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ESSAYS ON INCOME TAXES AND HOUSEHOLD PRODUCTION

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ESSAYS ON INCOME TAXES AND HOUSEHOLD PRODUCTION

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Couples make dynamic joint decisions, including how much each spouse works at home and in the market throughout life. By building a dynamic model of taxation, I quantify the welfare gains of moving to a gender-based tax. Further, I explore the implications of a gender-based income tax for labor market and time-use choices within a couple, taking into account changing labor market attachment through life. The key finding is that while gender-based taxation always improves household and social welfare, the model-specific household time allocations and government policy implications depend on underlying assumptions about gender differences.

I model the inefficiency of income tax due to pooling old individuals and young individuals who differ in their skill distribution and use of time. Because age is correlated with ability and time investments in education, allowing tax rules to vary with age shrinks labor distortions. I use an overlapping generations model to study the effect of an age-based income tax on efficiency. I analytically show the efficiency gains and I numerically estimate a welfare gain equivalent to 5% of aggregate consumption when age-based taxes are implemented.

Adult women generally, and married women in particular, spend more time than men doing housework and childcare activities. While gender differences in time-use patterns among adults at home are readily accepted and well documented, the onset and development of gender time-use differences over the adolescent years and into early adulthood are not well understood. In this research, I describe the development of time-use gender differences over the teenage years and into the early adult years using American Time Use Survey (ATUS) data, with a focus on activities relating to family

duties and child care activities. I find gender divergence in home duties prior to the teenage years, which sharply stratifies upon high school graduation. Further, I find that time-use outcomes disproportionately impact women from disadvantaged socio-economic and family backgrounds.

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Chapter 1

Gender-based Taxation and Lifecycle Allocations of Labor, Leisure and Household Chores

1.1 INTRODUCTION

It is well known that women's labor supply to the market has increased dramatically over the past 80 years. Women worldwide work in the market more than ever before. Further, married women make up a growing proportion of the female labor force, despite their weak historical attachment to the labor market. While two-income families are increasingly prevalent, many tax systems still adhere to tax structures designed with one earner in mind. These tax systems focus on total household income and often provide inefficient incentives to families choosing how much each spouse works. As an alternative to taxing household income, consider a gender-based tax, where each spouse faces a unique marginal income tax rate. The optimal design of a gender-based tax system requires understanding at a more fundamental level the trade-offs that a couple faces when making labor supply decisions. "Any discussion of the taxation of two-person households necessarily involves the recognition of the importance of household production."[1] In a couple setting, there is collaboration in providing for the family both in the market and in the home, and the balance of time use between a husband and wife evolves over the lifecycle. In order to understand the full implications of income taxation on members of a family, one must consider the impact taxation has on the evolution of time use throughout life.

I investigate the efficiency implications of a gender-based tax for a family in a lifecycle model in which labor supply elasticities evolve over time as the family makes time use choices throughout life. I develop a general multi-period model with a representative couple with unitary preferences. I examine implications for the couple that

[1] Apps and Rees (2007).

result from assumptions about gender differences, including differences in home productivity, market productivity, and returns to work experience. With this flexible model, I show the consequences of a gender-based tax on family decisions. Moreover, I test the robustness of policy implications across contrasting assumptions about gender differences.

While public policy offering different tax brackets to men and women may be infeasible or unlikely in some countries, this chapter contributes to a broader discussion about couple dynamics in differential taxation. There can be aspects of tax systems which correlate closely with a gender-based tax. For example, from 1982 to 1986, the U.S. tax system offered a second-earner deduction that "effectively lowered the tax rate on the lower-earning spouse in a married couple."[2] This theoretical essay offers a relatively simple approach for better understanding couple dynamics when each face different tax schedules.

Recent developments in formal economic models of gender-based taxation suggest welfare improvements when using a gender-based tax.[3] Of note is the work by Alesina, Ichino and Karabarbounis (2011), who model a gender-based tax in an environment where labor supply elasticities evolve endogenously. In an effort to build on the work of others, this essay offers two important contributions to the gender-based tax literature. This is the first study to model the optimal tax in a multi-period environment. Empirical facts suggest that lifecycle considerations tremendously influence family labor supply choices, and static economic models cannot generate changing attachment to the labor market over the lifecycle. Therefore, they fall short of capturing the effect of taxation on these patterns. For example, Apps and Rees (2007) use a static model and assume a wide distribution of female home productivity to match empirical observations of cross-sectional variation in women's time use. While productivity differences among women contribute to some of the observed variation, their model cannot address variation due to lifecycle patterns of time use among families. In contrast, allowing labor supply

[2] Williams (2012).

[3] Alesina, Ichino and Karabarbounis (2007), Boskin and Sheshinski (1983), and Apps and Rees (2007) model optimal taxation of couples and find that a gender-based tax is optimal.

patterns to develop endogenously over the lifecycle explains the predictive power of my model on lifecycle patterns when applying alternative tax treatments.

A second important contribution of this essay is its expansion of factors that lead to observable gender differences within a couple. Consideration of a gender-based tax presumes observable labor market differences between men and women. However, the fundamental differences driving the observable disparity are important to consider. Studying and modeling multiple reasons why gender differences may exist allows for a broader analysis of the consequences of a gender-based tax. Alesina, Ichino and Karabarbounis (2011) are the first to model labor supply elasticities endogenously. However, they only present two avenues for gender differences to arise, both of which lead to a career choice mechanism and market productivity differences. While market productivity differences between a husband and wife may play a role in a couple's division of labor, it is an incomplete description of the forces driving specialization decisions at home.[4] In this research, gender differences arise due to differences in market productivities, home productivities, preferences, and returns to work experience. I demonstrate that gender-based taxation is optimal regardless of the cause for gender differences.

While there are many facets of gender-based taxation, it is worth emphasizing that this essay focuses exclusively on the efficiency gains for a couple offered by a gender-based tax. I do not consider equity or redistribution (Kleven, Kreiner, and Saez (2009)),[5] nor do I consider the non-equal impact of non-gender-based taxes on men and women of any marital status (Grown & Valodia (2010)). While these are important areas within the gender-based tax literature, I find an important role for gender-based tax on efficiency grounds alone.

The essay is organized as follows. Section 1.2 presents a lifecycle model of a representative family. Section 1.3 discusses the analytics of the optimal gender-based tax

[4] McKinnish (2008) observes differences in labor market behavior in couples where both spouses appear to be highly educated and have high-income careers. Kurdek (2007) observes specialization in household chores among gay couples where both partners work full-time.

[5] Kleven, Kreiner, and Saez redistribute income using market participation of a second earner, who in practice is often female, as a signal.

and compares it to the optimal tax not based on gender. Section 1.4 introduces the methodology for conducting numerical simulations of the economy. Section 1.5 investigates the robustness of family and policy outcomes while varying foundational gender differences. This is done by altering assumptions on the structure of gender and simulating family and policy outcomes. Section 1.6 concludes with discussion and insights about gender-based tax policy.

1.2 LIFECYCLE MODEL

Consider a linear income tax framework to model the effect of a gender-based tax system on a family. The approach takes Harberger's original model which minimizes the excess burden of a tax and expands it in two fundamental ways. First, I expand his static model to a multi-period dynamic setting. A multi-period model allows me to explore the role of taxation on the interplay between spouses in their work choices over time. Second, I include the option for the government to tax based on gender. This simple mechanism contains potential power as a policy tool.

1.2.1 Households

I use a family labor supply model, treating the couple as a single unit. This unitary utility model assumes the couple makes all decisions, rather than considering individuals within the family as separate decision makers. Treating a couple as a single unit implies that members of a family share with each other, they cooperate, and they operate with family welfare in mind. Modeling the family as completely united oversimplifies to some degree the real dynamics in families. There are issues of intra-familial allocation, bargaining, and family formation that cannot be addressed in this chapter. However, the unitary model of the family is well suited to address the key issue of interest, specifically gender taxation over the lifecycle. The flexibility of the model in a multi-period setting allows me to demonstrate clearly responses to taxation due to lifecycle effects that have not been previously considered. The model implies that family members pool all household income and that couples respond symmetrically to each other's wage changes.

While this assumption is strong, it serves an important role. The income pooling assumption ensures that asymmetries in the response of a husband and wife to tax policies are generated from differences in time use responses, not differences in income sharing or bargaining power. Further, I make no assumptions about labor supply elasticities, and allow differences in time use patterns to emerge endogenously from the decision process of the family.

Suppose the economy has a representative family with two working individuals and with a unitary utility function. This treats the family as a single decision making unit, rather than considering individuals within the family as independent decisions makers. Any distributional need within the family is done through appropriate side payments. The family lives for T periods. The family is formed prior to beginning the first period. The family lifetime utility is the sum of period utility, with a time preference discount factor β. Let the preferences of the family each period be represented by a twice-differentiable quasiconcave preference function $U(C_t, L_{Ht}, L_{Wt})$, where C_t represents the total consumption of goods in period t by the household and L_{it} ($i=H,W$) represents the leisure of individual i.[6] This depiction assumes that the utility gained from consumption depends on its total amount, rather than how it is generated and shared within the household. Goods consumed may be purchased in the market, C_t^M, or produced domestically, C_t^D. Total consumption is the sum of market goods and goods produced at home.

$$C_t = C_t^M + C_t^D \tag{1.1}$$

The family consumes all their good each period as the consumption good cannot be saved. The family utility function contains a single argument for consumption, whether produced in the market or at home. Further, there is no spouse-specific consumption in the utility model, so consumption benefits the family as a whole, rather than an individual within the family.

[6] The utility function later includes additional arguments to reflect differences in preference for home production in the family.

Each member of the household is endowed with one unit of time each period. The time endowment can be used to leisure L_{it}, work in the market h_{it}, or work at home D_{it}. Leisure increases utility directly, but it detracts from the time available to work.

1.2.2 Production

The production technology at home is an important feature of the model, which may be used to generate gender differences in specific modeling cases. In order to remain general, the home production technology for the representative wife and husband are given.

$$C_{Wt}^{D} = q(D_{Wt}) \tag{1.2}$$

$$C_{Ht}^{D} = f(D_{Ht}) \tag{1.3}$$

The home production technologies for the wife and husband may be identical, as given by the condition that $f(x) = q(x)$ for any x. The production technology at home may favor the wife or husband in a given period with the condition that $f(x) \lesseqgtr q(x)$ for any x. The assumption of the model considers productivity difference at home to be exogenous. While the source of the difference could be attributed to biology or attributed to home production and childcare skill development before adulthood, the difference is considered to be exogenous to the model.

Market productivity is a feature of the model that can create gender differences in time use choices in specific environments. Productivity Y_{it} is a function of human capital φ_i at the onset of the first period as well as time spent working in the labor market each period. The representation allows for career choice to affect productivity by affecting the level of human capital. The representation also allows for previous work experience to impact market productivity if desired.

$$Y_{it} = \varphi_i g(h_{i1}, h_{i2}, \dots, h_{it}) \tag{1.4}$$

Given the model described, the family has a budget constraint each period represented in Equation 1.5 where $\tau_i > 0$ is the marginal tax rate.

$$C_t^M = Y_{Ht}(1 - \tau_H) + Y_{Wt}(1 - \tau_W) \tag{1.5}$$

Implicit in the family budget constraint is the assumption that spouses can make side payments. Family members face taxes on market earnings each period, and consumption is untaxed. There are no distributional concerns in the economy, and any role for gender-based taxation comes from improvements in efficiency.

1.2.3 Government

The government raises revenue to finance exogenous government expenditures G. Taxes are denoted by $T_{it} = Y_{it}\tau_i$ where $\tau_i > 0$ is the marginal tax rate, and T_{it} is the total tax liability. The government chooses the optimal tax policy before families make allocation decisions. Tax policy depends explicitly on the gender of the worker. Family members can face different marginal tax rates. The government tax policy does not change based on age, but the tax liability for a family likely changes over time due to different choices about labor market participation throughout life. The first-best solution is achieved through lump-sum taxation, which is not an available policy tool in this environment. The government must use the income tax to finance expenditures, implying a source of inefficiency in the economy. Because there is no distributional concern, the optimal tax policy most efficiently raises the required revenue. The government budget constraint is represented in Equation 1.6.

$$G = \sum_t Y_{Ht}\tau_H + Y_{Wt}\tau_W \tag{1.6}$$

The notation for the government budget constraint is simplified by applying the following definition. Let the lifetime production of a spouse be represented by Equation 1.7.

$$Y_i = \sum_{t=1}^{T} Y_{it} = \sum_{t=1}^{T} \varphi_i g(h_{i1}, h_{i2}, \ldots, h_{it}) \tag{1.7}$$

The government budget constraint in Equation 1.6 is now represented as follows.

$$G = Y_H\tau_H + Y_W\tau_W \tag{1.8}$$

1.2.4 Household Decision Rules

The family maximizes its intertemporal utility subject to a number of constraints. The program is represented by the following description.

$$\max_{\substack{C_t^M, C_t^D \; for \; t=1,2,\ldots,T \\ L_{it} \; for \; i=H,W;\; t=1,2,\ldots,T \\ h_{it} \; for \; i=H,W; t=1,2,\ldots,T \\ D_{it} \; for \; i=H,W; t=1,2,\ldots,T}} \sum_1^T \beta^{t-1} U(C_t, L_{Ht}, L_{Wt}) \tag{1.9}$$

Subject to:

$C_t^M \leq Y_{Ht}(1-\tau_H) + Y_{Wt}(1-\tau_W)$ for $t = 1,2,\ldots,T$ Budget Constraint (1.10)

$1 \geq L_{it} + h_{it} + D_{it}$ for $i = H, W; t = 1,2,\ldots,T$ Time Constraint (1.11)

$Y_{it} \leq \varphi_i g(h_{i1}, h_{i2}, \ldots, h_{it})$ for $i = H, W; t = 1,2,\ldots,T$ Market Production Technology (1.12)

$C_t^D \leq f(D_{Ht}) + q(D_{Wt})$ for $t = 1,2,\ldots,T$ Home Production Technology (1.13)

The household chooses allocation rules, given the government's choice of the tax rates. The household decision rules follow from the first-order conditions and budget constraints for the household each period. The first-order conditions are summarized by the following equations.[7]

$$\frac{\partial U}{\partial L_{it}} = \sum_{s=t}^{T} \left(\beta^{s-t-1} \frac{\partial U}{\partial C_s} \frac{\partial g(h_{i1}, h_{i2}, \ldots, h_{it}, \ldots, h_{is})}{\partial h_{it}} \varphi_i (1-\tau_i) \right) \quad \text{for } i = H, W \tag{1.14}$$

$$\frac{\frac{\partial U}{\partial L_{Wt}}}{\frac{\partial U}{\partial L_{Ht}}} = \frac{q'(D_{Wt})}{f'(D_{Ht})} \tag{1.15}$$

Equation 1.14 shows the household trade-off between leisure and market work in a given period. The marginal return to leisure is equal to the marginal return to working. The return to work includes the good produced, as well as the value of the future gains in productivity. Notice the tax rate explicitly affects the marginal value of work in each period. It affects the net return to time spent in the market in the current period. It also affects the net return to time spent in the market by influencing market productivity in future periods. Equation 1.15 summarizes the household decision rules when deciding how much each spouse contributes to household production. The ratio of the marginal benefit of leisure is equated to the ratio of the marginal product of home production. Equations 1.14 and 1.15 combined imply that the household maximizes utility when the marginal benefit of working at home equals the after-tax marginal benefit of working in

[7] See Appendix A-1 for a detailed derivation of household behavior.

the market. An increase in an individual's tax rate decreases the marginal benefit of working in the market for that individual. This model framework, with its household decision process, serve as a foundation as the government designs optimal tax strategies.

1.3 Optimal Tax Treatment: Analytical Results

A Ramsey Equilibrium requires that for a policy rule τ^*, the household allocation rules solve the household's problem, the government budget constraint is satisfied, and the policy rule τ^* is chosen to maximize utility for the household. The optimal tax can be solved analytically by maximizing welfare subject to the required constraints. However, the optimal tax is also found by minimizing the excess burden, the loss of utility greater than would have happened had lump-sum taxation been used (Rosen (1978)). The efficiency cost of a tax program is measured by its excess burden, which loss measures the effect of distorting relative prices due to taxation. For clarity of exposition, I follow the later approach. Exact measures of excess burden require a functional form on utility. Rather than assume a particular utility function, I appeal to Harberger's familiar approximation.[8] I derive the approximation of the excess burden for this model, expanding the framework of Boskin and Sheshinski (1983) and Mumford (2009)[9] to include multiple periods with multiple time and technology constraints. The excess burden of the entire time horizon is computed simultaneously, rather than computing the discounted excess burdens each period. This explicitly models the influence of price changes on demand in any period.[10] The excess burden for this economy is derived in Appendix A-2 and represented in Equation 1.16, where S_{njsit} is the substitution effect resulting from prices in the n^{th} budget constraint for price j in time period s given a price increase in i in time period t.

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[8] The generic approximation is the following: $EB = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\tau_i\tau_j S_{ij}$, where τ_i is the tax rate on good i and S_{ij} is the substitution effect for good i given an increase in the price of good j. See Harberger (1964) for additional detail.

[9] Mumford uses a similar set up to address a separate issue of child tax credits.

[10] Simultaneous modeling allows market labor supply to appear in its own-period budget constraint and all subsequent budget constraints, due to gains to labor market experience. To remain clear about which budget constraint and corresponding cross derivative matrix is being considered when referring to prices, let $P_{nh_{it}}$ represent a price implied by the n^{th} budget constraint.

$$EB = -\frac{1}{2}\left(\sum_j \sum_{s=1}^{T} \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} \tau_i \tau_j P_{sh_{js}} S_{njsit} P_{nh_{it}}\right) \qquad (1.16)$$

The compensated demands in Equation 1.16 are cross derivatives, and Appendix A-1 contains the explicit derivation of the cross derivative matrices.[11] The representation of the excess burden approximates the true excess burden of the policy as long as the compensated demand curves are highly linear.

The government's program finds the tax rates which minimize the excess burden, while raising the required revenue G, as shown in Equation 1.8, the government budget constraint. The government knows that an income tax policy necessarily involves a loss, and the government minimizes the loss subject to its revenue constraint over the lifecycle.

1.3.1 Optimal Gender-independent Taxation

For comparison purposes, first consider the case where the government cannot condition tax rates on gender. The equation for the excess burden simplifies in the following way, where EB^{NG} denotes the excess burden in a non-gender-based tax program.

$$EB^{NG} = -\frac{1}{2}\tau^2 \left(\sum_j \sum_{s=1}^{T} \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} P_{sh_{js}} S_{njsit} P_{nh_{it}}\right) \qquad (1.17)$$

When the government considers the optimal tax rate, without conditioning on gender, the government's program is represented in Equation 1.18, where μ is the multiplier on the government budget constraint.

$$\mathcal{L} = EB^{NG} - \mu\big((Y_H + Y_W)\tau - G\big) \qquad (1.18)$$

Taking first-order conditions and solving gives optimal tax values as functions of the revenue requirement G. The optimal tax level is given in the following equation.

$$\tau_{NG} = -\frac{\mu\big((Y_H + Y_W)\big)}{\left(\sum_j \sum_{s=1}^{T} \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} P_{sh_{js}} S_{njsit} P_{nh_{it}}\right)} \qquad (1.19)$$

The optimal gender-independent tax rate depends on three important elements. First, the tightness of the constraint μ plays a role in the size of the tax. The tightness of

[11] The cross derivative matrices are analogous to a Slutsky substitution matrix of a static model with a single constraint.

the government budget constraint multiplier is a function of the government revenue requirement, and as G increases, the optimal tax increases.

Second, the government considers the size of the total tax base when choosing the optimal tax rate. The total tax base refers to the total value of the taxable output generated by the family, $(Y_H + Y_W)$. The size of the tax base determines how much revenue is raised by the government for a given tax rate. For example, at a fixed tax rate, an economy with a large tax base brings in more revenue than an economy with a small tax base. The tax base determines how easily the government revenue requirement can be satisfied.

The non-gender-based tax rate in Equation 1.19 develops from a third important consideration, the sum of all labor supply responses to the tax for both spouses as seen in the denominator. The individual level of responsiveness is irrelevant except for its contribution to total responsiveness to a given tax rate. This means that relative differences in responses to wage changes play no role in the non-gender-based tax case, and the inability of the government to tax labor supply of each spouse differently decreases efficiency.

An economy without gender-based taxation cannot capitalize on differences in the size of the tax base and labor supply responses by treating workers differently. In the next section, we see that allowing gender-based taxation improves family and social outcomes by adjusting the tax rate to consider the relative size of the tax base and labor supply responses.

1.3.2 Optimal Gender-based Taxation

When the government considers the optimal tax rates using gender, the government's program is represented in Equation 1.20 where μ is the multiplier on the government budget constraint.

$$\mathcal{L} = EB - \mu(Y_H \tau_H + Y_W \tau_W - G) \tag{1.20}$$

Taking first-order conditions and solving gives optimal tax values as functions of the required revenue requirement G. The optimal tax levels are given in the following two equations.

$$\tau_H = \frac{G}{K}\left(\frac{2A_W}{(A_{HW}+A_{WH})}\frac{Y_H}{Y_W} - 1\right)Y_W \quad (1.21)$$

$$\tau_W = \frac{G}{K}\left(\frac{2A_H}{(A_{HW}+A_{WH})}\frac{Y_W}{Y_H} - 1\right)Y_H \quad (1.22)$$

The optimal gender-based tax rates are not necessarily equal. In order to understand the differences in the tax rates, I discuss each piece of the optimal tax equations. K is a constant, and the value of K is irrelevant, given that it does not underlie the difference between the gender-based tax rates. G is positive and appears symmetrically in the gender-based tax equation pair. The following notation definitions are applied in Equations 1.21 and 1.22:

$$A_H = \sum_s \sum_t \sum_{n=t}^{N} P_{sh_{Hs}} S_{nHsHt} P_{nh_{Ht}} \quad (1.23)$$

$$A_W = \sum_s \sum_t \sum_{n=t}^{N} P_{sh_{Ws}} S_{nWsWt} P_{nh_{Wt}} \quad (1.24)$$

$$A_{HW} = \sum_s \sum_t \sum_{n=t}^{N} P_{sh_{Hs}} S_{nHsWt} P_{nh_{Wt}} \quad (1.25)$$

$$A_{WH} = \sum_s \sum_t \sum_{n=t}^{N} P_{sh_{Ws}} S_{nWsHt} P_{nh_{Ht}} \quad (1.26)$$

Equations 1.23 - 1.26 capture the compensated changes of each spouse's labor supply over the lifecycle to changes in tax rates, and can be thought of as the total change in labor supply by individual *i* to a given change in effective wages of individual *j*. The values of each S_{njsit} are found in its cross derivative matrix in Appendix A-1. Given that these are symmetric matrices, all differences in optimal labor supply and optimal tax rates given in the model are not driven by differences in cross-wage elasticities. The sign of the cross price effects are with respect to wages, not taxes. Therefore, they have the opposite sign as the response to a tax. An increase in a tax rate effectively decreases the price of labor, which in turn decreases labor supplied. Equation 1.23 represents the sensitivities of a husband over his lifetime to a gender-based tax on his earnings applied all periods. Equation 1.24 represents the sensitivities of a wife over her lifetime to a tax on her earnings applied all periods. Equation 1.25 represents the sensitivities of a wife over her lifetime to a tax on her husband's earnings, which is the sum of the cross-price effects. Equation 1.26 represents the sensitivities of a husband over his lifetime to a tax on his wife's earnings. The size of the cross effects may be bigger or smaller than the own-price effects. The values come from different cross derivative matrices that satisfy different budget constraints and symmetry requirements, and the magnitudes and signs cannot be determined analytically in a multi-period setting.[12]

The gender-based tax rates, as seen in Equations 1.21 and 1.22, have important implications about the difference in the optimal tax rates for men and women and the causes for the difference. The gender-based tax rate difference develops from two important sources. First, the relative and absolute size of the tax base of each spouse plays a critical role in determining optimal taxes. Conceptually, the amount of tax revenue generated by a given tax rate is dependent on how much income is taxed. Unlike the case when gender is not considered, the relative levels of production by the husband and wife play a critical role in the optimal tax. In order to demonstrate this, I focus on the fraction inside the brackets. The ratio of the tax base is represented in Equation 1.27 and the direction of the inequality depends on model assumptions about gender differences.

$$\frac{Y_H}{Y_W} \gtreqless 1 \tag{1.27}$$

The government raises revenue more efficiently by taking into account the relative tax base when spouses produce differently in the market. For example, suppose the government wishes to generate half of the required revenue from non-identical spouses. The spouse with the relatively small tax base faces a higher tax rate than the spouse with the relatively large tax base, which is suboptimal. The government can improve efficiency by adjusting the tax rates according to the relative size of the tax base of each spouse. The absolute size of the tax base in relation to the responsiveness for each spouse is an important consideration, given that every dollar not contributed in taxes by one spouse must come from the other.

The tax rate difference between Equations 1.21 and 1.22 develops from a second source which is the labor supply responsiveness of each spouse. How individuals responds to changes in their own wages develops endogenously from the model of household choice.

[12] In a static model, one would require behavior to be symmetric, invariant to price normalizations, and consistent with a budget constraint to find signs and magnitudes on the cross derivatives. In a multi-period model, the values come from different cross derivate matrices that satisfy different budget constraints and symmetry rules, so I make no claim about the sign or magnitudes of A_3 and A_4.

$$A_H \lesseqgtr A_W \tag{1.28}$$

The inequalities in Equations 1.27 and 1.28 have implications for the optimal gender-based tax values, and the directions of the inequalities depend on model assumptions.

Analyzing efficiency gains due to a gender-based tax requires additional structure on how a husband and wife differ, whether through their abilities in home production, market production, preferences for domestic work, or differences in their returns to experience. Deciding who pays a higher marginal tax rate follows from these assumptions. Gender differences create differing behavioral responses, and the response differences determine the relative values of a gender-based tax. The form of the gender differences is the topic of the next sections, which present estimates on efficiency gains from the optimal gender-based tax in case study simulations.

1.4 Calibration Parameterization

In order to estimate efficiency gains and labor market responses, I conduct simulation experiments, which require additional structural assumptions about the theoretical economy. In this section I describe the process of designating functional forms, assigning meaningful parameter values and estimating optimal tax rates. The entire span of a family's career is broken into two time periods, young and old. It is important to recognize the choice of two periods of life as a generalization. The choice of age groups is arbitrary. The choice attempts to characterize young people as those finished with career choice considerations, involved in gaining work experience, and those most involved in investment aspects of home production. The young generation represents a family with the husband between the ages of 30 and 45. The old generation represents a family with the husband between the ages of 45 and 60 to avoid significant overlap with retirement. The model requires that the family unit is intact by the onset of the first period. While the age at first marriage is increasing in developed countries, Goodwin et al. (2009) reports that in 2002, more than 60% of men and more than 75% of women were married by age 30.

There are four contributing factors in the model that affect optimal tax rates. These factors are preferences of agents, market production technology, home production technology, and the exogenous level of government spending. Careful attention is given to the parameterization of each of these factors.

Preferences are assumed to be quasi-linear in consumption each period as shown in Equation 1.29. Quasi-linear preferences guarantee that a household response to a change in tax levels does not have an income effect.

$$U(C_t, L_{Ht}, L_{Wt}) = \alpha_C C_t + {L_{Ht}}^{\alpha_H} {L_{Wt}}^{\alpha_W} \tag{1.29}$$

The relative values for the preference parameters are chosen so that the amount of time devoted to leisure is about two-thirds of total time, consistent with Burda, Hamermesh, Weil (2008). They find that across 14 wealthy non-Catholic countries, men spend about 431 minutes per day working at home or in the market, and women spend on average 440 minutes. They report that in the United States, men spend about 475 minutes and women spend about 460 minutes working each day. These findings motivate the parameterization of the preference coefficients. The time preference discount factor β is assumed to be 0.9, given that the period time horizon is 15 years. An annual discount factor of 0.993 corresponds with β = 0.9. Frederick, Loewenstein, and O'Donoghue (2002) survey empirical estimates of time discounting and find that most estimates of annual discounting are between 0.8 and 1. An implied annual discount factor of 0.993 in this case is high, but within acceptable bounds. Choosing an annual discount value close to one highlights the role of other economic factors as they influence choices over the lifecycle.

The market production technology is assumed to be concave. The production function reflects learning-by-doing skill acquisition, with the full realization of skill level by the final period. Work experience and learning on the job influence skill realizations later in life. Card and DiNardo (2002) decompose the returns to experience for men in the United States, year by year. They report that returns to experience plateau around age 40 for college educated and non-college educated men alike. This suggests that for men, skill acquisition is complete by age 45. The LBD production function is a Mincer earnings function. The parameter φ_i is the efficiency unit of labor per efficiency unit of human capital, which can be influenced by a career choice prior to the first period. The parameter H_0 is the initial stock of human capital. I scale prices and the initial stock of human capital to be one.

$$g(h_{it-1}, h_{it}) = \varphi_i(H_0 + \beta_0 h_{it-1} + \beta_1 (h_{it-1})^2) h_{it} \tag{1.30}$$

I rely on the estimated coefficients of Heckman, Lochner and Cossa (2002) for the numerical exercises. I calibrate β_0 to be 1.5, which is in the middle of appropriate estimates. I calibrate β_1 to be -0.3, which is at the upper bound of the estimates. The numerical examples are sensitive to the market production technology parameters, and movement away from these calibrated values often produces corner solutions. Given that there are two channels of producing the consumption good, there is a small range of parameter values where families find it beneficial to use both means of production.

Few studies simulate market and home production together. I choose a home production technology similar to Alesina, Ichino, and Karabarbounis (2011) which is a Cobb-Douglas production function.

$$f(D_{H1}) = \frac{\varphi_H^D}{\gamma}(D_{H1})^{\gamma} \tag{1.31}$$

$$q(D_{W1}) = \frac{\varphi_W^D}{\gamma}(D_{W1})^{\gamma} \tag{1.32}$$

I calibrate the efficiency units of labor per efficiency unit of human capital for the husband to be 0.65. The corresponding value for the wife is 1, in cases where gender differences develop from home productivity differences. Otherwise, her value is assumed to match her husband's value. I use $\gamma = 1/3$. Given the lack of research on home productivity, these parameter values are chosen primarily to achieve interior solutions given the parameter values of the market productivities.

The level of exogenous government spending is chosen to be less than 10% of total output in equilibrium. The Heritage Foundation estimates that the per capita tax burden in the United States is near 30%. While there is a great deal of variation across countries in government spending, the rates in the United States are generally consistent with other developed countries.[13] The International Monetary Fund reports government spending per capita to be a large range, with upper estimates around 60% worldwide. However, I substantially reduce the level of exogenous government spending compared to empirical estimates, given that I only consider the portion of government spending not related to providing a public good to the family.

Table 1.1: Summary of Parameter Values, Sources, and Economic Interpretations

	Estimate	Source	Economic Interpretation
α_C	1/3	Burda, Hamermesh, Weil (2008)	Discount on consumption in utility function
α_H	1/3	Burda, Hamermesh, Weil (2008)	Share of husband's leisure in utility function
α_W	1/3	Burda, Hamermesh, Weil (2008)	Share of wife's leisure in utility function
β	0.9	Frederick, Loewenstein, and O'Donoghue (2002)	Time preference discount factor
φ_i	1.5 or 1.275	Gendered difference used in cases of market productivity difference	Efficiency units of production per efficiency unit of human capital
H_0	1.5	Heckman, Lochner, Cossa (2002)	Initial stock of human capital
β_0	1.5	Value dependent on case, Heckman, Lochner, Cossa (2002)	Returns to LBD technology
β_1	-0.3	Value dependent on case, Heckman, Lochner, Cossa (2002)	Diminishing returns to LBD technology
φ_H^D	0.65	Author's choice	Efficiency units of home production by husband
φ_W^D	0.65 or 1	Gendered difference used in cases of home productivity difference	Efficiency units of home production by wife
G	0.1	IMF Gov't Finance Statistics (2010)	Level of government spending
γ	0.5	Author's choice	Return to domestic labor

The function and parameter estimates allow for simulations of the economy in order to compare outcomes in an economy with and without gender-based taxation.

[13] See IMF Government Finance Statistics, 2010 and the 2011 Index of Economic Freedom.

1.5 GENDER DIFFERENCES AND IMPLICATIONS FOR GENDER-BASED TAXES

A gender-based tax presupposes fundamental differences between family members over their lifetimes. Economists observe behavioral outcomes and make assumptions about why gendered outcomes develop. In an effort to scrutinize the validity of the conclusions implied by the model, I assume gender differences emerge through different channels and compare couple and policy outcomes. Modeling and simulating several channels for gender differences to appear allows for a more broad analysis of the consequences of a gender-based tax. Modeling separately the implications of gender differences in market productivity, home productivity and preferences for domestic work, I present simulated numerical examples demonstrating the impact of a gender-based tax on family outcomes. I show efficiency gains and optimal tax rates in each case and discuss the implications of each model.

1.5.1 Differences in Market Productivity

Consider differences in labor market outcomes that occur due to exogenous market productivity differences between a husband and wife. This example explores the role of a gender-based tax when gender gaps occur due to market productivity differences, as represented by the condition that $\varphi_H \geq \varphi_W$. While the productivity difference could be the result of men investing in high-wage careers prior to the onset of the first period, it is assumed to be exogenous.[14] Because the tax directly impacts labor supply, its ability to offset labor productivity differences is strongest in this case. Table 1.2 reports that there are positive welfare implications of moving to a gender-based tax. The excess burden is lower under a gender-based tax. However, the improvement in efficiency is relatively small, reducing the excess burden by less than 2%. Under a gender-based tax, a wife's marginal tax rate is lower than her husband's rate.

[14]This example is similar to the model of Alesina, Ichino and Karabarbounis (2011), with the exception of a unitary utility function and an exogenous difference in market productivity, rather than allowing market productivity at the onset of the first period to develop out of a career choice mechanism. My findings in this case support their conclusions.

Table 1.2: Outcomes of Gender-Dependent Tax with Gender Difference in Market Productivity

	Gender-independent	Gender-dependent	Change
Excess burden (proportion of total tax)	1.013	0.996	-0.016
Marginal tax rate			
Wife	0.040	0.028	-0.313
Husband	0.040	0.045	0.125
Wife			
Market labor, young	0.143	0.155	0.088
Market labor, old	0.118	0.128	0.085
Home labor, young	0.160	0.160	0.000
Home labor, old	0.163	0.163	0.000
Husband			
Market labor, young	0.210	0.228	0.083
Market labor, old	0.170	0.185	0.088
Home labor, young	0.143	0.143	0.000
Home labor, old	0.150	0.148	-0.017
Gender difference (Husband-Wife)			
Market work time, young	0.068	0.073	0.074
Market work time, old	0.053	0.058	0.095
After-tax income	0.466	0.472	0.012

Due to lower labor productivity, a wife works less in the market than her husband in both periods, regardless of the tax scheme. A wife's market labor supply under a gender-based tax is 9% higher each period than her labor supply under a gender-independent tax. Although a husband faces a higher marginal tax rate, he spends more time in the labor market under a gender-based tax. His labor supply responses is the combined effect of his own price effects for all future periods, as well as the cross price effects on his wife's lower tax rate. In this case, we see an increase in his labor supply. Returns to labor market experience induce both members of the family to work less when old. Example 1.5.2 explores an evolving labor market attachment over time because of changing relative productivity over time.

The policy implications of this model with exogenous differences in market productivity are robust to parameter changes. If in fact the model assumptions are generally correct, if gender differences create market productivity differences prior to the onset of the first period and if those market productivity differences are stable throughout the lifecycle, the simulations of this model support tax policy which decreases the marginal tax rate for the average wife and increases the marginal tax rate for the average husband.

1.5.2 Gender Differences in Home Productivity

Suppose that gender differences in families stem from an exogenous difference in the abilities in home production, and the difference favors the wife, $f(D_{Ht}) \leq q(D_{Wt})$. While the source of the difference could be attributed to biology or attributed to home production and childcare skill development before adulthood, the difference is considered to be exogenous to the model. This model explores the role of a gender-based tax on market labor when gender gaps do not result from differences in labor market abilities. Suppose that market productivity is identical for men and women, who are born equally productive. Men and women improve their market productivity as they spend time working in the market, and this effect places a penalty on workers who devote time to leisure or home production early in life. Labor market gender differences form as spouses make different labor supply choices and thereby receive different returns to market work experience over time. Table 1.3 reports that there are positive welfare implications of moving to a gender-based tax. The excess burden is lower under a gender-based tax. However, the improvement in efficiency is relatively small. Under a gender-based tax, a wife's marginal tax rate is lower than her husband's.

Table 1.3: Outcomes of Gender-dependent Tax with Gender Difference in Home Productivity

	Gender-independent	Gender-dependent	Percent Change
Excess burden (proportion of total tax)	0.996	0.995	-0.001
Marginal tax rate			
Wife	0.033	0.008	-0.769
Husband	0.033	0.053	0.615
Wife			
Market labor, young	0.185	0.188	0.014
Market labor, old	0.150	0.153	0.017
Home labor, young	0.255	0.255	0.000
Home labor, old	0.260	0.260	0.000
Husband			
Market labor, young	0.258	0.260	0.010
Market labor, old	0.205	0.208	0.012
Home labor, young	0.148	0.148	0.000
Home labor, old	0.155	0.155	0.000
Gender difference (Husband-Wife)			
Market work time, young	0.073	0.073	0.000
Market work time, old	0.055	0.055	0.000
After-tax income	0.300	0.230	-0.233

Due to a higher productivity in domestic work, a wife devotes relatively more time to working at home and relatively less time to working in the market, regardless of the tax scheme. A wife's market labor supply under a gender-based tax is only 1% to 2% higher than her labor supply under a gender-independent tax. Although a husband faces a higher marginal tax rate, he spends 1% more time in the labor market under a gender-based tax. His labor supply responses is the combined effect of his own price effects for all future periods, as well as the cross price effects on his wife's lower tax rate. In this case, we see an increase in his labor supply. Boskin and Sheshinski (1983) derive the conditions on labor supply complimentarities which guarantee a lower tax for a wife.

These conditions become more difficult to guarantee when market productivities are identical. Further, a gender-based tax is less able to increase efficiency when underlying gender differences occur in dimensions that cannot directly be taxed. If inherent differences in gender do not impact market productivity, a gender-based tax is a weak instrument to address gender gaps in time-use outcomes.

1.5.3 Differences in Exogenous Preferences for Domestic Work

Observed gender differences between a couple could stem from differences in each person's preferences. This case explores the role of a gender-based tax in the presence of asymmetric preferences for domestic work, with a linear preference penalty for domestic work assigned to the husband. In this case, the excess burden is reduces by over 2.5% when comparing a gender-independent and gender-dependent tax. Under a gender-based tax, the husband pays a higher tax rate than his wife.

While the difference in work time in the market is not large, there is a large time discrepancy in housework within the couple. Given the husband's distaste for domestic work, the wife works at home considerably more than her husband.

Table 1.4: Outcomes of Gender-dependent Tax with Gender Difference in Preferences for Domestic Work

	Gender-independent	Gender-dependent	Percent Change
Excess burden (proportion of total tax)	1.019	0.990	-0.025
Marginal tax rate			
Wife	0.030	0.008	-0.750
Husband	0.030	0.045	0.500
Wife			
Market labor, young	0.210	0.230	0.095
Market labor, old	0.168	0.183	0.090
Home labor, young	0.145	0.143	-0.017
Home labor, old	0.148	0.148	0.000
Husband			
Market labor, young	0.293	0.323	0.103
Market labor, old	0.235	0.255	0.085
Home labor, young	0.023	0.023	0.000
Home labor, old	0.023	0.023	0.000
Gender difference (Husband-Wife)			
Market work time, young	0.083	0.093	0.121
Market work time, old	0.068	0.073	0.074
After-tax income	0.345	0.309	-0.104

1.5.4 Summary of Examples

The three examples in this section provide insight into tax policy. Each of the examples in this section demonstrates that efficiency improves when using a gender-based income tax, albeit a small improvement in each case. Specifically, the excess burden of a gender-based tax is about 2% less than the excess burden of a gender-independent tax. In the broader context of the gender-based tax conversation, there are both efficiency and equity considerations. If a more equitable distribution between men and women is desired, then a gender-based tax policy improves efficiency and equity simultaneously. While equity considerations are beyond the scope of this research, it is interesting that a gender-based tax does not require a balancing act between efficiency and equity, since a gender-based tax policy improves both simultaneously.

In each situation, the wife received a lower tax than her husband, regardless of the nature of the underlying gender difference between the husband and wife. The different approaches to generate observed gender differences did not impact the relative distribution of a gender-based tax.[15] Policy makers interested in designing gender-based tax policy can be confident that regardless of the source of the underlying difference between a husband and wife, the optimal gender-based tax is similar across all cases.

1.6 CONCLUSION

This chapter examines the efficiency implications of gender-based taxation over the lifetime of a couple. After deriving the optimal gender-based tax in a multi-period setting, I model gender gaps throughout life. The model evaluates a wide range of possible underlying gender differences, including market differences akin to those modeled in static studies on gender-based taxation. I also include differences in preferences and domestic productivity with minimal structure on gender differences.

I demonstrate that when using quasi-linear unitary utility modeling, couple outcomes and policy rules support a gender-based tax which lowers the marginal rate on the representative wife, regardless of the modeling assumptions that led her to choose less time that her husband in the labor market. In all cases, gender-based taxation improves efficiency by about 2%.

This chapter has implications for the broader conversation about couple dynamics in differential taxation. A second-earner deduction effectively lowers the tax rate on the lower-earning spouse in a married couple, which closely correlates with a gender-based tax. The results I find suggest that a second-earner deduction improves efficiency. In fact,

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[15] This finding depends in part on the selection of a quasi-linear utility function, which circumvents income effects. If in reality income effects are important for couples in their decision making, then optimal tax rates may not always favor the wife.

a second-earner deduction improves efficiency even for couples where gender roles are reversed.

It is worth discussing several important avenues for further research. The model as it stands could expand to better address taxation over the lifecycle. A more involved description of home production would include fertility as a choice variable, which could be influenced by a gender-based tax. I model two periods in this chapter. While the two-period model offers advantages in clarity and exposition, a model with more periods would likely generate more precise numerical approximations of the implications of a gender-based tax. I model one type of household, that with a husband and wife. A discussion of the implications of a gender-based tax beyond its impact on spouses would require the inclusion of other household compositions, such as single adults with and without children. Understanding the influence of a gender-based tax on incentives to marry and divorce would be of interest. Introducing heterogeneous households would provide an interesting avenue to explore the redistributive aspects of a gender-based tax that have not been addressed here. Finally, the model would be enriched by including both the intensive and extensive margin of the labor supply decision. There is much theoretical work that could broaden understanding about the full impact of a gender-based tax across the lifecycle, as this is a first step. Aside from modeling techniques, there is a need for additional research on the observed time use differences between men and women in domestic work and market work. Are gender differences in home productivity inherent or developed? Do perceptions about gender roles rather than productivity differences explain time use patterns of spouses? Few have studied home productivity differences and the source or formation of those differences. I hope that by focusing on the lifecycle implications within a family of gender-based tax, I have brought to light the critical role of relative productivity of husbands and wives. The potential power for gender-based tax policy to improve outcomes deserves additional attention.

Chapter 2

Correcting Labor Distortions using Age-based Income Tax

2.1 INTRODUCTION

Many countries are interested in redistributing wealth; however, redistribution using an income tax often results in inefficiency. Ideally a government would be able to tax permanent income or consumption, but the convention in most countries is to tax annual income. Governments trade the simplicity and transparency of an annual income tax for the efficiency of a lifetime income tax. Annual income tax systems distort labor market decisions, and for this reason, it is important to study tax systems that reduce taxation inefficiencies and distortions. One possibility is to base income tax on age.

There is a correlation between income and age. One may ask what drives relatively low incomes of young workers, and the answer is twofold. First, young workers are generally less-skill than older workers. They have completed less education and accumulated less experience. Firms pay lower wages to low-skill workers, so even full-time young workers typically have lower incomes than older workers. Second, young workers also spend time investing in education, and consequently they work fewer hours. This study models skill differences and time-use differences between age groups and demonstrates the ability of an age-based income tax to reduce labor distortions and increase social welfare.

Skill differences lead to inefficiency in annual income tax plans because of informational asymmetries. Individual wage rates and skill levels are private information. The government wants to encourage highly skilled workers to be productive. Therefore, the tax system cannot provide too much social insurance for low-skill workers, or high-skill workers will imitate them. By conditioning taxes on age, the government can decrease the size of the incentive compatibility distortion by offering different tax schedules to different ages. This creates a tax system that better matches lifetime skill profiles.

The intuition for why inefficiency arises from differences between young and old investing in education has to do with time substitutions away from the labor market. Young workers substitute some of the time that they could be working or consuming leisure for time spent investing in education. Pooling old and young individuals forces the two groups to consume at the same point. However, at a fixed level of leisure and consumption, young and old individuals face different marginal rates of substitution. An age-based income tax can take into account the education time-use wedge faced by younger individuals.

The main contribution of this chapter is to provide a tax system that eliminates inefficiency associated with pooling young and old together, when skill and time-use differences between the two groups exist. By using information about differences between young and old in skill distribution and time use, the age-based tax system reduces distortions on labor supply. In an overlapping generation version of a Mirrlees tax model, I show that age-based taxes reduce these distortions by separating individuals who face different skill-risk and time-use profiles. A second contribution of this chapter is to provide a quantifiable estimate of welfare gains. This chapter seeks to offer policy implications of this tax plan. When agents are concerned about lifetime income, lifetime income tax efficiency dominates an annual income tax. However, I use annual income tax which does not depend on income history as the policy tool. This policy tool is not chosen on efficiency grounds, but rather because of the widespread use of annual income taxes observed in most countries worldwide. Using annual income tax allows the model to offer practical insight into sources of inefficiency in current systems. I estimate the size of the welfare gain, I find that age-based taxes offer a welfare gain equivalent to a 5% increase in aggregate consumption.

Relevant literature on non-linear labor taxation dates back to Mirrlees (1971), who studies redistribution in the presence of informational asymmetries. He suggests that private information about labor productivity limits the amount of redistribution available to a planner. He also finds optimal marginal tax rates to be zero for the most productive workers. Saez (2001) further characterizes elasticities in an optimal non-linear tax system. More recently, Smyth (2006) addresses non-linear taxation of labor and capital simultaneously, and estimates optimal labor taxes to be relatively flat when separated from capital.

Recent theoretical work on non-linear labor taxation addresses the idea of allowing a tax system to be based on age. This research follows two lines. The first line focuses on using age to allow a tax system to be flexible to life cycle income and consumption patterns. The basic assumption is that a representative individual's consumption and income vary over the lifecycle. The underlying result of this literature is that tax plans (age-based or not) which account for lifecycle consumption and income patterns are more efficient than those which do not (Gervais (2009), Eroca and Gervais (2002), Lozachmeur (2006)).

A second branch of the age-based tax literature focuses on using age to capture skill differences over a heterogeneous population. Akerlof (1978) first suggests efficiency gains from conditioning taxes or transfers on income as well as other observable characteristics. He observes that "if a tax system could be differentiated between individuals according to some characteristic correlated with ability, then there would be a potential for reducing the conflict between redistribution and efficiency."[1] The correlation between age and ability motivates recent papers which build on Akerlof's observation. These New Dynamic Public Finance papers use dynamic versions of the Mirrlees (1971) optimal non-linear income tax model. Kremer (2002) argues that tax rates on young workers should be lower. Judd & Su (2006) assume that agents know with certainty their skill path at birth. They find that conditioning taxes on age increases optimal redistribution. They introduce important numerical methods to deal with multidimensional screening in optimal taxation. Golosov, Kocherlakota, and Tsyvinski(2003) allow agents to face an uncertain skill profile that evolves through life. They prove that any optimal age-based tax relies on labor supply each period. They use infinitely lived agents, and the model finds optimal taxes that rely on income history. Bloomquist and Michaeletto (2008) allow agents to face skill risk and restrict taxes to be

[1] Blomquist (2008), pg.1.

independent of past income realizations. In contrast to my model, they assume young do not invest in education, and they use a narrow social welfare concept to evaluate gains from age-based tax. They find that age-based taxes improve efficiency, but they do not include size estimates of the welfare gain.

The most complete treatment of age dependence is Weinzierl (2008), who models and estimates the impact of age-based tax. He builds a Mirrleesian model and presents age dependence as a partial reform for improving efficiency. He calibrates his model to PSID labor income data and estimates an increase in aggregate consumption. This chapter goes beyond the work of Weinzierl by including education in the tax problem. Weinzierl recognizes the importance of skill formation in the tax problem and mentions in his paper that including education is an important challenge for future work on age-based taxation. An important lesson of the age dependent tax literature is that despite differences in modeling approaches and underlying assumptions, they all provide a consistent result. Efficiency improves when allowing taxes to correlate with skill through age.

The rest of the chapter is organized as follows. In the next section, I describe the model environment and equilibrium. Section 2.3 presents analytical implications of the model. In section 2.4, I present five numerical examples which demonstrate the mechanisms behind inefficiencies and sources of welfare gain. In Section 2.5, I conclude.

2.2 Overlapping Generations Model

This study uses a Mirrlees optimal nonlinear income tax framework to model the effect of an age-based tax system. I expand Mirrlees' original model in two fundamental ways. First, I expand his static model to a two-period dynamic setting with overlapping generations. Thus the model naturally incorporates tax pools with agents from different ages. Second, I include exogenous educational investments and skill risk faced by agents. There is no growth or saving in the model. By excluding saving, the model accentuates the role of the planner in providing insurance against skill risk faced by agents. Agents have no access to precautionary saving, and only the government can insure agents against negative skill shocks.

2.2.1 Households

Each period n *ex ante* identical agents are born and live with certainty for two periods. Young agents are all low-skill, and young agents choose to spend time in leisure (l) or work (L), but all young agents spend time acquiring education (e). Old agents make labor and leisure decisions after their skill levels are realized. Agents have identical preferences for consumption c and leisure $l = 1\text{-}L$ that are represented by an additively separable utility function with a discount rate of β. Labor is explicitly modeled, and utility is decreasing in the second argument. The y and o subscripts denote young and old.

$$U = u\left(c_y, L_y + e\right) + \beta u(c_o, L_o) \tag{2.1}$$

Agents face an exogenous probability π_h of becoming high-skill when old, and a probability π_l of remaining low-skill when old. Skill is the only dimension for heterogeneity in the economy, and agents' skill realizations are private information. However, the government knows the exogenous probabilities and can use them in forming policy. There is no saving, and old agents make labor and leisure decisions after their skill levels are realized. Labor income is subject to non-linear income taxation $T(I_i)$, which yields the following budget constraint each period. The superscripts l and h represent values corresponding to low-skill and high-skill individuals respectively.

$$\begin{aligned} c_y &\leq I_y - T\left(I_y\right) \\ c_o^l &\leq I_o^l - T(I_o^l) \\ c_o^h &\leq I_o^h - T(I_o^h) \end{aligned} \tag{2.2}$$

High-skill and low-skill agents earn a wage of w_h and w_l, respectively, regardless of age. The wage is equal to the marginal product of labor, and agents face no idiosyncratic wage or skill shocks.

The model has only two periods as a means to clearly demonstrate the mechanism behind welfare improvements. Unlike many two-period overlapping generation models, this model does not include a retired cohort, given that labor taxation is the focus of the study. Agents maximize expected lifetime utility subject to a budget constraint when young and old. Because skill is realized before labor decisions are made, the agent decision problem reduces to agents maximizing utility each period by optimally choosing consumption and labor. The household problem is represented in the following maximization problem, where labor is expressed in terms of pre-tax income.

$$\max_{c_y, I_y, c_o^h, I_o^h, c_o^l, I_o^l} \left\{ u\left(c_y, \frac{I_y}{w_l} + e\right) + \beta\left(\pi_l u\left(c_o^l, \frac{I_o^l}{w_l}\right) + \pi_h u\left(c_o^h, \frac{I_o^h}{w_h}\right)\right)\right\} \quad (2.3)$$

Subject to budget constraints:

$$c_y \leq I_y - T(I_y)$$
$$c_o^l \leq I_o^l - T(I_o^l)$$
$$c_i^j \leq I_i^j - T(I_i^j)$$

As far as agents are concerned, the tax function $T(I)$ is taken as given, but an agent's post tax income depends on the realization of the tax function at the income level the agent selects.

2.2.2 Production

Since the focus of the chapter is non-linear income taxation, I simplify the production process. It is assumed that aggregate output Y of a single consumption good is produced using a concave technology and aggregate labor N is the only input.

$$Y = F(N) \quad (2.4)$$

Agents differ in their labor productivity, and contribute differently to the production process. High skill workers have a higher productivity weight, P^h, and contribute more to a firms labor supply than low skill workers who faces a productivity weight P^l. This is expressed in the production function by multiplying individual labor supply by individual productivity. Aggregate labor supply comes from summing the labor supply decisions of all agents in the economy, weighted by their individual productivity.

$$N = P^l L_y + \pi_l P^l L_o^l + \pi_h P^h L_o^h \quad (2.5)$$

Firms offer workers their marginal product of labor. High-skill and low-skill agents earn a wage of w_h and w_l, respectively, regardless of age.

$$w_h = P^h\big(F'(N)\big) \tag{2.6}$$
$$w_l = P^l\big(F'(N)\big)$$

2.2.3 Government

There is a benevolent government that is interested in maximizing social welfare while promoting efficiency. Social preferences for equality suggest a role for redistribution in the economy, and the government uses income tax to redistribute between any agents in the economy. However, stronger preferences for equality imply greater inefficiency. Social preferences are represented by a social welfare function $W_\rho(u)$ which represents the planner's attitude toward inequality in the parameter ρ. The function is strictly Paretian and concave. It is important to remember that agents are differentiated by skill and age. While social preferences dictate redistribution, they do not necessarily dictate equality for every ρ. Even in the Rawlsian case, non-symmetric wealth profiles can give rise to inequality in the optimal equilibrium.

The government uses income tax to optimally redistribute according to its social welfare objective, and the tax rates do not dependent on past tax history. The government observes pretax income, and it uses this information to optimally redistribute. The government does not observe skill level or hours worked. Each period the planner redistributes according to a nonlinear income tax function $T(I)$. Theoretically the government is free to choose any nonlinear function. Because I do not try to decentralize the tax equilibrium, no functional form for a tax function is specified. The government is only interested in redistribution, and it has a balanced budget each period. Below is the government balanced budget constraint.

$$T\big(I_y\big) + \Big(\pi_l T(I_o^l) + \pi_h T(I_o^h)\Big) \geq 0 \tag{2.7}$$

Each period the government offers a schedule of all pretax income levels and their corresponding post-tax incomes $B(I)=I-T(I)$. The tax rule is announced to all agents, and they use the tax schedule to make labor and consumption choices each period.

Since an agent self-selects a bundle in the tax system, the government must ensure that an individual has the incentive to select the point intended for her. Because skill is private information, the government must design the consumption and leisure bundles to encourage separation of the heterogeneous agents. For example, high skill workers must be compensated for their work with a high consumption bundle, or they may choose to work very little and imitate a low-skill worker's income level. High incomes require significantly more labor input for low-skill workers and are harder to imitate by low-skill workers. No incentive constraint is needed for low-skill workers. The government creates optimal tax policy that provides an incentive for high skill individuals to self-sort into the income bundles designed for them. Formally this is represented by an incentive compatibility constraint in the government's problem.

$$u\left(c_o^h, \frac{I_o^h}{w_h}\right) \geq u\left(c_o^l, \frac{I_o^h}{w_l}\right) \tag{2.8}$$

2.2.4 Steady State Equilibrium

The steady state solution to the planner's problem is equivalent to finding the solution to a static equilibrium in one period, and following the allocations every period. Since in steady state outcomes each period are identical, solving the static problem is equivalent to setting up an infinite planner's problem. The equilibrium is characterized by the following definition. Given tax policy function *T(I)*, a steady-state optimum is a set of value functions and decision rules for ages, $\{U_i^j, c_i^j, l_i^j\}$, and wages $\{w_l, w_h\}$ such that:

1. Households maximize utility as described in section 2.2.1, given wages and tax rates.
2. Wages $\{w_l, w_h\}$ are offered as described in section 2.2.2.
3. The labor market clears.

$$N = P^l L_y + \pi_l P^l L_o^l + \pi_h P^h L_o^h$$

4. The allocation is feasible.

$$c_y + \pi_l c_o^l + \pi_h c_o^h = F(N)$$

5. No individual has an incentive to imitate another type in any period.

$$u\left(c_i^j, \frac{I_i^j}{w_j}\right) \geq u\left(c_g^h, \frac{I_g^h}{w_j}\right) \quad \text{for all } i \neq g, j \neq h$$

The government maximizes social welfare and balances its budget, as described in section 2.2.3.

2.3 ANALYTICAL RESULTS

I demonstrate important model properties and mechanisms to reduce inefficiency and improve welfare when using an age dependent tax. The first result is the examination of the allocation made to the old high-skill workers. As is consistent with classical Mirrlees economies, the government achieves the optimal social allocation when it sets a zero marginal tax rate for the most-skill worker. The intuition for why the planner does not distort the labor decision of the high-skill worker comes from recognizing that high skill workers have the highest productivity per unit of labor. They contribute the most to aggregate output. By encouraging productivity among the high-skill, the planner increases social welfare. This does not mean that high skill workers pay no tax. In fact the opposite is true. While they pay a zero marginal tax at the equilibrium, they pay a positive average tax, which allows the planner to subsidize the consumption of low-skill workers. Theoretically, one obtains the result by solving the agent decision problem and comparing the solution to the planner's problem. The old high-skill workers set their marginal rate of substitution between consumption and labor to negative one. There is no labor distortion for old high-skill workers. This result holds in the model, whether or not a planner uses age-based taxes or age-independent taxes. There is no room for efficiency improvements when considering old-high skill workers.

The first best outcome of a fully optimal tax plan would be characterized by a zero marginal tax for all workers. In the Mirrleesian economy, the tax policy for low-skilled workers reveals inefficiency in the economy, and low-skilled workers are not offered the first best tax rate. Consider a planner implementing an age independent tax plan. She offers the same allocation to young workers and old low-skill workers. Consider the equation that characterizes the optimal marginal tax rate for an age-independent tax scheme, where λ_1 is the multiplier on the incentive compatibility constraint and the hat represents the deviating behavior of high-skill workers.

$$-MRS_y = 1 \;-\; \frac{\lambda_1}{u_y^{-\rho}}\left(\frac{\widehat{MRS}+1}{W^{\rho}}\right)\left(\frac{\frac{\partial u_y}{\partial c_l}}{\frac{\partial \hat{u}}{\partial c_l}}\right) \;+\; \frac{{u_o^l}^{-\rho}}{u_y^{-\rho}}\pi_l(MRS_o^l + 1)\left(\frac{\frac{\partial u_y}{\partial c_l}}{\frac{\partial u_o^l}{\partial c_l}}\right) \qquad (2.9)$$

If there were no distortions, the marginal rate of substitution for young would equal 1. I show this equation rather than just the optimal tax in order to demonstrate the interplay of the marginal rates of substitution later in this section. The last two terms represent distortion due to the income tax system. I consider the efficiency gain of each term separately.

The second term on the right in Equation 2.9 represents the efficiency loss due to the incentive compatibility constraint. The government must distort the bundle offered to low-skilled workers to ensure incentive compatibility. Utility levels for low-skilled workers must be pushed down in order to keep high-skilled workers from imitating low-skilled income levels. The planner must distort all low-skill workers, including the young. An age-based tax eliminates the need for an incentive compatibility constraint distorting young worker. The planner can prevent deviations of high-skill workers on the basis of age. Removing this source of inefficiency for all low-skill is equivalent to removing the second term in Equation 2.9. Equation 2.10 demonstrates the increased efficiency when a planner is not subject to an incentive compatibility constraint on any low-skill workers.

$$-MRS_y = 1 + \frac{{u_o^l}^{-\rho}}{u_y^{-\rho}} \pi_l (MRS_o^l + 1) \left(\frac{\frac{\partial u_y}{\partial c_l}}{\frac{\partial u_o^l}{\partial c_l}} \right) \tag{2.10}$$

The third term on the right in Equation 2.9 and the second term on the right of Equation 2.10 is the distortion due to time-use differences between young and old. As long as education investment is positive, this term is non-zero and marginal utilities differ in equilibrium. Young workers spend time investing in education, but old low-skilled workers do not invest in education. Both groups are constrained to supply the same level of labor, and both groups are consuming different levels of leisure, which is not optimal. The government forces young workers to oversupply labor and allows old low-skilled workers to undersupply labor.

I explore the time-use inefficiency in two cases. First I show the optimal tax when the planner faces no time use differences but must account for incentive compatibility. If no time-use differences exist, Equation 2.9 simplifies considerably.

$$-MRS^{l} = 1 \; - \; \frac{\lambda_1}{u_y^{-\rho}}\left(\frac{\widehat{MRS}+1}{W^{\rho}}\right)\left(\frac{\frac{\partial u_y}{\partial c_l}}{\frac{\partial \hat{u}}{\partial c_l}}\right) \; + \; \pi_l(MRS^{l}+1) \tag{2.11}$$

Rearranging Equation 2.11 and solving for the optimal marginal rate of substitution yields Equation 2.12, the optimal tax when only the incentive compatibility constraints distorts workers. The second term on the right of Equation 2.12 is the analog of the second term on the right of Equation 2.9.

$$-MRS^{l} = 1 \; - \; \frac{\lambda_1}{u_y^{-\rho}(1+\pi_l)}\left(\frac{\widehat{MRS}+1}{W^{\rho}}\right)\left(\frac{\frac{\partial u_y}{\partial c_l}}{\frac{\partial \hat{u}}{\partial c_l}}\right) \tag{2.12}$$

I now show how the planner corrects inefficiency due to time use when no incentive compatibility constraint is present. When time-use differences are present, the planner can correct the time-use wedge. To demonstrate this process, I temporarily assume there is no incentive compatibility constraint. The only source of inefficiency is due to offering all low-skill workers identical bundles, as represented in Equation 2.10. Given that the planner can separate low-skill workers based on age, efficiency can improve. Suppose the planner (consistent with feasibility, social maximization and without distorting high-skill workers) adjusts all consumption and leisure bundles such that old low-skilled must be offered the first best solution. In other words, suppose the planner offers old low-skill workers a point where the marginal rate of substitution equals one and the marginal tax equals zero. What is the implication of this allocation for the optimal tax rate on young workers? At the allocation described, the second term in Equation 2.10 is zero, as reflected by setting the marginal rate of substitution for old low-skill workers to one. The optimal tax for young workers is the first best solution, and the economy has no time-use inefficiency.

$$-MRS_y = 1 \tag{2.13}$$

Now consider the baseline economy with time-use and incentive compatibility inefficiencies. Consider the equations that characterize the optimal marginal tax rates for an age-based tax scheme. Conditioning taxes on age adds new tax options for the government. It no longer treats young low-skilled workers the same as old low-skilled workers. It can exclude old workers from choosing a young worker bundle, because the government can condition offerings by age. The result of differentiating tax rates by age has important efficiency improvements.

$$-MRS_y = 1 \tag{2.14}$$

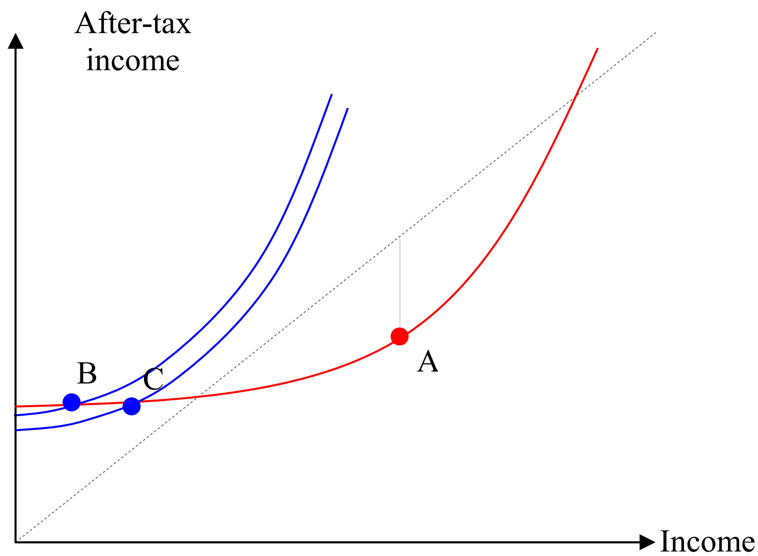
$$-MRS_o^l = 1 \; - \; \frac{\lambda_1}{{u_o^l}^{-\rho}}\left(\frac{\widehat{MRS}+1}{\pi_l W^{\rho}}\right)\left(\frac{\frac{\partial u_o^l}{\partial c_o^l}}{\frac{\partial \hat{u}}{\partial c_o^l}}\right) \tag{2.15}$$

It is immediately apparent that with age-based tax, there is no distortion on young workers. There is no skill heterogeneity within the young group, so the planner is not worried about preventing deviations among the young. The tax scheme also adjusts rates to account for educational investment by the young, and there is no distortion due to pooling people with different marginal utilities. It provides optimal allocations for young workers investing in education. The distortion on old low-skill workers has been reduced. They still face a distortion due to the incentive compatibility constraint. Utility levels for old low-skilled workers must be pushed down in order to keep high-skilled workers from imitating low-skilled income levels, so the government must distort the bundle offered to old low-skilled. Old low-skilled workers and young workers no longer use the same tax scheme, so the inefficiency due to pooling is not present under an age related tax system. The government can properly plan for all types of workers. It provides insurance for those remaining unskilled when old.

To summarize the results of the analytical findings, I present Figures 2.1 and 2.2, which provide graphical representations of the efficiency improvement under an age-based tax. Income represents lost leisure. After-tax income represents consumption. Therefore, utility is decreasing in income and increasing in after-tax income. High-skill workers generate more income for a given labor input, so high-skill workers have a flatter indifference curve, compared to low-skill workers. Figure 2.1 demonstrates the age-independent equilibrium. Old high-skill workers consume at point A, with a marginal tax rate of zero. At point A, high-skilled agents are below the 45 degree line, or in other words their pre-tax income is higher than their post-tax income. They pay a positive tax, even if not at the margin. The government is constrained to offer all unskilled workers point B, which is characterized by a positive marginal tax rate and a lump-sum transfer.

Young people choose the tax bundle represented at point B, but they also invest additional time in education. The investment in education effectively robs them of current leisure and pushes their utility below old low-skilled workers to point C.

Figure 2.1: Optimal Income Tax without Age

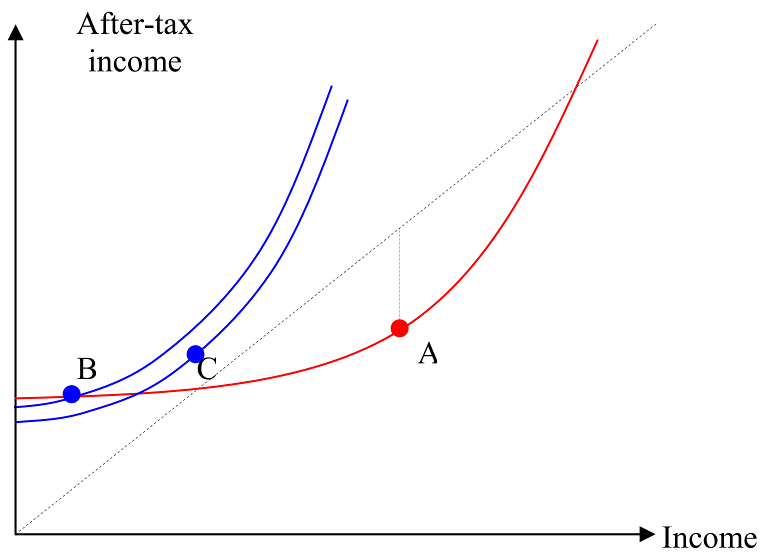


Suppose the government cannot observe age, but tries to set up incentive compatibility conditions to induce agents to sort by age and skill. This scenario is not possible, since old low-skilled workers would always imitate young workers.

Figure 2.2 provides a graphical representation of the economy under the age related tax system. Old skilled workers consume at point A, with a marginal tax rate of zero. The government offers old unskilled workers point B, characterized by a positive marginal tax rate and a lump-sum transfer. Young people choose the tax bundle represented at point C. The government offers young agents an undistorted bundle. Now that high-skilled workers are differentiated by age from low-skill workers, the government is not concerned about high-skill workers imitating young workers. Their labor supply increases, and they continue to invest time in education. This group's tax policies have two sources of inefficiency eliminated when taxes are conditioned on age.

The following section measures the size of the welfare improvements depicted in Figure 2.2 and the associated changes in allocations.

Figure 2.2: Optimal Age-dependent Income Tax



2.4 NUMERICAL EXAMPLES

In this section, I present numerical examples which demonstrate model properties. I estimate optimal allocations and give estimates for the size of welfare improvements when an age-based tax policy is used. I estimate parameters from a variety of sources. The model in this chapter has two periods, chosen as such to clearly demonstrate the role of age-based tax. It is important to recognize the choice of two periods of life as a generalization.[2] Care is needed in assigning meaningful parameter values to the model. Before assigning specific parameter values, it is useful to explicitly define the generations used in the calibration. Agents labor in both periods. In order to fit this fact, I focus on men in the calibrations, given that they have the most inelastic labor supply. The entire span of a man's education and career is then broken into two time periods, young and old. The young generation represents working men between the ages of 18 to 39. The old

[2] Weinzierl (2008) calibrates his wage distribution using a three period model .

generation represents working men between the ages of 40 to 60. Two aspects of the model influence the choice of the age cohorts. The model requires the completion of higher education within the first period. The United States Department of Education reports that in 2008, only 13% of men enrolled in post-secondary education are older than age 35, and only 5% of men enrolled full-time are over 35.[3] These data suggest that most men are finished acquiring education by age 40. The model also requires the full realization of skill level by the beginning of the second period. I simplify the skill acquisition process in the model to be completely exogenous; however, in reality education and experience influence skill realizations later in life. Card and DiNardo (2002) decompose the returns to experience for men in the United States, year by year. They report that returns to experience plateau around age 40 for college educated and non-college educated men alike. This suggests that for men, skill acquisition is achieved by age 40. Capping the older generation at age 60 avoids significant overlap with retirement periods later in life.

There are four contributing factors in the model that affect optimal tax rates. These factors are the government's aversion to social inequality, preferences of agents, level of exogenous education imposed on young agents, and the shape of the income distribution. Careful attention is given to the parameterization of each of these factors.

Social preferences for equality suggest a role for redistribution in the economy. In order to remain flexible in the level of social aversion to inequality, social preferences are represented by a Constant Elasticity Utilitarian Social Welfare Function. This function represents the planner's attitude toward inequality in the parameter $\rho \geq 0$. The function is strictly paretian and concave.

$$W_\rho(u) = \left(u\left(c_y, \frac{I_y}{w_l} + e\right)^{1-\rho} + \pi_l u\left(c_o^l, \frac{I_o^l}{w_l}\right)^{1-\rho} + \pi_h u\left(c_o^h, \frac{I_o^h}{w_h}\right)^{1-\rho} \right)^{1/1-\rho} \text{ for } \rho \neq 1 \qquad (2.16)$$

$$W_\rho(u) = \ln u\left(c_y, \frac{I_y}{w_l} + e\right) + \pi_l \ln u\left(c_o^l, \frac{I_o^l}{w_l}\right) + \pi_h \ln u\left(c_o^h, \frac{I_o^h}{w_h}\right) \text{ for } \rho = 1$$

[3] U.S. Department of Education, National Center for Education Statistics, Higher Education General Information Survey (HEGIS), "Fall Enrollment in Colleges and Universities" survey.

Notice that the purely Utilitarian social welfare case is obtained by setting $\rho = 0$ and the Rawlsian social welfare case is obtained as $\rho \to \infty$. It is important to remember that agents are differentiated by skill and age. While social preferences dictate redistribution, they do not necessarily dictate equality for every ρ. Even in the Rawlsian case, non-symmetric wealth profiles can give rise to inequality in the optimal equilibrium. Stronger preferences for equality imply a greater social gain from consumption and leisure bundles which improve equity. Most studies estimate only the utilitarian case, and I calculate a continuum of ρ to demonstrate the role of social aversion to inequality in equilibrium outcomes.

Preferences each period are represented by a CES utility function with non-separable consumption and leisure, where education is positive for young agents only.

$$u(c, L+e) = \frac{\left(c^{v}(1-L-e)^{1-v}\right)^{1-\gamma}}{1-\gamma} \tag{2.17}$$

A CES utility function is chosen based on the work of French (2005), who find that this utility function fits better than an additively separable utility function. Following his estimates, I set v equal to 1/3. This implies that agents spend about one-third of their time endowment working and gaining education if undistorted by taxes. The curvature of the utility function is an important parameter in tax problems, since it determines the efficiency cost of taxation. As noted by Tuomala (2009), "a concave utility of consumption means that income effects are weaker for high income earners, [which] push marginal tax rates down at high levels of income." The coefficient of relative risk aversion γ, which measures curvature of the utility function is set to equal 0.95. This parameter is chosen to be lower than typical estimates around 2 (see French (2005), Nishiyama and Smetters (2005)). A lower choice of γ facilitates the use of a Constant Elasticity Utilitarian Social Welfare Function, which is feasible when utility levels are positive.[4]

I set the level of exogenous education e to be 10% of the time endowment when young. This value is calculated in several steps. First, based on Department of Education

[4] See Mas-Colel, Whinston and Green for detail on restrictions to the social welfare function. Simulations for $\gamma = 2$ yields diverging utility levels when $\rho < 1$.

2008 enrollment statistics, I estimate the average time investment in education for men ages 18 to 40 who are enrolled in post-secondary education. I assume that a full-time student spends half his time endowment in education and a part-time student spends one-fourth his time endowment in education. Next I calculate the total number of males who are ages 18 to 40 in 2008 using United States Census estimates.[5] Finally, I compute the average educational investment for all men ages 18 to 40. As long as enrollment rates are assumed to be constant over time, this estimation is equivalent to following a cohort from 18 to 40 and estimating the time investment in education during the period. I find the average man invests about 10% of his time in education. Although this time investment seems small, it is important to recognize the impact this variable has when considering smaller age cohorts. For example, extrapolating from the age cohorts proposed by Weinzierl (2008) restricts the youngest age cohort to be ages 20 to 29. The estimate for time spent in education increases by 25% when using smaller cohorts.[6] The welfare gain of an age-based tax increases as educational investment time increases.

Specifying a skill distribution requires assumptions about inequality in the model economy. The simplified model presented here is not typical of previous simulations with static economies and more skill types. Mirrlees assumes a log-normal distribution of skill (see Mirrlees (1971)). Weinzierl (2008) estimates 10 skill types. In order to keep the simplified two-type skill distribution presented earlier, I appeal to using the standard deviation of wages as a measure of inequality within the economy, and match my model to observed values. Card and DiNardo (2002) estimate the standard deviation of wages for men in the United States to be 0.56, and McCall (2000) estimates a similar value, with a lower bound of 0.409. Card and DiNardo estimate the college-high school wage ratio for men ages 45 to 60 to be around 0.4. Assuming old low-skill workers are equivalent to old workers with no college degree, and applying their estimate to my model for the wages of old low-skill and old high-skill workers yields the productivity ratio $P^l/P^h =$

[5] Annual Estimates of the Resident Population by Sex and Age Groups for the United States: April 1, 2000 to July 1, 2008 (NC-EST2008-01).

[6] Education time investment consistent with Weinzierl's cohort size, and only two cohorts, implies an increase in welfare equivalent to an increase in aggregate consumption of 5.35%.

0.4. Putting the productivity ratio with the standard deviation estimates implies that the probability of remaining low-skill when old is about 15%. This is consistent with my measures of within-cohort inequality among men who are ages 40 to 60.[7] I rely on estimates of aggregate productivity reported by Card and DiNardo (2002) and estimates of marginal productivity reported by Smyth (2006) to back out estimated wages.

Table 2.1: Summary of Parameter Values, Sources, and Economic Interpretations

	Estimate	Source	Economic Interpretation
v	1/3	French (2005); Nishiyama, Smetters (2005)	Trade off between labor and leisure
γ	0.95	Lower than French (2005); Smyth (2006)	Risk aversion
e	0.10	Author's estimation	Time spent in education
P^l/P^h	0.40	Card, DiNardo (2002)	Productivity ratio
π_l	0.15	Card, DiNardo (2002); McCall (2000)	Probability of remaining low-skilled when old

2.4.1 Example 1: Comparing Age-independent Tax and Age-dependent Tax

The optimal age-based taxes and allocation for young, old low-skill and old high-skill workers differ substantially from the optimal age-independent taxes. This has real effects on consumption and labor allocations made by the government and on tax rates. I focus on three results from the simulations. I report the effect of age-based taxes on agent allocations, average tax rates, and welfare. These results give size estimates to the movements and reflect theoretical predictions about movements.

Effect of Taxes on Agent Allocations

Implementing an age-based tax has an impact on agent allocations. Because young agents work and invest in education, young agents spend too little time in leisure under the age-independent plan. They supply labor at the same level as old low-skill workers, and in addition they spend time in education. It is not surprising that the labor

[7] I calculated within-cohort inequality from the Consumer Expenditure Survey, year 2000.

input of young workers decrease by 55% when taxes are based on age. Young agents are given a subsidy under both tax schemes, but the subsidy with age-independent tax is more than double that given when taxes are not based on age. This subsidy funds a 57% increase in consumption when taxes are based on age, which balances the marginal rate of substitution with their high education and labor input. Under an age-independent tax plan, old low-skill agents necessarily have higher utility than young agents. As shown in Figure 2.1, old agents are given the same allocations as young agents, but the effective allocation is better for old agents who do not spend time in education. Old low-skill workers are paid a smaller subsidy, and consumption decreases by 33%. Old low-skill workers also increase their labor supply by 13%. High-skill workers increase their labor supply by 22% in order to fund a large subsidy to young workers. They also face decreased consumption, which overall leads them to have lower utility under the age-based plan. These results are summarized in Table 2.2. Notice that these calculations are for the case where $\rho = 0$, which is equivalent to the utilitarian case. The directions of the changes are similar for $\rho > 0$ and the effects of increasing social aversion to inequality are discussed later.

Table 2.2: Comparison of Optimal Allocations: Age-independent and Age-dependent Tax

	Age-independent	Age-dependent	Percent Change
Young			
L_y	0.008	0.000	-100.00%
$L_y + e$	0.108	0.100	-7.41%
C_y	0.085	0.148	74.12%
Old, low-skill			
L_o^l	0.008	0.009	12.50%
C_o^l	0.085	0.057	-32.94%
Old, high-skill			
L_o^h	0.343	0.419	22.16%
C_o^h	0.190	0.161	-15.26%

$\rho = 0$

Effect of Taxes on Average Tax Rates

Average tax rates are affected by age-based taxes. Under the age-independent tax system, the average tax schedule is necessarily the same for all agents with the same skill, regardless of age. However, when moving to the age-based case, average rates differ by skill and age. This is demonstrated in Table 2.3 below. Average tax is defined to be the difference between earned income and consumption, divided by earned income. The subsidy paid to young workers increases by 95% in the age-based case, while the subsidy paid to old low-skill workers decreases by 38%. The subsidy is paid to young workers in order to balance the marginal rate of substitution at the offer point. Young workers have no earned income and only invest in education and leisure under the age-based case, so an average tax is not reported. However, young workers have positive labor supply for values of ν as low as 0.5, and simulations using a ν higher than 1/3 show young workers receiving a substantially lower average tax than old workers.

Table 2.3: Comparing Average Tax Rates between Age-based and Age-independent Taxes

	Age	Low-skill	High-skill
Age-independent	18-39	-3.091	
	40-60	-3.091	0.787
Age-dependent	18-39	N/A	
	40-60	-1.887	0.861

$\rho = 0$

Effect of Taxes on Social Welfare

The effects of moving to an age-based income tax have interesting social implications, and the results are summarized in Table 2.4 below. First, the age-based tax increases social welfare, primarily by reducing distortions on young workers. Although the table reports social welfare, this is included only to show which plan is socially preferred. It is important to remember that social welfare numbers are ordinal, not cardinal. I report the welfare improvement by means of the increased equivalent consumption it would take the initial plan to achieve the same level of social welfare. The overall increase in social welfare is equivalent to a 5% increase in per capita consumption. Specifically, the age-independent planner can increase consumption by almost 5% at the age-independent allocations to achieve the same level of welfare. This gain is progressive, and concentrated among those with the lowest income. Increased redistribution benefits the young.

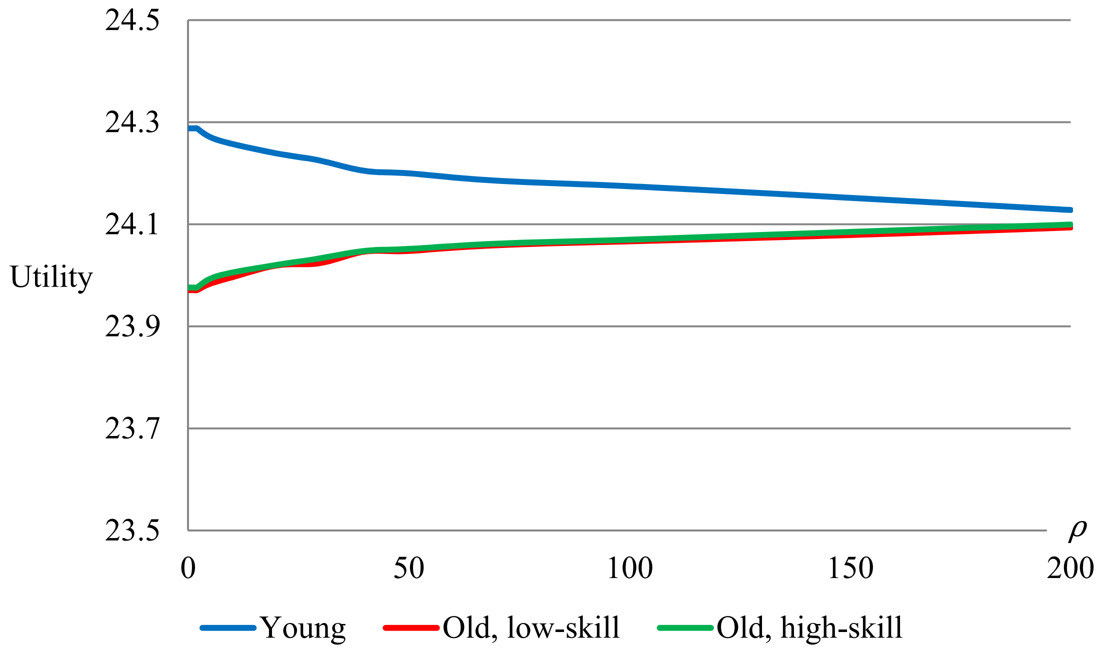
Table 2.4: Social Welfare Comparisons of Age-independent and Age-dependent Tax

	Age-independent	Age-dependent	Percent Change
Economy wide			
N	0.295	0.356	20.68%
Aggregate output	0.259	0.293	13.02%
Social welfare	48.192	48.263	
Equivalent consumption increase		0.007	4.78%

$\rho = 0$

The utilitarian planner has a strong desire to redistribute, and under symmetric allocations all utilities would be equal. Given the asymmetric skills endowments, agents are not equal in their expected lifetime utility for the utilitarian case. In the utilitarian case, young workers are allocated higher utility levels than old workers. As the planner increases in social aversion to inequality ρ, utility levels converge. This effect is demonstrated in Figure 2.3 below, which presents the optimal utility levels for workers as a function of ρ. As ρ increases, utility to the young decreases while utility of the old increases.

Figure 2.3: Impact of Social Aversion on Optimal Agent Utilities



It is interesting to note that only young agents prefer the age-based tax plan. If given an opportunity to vote on the plan, all old agents would vote against it. Although social welfare improves under the age-based tax plan, the plan would not carry support from the initial old generation, and unless a transition plan is included it would not be implemented.[8] It is not surprising to see the utility of old low-skill agents decrease under and age-based tax plan. When the government corrects the wedge between old low-skill workers and young workers, the allocations for low-skill agents are less desirable. Similarly, high-skill workers experience a tax increase of more than 120% in order to fund the large increase in tax subsidy paid to young workers under the age-based plan. Example 2.4.5 explores the age-based tax advantages from the perspective of a Pareto improvement, and it illustrates gains when restricting the planner to make only Pareto improvements.

The selected parameter values impact the magnitudes reported in this example, and I briefly discuss the effects of changing parameter values. As discussed earlier, increasing v increases labor supply at the optimal allocation. Increasing γ causes agents to become more risk averse and increase the intertemporal elasticity of substitution. The impact is seen the social planner's allocations to agents. The utilitarian planner chooses more equal utility levels for heterogeneous agents as γ increases. The welfare gains reported in this example reflects only 15% of old workers remaining low-skilled when old. Increasing the probability that a worker remains low-skill increases the pooling of young and old. The power of an age-based tax plan to separate agents increases as pooling increases.

In summary, Example 2.4.1 demonstrates a welfare gain equivalent to nearly 5% of aggregate consumption. This gain is progressive, and concentrated among those with the lowest income. Increased redistribution benefits the young, and this effect is seen most poignantly in the allocations of the utilitarian planner. The gap between old and young narrows as the planner becomes more averse to inequality.

2.4.2 Example 2: Age-dependent Tax with Homogenous Agents and No Private Information

There have been important papers in the age-based tax literature that assume all agents are homogenous. The basic assumption is that a representative individual's

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[8] I have not calculated a transition path to the age-based plan.

consumption and income varies over the lifecycle, and allowing a tax system to imitate income patterns improves over a tax schedule which does not. Modeling the assumption of homogeneous agents in this numerical example allows me to better illustrate the source of the efficiency gain in the previous example. Assume temporarily that all agents are homogeneous and all agents experience variation in income over the lifecycle. This is equivalent to modeling young agents as low-skill and old agents as high-skill. The planner designs a tax system that smooths consumption over the lifecycle and redistributes to the poor. The results of this simulation are summarized in Table 2.5 below.

Table 2.5: Age-independent Tax with Homogenous Agents and No Private Information

	Age-independent	Age-dependent	Percent Change
Economy wide			
N	0.408	0.408	0.00%
Per capita N	0.204	0.204	0.00%
Aggregate output	0.320	0.320	0.00%
Social welfare	48.310	48.310	
Equivalent consumption increase		0.000	0.00%

$\rho = 0$

This example demonstrates two important features of the age-based tax plan. First, no time use distortions are seen in the age-independent plan. When time use profiles are identical within a skill group, the planner can correct all time allocation issues using information about type and the corresponding type's decision rule. However, when a skill group draws from multiple age cohorts with different time-use profiles, the planner no longer corrects this distortion without using age-based taxes. This effect is demonstrated in detail in Example 2.4.4.

I argue in the analytical section that age and skill correlations play an important role in reducing distortion. Age gives the planner better information about skill, and by conditioning on age, a planner can reduce distortions caused by information asymmetries.

As this example demonstrates, when the planner knows the agent's type, age offers no improvement in information, and "progressive taxation can imitate optimal age-dependent tax rates" (Gervais (2009)). The taxes and allocations under the age dependence plan are identical to the age independence plan when no information asymmetries exist. Models which ignore heterogeneity and private information issues will likely find a small role for age-based tax. However, the first example demonstrates a sizable gain from an age-based tax system when modeling heterogeneity and private information. Moreover, the following example demonstrates that age-based tax plays an important role when private information is introduced, even when agents are homogeneous.

2.4.3 Example 3: Age-dependent Tax with Homogenous

Age-based tax plays an important role when agents have private information about their types. Homogeneous agents identically differ in skill over the life-cycle, which gives a skill distribution in the economy. Agents still may deviate from the optimal tax plan in an overlapping generation model. Assume for this example that all agents are homogeneous and all agents experience identical variation in income over the lifecycle. This is equivalent to modeling young agents as low-skill and old agents as high-skill. The planner designs a tax system that smooths consumption over the lifecycle and redistributes to the poor. However, the planner also must satisfy incentive compatibility to prevent high skill old agents from imitating low skill young agents. The results of this simulation are summarized in Table 2.6.

In the age independence case, the planner distorts young workers to prevent deviations. In the age dependence case, the planner prevents deviations using information on age, and the incentive compatibility constraint is irrelevant. Moving to an age-based tax plan improves efficiency by correcting labor distortions on young workers, and welfare improves under the age-based plan. The table below reports values for social welfare; however, these values are reported only for ordinal comparisons. The economy experiences an increase in welfare equivalent to nearly 7% increased consumption at the age-independent allocations.

Table 2.6: Age-independent Tax with Homogenous Agents and Private Information

	Age-independent	Age-dependent	Percent Change
Economy wide			
N	0.292	0.408	39.36%
Aggregate output	0.257	0.320	24.49%
Social welfare	48.225	48.310	
Equivalent consumption increase		0.010	6.85%

$\rho = 0$

This example illustrates two important points. First, comparing this example to the previous example highlights the role of age-based tax when private information is a concern. Models that ignore informational asymmetries will significantly underestimate the power of age-based tax models to improve efficiency. Second, the power of an age-based plan to alleviate labor distortions increases with the correlation between age and skill. Comparing this example to the first case, the correlation between age and skill is greater. The planner has more ability to reduce incentive compatibility distortions when age carries more information about skill. As the correlation between age and skill increases, the age-dependent tax becomes closer to a dynamic history dependent fully optimal tax.

2.4.4 Example 4: Age-dependent Tax with No Private Information

The large gain in welfare from moving young agents out of the incentive compatibility constraint suggest that private information is an important mechanism in the gains that come from an age-based tax. I relax this assumption while maintaining heterogeneous agents in order to demonstrate the effectiveness of age-based tax when no information asymmetries exist. In this case, the government can distinguish agents by skill. In the age independence case, young and old low-skill agents are still offered the same bundle, and young agents still invest in education. Thus, the only source of inefficiency is the time use wedge due to education of the young.

Table 2.7: Aggregate Comparisons of Age-independent and Age-dependent Tax

	Age-independent	Age-dependent	Percent Change
Economy wide			
N	0.386	0.383	-0.97%
Aggregate output	0.309	0.307	-0.62%
Social welfare	48.288	48.288	0.0002%
Equivalent consumption increase		0.00002	0.01%

$\rho = 0$

Implementing an age-based tax has a small impact on agent allocations. Because the planner has skill information, the planner is already able to offer allocations without distorting for incentive compatibility constraints. The only source for gain is correcting the time use wedge. The planner does this by lowering consumption of old low-skill workers to be below young workers. Welfare improves when moving to the age dependence tax plan; however, the gain is very small. The gains represent an increase in consumption of only 0.01%. This small effect suggests that the welfare improvement from correcting time use differences is small. A more important efficiency gain in the age-based tax problem comes from eliminating the incentive compatibility constraint on young workers. It is worth noting that educational investment is exogenously modeled to be constant for all agents, when in reality educational investments vary within a cohort and impacts future wages. This is an important area for future research in optimal labor taxation.

2.4.5 Example 5: Pareto Improvement of Age-based Tax

The analysis has focused on welfare from the perspective of the generalized social welfare function. However, as was noted earlier, the well-being of the initial old is sacrificed for the gain of young agents. I show the improvements of the age-based tax from the perspective of a Pareto improvement. Bloomquist and Michaeletto (2006) made the theoretical case for age dependence as a Pareto improving policy tool, and I demonstrate their theoretical result numerically in this example. I do this by restricting the planner to only offer allocations which improve the utility of each type. The results of this example are presented in Table 2.8.

Table 2.8: Comparison of Pareto Improving Allocations: Age-independent and Age-dependent Tax

	Age-independent	Age-dependent	Percent Change
Young	0.008	0.067	731.25%
L_y	0.108	0.167	54.17%
$L_y + e$	0.085	0.098	14.71%
c_y	0.076	0.028	-62.98%
Subsidy			
Old, low skill	0.008	0.006	-25.00%
L_o^l	0.085	0.085	-0.59%
C_o^l	0.076	0.078	3.12%
Subsidy			
Old, high skill	0.343	0.338	-1.46%
L_o^h	0.190	0.188	-1.32%
C_o^h	0.759	0.690	-9.14%
Tax			
Economy wide			
N	0.295	0.314	6.46%
Aggregate output	0.259	0.270	4.22%
Social welfare	48.192	48.197	
Equivalent consumption increase		0.074	1.33%

$\rho = 0$

Unlike the utilitarian example, the Pareto allocations include increased average tax rates for the young. Their subsidy is decreased. The young also increase effective labor supply by 54% which helps to boost consumption by 15%. Old low-skill agents decrease labor supply and slightly decrease consumption. Old high-skill agents decrease labor, consumption, and average tax in the Pareto improving case. These movements are in contrast to the utilitarian case where high-skill agents facilitated an increase in aggregate output. In the Pareto case, an increase in the labor supply of young workers causes the increased output in the economy.

The age-based tax increases social welfare, but the size of the welfare gain is much smaller when the planner is restricted to a Pareto improvement. The overall increase in social welfare is equivalent to a 1% increase in consumption, compared to a 5% increase in consumption for the utilitarian case. This suggests that a large portion of the utilitarian planner's gains are from alleviating distortions on young workers. The planner's ability to redistribute and improve welfare for the young specifically is greatly reduced when not able to expropriate larger taxes from high-skill workers.

2.5 CONCLUSION

In this chapter, I study an age-based tax system as a welfare improving tax policy. I use a dynamic Mirrleesian optimal tax model to study age-independent and age-dependent tax policies. In a baseline model, I show theoretically the sources of inefficiency. Then I simulate the model quantitatively. The numerical examples find an increase in welfare equivalent to a 5% increase in consumption. Average tax rates fall for young workers, the optimal tax is progressive, and age dependence provides large welfare gains for the young. Most of the welfare gain comes from eliminating inefficiency due to private information constraints. A smaller welfare gain comes from correcting an education time-use wedge between young and old. When considering only Pareto improving policies, the age-based tax plan offers a 1% increase in consumption.

This chapter demonstrates that age dependence, which is relatively simple to implement, is likely a powerful tax modification. There are two important challenges for future research. This chapter includes a basic skill distribution and two age cohorts, in order to clearly define the mechanisms for reducing distortions. It is important to expand the skill distribution and life cycle to reflect more realistic values. Another important area for future work is to carefully address the formation of skill as an endogenous choice variable in the early part of life. If skill is endogenous, then labor taxes likely play a role in education choices.

Chapter 3

Cinderella and Cinderelliott: Gender Differences in Adolescent and Young Adult Housework

3.1 INTRODUCTION

Researchers have shown that adult women generally, and married women in particular, spend more time than men in home production activities.[1] While adult gender differences in time use occur regardless of age, marital status or family status, these gender differences are most pronounced for married women with young children.[2] Married women are more likely to provide childcare than men, and women spend more time cleaning, cooking and shopping.

Tracing the stratification in time-use profiles across the adolescent years provides valuable insight into the process underlying adult time-use gender differences. While gender differences in time-use patterns among adults at home are readily accepted and well documented, the onset and development of gender time-use differences over the adolescent years and into early adulthood are not well understood. Interestingly, differences in time-use in home duties begin as less than 10 minutes per day and "gender differences in activities begin to appear in elementary school"[3] and persist through adolescence. While a few researchers find a relationship between age and time spent working at home for teenagers,[4] my focus on the evolution of gender differences well into young adulthood is new. Further, I demonstrate the impact of gender and other personal circumstances on home duties during a critical life period when individuals make choices that shape adult life.

Parents and policymakers alike have an interest in time-use patterns of teenagers transitioning into adulthood. Individuals embarking on adulthood are passing through a

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[1] Burda, Hamermesh, and Weil (2007).
[2] Apps and Rees (2005.)
[3] Hofferth (2001).
[4] Kalenkoski (2011), Hofferth (2001), and Gager et al. (1999).

critical juncture as they assume responsibility for their lives and implement plans to build their futures. Young adults make many important decisions that have a significant impact on their lives including choices about higher education, establishing independence, living at or away from home, beginning a career and forming personal family relationships. Individuals make time-use choices relating to home duties while simultaneously determining these life circumstances. On one hand, adolescents and young adults performing home duties likely benefit from the work. They build self-confidence, responsibility, and dependability, traits that likely impact future achievement and success in college and employment.[5] Among adolescents, caring for siblings with a mother present is correlated with higher perspective taking and social understanding among children.[6] Further, time spent working at home could play a role in forming healthy time-use patterns later in adulthood. However, time spent performing home duties requires trade-offs. Working at home boosts a person's home production comparative advantage, thus increasing the likelihood that the person will focus on home production activities in future family relationships.[7] Moreover, home duties can crowd out productive activities that promote achievement, such as studying, working, and extracurricular or volunteer activities. Performing home duties may hinder adolescents and young adults from pursuing other developmentally appropriate experiences.[8] The concern about the trade-off to teens performing home duties intensifies when coupled with the influence of family circumstance. Some worry that home duties disproportionately fall to girls and women from disadvantaged backgrounds including low-income and single-parent homes.[9] If home duties crowd out other productive activities, time-use at home is "one potential mechanism though which disadvantage negatively affects future outcomes through reduced homework time and reduced participation in extra-curricular activities."[10] This is

[5] Beach (1997), Call et al. (1995), and Kuperminc et al. (2009).
[6] Stewart and Martin (1984).
[7] Alesina et al. (2007).
[8] Dodson and Dickert (2004).
[9] Zick (1996) and Gager (1999).
[10] Kalenkoski et al. (2011). In a related issue, Oettinger (1999) finds evidence that working long hours at a job negatively affects grades for minority high school students.

especially worrisome if responsibilities at home disproportionately impact the college and career decisions of young adults, because of the persistent effects of these choices throughout life. The evolution of the gender gap in time-use patterns provides insight into weighing the costs and benefits of home duties for adolescents and young adults.

Parental and family characteristics likely influence the time adolescents and to a lesser degree, young adults spend performing home duties. Parental composition could play a role in gender differences in adolescent time use at home. For example, adolescent girls living in a single-parent home may be required to babysit or cook more often than adolescent girls living with two parents. Further, single mothers may rely on adolescent boys to do strength-intensive home duties. On the other hand, a single parent may not be able to provide supervision and support in performing tasks at home comparable to what married parents provide to their adolescents,[11] and gender differences among adolescents in single-parent and married-parent homes might not be the same. Prior research studying the impact of family size on the amount of time adolescents spend in home duties finds that adolescents with large families spend more time in home duties than adolescents with small families.[12] The literature does not clearly discuss the gender implications of family size. I expect an important interaction particularly among adolescent girls who may be expected to provide more childcare. Educational attainment among parents may influence parental values, views, goals and practices on gender differences. The role of parenting style on time use choices is not clear. It could be that more educated parents actively work to teach their children home and life skills, regardless of gender. Or it could be that if more educated parents value home production less than their less educated counterparts, we might expect to see children in these families spending less time in home duties. Family income may impact time-use decisions at home and will be considered. Understanding the role of family background is particularly important when studying adolescent gender differences and will be discussed further.

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[11] Astone and Mclanahan (1999).
[12] Cheal (2003).

Life choices begin to play an important role in time-use decisions during young adulthood. While it becomes more difficult to separately and clearly identify particular effects, economic theory supports a gendered approach to time spent in home duties in the presense of joint decisions about career, education and family status. For example family status variables such as cohabitation and marriage should produce a gendered response if couples find it beneficial to specialize, regardless of whether the specialization is driven by bargaining power, biology, culture or information assymetries in labor markets. Further, if young adults anticipate forming a couple relationship, men and women may differently invest in education and employment to align with their expectations about specialization within a family.

To demonstrate empirically the evolution of time use in home duties, I primarily analyze data from the American Time Use Survey (ATUS).[13] In order to analyze time-use patterns through adolescence and into young adulthood, I focus on individuals ages 15 to 30 between 2003 and 2011. I study the development of gender time-use gaps of a nationally representative sample of young adults. I use these data to describe the evolution of gender gaps in daily activities, with a focus on activities relating to home duties. I illustrate that gender time-use gaps increase precisely when individuals transition to adulthood and begin making decisions about their personal and professional futures. I also identify and quantify individual and family characteristics that disproportionately influence time-use at home.

3.2 DATA

I conduct empirical analysis of gender gaps over adolescent years into adulthood, with a focus on time spent in home duties. I analyze time use using individual-level data collected from time diaries from the ATUS between 2003 and 2011. The ATUS provides valuable information on time use of adolescents and young adults. The ATUS gives a

[13] In order to understand childhood time-use patterns for a cohort, time-use information in the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID) is analyzed in Appendix B-1. Using PSID data, I observe time-use patterns of children ages seven to eight in 1997 and follow individual children into adolescence until 2007.

snapshot of the previous day's activities using a time diary. It importantly provides detailed data on time use of teenagers and young adults. This national survey is conducted monthly in connection with the Current Population Survey (CPS) by the U.S. Census Bureau. Upon exit from the CPS sample, one household member at least 15 years old may be invited to participate in a phone interview. While characteristics of the CPS reference person determine selection of a household into the ATUS sample, the ATUS sample is not restricted to household heads or spouses. I use sampling weights provided by ATUS to make the ATUS representative of the United States national population. Time diary interviews occur throughout the year on any day of the week. A computer-assisted phone interview documents a 24-hour time diary, from 4 a.m. of the previous day until 4 a.m. of the current day. For each activity the respondent reports the duration of the activity, where the activity took place, and who else was present.

The ATUS contains 25,089 observations of individuals between ages 15 and 30 in the years of interest. After dropping missing observations, the final sample contains 24,949 observations. All the individuals in the sample have corresponding CPS profiles, and information relating to education, employment, income and demography are linked using these records.

I spotlight activities which relate to home duties. I aggregate the time spent throughout the day performing any home duty, including activities classified either as household activities or caring for others. Household activities include a broad spectrum of activities done at home, such as cleaning, laundering clothing, preparing food, and other activities relating to home care. Grocery shopping is also included in household activities. Many children and adolescents accompany parents in household shopping, which contributes to family well-being. Shopping for non-grocery items with non-household members could be a socializing activity for adolescents, and I do not consider it a household duty. Caring for others includes activities relating to childcare. About two-thirds of the time teenagers spend caring for children is in providing direct childcare. Caring for others also includes care given to adults, involvement in medical attention for an adult, and helping with bills. Appendix B-4 describes the time-use sub-aggregate categories and aggregation process in greater detail. While the process of grouping sub-aggregates into a single home duty category is somewhat subjective, I apply as the primary criterion the selection of activities which improve welfare of the family through the work of a family member.

Demographic controls are included in the analyses. Age is reported in years with categorical variables for each year to capture the impact of aging. Hispanic origin is considered categorically as is the impact of race, where the impact in gender time differences for black individuals is considered categorically. I include dichotomous region and urban variables to capture geographic effects on gender differences.

For individuals living with their parents, family background and parental characteristics are available through linked Current Population Survey information. The CPS contains data on each time taker's household, and I draw family and parental information from the final wave, most immediately before the time diary interview takes place. Data on parental characteristics are only available for individuals living with parents and are not representative given the selectivity patterns for young adults who choose to live at home. For this reason, I focus on adolescents who are 15 through 17 when discussing family characteristics and their impacts on gender differences in home duties. The sample includes the 3,797 adolescents who are between 15 and 17 who live at home with either a single mother or in a two-parent home. A teen is classified as living in a two-parent home if the mother indicates that she lives with her spouse. Otherwise a teen is classified as living in a single-mother household. The sample does not include adolescents living only with their fathers due to missing information about mothers' education levels. Living in a low income household is captured in a categorical variable coded as family income below $25,000 in 1997 dollars. This level of income roughly corresponds to having family income 50% to 75% above the poverty threshold, depending on family size. I deduce family size and number of children in the home by counting household members reported in the CPS. I capture the role of a mother's education in two categorical variables. The first variable indicates if a mother holds a high-school diploma. The second education variable shows if a mother has attended any amount of college.

3.3 TIME-USE PATTERNS BY GENDER

The motivation behind the present study is to determine the development and determinants of gender differences in time spent working at home. This section presents an unconditioned description of time-use patterns revealed in the data. Of the individuals in the ATUS sample, 51% are female and 49% are male. Broad sample characteristics of adolescents and young adults in the sample, including household circumstances and personal attributes, are shown in Table B-1 in Appendix B-1.

Consider first the time-use patterns of adolescents. The first four rows of Table 3.1 present the average time spent performing home duties for adolescents by age, along with the associated standard errors and resulting gender differences. Figure 3.1 contains a visual representation of Table 3.1. The average 15-year-old, regardless of gender, helps out at home more than 40 minutes per day, despite academic, social and physical demands that compete for time. By age 15 a 23 minute gender difference in time spent working at home is present, and this gender difference remains relatively stable through the adolescent years. These unconditional averages suggest gender differences between girls and boys begin prior to age 15 and persist through the adolescent years.[14]

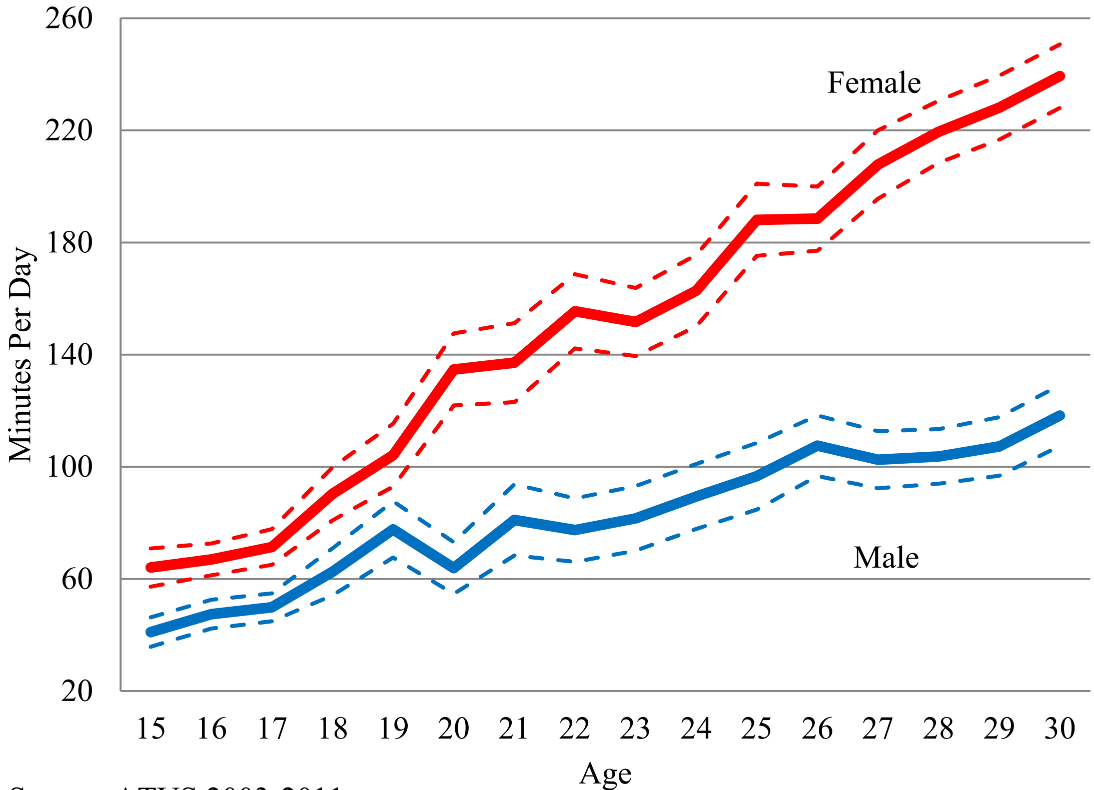
[14] Evidence from the Panel Study of Income Dynamics data support the finding of a small and stable gender gap prior to adulthood. PSID data show a stable gender gap around 10 minutes per day which is already present by ages seven and eight and persists through ages 17 and 18. PSID data emphasize the reality that gender differences in home duties begin early in life. The time-use differences observed in adulthood are part of a larger pattern of time-use differences beginning in childhood, persisting through adolescence, and stratifying in young adulthood. Appendix B-3 discusses these findings in detail.

Table 3.1: Average Minutes Per Day in Household Activities

Age	Male Mean	Male (SE)	Female Mean	Female (SE)	Female - Male Mean	Female - Male (SE)
Adolescent						
15	41	(2.67)	64	(3.48)	23	(4.39)
16	47	(2.62)	67	(2.90)	20	(3.90)
17	50	(2.54)	71	(3.25)	21	(4.12)
18	63	(4.28)	90	(4.84)	27	(6.46)
Young Adult						
19	78	(5.12)	104	(5.12)	26	(7.67)
20	64	(4.70)	135	(6.57)	71	(8.07)
21	81	(6.46)	137	(7.18)	56	(9.66)
22	77	(5.78)	155	(6.75)	78	(8.89)
23	82	(5.87)	152	(6.20)	70	(8.54)
24	89	(5.90)	163	(6.50)	74	(8.78)
25	97	(6.06)	188	(6.57)	91	(8.93)
26	108	(5.51)	189	(5.83)	81	(8.03)
27	103	(5.19)	208	(6.24)	105	(8.12)
28	104	(4.97)	220	(5.63)	116	(7.51)
29	107	(5.32)	228	(5.83)	121	(7.89)
30	118	(5.54)	239	(5.78)	121	(8.01)

Consider now the time-use patterns of individuals as they transition into adulthood. Beginning at age 19, immediately following the time of high school graduation, the gender gap sharply diverges, and the increase is primarily due to young adult women increasing time spent in home duties. Women spend an average of 104 minutes per day at age 19, which steadily increases by more than 120% over 11 years. The sharp increase in the time women spend at home results from exogenous forces as well as decisions that impact time use at home.

Figure 3.1: Average Time Spent in Housework



Source: ATUS 2003-2011.

The early genesis of behavioral differences in home duties is intriguing. While it is plausible that labor market forces and couple specialization in families contribute to gender differences in adulthood, it is difficult to explain why these patterns emerge early in life. Children often can't imagine themselves as adults, let alone as adults making simultaneous decisions about family formation, education and careers. Any perception the child has about gender roles at home or anticipation about future roles is likely projected onto a child through the parental, cultural and social settings under which the child grows. In an effort to better understand the impact of these forces influencing home duties, I turn attention to the roles of family attributes and parent characteristics in explaining gender differences.

3.4 The Role of Family and Parental Characteristics in Gender Differences for Adolescents

Adolescents, and to a lesser extent young adults, may be influenced by parental and family characteristics. Living in a single-parent home may influence the gendered activities within the home. Family size may also differentially impact adolescent boys and girls. Educational attainment among parents may influence parental values, goals, practices and views on gender differences. Maternal employment may impact the amount of time adolescents are supervised as well as family expectations about housework placed on adolescent girls and boys. Understanding the role of family background is particularly important when studying the causes of gender differences in adolescent home duties.

Table 3.2 reports multivariate estimates of time spent in home duties using Ordinary Least Squares regression. Estimates suggest that gender differences in home duties are largest for Hispanic teenagers. Hispanic girls spend 44 minutes more per day in home duties than Hispanic boys, compared to a 28 minute difference for non-Hispanics. This implies a relationship between the social and cultural context surrounding an adolescent and the resulting behaviors in home duties. There is little evidence that family characteristics impact gender differences during adolescence. Family income, living in a single-parent home, and a mother's education level do not significantly impact either the time spent in home duties or the resulting gender differences.

Table 3.2: Impact of Family Background and Characteristics on Gender Differences in Home Duties

Dependent variable: Minutes per day in home duties		
	Estimate	(SE)
Intercept	65.09***	(10.83)
Female	27.78**	(12.71)
Age 16	9.41	(5.27)
Female * Age 16	-7.82	(7.46)
Age 17	10.32*	(5.28)
Female * Age 17	-6.47	(7.62)
Black	-12.08	(6.73)
Female * Black	9.58	(9.37)
Hispanic	-6.18*	(5.62)
Female * Hispanic	16.08***	(7.97)
Number of children under 5	11.18*	(5.23)
Female * Number of children under 5	12.83	(7.48)
Income less than $25,000	-5.22	(6.52)
Female * Income less than $25,000	11.16	(9.39)
Two parent home	1.36	(5.70)
Female * Two parent home	0.22	(7.93)
Mother attended college	-5.85	(4.63)
Female * Mother attended college	-1.25	(6.58)
Sample Size	3,797	
R squared	0.052	

Significant at the 1% level (***), 5% level (**), and 10% level (*).

Girls from low-income families, single-parent families, and families without a well-educated mother do not do significantly more housework than other teenagers. Living in a home with young children increases the time spent in home duties for both genders; however adolescent girls spend an estimated 13 minutes more per day for each additional child under age five, which is almost significant at the 10% level.

Even after controlling for family background and characteristics, gender is an important component of home duties. Adolescent girls spend 27 minutes more per day in home duties than adolescent boys, *ceteris paribus*. I find no significant age and gender interactions; adolescents have a constant gender difference in home duties through adolescence. These findings show that an underlying significant, constant, and persistent gender difference during adolescence remains unexplained, and suggests that gender specialization begins at a young age.

3.5 The Roles of Age, Family Status, and Employment in Gender Differences for Young Adults

This section restricts attention to young adults who are at least 19 years old, given the fundamental difference in the lives of adolescents and young adults. The ATUS sample contains 19,064 young adult observations with full information on the variables of interest. The sharp increase in home duties by women entering young adult life could be due to exogenous age effects. I test for the importance of age in impacting gender differences in home duties, and Table 3.3 reports multivariate estimates using OLS regression. The column labeled "Age Only Estimates" in Table 3.3 reports coefficients and standard errors. These estimates show predictive power in age and gender interactions. For example, at age 20, women are estimated to spend 43 minutes more than men in daily home duties. By age 30, women are estimated to spend 93 minutes more than men in home duties. Given the raw gender difference observed previously in Figure 3.1, these results are unsurprising.

Table 3.3: Impact of Family Characteristics on Gender Differences in Home Duties

Dependent variable: Minutes per day in home duties				
	Age and personal characteristics		Age only	
	Estimate	(SE)	Estimate	(SE)
Intercept	110.17***	(8.56)	100.07***	(8.29)
Female	40.58***	(10.25)	2.64	(9.14)
Black	-17.51***	(4.73)	-11.38*	(5.29)
Female * Black	-15.89**	(6.36)	-4.29	(7.03)
Hispanic	-12.20***	(3.78)	-0.34	(4.03)
Female * Hispanic	8.43	(5.36)	48.36***	(5.75)
Live with parent	2.01	(3.75)		
Female * Live with parent	-9.56	(5.44)		
Live with unmarried partner	16.28***	(5.85)		
Female * Live with unmarried partner	13.78**	(8.12)		
Married	8.27**	(4.88)		
Female * Married	34.53***	(6.33)		
Parent	72.18***	(4.79)		
Female * Parent	89.70***	(6.03)		
Employed	-43.41***	(3.72)		
Female * Employed	-43.37***	(4.98)		
Currently enrolled in college	-20.45***	(3.79)		
Female * Currently enrolled in college	-2.94	(5.23)		
Age 19	22.67***	(7.92)	16.16	(8.66)
Age 20	6.53	(7.75)	0.40	(8.20)
Age 21	22.78***	(7.88)	18.31**	(8.29)
Age 22	17.40***	(7.84)	15.04	(8.13)
Age 23	19.24***	(7.88)	19.51**	(8.16)
Age 24	22.71***	(8.16)	26.60***	(8.33)
Age 25	27.82***	(8.32)	35.24***	(8.40)
Age 26	32.25***	(8.40)	43.76***	(8.39)
Age 27	28.60***	(8.40)	40.10***	(8.29)

Continued on page 69

Significant at the 1% level (***), 5% level (**), and 10% level (*).

Table 3.3 Continued

Dependent variable: Minutes per day in home duties				
	Age and personal characteristics		Age only	
	Estimate	(SE)	Estimate	(SE)
Age 28	24.20***	(8.48)	41.50***	(8.27)
Age 29	24.54***	(8.26)	45.58***	(8.03)
Age 30	34.23***	(8.62)	56.21***	(8.41)
Female * Age 19	-12.08	(11.35)	-3.59	(12.36)
Female * Age 20	16.75	(11.00)	42.96***	(11.57)
Female * Age 21	-5.18	(11.23)	28.18**	(11.71)
Female * Age 22	-5.44	(11.22)	47.21***	(11.51)
Female * Age 23	-8.96	(11.21)	42.04***	(11.35)
Female * Age 24	-12.47	(11.63)	46.46***	(11.66)
Female * Age 25	-6.06	(11.87)	63.65***	(11.79)
Female * Age 26	-12.39	(11.90)	56.26***	(11.63)
Female * Age 27	-11.38	(12.02)	79.03***	(11.64)
Female * Age 28	-7.62	(12.10)	86.92***	(11.59)
Female * Age 29	-4.52	(11.98)	93.14***	(11.42)
Female * Age 30	-15.35	(12.34)	92.62***	(11.80)
Sample size	19,064		19,064	
R squared	0.3098		0.1147	

Significant at the 1% level (***), 5% level (**), and 10% level (*).

The age-only estimates in Table 3.3 suggest that age significantly explains increases in gender differences. However, it could be the case that sharp increases in home duties by women entering young adult result from endogenous decisions correlated with age. Young adults make choices about higher education, establishing independence, living at or away from home, beginning a career, and forming personal family relationships. Individuals make time-use choices relating to home duties while jointly determining these life circumstances. In order to understand how much of the gender difference can be explained by personal characteristics rather than age, Table 3.3 reports estimates for both age and personal characteristics.[15]

The estimates in the "Age and Personal Characteristics" column of Table 3.3 demonstrate the importance of personal, educational and professional characteristics in determining gender differences in home duties. Race plays a role in gender differences, once accounting for personal characteristics. Black men and women spend less time in home duties than their non-black counterparts, and the gender difference between black individuals is 17 minutes smaller than the gender difference in home duties for non-black individuals. Ethnicity plays no role in gender differences, once controlling for personal and family characteristics.

While educational activities impact men and women equally, professional activities differentially impact men and women in home duties. Current enrollment in college, either full-time or part-time, decreases the time spent in home duties for men and women, but college attendance does not impact the gender difference in home duties.[16] Professional activities substantially narrow gender differences in home duties. Working men and women experience an estimated gender difference in home duties that is 43 minutes smaller than non-working men and women. Working women spend 87 minutes less per day in home duties than women who don't work, even after controlling for family characteristics.

Beyond professional and educational pursuits, personal and family characteristics determine gender differences in home duties. Living with a parent as a young adult does not impact the time men spend in home duties; however, living with a parent reduces women's time spent in home duties by 10 minutes each day.[17] Moving away from home, an advancing step in independence and maturity, increases gender differences in home duties. Individuals who form couple relationships demonstrate progressive specialization in those relationships. Living with an unmarried partner increases the time spent in home

[15] While recognizing that endogeneity impacts the estimates, the analytical specification for age and personal characteristics nonetheless includes behavioral choice variables.
[16] Educational attainment plays no role in gender differences in home duties, and the insignificant estimates are not reported.
[17] The estimates for the impact of females living with a parent are significant only at the 15% level.

duties for men and women, but women increase their time use by 14 minutes more. The time use differences of men and women in cohabiting relationships suggest that even young couples without the formal commitments of marriage and children find it beneficial on average to specialize in work. The level of specialization in a couple relationships grows with the level of formal commitment to the relationship. The gender difference in home duties is more pronounced among married individuals, where married women spend on average 35 minutes more in daily home duties than married men. Parenthood is another life decision that differentially impacts men and women in time spent in home duties. As expected, mothers and fathers both spend more time working at home than men and women without children. Young adult parents necessarily have young children, who are particularly time intensive. Parenthood differentially impacts parents as mothers spend 90 minutes more per day performing home duties than fathers.

The significance of age and gender interactions disappears once accounting for personal characteristics and circumstances. Restricting the model to exclude all age and gender interactions does not significantly change the predictive power of the estimates at the 1% level.

Even after controlling for personal and professional choices, gender is an important component of home duties. Young adult women daily spend an average of 40 minutes more than young adult men performing home duties. Gender differences in home duties are estimated to be small and not statistically different from zero for employed men and women who are single and have no children. In contrast, for a married couple with a historically traditional profile, where the husband works in the market and the wife cares for children and the home, the estimated gender difference in home duties is over 200 minutes, about three hours per day. These results indicate that while a small gender difference in home duties may exist prior to adulthood, the growth of those gender differences in home duties results in large part from specialization within couple relationships.

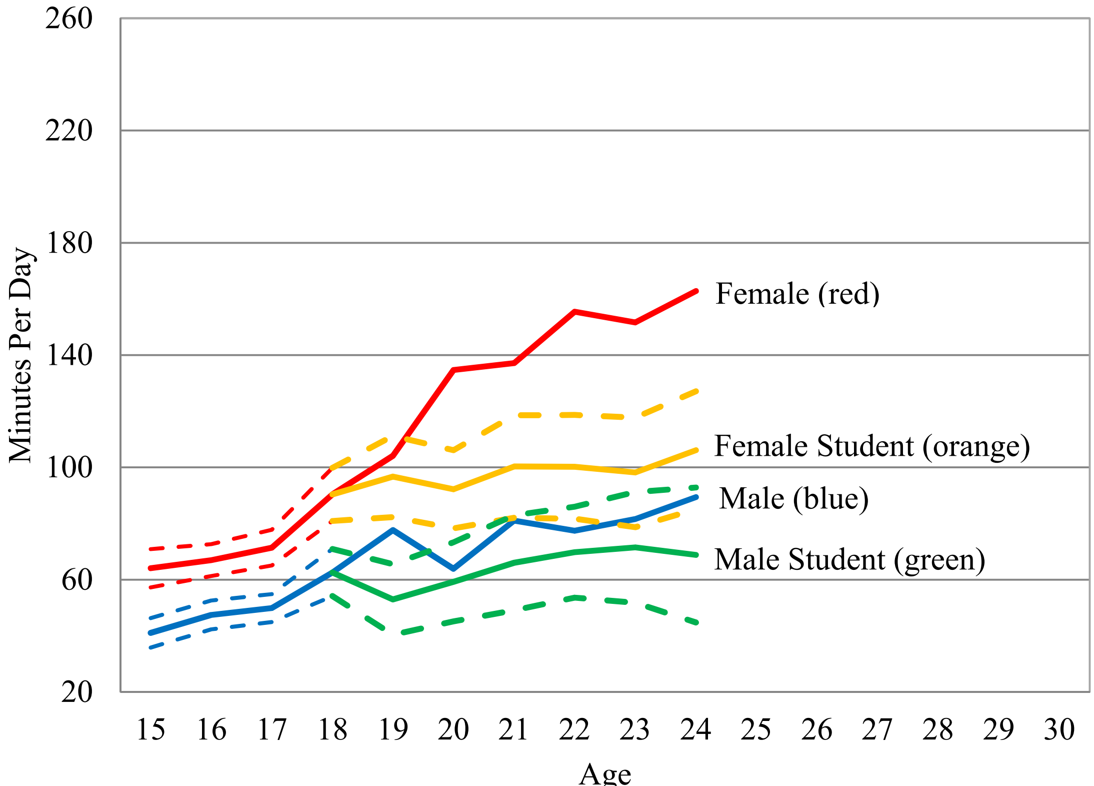
3.6 THE HOME DUTIES PROFILE OF COLLEGE STUDENTS AGES 19-24

There is interest in understanding the behavior of college students to better promoting college success. Enrollment in college takes advanced planning, financial resources, and a time commitment while enrolled. College students who choose to attend school as they enter adulthood necessarily commit to a rigorous schedule in order to achieve their educational goals. Table 3.4 and Figure 3.2 describe a sub-sample which includes only students enrolled in college between the ages of 19 and 24.

Table 3.4: Average Minutes Per Day in Household Activities, Student Sub-sample

Age	Male		Female		Female - Male	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Young Adult						
19	53	(6.41)	97	(7.39)	44	(9.78)
20	59	(7.18)	92	(7.10)	33	(10.10)
21	66	(8.65)	100	(9.30)	34	(12.71)
22	70	(8.26)	100	(9.42)	30	(12.53)
23	72	(10.07)	98	(9.96)	27	(14.17)
24	69	(12.27)	106	(10.70)	37	(16.28)

Figure 3.2: Average Time Spent in Housework, including Student Sub-Sample



Source: ATUS 2003-2011.

The time spent in home duties young adult men attending college mirrors the time spent by men not enrolled. Men, whether or not they attend school, gradually increase their input into home duties. Women enrolled in college, on the other hand, show marked differences in home duties compared to women not enrolled. Women attending college gradually increase time spent in home duties, rather than dramatically increase home duties inputs as non-attending women do. This leads to a gender difference between enrolled men and women that remains stable at the levels observed during high school. While the regression estimates find no evidence that the past level of education impacts time spent at home, regression estimates and differences in raw averages describing students show that school enrollment is correlated with less time spent in home duties.

3.7 INCIDENCE AND INTENSITY

The decision to participate in a particular home duty on a given day, the incidence, may be a separate decision than that of how much time to spend performing the activity, the intensity. Some adolescents and young adults provide childcare, either to their own children or to siblings. While these individuals find themselves providing care on a given day, they may have flexibility in how much time they spend. Young adults may decide to eat out rather than cook at home, or hire a cleaning service. These examples demonstrate the need to consider the relative contributions of incidence and intensity to the overall trends in gender differences.

The overall minutes worked in domestic duties D_{it} by person i at age t differ across genders and ages. When average minutes worked change with age, it is helpful to know how much of that change is due to the relative contributions of the intensive and extensive margins. Equation 3.1 describes the change in average minutes spent in domestic duties from one age to the next.

$$\Delta D_{it} = D_{it} - D_{it-1} \tag{3.1}$$

For small incremental changes each period, the decomposition of Equation 3.1 can be approximated by Equation 3.2 where $\Delta d_{it} p_{it}$ is the contribution of the intensive margin to the change across the time horizon for type i individuals, and $\Delta p_{it} d_{it}$ is the contribution of the extensive margin to the overall change.[18]

$$\Delta D_i \approx \sum_{t=L}^{H} \Delta d_{it} p_{it} + \Delta p_{it} d_{it} \tag{3.2}$$

So far, the derivation remains focused on a particular individual. Understanding gender differences involves simultaneous changes for both types of individuals. Examining the impact of each margin in a changing gender gap requires differencing Equation 3.2 by gender, as seen in Equation 3.3.

$$\Delta D_F - \Delta D_M \approx \left(\sum_{t=15}^{30} \Delta d_{Ft} p_{Ft} + \Delta p_{Ft} d_{Ft}\right) - \left(\sum_{t=15}^{30} \Delta d_{Mt} p_{Mt} + \Delta p_{Mt} d_{Mt}\right) \tag{3.3}$$

Rearranging terms enables the equation to be grouped by margin, rather than gender. This allows Equation 3.4 to express the overall gender difference on the left hand side in terms of the relative importance of gender differences along each margin.

[18] For a derivation of the decomposition, see Blundell et al. (2011) and the associated IFS working paper.

$$\Delta D_F - \Delta D_M \approx \left(\sum_{t=15}^{30} \Delta d_{Ft} p_{Ft} - \Delta d_{Mt} p_{Mt}\right) + \left(\sum_{t=15}^{30} \Delta p_{Ft} d_{Ft} - \Delta p_{Mt} d_{Mt}\right) \quad (3.4)$$

The left hand side of Equation 3.4 is calculated from estimates in Table 3.1. Before calculating the relative contributions of each margin, I present estimates for gender differences in intensity and incidence of home duties for adolescents and young adults.

Consider first the daily participation rates in home duties by adolescents and young adults. Table 3.5 presents the proportion of respondents who spent any amount of time performing a home duty during the sample day. While gender differences in participation rates vary from year to year, rates appear to be stable around 16% through the adolescent and young adult years. In following the extensive margin of home duties for women as they age, a clear pattern of increased participation emerges resulting in 90% of women participating in home duties by age 30. The participation patterns for men show a similar increase in participation over time, rising to over 70% of men participating in home duties by age 30.

Table 3.5: Proportion Participating in Home Duties (Time Use > 0)

Age	Male		Female		Female - Male	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Adolescent						
15	0.54	(0.02)	0.66	(0.02)	0.12	(0.02)
16	0.55	(0.01)	0.69	(0.01)	0.14	(0.02)
17	0.54	(0.02)	0.70	(0.01)	0.17	(0.02)
18	0.57	(0.02)	0.70	(0.02)	0.13	(0.03)
Young Adult						
19	0.66	(0.02)	0.73	(0.02)	0.07	(0.03)
20	0.58	(0.02)	0.78	(0.02)	0.19	(0.03)
21	0.57	(0.02)	0.76	(0.02)	0.19	(0.03)
22	0.62	(0.02)	0.81	(0.02)	0.19	(0.03)
23	0.64	(0.02)	0.84	(0.01)	0.19	(0.02)
24	0.63	(0.02)	0.81	(0.01)	0.18	(0.03)
25	0.65	(0.02)	0.85	(0.01)	0.20	(0.02)
26	0.73	(0.02)	0.85	(0.01)	0.12	(0.02)
27	0.73	(0.02)	0.87	(0.01)	0.14	(0.02)
28	0.72	(0.02)	0.91	(0.01)	0.19	(0.02)
29	0.69	(0.02)	0.91	(0.01)	0.22	(0.02)
30	0.73	(0.02)	0.90	(0.01)	0.18	(0.02)

Turning attention to the intensive margin, trends in conditional time spent in home duties clearly show the development of a wide gender gap. As shown in Table 3.6, there is a small gender difference in conditional time-use in home duties for high school-aged adolescents. Beginning at ages 19, young adult women increasing their intensity each year an average of eleven minutes per day, while their male counterparts increase intensity by an average of four minutes per day. The increase in intensity results in a 100 minute conditional gender difference between men and women by age 30.

Table 3.6: Average Daily Minutes Spent in Home Duties Conditional on Participation

Age	Male		Female		Female - Male	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Adolescent						
15	75	(4.23)	97	(4.65)	22	(6.29)
16	86	(4.11)	96	(3.70)	11	(5.53)
17	93	(3.89)	102	(4.10)	9	(5.65)
18	110	(6.54)	128	(6.12)	19	(8.96)
Young Adult						
19	118	(6.96)	143	(6.79)	25	(9.72)
20	109	(6.92)	173	(7.40)	64	(10.31)
21	141	(9.40)	180	(8.20)	39	(12.48)
22	125	(8.11)	192	(7.40)	67	(10.98)
23	127	(8.00)	181	(6.74)	54	(10.46)
24	142	(7.80)	200	(6.95)	58	(10.44)
25	148	(8.01)	220	(6.92)	72	(10.59)
26	147	(6.67)	222	(6.04)	75	(8.99)
27	140	(6.29)	239	(6.43)	99	(9.00)
28	145	(6.05)	242	(5.71)	97	(8.32)
29	156	(6.60)	250	(5.92)	94	(8.87)
30	163	(6.64)	264	(5.84)	101	(8.84)

The decomposition given in Equation 3.4 and the data presented in Tables 3.1, 3.5 and 3.6 reveal interesting patterns in gender differences among adolescents and young adults. Table 3.7 summarizes the results. Between ages 15 and 30, the gender difference in home duties increases from 23 minutes to 121 minutes, an increase of 98 minutes. An increase in the gender difference in intensity accounts for approximately 81% of the total increase, and an increased gender difference in participation accounts for 19% of overall changes in gender differences in home duties. Restricting attention to adolescents shows a small increase in overall gender difference, with importance of both incidence and intensity contributing to the increase.

Table 3.7: Relative Contributions of Intensive and Extensive Gender Differences to Overall Changes in Gender Differences in Home Duties

	Gender Difference	Contributing Margin	
		Intensity	Incidence
Ages 15-30			
Minutes	98.03	81.09	19.07
Percent	1.00	0.81	0.19
Ages 15-18			
Minutes	4.78	2.90	1.39
Percent	1.00	0.68	0.32
Ages 19-30			
Minutes	93.25	78.19	17.68
Percent	1.00	0.82	0.18

The average increase in the raw gender difference primarily results from increases in the amount of time women spent at home along the intensive margin. The stable gender difference in participation rates through adolescence and young adulthood suggest that the daily participation rates are less important than work intensity in explaining the observed gender differences in home duties through young adulthood.

3.8 Controlling for Cohort Effects in Time-use Patterns

In order to test whether the cross-sectional results are significantly impacted by cohort effects, this section controls for cohort effects. While the data set does not contain repeated information about an individual over time, I select the repeated cross-sections into a cohort pseudo-panel over seven years to control for cohort effects. This approach demonstrates the minimal role of cohort effects behind gender difference in the full sample. The analysis focuses on adolescents who are ages 15 and 16 in 2003, and I annually observe the cohort until ages 23 and 24 in 2011. A pseudo-cohort analysis represents the experiences of people belonging to a particular cohort, and does not track the experiences of individuals over time. Teenagers and young adults make up a small proportion of the ATUS. Despite the large sample size of the ATUS, when disaggregating the data by birth cohort, the final sample size reduces to 2,887 individuals. Of the individuals in the ATUS sample, 51.8% are female and 48.2% are male. Characteristics of the teenagers in the sample, including household circumstances and personal attributes, are shown in Table B-1 in Appendix B-1.

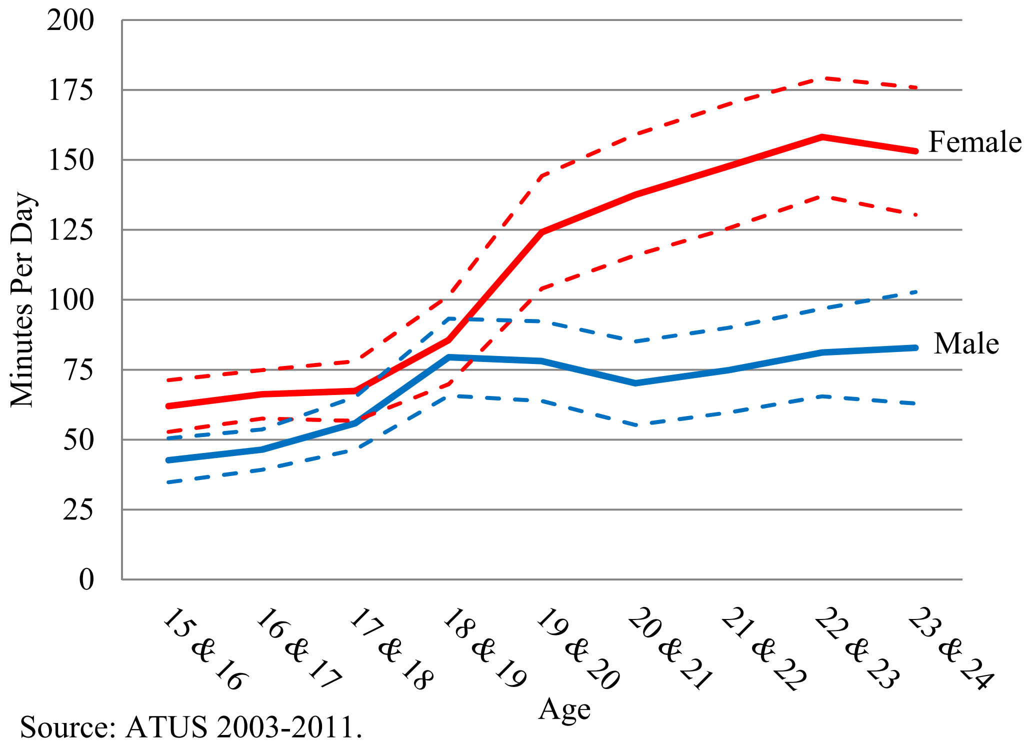
There is no evidence of cohort effects playing a role in the time-use patterns. Table 3.8 and Figure 3.3 summarize cohort sub-sample time use patterns. These patterns illustrate similar time in home duties, gender differences in time use, and aging patterns in time use in home duties by men and women. As is seen in the full sample, the cohort sub-sample demonstrates a small gender difference in home duties through adolescence, which substantially increases as women transition to adulthood. The time use profiles of the cohort sub-sample are nearly identical to the full sample in both magnitude and gender difference.

Table 3.8: Average Daily Minutes Spent in Household Activities

Ages	Male		Female		Female - Male
	Mean	(SE)	Mean	(SE)	
Adolescent					
15 & 16	43	(4.0)	62	(4.7)	19 ***
16 & 17	46	(3.7)	66	(4.4)	20 ***
17 & 18	56	(4.8)	67	(5.4	12
18 & 19	79	(7.0)	86	(8.1)	6
Young Adult					
19 & 20	78	(7.3)	124	(10.3)	46 ***
20 & 21	70	(7.6)	138	(11.0)	67 ***
21 & 22	75	(7.7)	148	(11.3)	73 ***
22 & 23	81	(8.0)	158	(10.8)	77 ***
23 & 24	83	(10.2)	153	(11.6)	70 ***

Significant at the 1% level (***).

Figure 3.3: Average Time Spent in Housework



Source: ATUS 2003-2011.

3.9 Conclusion

The examination of gender differences in home duties reveals important patterns in male and female behavior through adolescence and young adulthood. Adolescents exhibit a gender difference in home duties which is present by 15. Through adolescence, the gender difference is clear, consistent, and significant. Family circumstances in adolescence play a small role in determining gender differences. At the onset of young adulthood, the gender difference grows and the growth is attributed to individuals forming couple relationships and entering parenthood. While these personal choices increase the incidence of participation in home duties equally for men and women, these choices differentially impact the intensity of women in their home duties.

In terms of policy, the results suggest a need to educate adolescents about the impact of life choices in young adulthood. Young adult women in couple relationships or entering parenthood demonstrate clear patterns of spending time at home and cut back on work and education. In revealing time-use patterns of adolescents and young adults, this research prompts several questions deserving further attention. First, are these findings on gender differences in home duties unique to the United States or do they describe the experience of adolescents and young adults worldwide? Adolescents living in developing countries likely spend more time in home duties than those in developed countries, but the impact on gender differences is not apparent. Further work is also needed in identifying causal factors for observed gender differences among children and adolescents. A causal factor could be differences in preferences. Recently the ATUS added information about emotions experienced while engaged in various activities. This information could deepen the understanding about why gender differences develop prior to couple formation. Given the unknown causes and long-lasting consequences of early gender differences, this is a topic deserving further research.

Appendix A-1: Derivation of the Cross Derivatives for the Excess Burden in Chapter 1

Performing comparative static analysis allows me to investigate the sensitivity of the equilibrium when taxes change household demands for individual variables. By focusing on the compensated responses to tax changes, I show the derivation of the cross derivatives referred to in Equation 1.16 which characterizes the excess burden of a tax program.[42] The resulting cross derivatives are the multi-period analog to a Slutsky matrix in a single-period model with one constraint. The comparative statics are obtained by differentiating with respect to the change in prices generated from tax changes. The cross derivatives are obtained by considering the effects of a compensated change in price, where income is compensated to keep utility constant. The family maximizes its intertemporal utility subject to a number of constraints.

$$\max_{\substack{C_t^M, C_t^D \; for\; t=1,2,\dots,T \\ L_{it}\; for\; i=H,W;\; t=1,2,\dots,T \\ h_{it}\; for\; i=H,W; t=1,2,\dots,T \\ D_{it}\; for\; i=H,W; t=1,2,\dots,T}} \sum_1^T \beta^{t-1} U(C_t, L_{Ht}, L_{Wt}) \qquad \text{(A-1.1)}$$

Subject to:

$C_t^M \leq Y_{Ht}(1-\tau_H) + Y_{Wt}(1-\tau_W) + I_t$ for $t = 1,2,\dots,T$ Budget Constraint (A-1.2)

$1 \geq L_{it} + h_{it} + D_{it}$ for $i = H, W; t = 1,2,\dots,T$ Time Constraint (A-1.3)

$Y_{it} \leq \varphi_i g(h_{i1}, h_{i2}, \dots, h_{it})$ for $i = H, W; t = 1,2,\dots,T$ Market Production Technology (A-1.4)

$C_t^D \leq f(D_{Ht}) + q(D_{Wt})$ for $t = 1,2,\dots,T$ Home Production Technology (A-1.5)

Notice the inclusion of outside income I_t in this representation. No source of outside income exists in this economy, and I_t can be considered equal to zero. While there is no source of outside income in this economy, outside income is included to be clear about how income effects are included in calculating compensated demands later in the model. The program is represented by the following Lagrangian, where the time constraint

[42] Intriligator gives a derivation of the effects of a compensated price change for the case of one budget constraint. The case of three constraints follows here as an extension of his work.

allows leisure to be substituted out and the market production technology is substituted into the family budget constraint each period.

$$\mathcal{L} = \sum_1^T \beta^{t-1} U(C_t, 1 - h_{Ht} - D_{Ht}, 1 - h_{Wt} - D_{Wt}) + \sum_1^T \lambda_t\big(-C_t^M + \varphi_H g(h_{H1}, h_{H2}, \ldots, h_{Ht})(1 - \tau_H) + \varphi_W g(h_{W1}, h_{W2}, \ldots, h_{Wt})(1 - \tau_W)\big) + \sum_1^T \chi_t\big(-C_t^D + f(D_{Ht}) + q(D_{Wt})\big) \quad \text{(A-1.6)}$$

Let $\boldsymbol{X}$ denote a Vx1 vector of all choice variables for the family. Given that there are six choice variables each time period, $V=6T$.

$$\boldsymbol{X} = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ \cdot \\ \cdot \\ \cdot \\ X_V \end{bmatrix} = \begin{bmatrix} C_1^M \\ C_1^D \\ h_{H1} \\ h_{W1} \\ D_{H1} \\ D_{W1} \\ \cdot \\ \vdots \\ C_n^M \\ C_n^D \\ h_{HT} \\ h_{WT} \\ D_{HT} \\ D_{WT} \end{bmatrix} \quad \text{(A-1.7)}$$

Further, let $\boldsymbol{\Lambda}$ denote an Nx1 vector of all constraints, with the subscripts corresponding to the variable names. For this particular model there are $2T$ constraints; however, any number of constraints could be included.

$$\boldsymbol{\Lambda} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \cdot \\ \cdot \\ \cdot \\ \lambda_N \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \cdot \\ \cdot \\ \cdot \\ \lambda_T \\ \chi_1 \\ \chi_2 \\ \vdots \\ \cdot \\ \chi_T \end{bmatrix} \quad \text{(A-1.8)}$$

The Lagrangian produces a system of first order equations with the following forms, where v denotes the position in the X matrix and n denotes the position in the $\boldsymbol{\Lambda}$ matrix.

$$\frac{\partial \mathcal{L}}{\partial C_t^M} = \frac{\partial \mathcal{L}}{\partial X_v} = \beta^{t-1}\frac{\partial U}{\partial C_t} - \lambda_t = 0 \tag{A-1.9}$$

$$\frac{\partial \mathcal{L}}{\partial C_t^D} = \frac{\partial \mathcal{L}}{\partial X_{v+1}} = \beta^{t-1}\frac{\partial U}{\partial C_t} - \chi_t = 0 \tag{A-1.10}$$

$$\frac{\partial \mathcal{L}}{\partial h_{Ht}} = \frac{\partial \mathcal{L}}{\partial X_{v+2}} = -\frac{\partial U}{\partial L_{Ht}} + \sum_{z=t}^{T}\lambda_z \frac{\partial g(h_{H1},h_{H2},\dots,h_{Ht},\dots,h_{Hz})}{\partial h_{Ht}}\varphi_H(1-\tau_H) = 0 \tag{A-1.11}$$

$$\frac{\partial \mathcal{L}}{\partial h_{Wt}} = \frac{\partial \mathcal{L}}{\partial X_{v+3}} = -\frac{\partial U}{\partial L_{Wt}} + \sum_{z=t}^{T}\lambda_z \frac{\partial g(h_{W1},h_{W2},\dots,h_{Wt},\dots,h_{Wz})}{\partial h_{Wt}}\varphi_W(1-\tau_H) = 0 \tag{A-1.12}$$

$$\frac{\partial \mathcal{L}}{\partial D_{Ht}} = \frac{\partial \mathcal{L}}{\partial X_{v+4}} = -\frac{\partial U}{\partial L_{Ht}} + \chi_t f'(D_{Ht}) = 0 \tag{A-1.13}$$

$$\frac{\partial \mathcal{L}}{\partial D_{Wt}} = \frac{\partial \mathcal{L}}{\partial X_{v+5}} = -\frac{\partial U}{\partial L_{Wt}} + \chi_t q'(D_{Wt}) = 0 \tag{A-1.14}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_t} = \frac{\partial \mathcal{L}}{\partial \boldsymbol{\Lambda}_t} = -C_t^M + \varphi_H g(h_{H1},h_{H2},\dots,h_{Ht})(1-\tau_H) + \varphi_W g(h_{W1},h_{W2},\dots,h_{Wt})(1-\tau_W) = 0 \tag{A-1.15}$$

$$\frac{\partial \mathcal{L}}{\partial \chi_t} = \frac{\partial \mathcal{L}}{\partial \boldsymbol{\Lambda}_{T+t}} = -C_t^D + f(D_{Ht}) + q(D_{Wt}) = 0 \tag{A-1.16}$$

Let $\boldsymbol{p}$ represent an NxV matrix of the prices implied by Equations A-1.15 and A-1.16, the budget constraints and the home production constraints. The first T rows contains prices from the budget constraint. The last T rows contain prices from the home production technology constraints. Using matrix notation, Equations A-1.9 - A-1.16 can be summarized by these two equations:

$$-\boldsymbol{pX}(\boldsymbol{p}) = \boldsymbol{0} \tag{A-1.17}$$

$$\frac{\partial U}{\partial \boldsymbol{X}} - \boldsymbol{\Lambda}(\boldsymbol{p})'\boldsymbol{p} = \boldsymbol{0} \tag{A-1.18}$$

The comparative statics of individual variables responding to changes in taxation are obtained by differentiating Equations A-1.17 and A-1.18 with respect to the change in prices generated from tax changes. The cross derivatives are obtained by considering the effects of a compensated change in price in a given constraint n, where income is compensated to keep utility constant. Market labor supply appears in its own-period budget constraint and all subsequent budget constraints, due to gains to labor market experience. In order to remain clear about which budget constraint and corresponding cross derivative matrix is being considered when referring to prices, I introduce the following update to the pricing notation for labor supply. Let $P_{nh_{i1}}$ represent the price for the market labor supply for spouse *i*, where n refers to prices implied by the corresponding period containing a price for market labor supply for spouse *i*. Totally differentiating Equation A-1.1 gives:

$$dU = \frac{\partial U}{\partial \boldsymbol{X}}(\boldsymbol{X})d\boldsymbol{X} = \boldsymbol{\Lambda}'\boldsymbol{p}(d\boldsymbol{X}) \tag{A-1.19}$$

Totally differentiating Equation A-1.18 gives

$$dI_n = \boldsymbol{p}_n(d\boldsymbol{X}) + (d\boldsymbol{p}_n)\boldsymbol{X} \;\; \text{for all } n \tag{A-1.20}$$

Holding utility constant ($dU = 0$) requires that $\boldsymbol{p}_n(d\boldsymbol{X}) = 0$, given that each entry of $\boldsymbol{\Lambda}$ is non-zero in equilibrium. Applying the condition of constant utility to Equation A-1.19 gives that for a compensated price change,

$$dI_n = (d\boldsymbol{p}_n)\boldsymbol{X} \;\; \text{for all } n \tag{A-1.21}$$

For example, if p_{nl} increases to $p_{nl} + dp_{nl}$, the added income $dI_n = (dp_{nl})X_l$ into budget constraint n affected by the price change will guarantee that utility is constant.

In order to represent the comparative static equations in matrix form, I first introduce the matrix $\boldsymbol{H}$, known as the Hessian. It is the second order partial derivatives of the utility function, and assuming that $U(\cdot)$ is twice differentiable with continuous second order partial derivatives, this Hessian matrix is symmetric by Young's theorem. As long as the market production technology and the home production technologies exhibit constant or diminishing returns to scale, the Hessian matrix is negative definite.

I differentiate Equations A-1.17 and A-1.18 with respect to p_{nl} , where $dI_n = (dp_{nl})X_l$ in each constraint containing p_{nl}.

$$-\sum_j p_{nj}\frac{\partial X_j^*}{\partial p_{nl}} = 0 \tag{A-1.22}$$

$$\sum_k \frac{\partial^2 U}{\partial X_j \partial X_k}\frac{\partial X_k^*}{\partial p_{nl}} - \sum_m \left(p_{nj}\frac{\partial \Lambda_m^*}{\partial p_{nl}} - \lambda_n^* \delta_{njl}\right) = 0 \text{ for all } j \tag{A-1.23}$$

where δ_{njl} is equal to one if j equals l and the (n,j) entry of the $\boldsymbol{p}$ matrix is non-zero, and δ_{njl} equals zero otherwise. This captures the direct effect of a price change. Let $\boldsymbol{\Delta_n}$ be the matrix formed by the placing each value of δ_{njl} with similar n in the (j,l) position of the matrix. Further, define another matrix $\boldsymbol{\Delta}$ as follows:

$$\mathbf{\Delta} = [\lambda_1 \mathbf{\Delta_1}, \lambda_2 \mathbf{\Delta_2}, \dots, \lambda_N \mathbf{\Delta_N}] \quad \text{(A-1.24)}$$

The sensitivities can be summarized by the following two matrices.

$$\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_n}} = \begin{pmatrix} \frac{\partial X_1^*}{\partial p_{n1}} & \frac{\partial X_1^*}{\partial p_{n2}} & \cdot \ \cdot \ \cdot & \frac{\partial X_1^*}{\partial p_{nN}} \\ \frac{\partial X_2^*}{\partial p_{n1}} & \frac{\partial X_2^*}{\partial p_{n2}} & \cdot \ \cdot \ \cdot & \frac{\partial X_2^*}{\partial p_{nN}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \frac{\partial X_N^*}{\partial p_{n1}} & \frac{\partial X_N^*}{\partial p_{n2}} & \cdot \ \cdot \ \cdot & \frac{\partial X_N^*}{\partial p_{nN}} \end{pmatrix} \quad \text{(A-1.25)}$$

$$\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p_n}} = \begin{pmatrix} \frac{\partial \boldsymbol{\Lambda}_1^*}{\partial p_{n1}} & \frac{\partial \boldsymbol{\Lambda}_1^*}{\partial p_{n2}} & \cdot \ \cdot \ \cdot & \frac{\partial \boldsymbol{\Lambda}_1^*}{\partial p_{nN}} \\ \frac{\partial \boldsymbol{\Lambda}_2^*}{\partial p_{n1}} & \frac{\partial \boldsymbol{\Lambda}_2^*}{\partial p_{n2}} & \cdot \ \cdot \ \cdot & \frac{\partial \boldsymbol{\Lambda}_2^*}{\partial p_{nN}} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \frac{\partial \boldsymbol{\Lambda}_N^*}{\partial p_{n1}} & \frac{\partial \boldsymbol{\Lambda}_N^*}{\partial p_{n3}} & \cdot \ \cdot \ \cdot & \frac{\partial \boldsymbol{\Lambda}_N^*}{\partial p_{nN}} \end{pmatrix} \quad \text{(A-1.26)}$$

Equations found in A-1.22 and A-1.23 for all values of *I* can be written in matrix form.

$$-\boldsymbol{p_n} \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_n}}\right)_{comp} = 0 \quad \text{(A-1.27)}$$

$$-\boldsymbol{p_n} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p_n}}\right)_{comp} + \boldsymbol{H} \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_n}}\right)_{comp} = \lambda_n \boldsymbol{\Delta_n} \quad \text{(A-1.28)}$$

Equivalently,

$$\begin{pmatrix} 0 & -\boldsymbol{p} \\ -\boldsymbol{p}' & \boldsymbol{H} \end{pmatrix} \begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p_n}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_n}}\right)_{comp} \end{pmatrix} = \begin{pmatrix} \boldsymbol{0} \\ \lambda_n \boldsymbol{\Delta_n} \end{pmatrix} \quad \text{(A-1.29)}$$

I define the following new matrix.

$$\begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p}}\right)_{comp} \end{pmatrix} = \left[\begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p_1}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_1}}\right)_{comp} \end{pmatrix}, \begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p_2}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_2}}\right)_{comp} \end{pmatrix}, \dots, \begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p_T}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p_T}}\right)_{comp} \end{pmatrix} \right] \quad \text{(A-1.30)}$$

I use the definitions in Equations A-1.31 and A-1.25 in order to represent in matrix notation the effect of a price change in any constraint as follows:

$$\begin{pmatrix} 0 & -\boldsymbol{p} \\ -\boldsymbol{p}' & \boldsymbol{H} \end{pmatrix} \begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p}}\right)_{comp} \end{pmatrix} = \begin{pmatrix} \boldsymbol{0} \\ \Delta \end{pmatrix} \tag{A-1.31}$$

Since the bordered Hessian is negative semi-definite, I can invert the matrix and pre-multiply it to both sides to isolate the comparative statics for a given price change.

$$\begin{pmatrix} \left(\frac{\partial \boldsymbol{\Lambda}^*}{\partial \boldsymbol{p}}\right)_{comp} \\ \left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p}}\right)_{comp} \end{pmatrix} = \begin{pmatrix} 0 & -\boldsymbol{p} \\ -\boldsymbol{p}' & \boldsymbol{H} \end{pmatrix}^{-1} \begin{pmatrix} \boldsymbol{0} \\ \Delta \end{pmatrix} \tag{A-1.32}$$

This equation gives the compensated changes in the quantities of commodities demanded as prices in general vary. It applies to taxes for this specific model. The matrix $\left(\frac{\partial \boldsymbol{X}^*}{\partial \boldsymbol{p}}\right)_{comp}$ found in Equation A-1.32 contains a cross derivative matrix associated with each constraint in the model. The solutions to Equation A-1.32 are those needed in Equation 1.16 characterizing the excess burden of a tax.

Appendix A-2: Derivation of the Excess Burden in Chapter 1

I derive the approximation of the excess burden for this model, expanding the framework of Boskin and Sheshinski (1983) and Mumford (2009) to allow for a multi-period setting. The excess burden of the entire time horizon is computed simultaneously, rather than computing the discounted excess burdens each period. This explicitly models the influence of price changes on any demand in any period. To derive the excess burden for this economy, assume the prices of goods are constant, and the only price distortions in the economy are due to taxation. Because this is a minimization problem, all demands are compensated or Hicksian demands. The excess burden is the sum of the compensated deadweight loss triangles due to gender-based taxation. Only the prices on market labor supply are included in the formulation of the excess burden, because they are the only prices directly affected by tax rates. This does not mean that taxes do not impact optimal levels of domestic production or consumption. Decision rules about home production and consumption adjust when taxes are introduced into the economy; however, these adjustments are efficient and do not contribute to the dead-weight loss of the taxes.[1] I represent the excess burden in Equation A-2.1 where j denotes the individual and s denotes the time period.[2]

$$EB = -\frac{1}{2}\left(\sum_j \sum_s^T \Delta P_{sh_{js}} \Delta h_{js}^{comp}\right) \tag{A-2.1}$$

A change in the price of one spouse's market labor in a given period influences the labor supply of both spouse's compensated demands in all periods. The total change in labor supply for an individual is the accumulated partial effects of each price change affected by the tax change. Some of the effects of a price change are due to the direct effect of the

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[1] The impact of the tax rates on all variables, including consumption and domestic production is seen in Appendix A-1, Equation A-1.32.

[2] Because market labor supply appears in its own-period budget constraint and all subsequent budget constraints, due to gains to labor market experience, it is important to remain clear about which cross derivative matrix is being considered when referring to prices. Let $P_{nh_{it}^M}$ represent the price for market labor supply where n refers to the n^{th} budget constraint in matrix $\boldsymbol{\Lambda}$.

price change, as reflected in the t^{th} cross derivative matrix. Other effects are evident in subsequent cross derivative matrices, since the price change impacts future productivities. Equation A-2.2 is the mathematical description of this impact.

$$\Delta h_{js}^{comp} = \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} \left(\frac{\partial h_{js}}{\partial P_{nh_{it}}}\right)^{comp} \Delta P_{nh_{it}} \tag{A-2.2}$$

Substituting Equation A-2.2 into the excess burden formula for all individual-time combinations gives Equation A-2.3, where s and t are subscripts representing the two time periods and j and i are the subscripts representing summing over husband and wife types.

$$EB = -\frac{1}{2}\left(\sum_j \sum_{s=1}^{T} \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} \Delta P_{sh_{js}} \left(\frac{\partial h_{js}}{\partial P_{nh_{it}}}\right)^{comp} \Delta P_{nh_{it}}\right) \tag{A-2.3}$$

The price change for leisure of spouse i due to the gender-based income tax policy for that spouse is given by $\Delta P_{nh_{it}} = (1-\tau_i)P_{nh_{it}} - P_{nh_{it}} = -\tau_i P_{nh_{it}}$. A positive value of τ_i indicates a tax on spouse i, and a negative value indicates a subsidy. Equation A-2.4 reflects the substitution of the gender-based tax into the previous equation.

$$EB = -\frac{1}{2}\left(\sum_j \sum_{s=1}^{T} \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} \tau_i \tau_j P_{sh_{js}} \left(\frac{\partial h_{js}}{\partial P_{nh_{it}}}\right)^{comp} P_{nh_{it}}\right) \tag{A-2.4}$$

Notice that the partial derivatives are compensated demands, which appear in the cross derivative matrix implied by each constraint. They can be notated as S_{njsit}. Using the alternative notation links Equation 1.16 and Equation A-2.4.[3]

$$EB = -\frac{1}{2}\left(\sum_j \sum_{s=1}^{T} \sum_i \sum_{t=1}^{T} \sum_{n=t}^{T} \tau_i \tau_j P_{sh_{js}} S_{njsit} P_{nh_{it}}\right) \tag{A-2.5}$$

The representation of the excess burden in Equation 1.16 approximates the true excess burden of the policy as long as the compensated demand curves are highly linear.

[3]The formulation appears slightly different from Harbergers, given that his prices dropped out after normalization. These prices are normalized such that the consumption good has a price of one each period, but the market productivities are not one, and are still visible in the excess burden equation.

Appendix A-3: Definitions of Notation in Chapter 1

A_H	husband's combined own-price responses to gender-based tax on all his earnings
A_W	wife's combined own-price responses to a gender-based tax on all her earnings
A_{HW}	husband's combined cross-price responses to a gender-based tax on his wife's earnings
A_{WH}	wife's combined cross-price responses to a gender-based tax on her husband's earnings
C_t	family consumption in time period t
C_t^M	family consumption generated by market production in time period t
C_t^D	family consumption generated by domestic/home production in time period t
D_{it}	time spent working in domestic duties by individual i in time period t
EB	excess burden
EB^{NG}	excess burden in a non-gender-based tax program
$f(\cdot)$	home production technology faced by a husband
G	exogenous government expenditures
$g(\cdot)$	market production technology faced by an individual
H	subscript denoting a husband
H_0	initial stock of human capital in production parameterization
h_{it}	time spent working in the market by individual i in the market in time period t
i	subscript denoting individual in the family, either husband or wife
j	subscript denoting individual in the family, either husband or wife
K	constant characterizing the gender-based optimal tax
$\mathcal{L}$	Lagrangian
L_{it}	leisure by individual i in time period t
m	subscript referring to cross-derivative matrix of interest
N	number of constraints in the model
n	subscript denoting position in vector $\boldsymbol{\Lambda}$
$q(\cdot)$	home production technology faced by a wife

$P_{th_{is}}$ net return to market labor in time period s done by individual i in time period t

S_{nitjs} substitution effect in the n^{th} budget constraint for good i in time t given a price increase in good j in time s

s subscript denoting time period

T number of time periods in the model

t subscript denoting time period

$U(\cdot)$ family utility function, twice-differentiable and quasi-concave

V dimension of the vector $\boldsymbol{X}$

v subscript denoting row in vector $\boldsymbol{X}$

W subscript denoting a wife

$\boldsymbol{X}$ vector of choice variable for a family

Y_{it} market production by individual i in time period t

Y_i lifetime market production by individual i in time period t

α_C consumption weight in Cobb-Douglass utility parameterization

α_i weight for leisure of individual i in Cobb-Douglass utility parameterization

β time preference discount factor

β_0, β_1 parameters in a Mincer learning by doing production parameterization

γ productivity weight in home production technology parameterization

$\boldsymbol{\Lambda}$ vector of constraints for a family maximizing utility

λ_t multiplier for the budget constraint in time t in household maximization

μ multiplier on the government budget constraint

φ_i efficiency unit of market labor per efficiency unit of human capital of individual i

φ_i^D efficiency unit of domestic labor for individual i

T_{it} total tax liability faced by individual i in time period t

τ_i marginal tax rate faced by individual i

τ_{NG} optimal tax in a non-gender-based tax program

χ_t multiplier for home production technology in time t in household maximization

Appendix B-1: Description of ATUS Data in Chapter 3, Full Sample

Table B-1: Description of ATUS 2003-2011 Data in Chapter 3, Full Sample

	Age 15	Age 23	Age 30
Proportion			
Female	0.49 (0.01)	0.52 (0.01)	0.50 (0.01)
Male	0.51 (0.01)	0.48 (0.01)	0.50 (0.01)
White	0.79 (0.02)	0.80 (0.02)	0.78 (0.02)
Black	0.15 (0.00)	0.13 (0.00)	0.10 (0.00)
Hispanic	0.22 (0.01)	0.21 (0.01)	0.20 (0.00)
Proportion participating in household duties on sample day	0.60 (0.02)	0.74 (0.02)	0.82 (0.02)
Average minutes per day in			
Household duties	52.4 (1.3)	118.0 (3.3)	179.2 (3.9)
Labor force	20.9 (0.5)	270.7 (7.5)	283.1 (6.1)
Proportion living in			
Midwest	0.23 (0.01)	0.24 (0.01)	0.24 (0.01)
Northeast	0.16 (0.00)	0.19 (0.01)	0.17 (0.00)
South	0.35 (0.01)	0.35 (0.01)	0.34 (0.01)
West	0.26 (0.01)	0.21 (0.01)	0.25 (0.01)
Metro area	0.86 (0.02)	0.88 (0.02)	0.87 (0.02)
Proportion of families who			
Own their homes	0.76 (0.02)	0.51 (0.01)	0.59 (0.01)
Rent their homes	0.23 (0.01)	0.47 (0.01)	0.40 (0.01)
Number of people living in the home			
Aged 0 to 4	0.10 (0.00)	0.38 (0.01)	0.55 (0.01)
Aged 5 to 9	0.25 (0.01)	0.13 (0.00)	0.41 (0.01)
Aged 10 to 14	0.54 (0.01)	0.08 (0.00)	0.19 (0.00)
Aged 15 to 19 (excluding observation)	0.44 (0.01)	0.16 (0.00)	0.04 (0.00)
Aged 19 and older (excluding observation and parents)	0.36 (0.01)	0.86 (0.02)	0.92 (0.02)

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*Income figures are in 1997 dollars.

Table B-1 Continued

	Age 15	Age 23	Age 30
Proportion			
Married	0.01 (0.00)	0.16 (0.00)	0.57 (0.01)
Living with an unmarried partner	0.00 (0.00)	0.11 (0.00)	0.07 (0.00)
Who are parents	0.00 (0.00)	0.24 (0.01)	0.54 (0.01)
Ave. number of children of respondents	0.00 (0.00)	0.36 (0.01)	1.06 (0.02)
Proportion			
U.S. citizens	0.95 (0.02)	0.87 (0.02)	0.83 (0.02)
Immigrants	0.07 (0.00)	0.16 (0.00)	0.22 (0.00)
Proportion with family income			
Below $25,000	0.18 (0.00)	0.30 (0.01)	0.20 (0.00)
Between $25,000 and $49,999	0.22 (0.01)	0.26 (0.01)	0.26 (0.01)
Between $50,000 and $74,999	0.19 (0.00)	0.16 (0.00)	0.22 (0.00)
Between $75,000 and $99,999	0.14 (0.00)	0.10 (0.00)	0.13 (0.00)
At least $100,000	0.16 (0.00)	0.09 (0.00)	0.12 (0.00)
Proportion			
Not in the labor force	0.69 (0.02)	0.13 (0.00)	0.15 (0.00)
Employed	0.17 (0.00)	0.78 (0.02)	0.80 (0.02)
High school graduates, not in college	0.01 (0.00)	0.28 (0.01)	0.26 (0.01)
Bachelor's degree	0.00 (0.00)	0.22 (0.01)	0.28 (0.01)
Living with mother/step-mother	0.92 (0.02)	0.42 (0.01)	0.12 (0.00)
Proportion with mother who			
Did not graduate from high school	0.13 (0.00)	0.07 (0.00)	0.03 (0.00)
Graduated from high school	0.25 (0.01)	0.13 (0.00)	0.04 (0.00)
Attended college but did not graduate	0.29 (0.01)	0.11 (0.00)	0.02 (0.00)
Proportion whose time diary was done on a weekday	0.73 (0.02)	0.72 (0.02)	0.70 (0.02)

*Income figures are in 1997 dollars.

Appendix B-2.1: Description of ATUS Data in Chapter 3, Cohort Sub-Sample

Table B-2.1: Description of ATUS 2003-2011 Data in Chapter 3, Cohort Sub-sample

	Ages 15 & 16	Ages 22 & 23
Sample size	849	389
Proportion		
Female	0.53 (0.02)	0.53 (0.02)
Male	0.47 (0.02)	0.47 (0.02)
White	0.75 (0.01)	0.78 (0.01)
Black	0.18 (0.01)	0.12 (0.01)
Hispanic	0.16 (0.01)	0.23 (0.01)
Proportion participating in household duties on sample day	0.61 (0.02)	0.75 (0.01)
Average minutes per day in		
Household duties	53.0 (3.1)	120.0 (5.4)
Labor force	35.5 (3.6)	223.8 (8.9)
Proportion living in		
Midwest	0.22 (0.01)	0.20 (0.01)
Northeast	0.20 (0.01)	0.14 (0.01)
South	0.31 (0.02)	0.39 (0.02)
West	0.26 (0.02)	0.28 (0.02)
Metro area	0.82 (0.01)	0.86 (0.01)
Proportion of families who		
Own their homes	0.75 (0.01)	0.58 (0.02)
Rent their homes	0.24 (0.01)	0.41 (0.02)
Number of people living in the home		
Aged 0 to 4	0.11 (0.01)	0.37 (0.02)
Aged 5 to 9	0.19 (0.02)	0.10 (0.01)
Aged 10 to 14	0.60 (0.02)	0.08 (0.01)
Aged 15 to 19 (excluding observation)	0.45 (0.02)	0.23 (0.02)

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*Income figures are in 1997 dollars.

Table B-2.1 Continued

	Ages 15 & 16	Ages 22 & 23
Proportion		
Married	0.00 (0.00)	0.13 (0.01)
Living with an unmarried partner	0.01 (0.00)	0.08 (0.01)
Who are parents	0.00 (0.00)	0.24 (0.01)
Ave. number of children of respondents	0.00 (0.00)	0.36 (0.03)
Proportion		
U.S. citizens	0.93 (0.01)	0.90 (0.01)
Immigrants	0.08 (0.01)	0.14 (0.01)
Proportion with family income		
Below $25,000	0.18 (0.01)	0.29 (0.02)
Between $25,000 and $49,999	0.21 (0.01)	0.23 (0.01)
Between $50,000 and $74,999	0.17 (0.01)	0.14 (0.01)
Between $75,000 and $99,999	0.23 (0.01)	0.17 (0.01)
At least $100,000	0.08 (0.01)	0.13 (0.01)
Proportion		
Not in the labor force	0.51 (0.02)	0.17 (0.01)
Employed	0.30 (0.02)	0.69 (0.02)
Part-time	0.28 (0.01)	0.28 (0.01)
Full-time	0.02 (0.00)	0.41 (0.01)
Average hours usually worked per week	3.85 (0.28)	22.06 (0.49)
Proportion		
Not high school graduates	1.00 (0.00)	0.10 (0.01)
In high school	0.92 (0.01)	0.00 (0.00)
High school graduates, not in college	0.00 (0.00)	0.30 (0.02)
In college	0.01 (0.00)	0.28 (0.02)
Bachelor's degree	0.00 (0.00)	0.16 (0.01)
Not in school	0.07 (0.01)	0.71 (0.02)
Proportion living with		
Mother/step-mother	0.93 (0.00)	0.53 (0.01)
Father/step-father	0.75 (0.01)	0.40 (0.01)
Time diary done on a		
Weekday	0.71 (0.02)	0.73 (0.02)
Holiday	0.03 (0.01)	0.02 (0.00)

*Income figures are in 1997 dollars.

Appendix B-2.2: Description of PSID Data in Chapter 3

The PSID contains information on time use of children and adolescents. The final sample size reduces to 96 individuals who are observed beginning in 1997 and followed until 2007. In contrast to the ATUS, PSID interviews occur on weekdays between March and December, excluding summer months of June, July and August. Characteristics of the respondents in the sample, including household circumstances and personal attributes, are shown in Table B-2.2.

Table B-2.2: Description of PSID Data in Chapter 3, Demographic and Socioeconomic Factors

	1997	2002	2007
Sample size	96		
Proportion			
Female	0.45 (0.05)		
Male	0.55 (0.05)		
White	0.61 (0.05)		
Black	0.19 (0.04)		
Hispanic	0.12 (0.03)		
Other race, ethnicity	0.09 (0.03)		
Age	7.10 (0.03)		
Proportion participating in household duties	0.46 (0.05)	0.47 (0.05)	0.34 (0.05)
Average minutes per day in household duties	12.61 (2.18)	18.16 (3.89)	13.68 (3.79)
Number of siblings	1.58 (0.11)	1.59 (0.11)	
Proportion living with			
Both biological parents	0.76 (0.04)	0.74 (0.04)	0.00 (0.00)
Biological mother only	0.21 (0.04)	0.23 (0.04)	0.00 (0.00)
Biological father only	0.01 (0.01)	0.01 (0.01)	0.00 (0.00)

Continued on page 97

*1997 dollars.

Table B-2.2 Continued

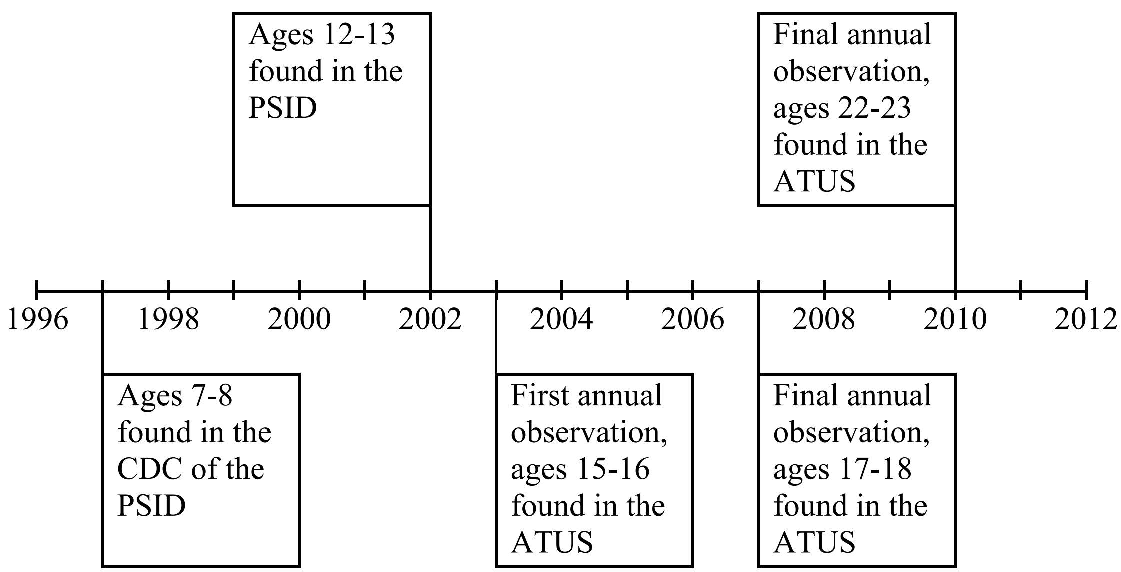
	1997	2002	2007
Proportion living in			
Midwest	0.22 (0.04)	0.22 (0.04)	0.22(0.04)
Northeast	0.22 (0.04)	0.20 (0.04)	0.20 (0.04)
South	0.24 (0.04)	0.24 (0.04)	0.25 (0.04)
West	0.33 (0.05)	0.34 (0.05)	0.33 (0.05)
Total family income*	52,385 (4,722)	79,603 (10,586)	85,608 (10,122)
Proportion who are employed			
Fathers/step-fathers	0.81 (0.02)	0.82 (0.02)	0.78 (0.02)
Mothers/step-mothers	0.62 (0.05)	0.79 (0.04)	0.79 (0.04)
Annual hours worked			
Fathers/step-fathers	1,794 (60)	1,799 (84)	1,764 (71)
Mothers/step-mothers	1,001 (94)	1,357 (100)	1,275 (88)
Weekly hours of household duties			
Fathers/step-fathers	7.25 (0.89)	8.12 (0.91)	5.11 (0.59)
Mothers/step-mothers	23.58 (1.60)	23.20 (1.39)	22.03 (1.57)
Years of education			
Fathers/step-fathers	10.39 (0.39)	10.86 (0.37)	10.05 (0.39)
Mothers/step-mothers	12.81 (0.36)	12.88 (0.34)	12.73 (0.35)
Number of family dinners together weekly	4.80 (0.21)	4.74 (0.20)	3.12 (0.19)

*1997 dollars.

Appendix B-3: Childhood and Adolescent Time-use Patterns in Home Duties from PSID Data in Chapter 3

I conduct empirical analysis of gender gaps over adolescent years into adulthood, with a focus on time spent in home duties. I analyze time use using individual-level data collected from time diaries from the 1997 to 2007 CDS of the PSID. The PSID and ATUS data misalign by two years; however, the misalignment is believed to be close enough that no significant cohort effects interfere with the analysis. Comparing household time-use values between the two data sets reveals that the PSID consistently reports lower values than the ATUS. Some of the discrepancy can be attributed to systematic underreporting in PSID data; often the minutes spent in various activities do not sum to a full day.

Figure B-3.1: Cohort Overlap of PSID and ATUS Samples



The PSID provides time-use information on children and adolescents using a time diary. The PSID is a longitudinal survey of United States families. Beginning in 1997, the PSID added the CDS in which time-use data are collected. The CDS samples all PSID families with children aged 0 to 12 years beginning in 1997. The CDS randomly selects two children per household when more than two children live in the household. By using weights, the sample is representative of the United States population of children. The CDS follows previously sampled children into adolescence by re-sampling in 2002 and 2007. Time diary interviews occur between March and December, excluding summer months of June, July and August, and the diary describes a week day. The diary information originates from a mailed paper diary that is mailed before a scheduled interview, with instructions to complete prior to the interview.[1] The child and primary care giver record time spent in activities during a 24-hour period from midnight to midnight. Respondents provide information about their primary activities, and the responses code into activity categories.

While the PSID importantly provides panel information on individuals over time, the sample size is small. Limiting the analysis to children aged seven and eight in 1997 gives a sample size of 96. The non-weighted sample is 45% female and 55% male. The data on home duties are generally consistent with research on children's time use; however, the results can not necessarily be generalized given the lack of precision in the estimates. Table B-2.2 in Appendix B-2.2 presents demographic and socio-economic characteristics of the children in the sample, including household circumstances and personal attributes.

I focus on time use relating to home duties. Similar to what is done using ATUS data, I aggregate the time spent throughout the day performing any home duty, including household activities and caring for others. Appendix B-4 describes the time-use sub-aggregate categories and aggregation process in greater detail.

Children ages seven and eight exhibit small and insignificant gender differences in time spent in home duties. At this young age, girls are observed spending an average of six minutes more than boys performing home duties. The time-use gap remains relatively stable over the next 10 years with adolescent girls performing home duties for seven

[1] "During the in-house CDS interview or by telephone, the interviewer reviewed and edited the diary with the child and primary caregiver or, in the situations where the diary was not completed in advance, the interviewer administered the diary as an interview. On average, the review/ interview time was just under 17 minutes per diary, per child" (User Guide to CDS-II, p. 47).

minutes more than their male peers by ages 17 and 18, and Table B-3.1 reports the findings. The data are consistent with a positive gender gap, but the sample size is too small and variation too large to give tighter estimates of the true gender gap. While the gender gap is statistically insignificant at the 10% level, the stability of the pattern over time lends support to a gender gap in home duties.

Table B-3.1: Average Minutes per Day in Household Activities, PSID 1997-2007

Ages	Male	Female	Female - Male
7 & 8	9.8 (1.9)	16.1 (2.5)	6.2 (4.4)
12 & 13	14.3 (2.2)	22.9 (5.3)	8.7 (8.1)
17 & 18	10.4 (2.3)	17.7 (5.1)	7.3 (7.9)

Significant at the 5% level (*).

The data reveal further insights into time-use patterns when studied along the extensive and intensive margins. Home duty participation rates indicate a decreasing gender gap along the extensive margin. At ages seven and eight, girls have a high participation rate of 58%. At this young age, 50% more girls than boys help at home in some way on a given day. The daily participation of girls and boys in home duties drops as they age, with a sharper drop among girls. By ages 17 and 18, teenage girls participate in home duties six percentage points more than teenage boys, and the difference between girls and boys is no longer significant. Table B-3.2 reports these effects.

Table B-3.2: Proportion Participating in Household Activities (i.e. Time-use > 0), PSID 1997-2007

Ages	Male	Female	Female - Male
7 & 8	0.37 (0.05)	0.58 (0.05)	0.21* (0.10)
12 & 13	0.41 (0.05)	0.54 (0.05)	0.13 (0.10)
17 & 18	0.31 (0.05)	0.38 (0.05)	0.06 (0.09)

Significant at the 5% level (*).

While the gender gap declines on the extensive participation margin during adolescence, there is evidence of a small gender gap developing along the intensive margin of conditional time use. As shown in Table B-3.3, at ages seven and eight, there is no significant gender gap in average minutes spent in home duties. Girls ages seven and eight involved in home duties spend on average 28 minutes, while involved boys spend nearly 27. By ages 12 and 13 a small gender gap appears. By ages 17 and 18 the gap increases but is not significant.

Table B-3.3: Average Minutes per Day in Household Activities, Conditional on Participation, PSID 1997-2007

Ages	Male	Female	Female - Male
7 & 8	26.6 (2.3)	27.8 (2.7)	1.1 (5.0)
12 & 13	34.9 (2.2)	42.6 (6.6)	7.7 (9.8)
17 & 18	33.2 (3.0)	47.2 (7.7)	14.0 (11.7)

Two important facts emerge from analyzing this alternate data. First, a similar pattern seen in the PSID that validates and strengthens the findings about gender differences in time use in the ATUS during adolescence. While the magnitudes in the PSID are consistently underestimated relative to the ATUS, they show a consistent gender difference beginning prior to age 15 and persisting through adolescence. Second, PSID data emphasize the reality that gender differences in home duties begin early in life. The time-use differences observed in adulthood are part of a larger pattern of time-use differences beginning in childhood, persisting through adolescence, and stratifying in young adulthood.

Appendix B-4: Descriptions of Time-use Variables in Chapter 3

I classify household duties as the combination of all activities involving housework or providing caring for another person. I include grocery shopping time as a household duty but do not include other types of shopping. Many children accompany parents in shopping duties. However, as adolescents age, they increasingly use shopping as a socializing activity with friends. In order to focus on household duties in both the PSID and ATUS, I do not consider non-grocery shopping as a household duty. While I could include non-socializing shopping time in the ATUS time-use profiles, I cannot include them in the PSID. In order to remain consistent and as comparable as possible between the data, I only consider grocery shopping. All categories report the number of minutes spent in a particular type of activity. The variable codes and variable descriptions are found in the following tables.

I obtain the ATUS data through the ATUS data extractor. The extractor matches variables from the 2003 through 2011 ATUS surveys with the household CPS exit survey. Table B-4.1 indicates the time use variable codes used in the time-use analysis.

Table B-4.1: Home Duties Time-use Variable Codes, 2003-2011 ATUS

Childcare and Adult Care Variables	
bls_carehh_kid	Caring for and helping household children
bls_carehh_kidother	Caring for household children (except activities related to education and health)
bls_carehh_kideduc	Activities related to caring for household children's education
bls_carehh_kidhealth	Activities related to caring for household children's health
bls_carehh_adult	Caring for and helping household adults
bls_carenhh_kid	Caring for and helping non-household children
bls_carenhh_adult	Caring for and helping non-household adults
bls_carenhh_adultcare	Caring for non-household adults
bls_carenhh_adulthelp	Helping non-household adults
bls_hhact_hwork	Housework
bls_hhact_food	Food preparation and cleanup
bls_hhact_lawn	Lawn and garden care
bls_hhact_hhmgmt	Household management
bls_hhact_inter	Interior maintenance, repair, and decoration
bls_hhact_exter	Exterior maintenance, repair, and decoration
bls_hhact_pet	Caring for animals and pets
bls_hhact_vehic	Caring for vehicles
bls_hhact_tool	Caring for appliances, tools, and toys
bls_purch_groc	Grocery shopping

I obtain the PSID data through the Institute for Social Research at the University of Michigan. The variables are consistent across the three years, and Table B-4.2 indicates the time-use variable codes used in the time-use analysis.

Table B-4.2: Home Duties Time-use Variable Codes, 1997, 2003, 2007 PSID

Childcare and Adult Care Variables	
wdYY_209	Baby care; care to children age 4/under, household members
wdYY_219	Giving child care; children ages 5-17, household members
wdYY_218	Giving child care; mixed ages or na age, household members
wdYY_248	Playing with household babies aged 0-2
wdYY_221	Helping children learn; non-homework, household members
wdYY_258	Coaching/leading outdoor activities, household members
wdYY_222	Helping with homework/supervising homework, household members
wdYY_236	Giving child orders/instructions, household members
wdYY_237	Disciplining child, household members
wdYY_239	Conversations w/ hh children only
wdYY_249	Indoor playing with household children
wdYY_259	Outdoor playing with household children
wdYY_238	Reading to a household child
wdYY_269	Medical care for a household child: home/outside home
wdYY_278	Babysitting (unpaid), non-household children
wdYY_277	Coordinating/facilitating social activ., non-household children
wdYY_279	Other child care, non-household children
wdYY_412	Medical care to adults in hh
wdYY_421	Routine non-medical care to adults in hh
wdYY_422	Help/care to relatives not living in hh
wdYY_423	Help and care to neighbors, friends
wdYY_424	Help and care to others, na relationship
wdYY_108	Meal preparation
wdYY_109	Serving food, setting table
wdYY_118	Washing/rinsing dishes, load dishwasher
wdYY_119	Meal cleanup, clearing table
wdYY_129	Routine indoor cleaning/chores housework
wdYY_148	Laundry - wash, doing laundry
wdYY_149	Laundry: sort/dry/iron/fold/mend/put away
wdYY_161	Repairs/maintenance, indoors
wdYY_173	Care of houseplants
wdYY_165	Repairs indoors: fix/repair appliances

Continued on page 105

YY is a placeholder for year.

Table B-4.2 Continued

Childcare and Adult Care Variables	
wdYY_166	Repairs indoors: fix/repair furniture
wdYY_191	Other indoor household activities
wdYY_128	Miscellaneous, na if indoor or outdoor
wdYY_171	Gardening, weeding, composting
wdYY_139	Routine outdoor cleaning/chores yard work
wdYY_162	Repairs/maintenance, exterior
wdYY_164	Home improvements: additions/remodeling
wdYY_168	Improvements to grounds around house
wdYY_192	Other outdoor activities
wdYY_189	Pet care; play w/pet; walking the dog
wdYY_163	Car care; necessary/routine car repairs
wdYY_167	Car maintenance.: change oil/tires, washed car
wdYY_193	Household paperwork; paying bills, etc.
wdYY_194	Watching another do typically female tasks
wdYY_195	Watching another do typically male tasks
wdYY_196	Watching another do other household tasks
wdYY_197	Other household chores (no travel)
wdYY_301	Groceries/supermarket/shopping for food

YY is a placeholder for year.

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