred to as the *payment standard*. The ratio r_{TANF}^k is used in some markets to adjust the total TANF amount.[48]

F Marriage market numerical algorithm

In this appendix we describe the iterative algorithm and the solution approximation method that we use to calculate the market clearing vector of Pareto weights. The algorithm is based on that presented in Galichon, Kominers and Weber (2014, 2016). We first note that using the conditional choice probabilities from equation (5) we are able to write the quasi-demand equation of type-i men for type-j spouses as

$$\sigma_\theta \times \left[\ln \mu_{ij}^d(T, \boldsymbol{\lambda}^i) - \ln \mu_{i0}^d(T, \boldsymbol{\lambda}^i)\right] = U_{ij}^i(T, \lambda_{ij}) - U_{i0}^i(T). \tag{F.1}$$

Similarly, the conditional choice probabilities for females from equation (6) allows us to express the quasi-supply equation of type-j women to the $\langle i, j \rangle$ submarket as

$$\sigma_\theta \times \left[\ln \mu_{ij}^s(T, \boldsymbol{\lambda}^j) - \ln \mu_{0j}^s(T, \boldsymbol{\lambda}^j)\right] = U_{ij}^j(T, \lambda_{ij}) - U_{0j}^j(T). \tag{F.2}$$

The algorithm proceeds as follows:

1. Provide an initial guess of the measure of both single males $0 < \mu_{i0}^d < m_i$ for $i = 1, \ldots I$, and single females $0 < \mu_{0j}^s < f_j$ for $j = 1, \ldots, J$.

2. Taking the difference of the quasi-demand (equation (F.1)) and the quasi-supply (equation (F.2)) functions for each $\langle i, j \rangle$ submarriage market and imposing the market clearing condition $\mu_{ij}^d(T, \boldsymbol{\lambda}^i) = \mu_{ij}^s(T, \boldsymbol{\lambda}^j)$ we obtain

$$\sigma_\theta \times \left[\ln \mu_{0j}^s - \ln \mu_{i0}^d\right] = U_{ij}^i(T, \lambda_{ij}) - U_{i0}^i(T) - \left[U_{ij}^j(T, \lambda_{ij}) - U_{0j}^j(T)\right], \tag{F.3}$$

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[48]As in the case of Food Stamps, we do not consider the similar gross and net income eligibility rules that exist for TANF, as well as the corresponding asset tests. We also do not consider eligibility time limits.

which given the single measures μ_{i0}^d and μ_{0j}^s (and the tax schedule T) are only a function of the Pareto weight for that submarriage-market λ_{ij}. Given our assumptions on the utility functions, there exists a unique solution to equation (F.3). This step therefore requires solving for the root of $I \times J$ univariate equations.

3. From *Step 2*, we have a matrix of Pareto weights $\boldsymbol{\lambda}$ given the single measures μ_{i0}^d and μ_{0j}^s from *Step 1*. These measures can be updated by calculating the conditional choice probabilities (equations (5) and (6)). The algorithm returns to Step 2 and repeats until the vector of single measures for both males and females has converged.

In practice, we are able to implement this algorithm by first evaluating the expected utilities $U_{ij}^i(T, \lambda)$ and $U_{ij}^j(T, \lambda)$ for each marital match combination $\langle i, j \rangle$ on a fixed grid of Pareto weights $\lambda \in \boldsymbol{\lambda}^{\mathrm{grid}}$ with $\inf[\boldsymbol{\lambda}^{\mathrm{grid}}] \gtrsim 0$ and $\sup[\boldsymbol{\lambda}^{\mathrm{grid}}] \lesssim 1$. We may then replace $U_{ij}^i(T, \lambda)$ and $U_{ij}^j(T, \lambda)$ with an approximating parametric function so that no expected values are actually evaluated within the iterative algorithm.

Note that calculating the expected values within a match are (by many orders of magnitude) the most computationally expensive part of the algorithm. While our empirical exercise incorporates market variation in taxes and transfers, in an application where each market only differs by the population vectors and/or the demographic transition functions, the computational cost in calculating the equilibrium for all markets is *approximately independent* of the number of markets K considered. This follows given that the initial evaluation of expected values on $\boldsymbol{\lambda}^{\mathrm{grid}}$ is independent of market in this case.

G   Estimation moments

In this appendix we describe the set of targeted estimation moments. Recall that there are nine markets ($K = 9$) and three education groups/types for both men ($I = 3$) and women ($J = 3$) in our empirical application. The first set of moments (denoted G1) relate to the marriage market. Within each market, we describe the number of single men and women by own education, and married households by joint education ($K \times [I + J + I \times J]$ moments). The second set of moments (G2) describe labour supply patterns. By market, gender, marital status and own education, we describe mean conditional work hours and employment rates ($K \times 4 \times [I + J]$ moments); aggregating over markets, we describe the fraction of individuals in non-employment/part-time/full-time status by gender, marital status, the presence of children, and own/joint education level (for

singles/couples respectively) ($6 \times [I + J] + 12 \times I \times J$ moments); the mean and standard deviation of conditional work hours is described by gender, marital status, and own education, while mean conditional hours for married men and women are also described by joint education levels ($8 \times [I + J] + 2 \times I \times J$ moments). The third set of moments (G3) describe accepted wages. The mean and standard deviation of accepted log-wages are described by gender, marital status, and own education ($4 \times [I + J]$ moments). The fourth set of moments (G4) describe earnings, with the mean and standard deviation calculated using the same set of conditioning variables as for wages (again, $4 \times [I + J]$ moments). The fifth set of moments (G5) relate to home time. Similar to labour supply, we describe the fraction of individuals with low/medium/high unconditional home hours by gender, marital status, children, and own/joint education level (for singles/couples respectively) ($6 \times [I + J] + 12 \times I \times J$ moments); the mean and standard deviation of unconditional home hours is described by gender, marital status, and own education, while mean unconditional home hours for married men and women are also described by joint education levels ($8 \times [I + J] + 2 \times I \times J$ moments). In total, we have 765 moments.

H Additional tables and results

H.1 Parameter estimates

In Table 7 we present our model estimates, together with the accompanying standard errors, and the sets of moments that have an important influence on each parameter. We obtain these sets following the approach of Andrews, Gentzkow and Shapiro (2017). This defines the local sensitivity of the parameter estimates with respect to the moment vector as the $B \times M$ matrix $\mathbf{S_m} = \left[\mathbf{D_m^\mathsf{T} W D_m} \right]^{-1} \mathbf{D_m^\mathsf{T} W}$. Given the scale of our moments are not always comparable, we multiply each element $[\mathbf{S_m}]_{bm}$ by the standard deviation of the mth moment, $\sqrt{[\mathbf{\Sigma}]_{mm}}$. For each parameter we calculate the moment with maximum (absolute) sensitivity, and consider any moment whose sensitivity is at least 20% of the maximal as being important. As we consider sets of moments, we describe a set as being important if at least one moment from that set is important according to this criterion.

H.2 Social-welfare weights

The redistributive preference of the government is reflected by the parameter δ, which enters the utility transformation presented in equation (13). In Table 8 we present the

Table 7: Parameter estimates

	Estimate	Standard error	Sensitivity moments
Log-wage offers:			
Male, high school and below: mean	2.635	0.003	G2, G3, G4, G5
Male, high school and below: s.d.	0.407	0.002	G3, G4
Male, some college: mean	2.890	0.003	G3, G4, G5
Male, some college: s.d.	0.404	0.002	G3, G4
Male, college: mean	3.400	0.003	G3, G4
Male, college: s.d.	0.528	0.003	G3, G4
Female, high school and below: mean	2.070	0.007	G2, G3, G4, G5
Female, high school and below: s.d.	0.523	0.003	G3, G4
Female, some college: mean	2.484	0.003	G3, G4, G5
Female, some college: s.d.	0.457	0.002	G3, G4
Female, college: mean	2.944	0.002	G3, G4, G5
Female, college: s.d.	0.501	0.002	G3, G4
Preference parameters:			
Leisure scale	0.253	0.028	G2, G5
Home good scale	0.495	0.028	G2, G5
Leisure curvature, σ_ℓ	1.826	0.097	G2, G5
Home good curvature, σ_Q	0.079	0.024	G5
Fixed costs (kids)	99.778	1.431	G2, G5
Marital shock, s.d.	0.123	0.004	G1, G2, G5
State specific error, s.d.	0.284	0.004	G2, G5
Home production technology:			
Male production share	0.168	0.005	G2, G5
Single prod. (no children), high school and below	1.970	0.106	G2, G5
Single prod. (no children), some college	1.946	0.092	G2, G5
Single prod. (no children), college	2.608	0.127	G2, G5
Male prod. (children)	3.319	0.210	G2, G5
Female prod. (children), high school and below	3.686	0.243	G2, G5
Female prod. (children), some college	4.079	0.278	G2, G5
Female prod. (children), college	5.123	0.372	G2, G5
HH prod. (children) female, high school and below	1.926	0.091	G2, G5
HH prod. (children) female, some college	2.715	0.147	G2, G5
HH prod. (children) female, college	2.421	0.126	G2, G5
HH prod. (children) educ. homogamy, high school and below	1.831	0.042	G2, G5
HH prod. (children) educ. homogamy, some college	1.176	0.009	G1, G2, G5
HH prod. (children) educ. homogamy, college	1.694	0.042	G1, G2, G5

Notes: All parameters estimated simultaneously using a moment based estimation procedure as detailed in Section 4 from the main text. See Online Appendix G for a definition of the moment groups, and footnote 29 for a description of the method used to calculate standard errors. All incomes are expressed in dollars per-week in average 2006 prices.

underlying average social-welfare weights for alternative values $\delta \in \{-1, 0\}$. Given the maintained symmetry of the tax schedule, we present these welfare weights as a function of the lowest and highest earnings of a couple. For example, at the optimum, the table shows that when $\delta = 0$ the government would value a dollar transfer to a single earner couple with annual earnings \$37,500–\$60,000 approximately 1.9 ($\approx 1.221/0.638$) times as much as would if annual earnings were \$110,000–\$150,000. When $\delta = -1$ these weights decline much more rapidly, implying a much stronger redistributive motive (in the context of the preceding example, the relative value is now 2.8).

H.3 Marriage matching patterns with restricted tax schedules

We describe marriage matching patterns when the form of jointness in the tax schedule is restricted. As described in the Section 5.3 from the main text, we consider i) individual taxation; ii) joint taxation with income splitting; iii) joint taxation with income aggregation. Table 9 presents the marriage matching functions. Relative to the unrestricted schedule, the greatest differences emerge when the tax schedule exhibits a strong non-neutrality with respect to marriage. Under joint taxation with income aggregation there is a 15 percentage point lower marriage rate, and reduced assortative mating.

H.4 Gender based taxation

In Section 5.4 we discussed results when we allowed the tax schedule for both single individuals and married couples to vary by gender. In Figure 8 we present the marginal tax rate schedules for the husband (when we fix the value of his wife's earnings) and the marginal tax rate schedules for the wife (when we fix the value of her husband's earnings). Except at low earnings, married women typically have lower marginal tax rates than do men. For single individuals, we present the net-income schedule (rather than marginal tax rates) as there are important differences in out-of-work income. See Figure 9. Here we show the net-income schedule for single men and single women, together with the optimal schedule when the tax schedule for single individuals is gender neutral. At the optimum, single women have both higher out-of-work income and lower marginal tax rates than do single men.

Table 8: Social-welfare weights under optimal system

		Lowest earnings range ($000s)								
		0–12.5	12.5–25	25–37.5	37.5–60	60–85	85–110	110–150	150–190	190+
$\delta = 0$:	0–12.5	2.735 [0.563]	–	–	–	–	–	–	–	–
	12.5–25	1.964 [5.090]	1.461 [4.361]	–	–	–	–	–	–	–
	25–37.5	1.543 [7.968]	1.183 [8.751]	0.985 [3.927]	–	–	–	–	–	–
	37.5–60	1.221 [10.134]	0.974 [8.579]	0.827 [7.104]	0.707 [3.114]	–	–	–	–	–
	60–85	0.948 [7.114]	0.786 [5.268]	0.681 [4.321]	0.591 [3.848]	0.501 [1.267]	–	–	–	–
	85–110	0.772 [2.280]	0.657 [1.551]	0.578 [1.255]	0.507 [1.118]	0.435 [0.770]	0.381 [0.120]	–	–	–
	110–150	0.638 [2.501]	0.555 [1.568]	0.495 [1.207]	0.441 [1.046]	0.383 [0.711]	0.338 [0.222]	0.301 [0.103]	–	–
	150–190	0.496 [1.159]	0.442 [0.643]	0.401 [0.464]	0.362 [0.376]	0.320 [0.237]	0.285 [0.071]	0.257 [0.064]	0.223 [0.009]	–
	190+	0.388 [0.485]	0.354 [0.233]	0.326 [0.155]	0.298 [0.123]	0.268 [0.074]	0.242 [0.021]	0.220 [0.019]	0.193 [0.005]	0.170 [0.001]
$\delta = -1$:	0–12.5	2.938 [1.780]	–	–	–	–	–	–	–	–
	12.5–25	2.117 [8.074]	1.523 [4.791]	–	–	–	–	–	–	–
	25–37.5	1.574 [8.967]	1.171 [8.659]	0.913 [3.704]	–	–	–	–	–	–
	37.5–60	1.181 [9.451]	0.904 [7.791]	0.719 [6.513]	0.574 [2.865]	–	–	–	–	–
	60–85	0.813 [6.155]	0.646 [4.920]	0.525 [4.074]	0.427 [3.656]	0.325 [1.237]	–	–	–	–
	85–110	0.588 [1.846]	0.481 [1.458]	0.400 [1.209]	0.331 [1.088]	0.257 [0.770]	0.206 [0.122]	–	–	–
	110–150	0.425 [2.070]	0.359 [1.481]	0.306 [1.174]	0.258 [1.041]	0.205 [0.728]	0.167 [0.228]	0.137 [0.106]	–	–
	150–190	0.281 [1.036]	0.247 [0.622]	0.218 [0.470]	0.188 [0.391]	0.153 [0.251]	0.127 [0.076]	0.106 [0.068]	0.085 [0.010]	–
	190+	0.181 [0.449]	0.165 [0.236]	0.150 [0.166]	0.132 [0.134]	0.110 [0.082]	0.093 [0.024]	0.078 [0.021]	0.064 [0.006]	0.051 [0.001]

(Row label, left side, rotated: Highest earnings range ($000s))

Notes: Table presents average social-welfare weights and joint probability mass under the optimal system for alternative δ values. The probability mass is presented in brackets. Earnings are in dollars per week in 2006 prices. Welfare weights are obtained by increasing consumption in the respective joint earnings bracket (with fraction $s_{ij}(\lambda_{ij})$ of this increase in an $\langle i, j \rangle$ match accruing to the female) and calculating a derivative of the social-welfare function; weights are normalized so that the probability-mass-weighted sum under the optimal tax system is equal to unity.

Table 9: Marriage matching functions

		Women		
		High school and below	Some college	College and above
(a). Unrestricted				
		–	0.117	0.090	0.077
Men	High school and below	0.136	0.156	0.061	0.039
	Some college	0.094	0.036	0.106	0.044
	College and above	0.055	0.028	0.059	0.187
(b). Independent				
		–	0.095	0.092	0.105
Men	High school and below	0.119	0.176	0.061	0.036
	Some college	0.099	0.038	0.104	0.038
	College and above	0.073	0.030	0.058	0.168
(c). Income splitting				
		–	0.104	0.102	0.115
Men	High school and below	0.137	0.167	0.055	0.032
	Some college	0.109	0.036	0.099	0.035
	College and above	0.074	0.031	0.059	0.165
(d). Income aggregation				
		–	0.165	0.135	0.136
Men	High school and below	0.198	0.118	0.046	0.029
	Some college	0.139	0.028	0.081	0.032
	College and above	0.099	0.027	0.053	0.150

Notes: Table shows marriage matching function under alternative tax schedule specifications. *Unrestricted* corresponds to the schedule described in Section 5.1. *Independent*, *Income splitting*, and *Income aggregation* respectively refer to independent individual taxation, and joint taxation with income splitting and aggregation. See Section 5.3 for details.

(a) Husband's marginal tax rate

(b) Wife's marginal tax rate
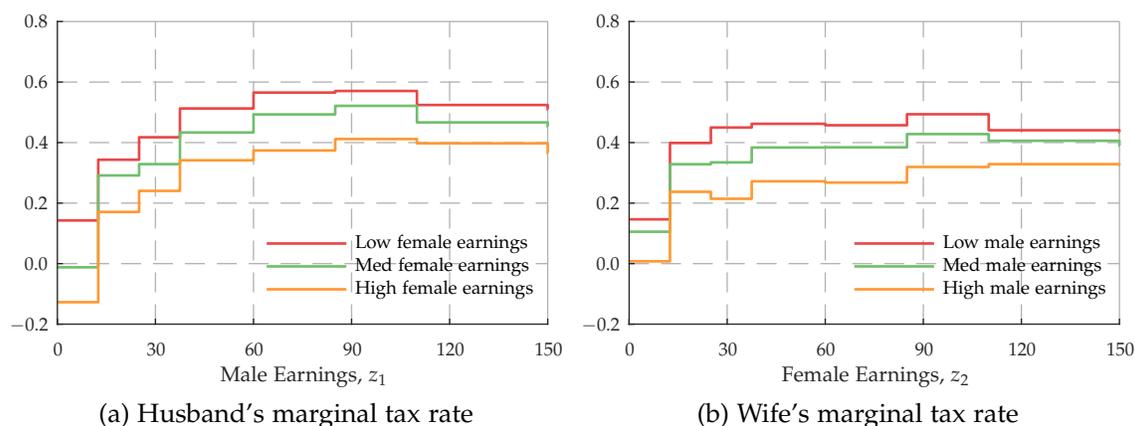
Figure 8: Optimal tax schedule with gender based taxation with $\delta = 0$. In panel (a) we show marginal tax rates for married men conditional on alternative values of female earnings. Panel (b) shows marginal tax rates for married women conditional on alternative values of female earnings. All incomes are in thousands of dollars per year, expressed in average 2006 prices. See Footnote 35 for a definition of *low*, *medium*, and *high* spousal earnings levels.
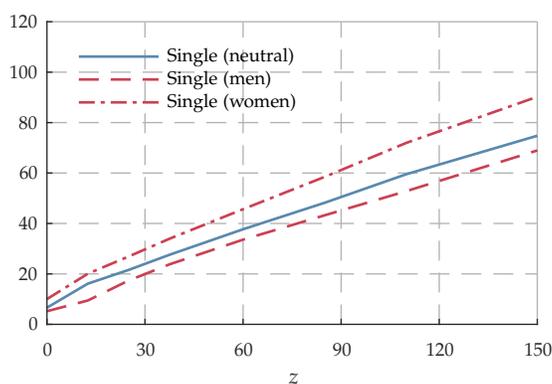

Figure 9: Net income schedule for single individual's with $\delta = 0$ under alternative tax specifications. The blue line shows the gender neutral net income schedule for single individuals when only taxes for married couples may be gender specific. The brick red lines are obtained when we allow a gendered tax schedule for both married couples and singles. The dashed (dash-dot) line shows the net income schedules for single men (women). All incomes are in thousands of dollars per year, expressed in average 2006 prices.

H.5 Sensitivity to node choice

Our main simulation results consider the choice of a tax schedule where the number of earnings nodes for each *individual* is exogenously set at $N = 10$ values. Here we repeat our analysis from Section 5.2 when $\delta = 0$, but with $N = 18$ and $\mathcal{Z} = \{0, 12500, 18750, 25000, 31250, 37500, 48750, 60000, 72500, 85000, 98000, 110000, 135000, 150000, 170000, 190000, 220000, 250000\}$.[49] This permits a considerably more detailed characterisation of the tax schedule, now being represented by a total of 189 tax parameters (compared to 65 tax parameters in the $N = 10$ parametrization). In Figure 10 we present the net-income schedules for singles and couples under this parametrization. For comparison, the original schedule from Figure 5 is reproduced alongside. The structure of taxes, including the implied degree of tax jointness, is clearly seen to be very similar in the two cases, with the surface in the $N = 18$ case essentially an interpolating polygon subdivision of the $N = 10$ case.

(a) Net income function, $N = 10$ (b) Net income function, $N = 18$
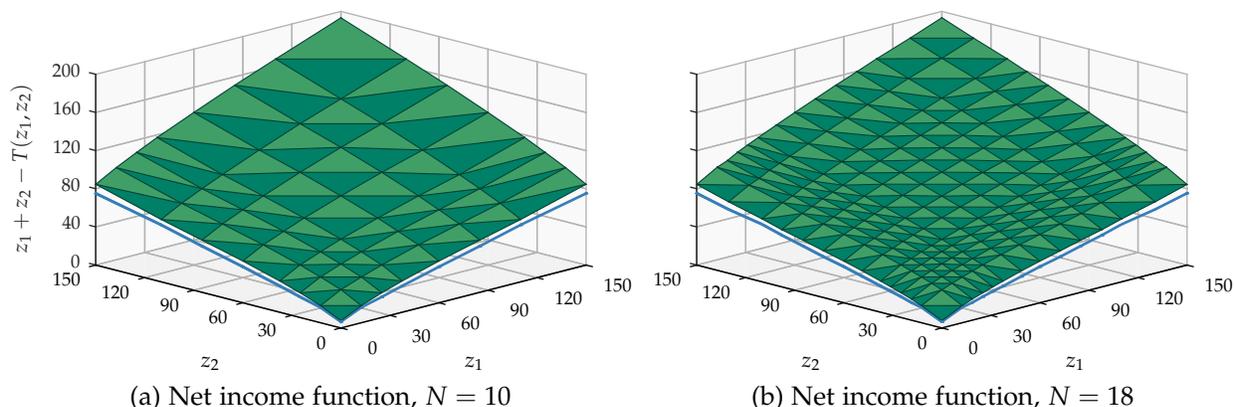
Figure 10: Optimal tax schedule with $\delta = 0$ under alternative node specifications. In panel (a) we show net income as a function of labour earnings for single individuals (blue line) and couples (three-dimensional surface), with $N = 10$ earnings nodes (65 tax parameters). In panel (b) the same net income functions that are obtained with $N = 18$ earnings nodes (189 tax parameters) are shown. All incomes are in thousands of dollars per year, expressed in average 2006 prices.

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[49]Increasing the number of earnings nodes in the tax system requires a simultaneous increase in the number of wage integration nodes. If the distance between the earnings nodes becomes too narrow, the joint density in a triangle may become zero, in which case the welfare function and constraints will become locally flat as elements of β_T are varied. This is also why we do not attempt to endogenously determine the node positions together with the tax level parameter vector $\mathbf{t}_{N \times 1}$ and matrix $\mathbf{T}_{N \times N}$.

(a) Baseline model

(b) Increased wage gap ($\Delta\mathbb{E}[\ln w_j] = -0.5$)

(c) Reduced assortative mating ($\varrho = \sigma_\theta$)

(d) Zero home time efficiency ($\zeta = 0$)
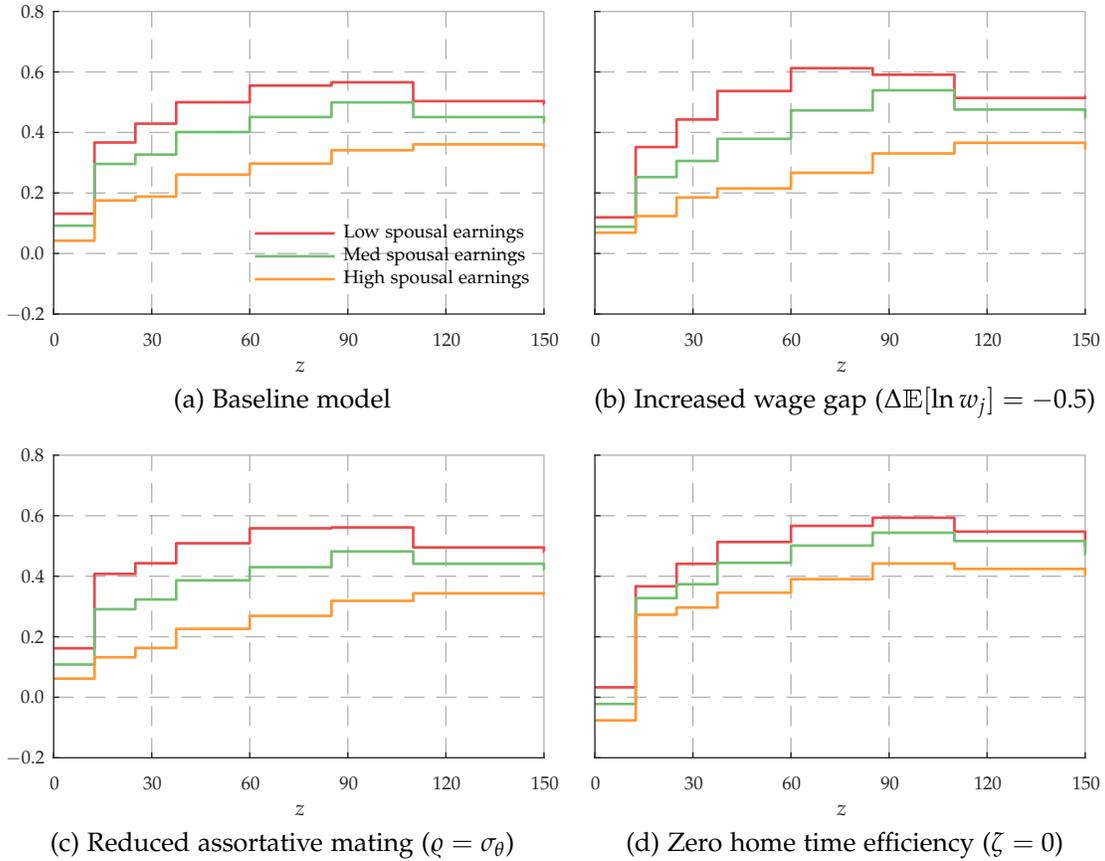
Figure 11: Perturbations of optimal tax schedule with $\delta = 0$. The figure shows marginal tax rates under: (a) the baseline model; and perturbations where: (b) The gender wage gap is increased; (c) assortative mating is reduced through inclusion of an additive utility cost for educationally homogamous marriages; (d) the home time efficiency parameter is reduced to zero everywhere. Marginal tax rates are shown conditional on spousal earnings, z_2. See Footnote 35 for a definition of *low*, *medium*, and *high* spousal earnings.

H.6   Perturbation experiments

In Section 5.6 we described the design implications of increasing the gender wage gap. Here we present results from this experiment, and also presents additional perturbation comparative static exercises. In what follows, we define $\Delta T'(z) \equiv T'(z, Low) - T'(z, High)$ to be the difference in average marginal tax rates at earnings z, as the spousal earnings level is changed from *Low* to *High*. In our baseline model from Section 5.2 when $\delta = 0$, we have $\Delta T'(30000) = 24.1\%$ and $\Delta T'(70000) = 25.8\%$. The baseline marginal tax rate schedule is reproduced as Figure 11a.

Gender wage gap. We consider an exogenous increase in the gender wage gap by reducing the mean of the offered log wage distribution for women. Intuitively, the more dissimilar are spouses, the greater scope is there to achieve welfare gains from introducing some degree of jointness in the tax system. In Figure 11b we consider a change in mean offered log wages of $\Delta\mathbb{E}[\ln w_j] = -0.5$ for all female types $j = 1, \ldots J$. This perturbation results in increased negative tax jointness, and we now obtain $\Delta T'(30000) = 25.8\%$ and $\Delta T'(70000) = 34.6\%$. There are also important changes in the tax schedule for single individuals (not shown), with marginal tax rates increasing by around 10 percentage points on average. This change partially offsets the impact that changes in the wage distribution have on within household inequality, but still, in the new equilibrium the wife's Pareto weight is everywhere lower. Relative to a system of independent taxation, the unrestricted schedule represents a welfare gain that is equivalent to almost 4% of tax revenue. When the income differences are increased further, there are even larger increases in tax jointness, and even larger welfare gains. For example, when $\Delta\mathbb{E}[\ln w_j] = -1$ we obtain a welfare gain equivalent to around 6.5%.

Assortative mating. Related to the above, we consider how the degree of *assortative mating* influences the design problem. Frankel (2014) considered a simple binary model to analyse taxation design when couples have correlated types. In the context of uncorrelated types (as in KKS) negative jointness is obtained, although this result is shown to be attenuated when the degree of exogenous assortative mating is increased. In our environment, we *endogenously* change the degree of assortative mating by augmenting the individual utility function to include the additive payoff $\overline{\theta}_{ij}$. In what follows, we set $\overline{\theta}_{ij} = -\varrho \times \mathbb{1}[i = j]$ so that a value $\varrho > 0$ reduces the utility in educationally homogamous marriages but does not have a direct impact on the time allocation problem. In Figure 11c we show the impact that this modification has on the structure of marginal rates when $\delta = 0$. In the illustrations here, we set $\varrho = \sigma_\theta$ so the reduction in expected utility is equal in value to a one-standard-deviation idiosyncratic marital payoff. This reduction in correlation among types *increases* the degree of negative tax jointness, with $\Delta T'(30000) = 28.0\%$ and $\Delta T'(70000) = 29.0\%$. There are only very small changes in the tax schedule for single individuals. Under this parametrisation we obtain larger welfare gains from jointness: individual taxation implies a welfare loss that is equivalent to 2.6% of tax revenue.

Home production. It has long been recognised that home production activities provide an important economic benefit associated with marriage. The design problem faced by the social planner is also different in a model with home production versus a model without home production. First, it affects the degree of inequality both across and within households. Those households with low wages are able to substitute away from market work towards home activities (reducing between household inequality). Yet, the differences in home productivity across households may increase the extent of inequality. Second, as men and women differ in their home productivity, a model without home production has consequences for the economic value both within and outside marriage and therefore within-household inequality. Third, if time spent in home production is not taxed while the time spent in market activities is taxed, then the planner must consider how taxes distort relative factor input prices. Fourth, a model without home production implies different own-wage and cross-wage labour supply elasticities. Fifth, complementarity in the home production technology is a crucial determinant of the degree of assortative mating, and a model without home production would imply very different marital patterns.

Given the wide ranging and complex effects that home production has upon the design problem, we consider a quantitative exploration that involves changing the home time efficiency parameter vector $\zeta = \{\zeta_{i0}, \zeta_{0j}, \zeta_{ij}\}_{i \leq I, j \leq J}$. In Figure 11d we present results setting $\zeta = 0$. Conditional on spousal earnings, the marginal tax rate structure is more progressive, and the degree of tax jointness is decreased. We now have $\Delta T'(30000) = 14.5\%$ and $\Delta T'(70000) = 17.6\%$. The same pattern is true for single individuals. Namely, marginal tax rates decrease at low earnings, but otherwise increase.

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