Essays on Heterogeneous Agents: Political Economy and Labor Markets

Dissertation zur Erlangung des akademischen Grades
Doktor rerum politicarum
der Technischen Universität Dortmund

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September 2010

Contents

Acknowledgements

This thesis would not exist in its current form without the help of a number of people whom I want to thank at this opportunity. Ludger Linnemann and Andreas Schabert have provided me with the best supervision I can imagine. In changing roles, they have motivated me with their positive feedback and stimulated me with their critique. I have benefitted much from their constructive and precise recommendations.

Another important role in the creation of this thesis was played by Falko Jüßen. The work with Falko as a co-author has been not only productive, but also instructive, inspiring, and – fun! Falko's comments and suggestions also improved my other papers substantially.

I also want to thank the two Graduate Schools I attended and which taught me many valuable skills. The Brown Bag seminars have been both a regular piece of inspiration and a commitment device. Financial support by the Technische Universität Dortmund and the SFB 475 of the German Research Association has allowed me to present my work on many conferences and is gratefully acknowledged. My thanks also go to those classmates and colleagues on all stages of my post-graduate studies who enriched this phase of my life.

Credit is also deserved by a number of professors who have not been directly engaged in the supervision of my thesis but whose teaching has enforced my interest and joy in economics. An incomplete list contains Jürgen von Hagen, Matthias Hoffmann, Heinz Holländer, Wolfgang Leininger, Monika Merk, and Michael Roos.

Members of my family have taught me important parts of being a researcher. My thanks go to my mother Gerda for teaching me precision and commitment, to my sister Barbara for teaching me arguing and impartiality, and to my father Willi for teaching me curiosity and doubt.

This work is for Annika – just as everything I do or am.

Chapter 1

Introduction

In macroeconomics, it is common to use representative-agent models to study aggregate dynamics. Macroeconomists are, however, also interested in topics whose study requires the explicit consideration of heterogeneity among economic agents. Such topics include the uneven distribution of labor and income, changes in the demographic composition of the economy, conflicts between agents with different interests, or subgroup differences in behavior to name but a few. Addressing such topics theoretically requires the use of heterogeneous-agents models.

This thesis presents four applications of heterogeneous-agents models. Chapters 2 and 3 present essays on the political economy of the welfare-state in the presence of income heterogeneity. Chapters 4 and 5 present essays on heterogenous-agents models addressing empirically observed differences in labor supply by gender, marital status, and wage potentials.

Chapters 2 and 3 deal with political economy under imperfect information. Taking into account imperfect information has proven to be useful in explaining a wide range of seemingly irrational observations in different fields of economics (see e.g. Sims 2003 and Veldkamp 2009 for examples in monetary economics and finance). The essays presented in Chapters 2 and 3 demonstrate that two puzzling observations in voting behavior can be explained within simple models of majority voting when one incorporates imperfect information.

Choices under imperfect information seem especially relevant in the field of political economy. When information is costly, each individual voter has little incentive to be informed since the impact of individidual votes is negligible (Downs 1957). In democracy, social choices may therefore be made by a continuum of poorly informed individuals.

Chapter 2 addresses the relation between the skewness of the income distribution and the redistribution of income by the government. Full-information models of voting on redistribution state that the degree of income redistribution should depend positively on income skewness (Meltzer and Richard 1981). Accordingly, income redistribution should increase when the skewness of the income distribution increases. Empirically, the opposite is frequently observed (see e.g. Rodríguez 1999 and Kenworthy and McCall 2008). Chapter 2 demonstrates that this observation can be rationalized in a majority-voting model (in the style of Romer 1975, Roberts 1977, and Meltzer and Richard 1981) when incorporating imperfect information.

The chapter presents a model where agents are heterogeneous with respect to income and have heterogeneous expectations due to imperfect information. In this model, it is important to distinguish between sources of changes in income skewness. Two sources of such changes are discussed: rising polarization and upward mobility, which both increase income skewness. In the model, these developments affect redistribution in different ways.

Rising polarization, i.e. income growth of the rich, increases the degree of redistribution sought by agents in the middle of the income distribution which unambiguously increases the rate of redistribution implemented in the political process. Upward mobility, i.e. the catching-up of some agents to richer population groups, additionally shifts voting power to richer population groups. Under imperfect information, this can lead to a median voter who votes for less redistribution even though this voter would in fact gain from more redistribution.

Reasonable degrees of informational imperfection are sufficient to generate increasing income skewness and decreasing redistribution in the presence of upward mobility. While previous contributions on imperfect-information models of voting behavior (e.g. Laslier, Trannoy, and van der Straeten 2003 and Hansen 2005) have focussed on the level of government size or redistribution, the model presented in Chapter 2 shows that the imperfect-information framework can also be used to explain seemingly anomalous changes in these measures.

Chapter 3 of this thesis addresses the asymmetry between the speed of implementations of public interventions and the speed of their removals (as observed by e.g. Lindbeck 2003 and Hercowitz and Strawczynski 2004). Especially welfare-state measures tend to persist even when they seem to have become suboptimal due to changes in the economic environment. Such persistence seems anomalous in light of voting models with perfectly informed voters who should remove any suboptimal system immediately.

The essay presented in Chapter 3 proposes an information-based explanation for the persistence of the welfare state. The chapter presents a structural model where rationally inattentive voters decide upon implementations and removals of social insurance. In this model, welfare-state persistence arises from disincentive effects of social insurance on attentiveness. The welfare state crowds out private financial precautions and with it agents' attentiveness to changes in economic fundamentals. When welfare-state arrangements are pronounced, agents realize changes in economic fundamentals later and reforms have considerable delays. Previous contributions (Hassler, Rodríguez Mora, Storesletten, and Zilibotti 2003; Beetsma, Cukierman, and Giuliodori 2009) have attributed welfare-state persistence to the effects of welfare-state measures on the future distributional conflict, whereas the model presented in Chapter 3 demonstrates that, in a set-up similar to Hassler, Rodríguez Mora, Storesletten, and Zilibotti (2003), welfare-state persistence can also arise due to informational imperfections.

While it has been important in Chapters 3 and 4 that economic agents differ by income and expectations, Chapters 4 and 5 focus on heterogeneity by gender and marital status. This part of the thesis considers labor supply by different population subgroups. Chapter 4 addresses the observed distinct trends in hours worked by subgroups formed by gender and marital status. Chapter 5 focusses on married women and further disaggregates their hours worked by characteristics of the husband. The models presented in the chapters are collective household models (Chiappori 1988; Chiappori 1992) which consider the household as a group of individuals with different interests rather than a single decision unit.

Chapter 4 investigates trends in labor supply by gender and marital status in the US over the last decades. Heterogeneous households and the possibility to trade home labor are incorporated into a household model of labor supply (in the style of Jones, Manuelli, and McGrattan 2003). The chapter demonstrates that the observed group-specific trends in hours can simultaneously be explained as optimal reactions to rising attractiveness of outsourcing labor in home production within such model.

When more households decide to outsource labor in home production, some agents previously engaged in this activity gain time for market work. Thus market hours of married women, single women, and single men increase. The effect on married women is strongest since they tend to work most in home production due to intra-household specialization. Married men, by contrast, are affected in the opposite direction. Average market hours in this group decrease since some married men loose intra-household bargaining power due to the improved earnings potentials on the market for home labor which favor their wives.

A quantitative version of the model is successful at matching the trends in hours by gender and marital status. This version of the model is used to assess the relative importance of different explanations for the trends in hours at the subgroup level. In line with previous studies (see e.g. Jones, Manuelli, and McGrattan 2003 and Eckstein and Lifshitz 2009), the results indicate that gender-specific developments in wages are important but not sufficient to explain the observed trends. Taking into account increased outsourcing of labor in home production improves the model's predictions for all four subgroups.

Chapter 5 of this thesis investigates the pattern of wives' hours disaggregated by the husband's wage decile. In the US, this pattern has changed from downward-sloping to hump-shaped (see e.g. Juhn and Murphy 1997 and Schwartz 2010). The chapter demonstrates that this development can be explained within a standard model of household specialization (in the style of Apps and Rees 1997) when taking into account trends in assortative mating (as documented by e.g. Pencavel 1998 and Morissette and Hou 2008 for education).

The chapter presents a model in which assortative mating determines the wage ratios within individual couples and thus the efficient time allocation of spouses. The economy-wide pattern of wives' hours by the husband's wage depends on the degree of assortative mating. With high degrees of assortative mating, men with high wages are married to women with high own earnings potentials who, consequently, work much. The pattern of wives' hours by the husband's wage is therefore increasing when the degree of assortative mating is high. By contrast, under random mating, this pattern is decreasing. In this situation, couples in which the husband's wage is high have the strongest incentives for intra-household specialization. Wives in these couples then supply the fewest market labor on average, as observed in the data in the 1970's. Intermediate degrees of assortative mating are a mixture of the extreme situations. With the effects of assortative mating being dominant at the low end of the wage distribution and the effects of random mating being dominant at the other end, the pattern of wives' hours by the husband's wage is hump-shaped as observed empirically in recent years.

A quantitative analysis of the model suggests that changes in the gender wage gap are responsible for the overall increase in hours worked by wives. By contrast, the fact that the most pronounced increase has been observed for wives married to high-wage men is a result of trends in assortative mating.

Chapter 6 concludes the thesis.

Chapter 2

Imperfect Information and the Meltzer-Richard Hypothesis

2.1 Introduction

It is a common view that democratically implemented income redistribution should always favor the receiver of the median income. In this view, the individually optimal degree of redistribution is a downward-sloping function of one's income and the median income receiver is thus also the median voter. A clear-cut prediction that arises from such consideration is the Meltzer-Richard hypothesis (Meltzer and Richard 1981): the extent of redistribution rises when the mean-to-median ratio of the income distribution increases since the median voter will then gain more from redistribution. Income skewness and redistribution should thus be positively related. In this chapter[1], I show that, in a model with imperfect information, redistribution can also decrease in response to a rise in income skewness depending on the source of such rise.

The Meltzer-Richard hypothesis is an important part of economic arguing. The negative link between income inequality and economic growth (Alesina and Rodrik 1994; Persson and Tabellini 1994) builds on this hypothesis. The argument that more unequal societies have slower growth relies on the disincentive effects caused by more pronounced income redistribution sought by the relatively poorer median voter.

[1] The chapter is based on Bredemeier (2010a).

However, empirical evidence regarding the link between income skewness and redistribution is anything as clear as the theoretical prediction. While a positive relation between income skewness and redistribution is indeed observed in some empirical studies, there are also studies which report the opposite. Cross-country studies find evidence supporting the Meltzer-Richard hypothesis (Easterly and Rebelo 1993; Lindert 1996; Milanovic 2000; Mohl and Pamp 2009) as well as contradictory results (Keefer and Knack 1995; Perotti 1996; Bassett, Burkett, and Putterman 1999). Cross-sectional studies within one country reveal evidence in favor of the hypothesis at the municipality level (Alesina, Baqir, and Easterly 2000 for the US, Borge and Rattsø 2004 for Norway) or comparing Brazilian states (Mattos and Rocha 2008) but also rejecting findings at the level of US states (Gouveia and Masia 1998; Rodríguez 1999).

Concerning time-series evidence, the study by Meltzer and Richard (1983) supports the theoretical prediction. The authors analyze US time series data of government spending and conclude that the spending level is positively related to the mean-to-median income ratio. Subsequent studies on similar questions arrive at the contrary (Rodríguez 1999; Kenworthy and McCall 2008). These studies report situations of increasing income skewness that are accompanied by cut-backs in the welfare state. Such episodes include e.g. the reductions in redistributive efforts implemented by the Reagan and Thatcher administrations around 1980 when mean-to-median income ratios were steadily increasing. Such developments are alien to a standard majority voting model.

In this chapter, I argue that it is not sufficient to consider the skewness of the income distribution alone. When income skewness changes, it is important to distinguish between sources of such changes. I discuss two developments in the income distribution which have the same effect on skewness but may affect democratically implemented redistribution in different ways: rising polarization and upward mobility. Rising polarization is a development where those who are rich anyway become even richer. Thus differences between population groups become more severe and the population more polarized (see e.g. Esteban and Ray 1994).[2] In contrast to this, upward mobility describes a development where initially poor individuals catch up to richer population groups and move up in

[2] Polarization would also increase if poor agents became poorer. However, this would decrease the mean-to-median income ratio. I will thus concentrate on the case where rich agents become richer and use the term 'rising polarization' accordingly.

the income distribution (see e.g. Bénabou and Ok 2001).

These two developments are illustrated in Figure 2.1. Panel (a) of the figure shows a log-normal income distribution with its mean (dotted vertical line) exceeding its median (thin vertical line). In panel (b), the same distribution is represented by the thin curve. The thick curve represents the distribution after a rise in polarization, i.e. an income increase for some agents above mean income. Correspondingly, more mass lies at the very right tail of the distribution. Mean income rises while median income is not affected. Finally, panel (c) of the figure illustrates an example of upward mobility. Here, starting from the log-normal distribution (thin curve), some agents poorer than the median move towards richer population groups. Reflecting this, less mass lies at the very left tail of the distribution. Also in this scenario, mean income increases and median income is constant.

Both developments increase income skewness and therefore have the same effect on redistribution in a voting model with perfect information. However, in a model with imperfect information, these developments affect redistribution in different ways. While rising polarization generates the standard effect, upward mobility can result in decreasing redistribution.

The importance of informational imperfections in democratic decision making has been stressed by Downs (1957). Downs pointed out that even small information costs can lead voters to be rationally ignorant and cause pronounced uncertainty about issues important for the optimal vote. Understood broadly, imperfect information also comprises all differences between complete information and information that is reflected in behavior (Sims 2003). Such differences can arise from cognitive differences at any stage in the process between observing an information and the implementation of the appropriate response. Even with perfect information available, if voters choose not to use all information, have difficulties figuring out the appropriate response, or make mistakes while translating decisions into behavior, political decisions may appear as if voters had imperfect information in the first place. It is an important feature of the model presented in this chapter that agents who are identical except for beliefs can vote differently. In the model, this is a result of imperfect information which may, however, not be the only reason for the existence of such differences in votes. They would also occur if voters had perfect information but made random mistakes in determining

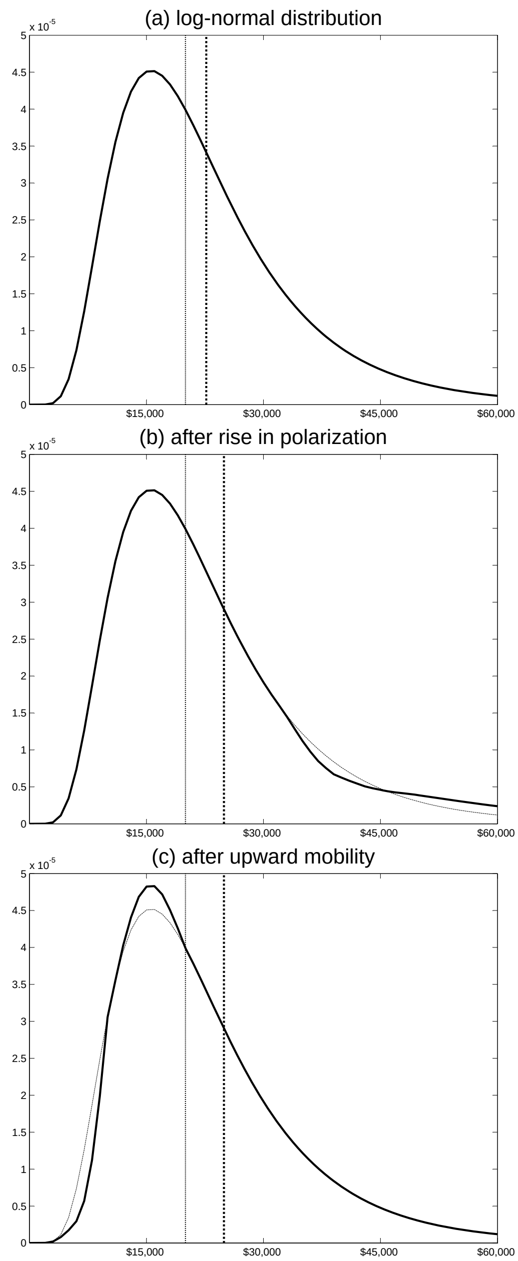

Figure 2.1: Three income distributions (thick curves) with mean (thick vertical line), median (thin vertical line), and baseline log-normal distribution (thin curve).

the optimal tax rate or, in the terminology of e.g. Shue and Luttmer (2009), misvoted. Recent papers use concepts related to imperfect information to study voting behavior, both theoretically (Gershkov and Szentes 2009; Hansen 2005; Dhami 2003) and empirically (Mullainathan and Washington 2009; Shue and Luttmer 2009).

This chapter presents a model of direct democracy with selfish voters, perfect markets, and complete enforcement in which the relation between income skewness and redistribution depends on the causes of changes in income skewness. The model is a version of the Romer-Roberts-Meltzer-Richard model (Romer 1975; Roberts 1977; Meltzer and Richard 1981). Agents differ with respect to their productivity and, in consequence, income. The main difference to the standard model is imperfect information about the productivity distribution. Under perfect information, the extent of redistribution would be determined by the interest of the median-income earner with high-income agents wishing less redistribution and low-income agents more.

In this model, the optimal vote for an agent depends on her own productivity and the average productivity in the economy. While the agent knows her own productivity for sure, she is assumed to be only imperfectly informed about productivities of others and thus about average productivity. Such assumption can be justified by the empirical findings of e.g. Betts (1996) and Ellison, Lusk, and Briggeman (2010). Betts (1996) find that people tend to misestimate average wages even in their own industry. Furthermore, perceptions differ across individuals with a variation coefficient of roughly 30%. Ellison, Lusk, and Briggeman (2010) report even higher variations of beliefs when people are asked to estimate the income of other population groups.

The model population is populated by three classes of agents who differ by productivity, a lower, a middle, and an upper class. Within classes, agents are identical except for beliefs about the productivity distribution. Votes on the degree of income redistribution are based on these beliefs and consequently even agents with the same productivity can vote differently. However, this does not happen in the lower and upper classes. In these classes, agents are sure to be at the bottom or the top of the distribution no matter how it is shaped. Independent of their beliefs about the shape of the distribution, these individuals will vote for either maximum redistribution or none at all.

In the middle class, the informational imperfection is relevant.

Agents in this class are in the interior of the productivity distribution. And since votes depend on individuals' relative productivity, the exact shape of the distribution is important for these voters. Even though agents in the middle class have the same productivity, they differ in their beliefs about the average productivity of others. In the middle class, there is thus a distribution of votes around the optimal vote. The election outcome is determined by the vote of the economy-wide median voter. Voting powers of the upper and lower classes determine which vote from the distribution of middle-class votes is decisive.

In this set-up, it is important to distinguish between causes of changes in the mean-to-median income ratio when analyzing the effect on redistribution. When income skewness rises, the optimal rate of redistribution for the middle class increases. Under rising polarization, this unambiguously increases implemented redistribution. However, upward mobility has a second, counter-acting effect. When some agents catch up to richer population groups, shifts in voting power move the quantile of the median voter in the belief distribution towards voting for fewer redistribution. Depending on the magnitude of the informational imperfection, the second effect can dominate the first one and one can observe a negative relation between income skewness and redistribution.

Upward mobility is more likely to cause decreasing redistribution the more people disagree in their beliefs about average income in the economy. A quantification of model parameters shows that empirically reasonable degrees of disagreement are sufficient for the second effect to dominate. Empirical evidence on developments in the income distribution like Esteban and Ray (1994) and the key figures of the Luxembourg Income Study support the view that seemingly anomalous reductions in redistribution around 1980 were indeed preceded by upward mobility.

Some previous contributions on imperfect information in models of voting on redistribution have studied related questions. Dhami (2003) analyzes the effects of inequality on redistribution in a model of representative democracy where voters have asymmetric information about politicians' redistributive ambitions. Hansen (2005) and Laslier, Trannoy, and van der Straeten (2003) use similar models to the one presented in this chapter. Hansen (2005) uses a Romer-Roberts-Meltzer-Richard type model with imperfect information about government efficiency and studies biases in the level of government size that can arise due to the information friction. Laslier, Trannoy, and van der Straeten (2003) address the topic of overtaxation in a model with uncertainty about the potential productivity of the unemployed. Both studies however do not cover the relation between changes in income skewness and changes in redistribution.

Bénabou and Ok (2001) and Alesina and La Ferrara (2005) have studied the influence of a prospect of upward mobility on voting decisions under perfect information. They demonstrate that such prospect can lead to less income redistribution. These studies however do not perform a comparative-static analysis of how election outcomes change once some agents have actually experienced upward mobility.

The remainder of the chapter is organized as follows. Section 2.2 describes the set-up of the model and solves for individual decisions and collective choices. Section 2.3 presents a comparative-static analysis of changes in the mean-to-median ratio distinguishing between rising polarization and upward mobility. Section 2.4 concludes.

2.2 The Model

2.2.1 Model set-up

In this section, I describe the structure of the model. It is a version of the Romer-Roberts-Meltzer-Richard model (Romer 1975; Roberts 1977; Meltzer and Richard 1981). Agents differ with respect to their productivity and, in consequence, income. In contrast to the standard model, agents are imperfectly informed about the productivity distribution.

Preferences and Technology. I consider an economy that is populated by a mass-1 continuum of agents behaving according to the following preferences:

$$u_i = c_i - \frac{\phi}{2} n_i^2, \tag{2.1}$$

where c_i denotes agent i's consumption and n_i is the amount of hours worked. If working, agents produce consumption goods y_i with linear technology

$$y_i = a_i n_i, \tag{2.2}$$

where a_i is an agent-specific productivity.

The composition of the economy is characterized by discrete differences in productivity. There are three productivity levels. Agents either have a low productivity normalized to 0, a medium one, a_1, or a high

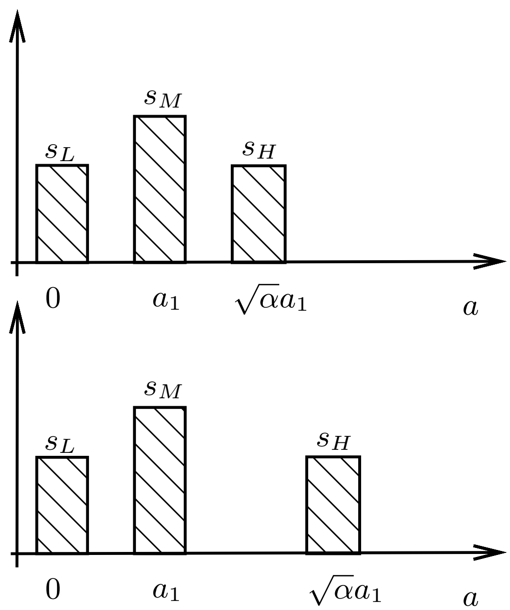

Figure 2.2: Two examples of a productivity distribution.

one, a_2, where $a_2 = \sqrt{\alpha} \cdot a_1$, $\alpha > 1$. Agents with zero productivity will decide not to work. The population can thus be split up into three groups, which are labeled according to their productivities:

(i) an upper class with high-productivity agents, labeled "H" for high

(ii) a middle class with medium-productivity agents, labeled "M" for medium

(iii) a lower class with agents who do not work, labeled "L" for low

Group sizes are denoted by s_L, s_M, and s_H, respectively, $s_L + s_M + s_H = 1$. I assume that no group contains more than mass $\frac{1}{2}$ of agents. This assumption guarantees that the median gross income falls into group M.

Note that both, α and $\frac{s_H}{s_L}$ are determinants of the skewness of the productivity distribution, which is illustrated in Figure 2.2. With $\sqrt{\alpha} =$

$\frac{s_H+s_L}{s_H}$ the distribution is symmetric (as in the upper part of the figure where $s_H = s_L$ and $\alpha = 4$). If $\sqrt{\alpha} > \frac{s_H+s_L}{s_H}$, the distribution is skewed to the right (as in the lower part of the figure where still $s_H = s_L$ but $\alpha > 4$) and vice versa. Skewness of the income distribution, which is key for the extent of redistribution sought by the middle class, jointly results from the skewness of the productivity distribution together with endogenous labor supply decisions.

Political Environment. The economy redistributes income through a linear income tax τ, the proceeds of which are to be distributed equally among the total population. Thus, an agent's net amount of consumption is a linear combination of his own gross earnings and the average earnings in the economy,

$$c_i = (1 - \tau) \cdot y_i + \tau \cdot y, \tag{2.3}$$

where y denotes the average gross income.[3]

The redistribution rate $\tau \in [0, 1]$ is determined in direct democracy by pairwise votes over proposals. All agents participate in this vote. Furthermore, I assume that agents vote truthfully in the sense that they vote for their individual expected-utility maximizing τ. Since any single voter has zero mass in this model, I abstain from analyzing strategic voting behavior and assume "sincere" (Bearse, Cardak, Glomm, and Ravikumar 2009) or "naive" (Feddersen and Pesendorfer 1997) voting.

Informational Environment. Agents are aware of the structure of the economy and know all parameter values except for other agents' productivities. The latter reflects the empirical evidence that there is disagreement about other people's wages (Betts 1996; Ellison, Lusk, and Briggeman 2010). For agents in groups M and H, this is tantamount to not knowing the productivity parameter α. This parameter measures the difference between the middle and the upper class and is one determinant of the skewness of the productivity distribution. The parameter is drawn from a uniform distribution on $(1, \infty)$. Agents cannot observe this draw. After α is drawn, each agent receives an imperfect signal α_i^S about α, which equals the true value in expectation. Agents' sig-

[3]The literature on voting about redistribution usually studies voting on the parameterization of some given redistribution scheme. In more general set-ups, voting equilibria may not exist (see e.g. Mueller 2003).

nals are independently drawn from an identical uniform distribution on $[\alpha - \varepsilon, \alpha + \varepsilon]$.

Even though agents do not know others' productivities with certainty, they know their own group and the ordering of productivities by groups. I.e. agents know that

$$a_2 > a_1 > 0. \tag{2.4}$$

For analytical simplicity, I will restrict the analysis to parameter constellations which fulfill

$$\alpha > 1 + 2\varepsilon \tag{2.5}$$

such that no signal contradicts condition (2.4). Furthermore, under this condition, beliefs will not be biased. For the main results of the model, this parameter restriction is innocuous since unbiasedness of beliefs is not crucial.

Time Structure. The timing of events is the following. First, the productivity parameter α is drawn. The draw is unobservable for agents. Second, agents receive signals $\{\alpha_i^S\}$ and update their beliefs. Third, the election over the redistribution parameter τ takes place and the median vote is implemented. Fourth, agents decide how much to work and produce gross income. Finally, redistribution is performed and goods are consumed.

2.2.2 Individual decisions

In this section, I present the optimal decisions of individual agents. Detailed derivations of decisions at the individual level can be found in the appendix.

Labor supply decisions and income distribution. Agents have to decide on how much they want to work. When taking this decision, agents take into account the degree of income redistribution. For agents in group L, it is optimal not to work while agents in the other groups work positive hours. Equalizing marginal benefits and costs from working, given a tax rate τ, results in

$$n_i = \frac{(1-\tau)\, a_i}{\phi} \quad \forall i. \tag{2.6}$$

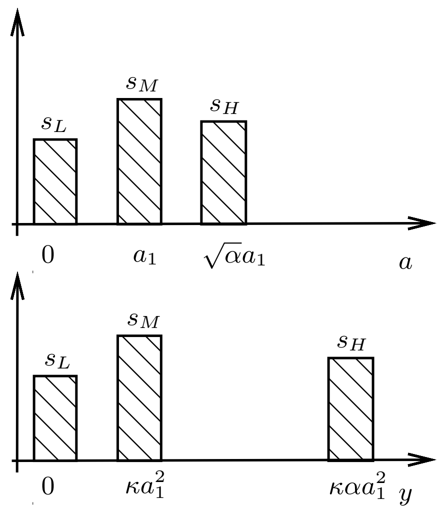

Figure 2.3: Example of a productivity and the corresponding income distribution ($\kappa = \frac{1-\tau}{\phi}$), relative income difference: $\frac{y_H}{y_M} = \alpha$.

Redistribution reduces labor supply through a standard disincentive effect. It has the same effect on aggregate income, which is

$$y = (1-\tau) \cdot \frac{1}{\phi} \cdot \left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] \tag{2.7}$$

as a result of individual labor supply decisions.

Labor supply decisions as described by equation (2.6) imply that income is a quadratic function of productivity as can be seen from Figure 2.3. The mean-to-median income ratio is

$$y/\left[(1-\tau) \cdot \phi^{-1} \cdot (a_1)^2\right] = s_M + s_H\alpha. \tag{2.8}$$

The income distribution is skewed to the right and the mean-to-median ratio greater than 1 if $\alpha > \frac{s_H+s_L}{s_H}$ and vice versa.

Preferred tax rates. When agents vote for a certain tax rate τ, they form rational expectations about the disincentive effects of redistribution. Rationally anticipating subsequent labor supply decisions of all agents, an agent votes for the tax rate which maximizes her expected indirect utility.

For a non-working agent, $i \in L$, transfers are the only source of income. Since she does not work, expected indirect utility is

$$E_i u_i = \tau \cdot (1-\tau) \cdot \frac{1}{\phi} \cdot \left[s_M E_i (a_1)^2 + s_H E_i (a_2)^2 \right] \quad \forall i \in L. \tag{2.9}$$

The tax rate which maximizes expected indirect utility for this agent is independent of expected productivities and

$$\tau_i = \frac{1}{2} \quad \forall i \in L, \tag{2.10}$$

which is the Laffer-curve maximizer in this model. For agents in this group, the optimal rate of redistribution does not depend on the shape of the income distribution. They are transfer receivers independent of the exact shape of the distribution.

In contrast to this, the skewness of the distribution matters for the preferred tax rate of agents in the middle class. Agents in this group receive their own net income as well as transfers and incur utility losses from working. Their expected indirect utility is

$$\begin{aligned} E_i u_i = & (1-\tau)^2 \frac{(a_1)^2}{\phi} + \tau \cdot (1-\tau) \cdot \frac{s_M (a_1)^2 + s_H E_i \alpha (a_1)^2}{\phi} \\ & - \frac{\phi}{2} \cdot \frac{(1-\tau)^2 (a_1)^2}{\phi^2} \quad \forall i \in M, \end{aligned} \tag{2.11}$$

which is maximized by

$$\tau_i = \max \left[\frac{1 - (s_M + s_H E_i \alpha)}{1 - 2 (s_M + s_H E_i \alpha)}, 0 \right] \forall i \in M. \tag{2.12}$$

Equation (2.12) is the belief-vote mapping for middle-class agents. The term in the round brackets is the expected mean-to-median income ratio. All agents determine their vote according to their perceived position relative to mean income. For agents in the middle class, this coincides to the perceived mean-to-median income ratio. The preferred tax rate of a middle-class agent is a (weakly) upward sloping function of her expectation of productivity differences, $E_i \alpha$. When $E_i \alpha$ is relatively high, the agent believes that income differences between the upper and the middle class are pronounced and that she can gain much from taxing the members of the upper class. In the opposite case, when $E_i\alpha$ is relatively low, the agents believes to pay more taxes in order to finance transfers to the lower class. A middle-class agent i votes for positive redistribution only if the expected mean-to-median ratio is above 1, i.e. if she believes the income distribution is skewed to the right.[4]

Finally, members of the upper class can only loose from redistribution. Their expected indirect utility,

$$\begin{aligned} E_i u_i = & (1-\tau)^2 \frac{(a_2)^2}{\phi} + \tau \cdot (1-\tau) \cdot \frac{s_M E_i \left(\alpha^{-1/2} a_2\right)^2 + s_H (a_2)^2}{\phi} \\ & - \frac{\phi}{2} \cdot \frac{(1-\tau)^2 (a_2)^2}{\phi^2} \quad \forall i \in H \,, \end{aligned} \tag{2.13}$$

is a strictly downward sloping function of the tax rate τ, since agents know for sure that $\alpha > 1$. Agents in group H therefore vote for

$$\tau_i = 0 \quad \forall i \in H. \tag{2.14}$$

Considering the expected indirect utility functions (2.9), (2.11), and (2.13), one can see that all have a unique maximizer on $[0,1]$. Thus, preferences over τ are single-peaked for all agents. When determining election outcomes, the median-voter theorem is therefore applicable.

2.2.3 Belief formation and belief distribution

To determine the median voter, the distribution of votes has to be considered. Since agents in group M vote based on subjective beliefs, the distribution of beliefs needs to be determined first. This distribution arises as a result of agents' belief updating based on their individual signals.

The structure of the economy is common knowledge. However, before receiving the signal, agents only know that α is not less than 1. All values above 1 are equally likely from the perspective of agents. An agent's prior belief about the productivity difference α is thus a uniform distribution on $(1,\infty)$.

[4]The expression on the right hand side of equation (2.12) is also positive if the expected mean-to-median ratio is less than one half and would then describe a minimizer outside $[0,1]$. However, this case is excluded by the assumed restrictions on group sizes.

The signal α_i^S carries information about values of α which are impossible. Specifically, after receiving her signal, an agent knows that α cannot be above $\alpha_i^s + \varepsilon$ or below $\alpha_i^s - \varepsilon$. Such values would not have been compatible with the signal. Under condition (2.5), it holds that $\alpha_i^s - \varepsilon > 1$. The support of the posterior distribution is thus

$$\left[\alpha_i^S - \varepsilon,\, \alpha_i^S + \varepsilon\right].$$

Since the signal is uniformly distributed, the agent can not differentiate between values in the support. All values $\alpha \in \left[\alpha_i^S - \varepsilon,\, \alpha_i^S + \varepsilon\right]$ are associated with the same density for the received signal α_i^S. The posterior distribution is thus uniform on above support.

Correspondingly, the posterior expectation of agent i is the arithmetic mean of the upper and the lower bound of the support:

$$\mu_i = E_i\left[\alpha\right] = \alpha_i^S. \tag{2.15}$$

Since there is a continuum of agents, each possible signal realization on $[\alpha - \varepsilon, \alpha + \varepsilon]$ is drawn by an equal mass of agents. According to (2.15), all agents build mean beliefs equal to their received signals. The distribution of mean belief is thus identical to the distribution of signals and given by

$$g\left(\mu\right) = \begin{cases} \frac{1}{2\varepsilon}, & \alpha - \varepsilon \leq \mu \leq \alpha + \varepsilon \\ 0, & \text{else} \end{cases}, \tag{2.16}$$

where $g\left(\mu\right)$ denotes the density of a specific belief μ. The distribution of beliefs is the same across all groups and equal to the economy-wide distribution described by equation (2.16). Beliefs are unbiased, i.e. the economy-wide mean belief is true, $\bar{\mu} = \int \mu g\left(\mu\right) d\mu = \alpha$. Nevertheless, almost every agent misestimates α in one or the other direction.

2.2.4 Election outcomes

Since preferences over the tax rate τ are single peaked, the median vote is the unique Condorcet winner. The cumulative density F of votes and the determination of the median voter are illustrated in Figure 2.4. The distribution of votes in the economy is as follows: On the one hand, there is a mass of people at both extremes. Fraction s_H of agents (the upper class H) vote for zero redistribution, $F\left(0\right) = s_H$. Fraction s_L of agents (the lower class L) vote for the Laffer-curve maximizing tax rate,

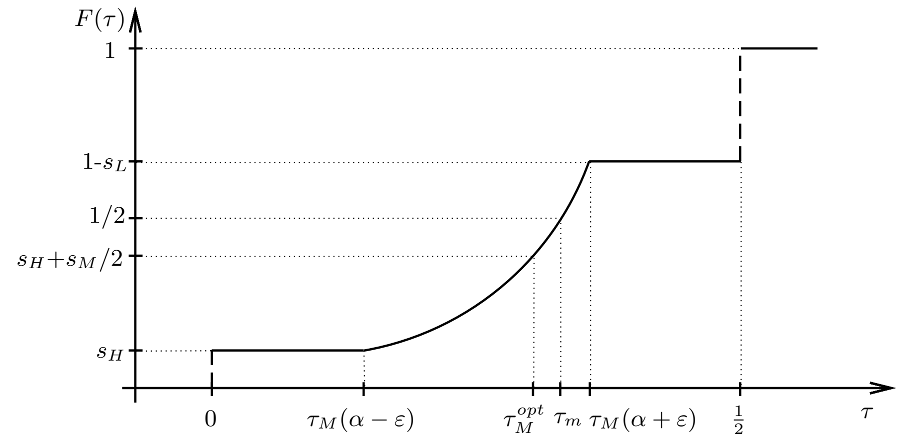

Figure 2.4: The distribution of votes and the election outcome.

$F\left(\frac{1}{2}\right) = 1 - s_L$. On the other hand, there is non-degenerate distribution of votes between these two extremes. Since beliefs about α differ across agents, votes of agents in the M group differ from one another. Beliefs are unbiased within groups, therefore the optimal tax rate for the middle class, τ_M^{opt}, is always the median of the vote distribution *within the M group.*

Where the *economy-wide* median voter is located depends on relative group sizes. As neither group L nor group H contains at least 50% of the population, the median voter is surely a member of the M group. The economy-wide median voter, m, is the agent whose preferred tax rate τ_m is such that M-group voters of mass $\frac{1}{2} - s_H$ opt for less redistribution than herself since mass s_H of voters vote for zero redistribution anyway. Thus the median voter is at the lower $\frac{\frac{1}{2}-s_H}{s_M}$ quantile of the vote distribution within the M group. For agents in the middle class, τ_i is an upward sloping function of $E_i\alpha$, see equation (2.12). Therefore, the median voter is also at the lower $q_m = \frac{\frac{1}{2}-s_H}{s_M}$ quantile of subjective expectations of income differences α.

The distribution of subjective expectations is characterized by equation (2.16). Since the distribution is uniform on $[\alpha - \varepsilon, \alpha + \varepsilon]$, the lower q_m quantile can be calculated as $(1 - q_m) \cdot (\alpha - \varepsilon) + q_m \cdot (\alpha + \varepsilon)$. The median voter's expectation of α is thus

$$\mu_m = \alpha + \frac{s_L - s_H}{s_M}\varepsilon. \tag{2.17}$$

If and in which direction the median voter's belief differs from the truth, depends on the relative sizes of the upper and lower class.[5] Applying the belief-vote mapping of the middle class (2.12) to this belief, the preferred redistribution rate of the median voter and thus the implemented rate of redistribution is

$$\tau_m = \max\left[\frac{1-(s_M + s_H\mu_m)}{1-2\,(s_M + s_H\mu_m)}, 0\right]. \tag{2.18}$$

Positive redistribution occurs when

$$\alpha + \frac{s_L - s_H}{s_M}\varepsilon > \frac{s_L}{s_H} + 1, \tag{2.19}$$

i.e. when the median voter believes the income distribution to be right skewed and, equivalently, the mean-to-median income ratio to exceed 1.

In this framework with imperfect information, implemented redistribution does not necessarily have to be optimal for the median-income receiver as it would have to be under perfect information. The implemented tax rate given by equation (2.18) coincides with the optimal tax rate for agents in the middle class only if the lower and the upper class are of equal size. Then, by coincidence, the median voter will be exactly in the center of the belief distribution of the middle class and have unbiased beliefs about the productivity distribution.

If upper and lower class are of unequal size, however, the median voter will be someone who misestimates the skewness of the productivity distribution and therefore votes for a potentially suboptimal redistribution rate. The larger of the two other groups forms a majority together with a minority of the middle class which misestimates productivity skewness. This majority can prevent any lower or higher tax rate even if it would improve the situation of some of its members (who, however, are not aware of this).

[5] To obtain the expression for μ_m in equation (2.17), use that $s_L + s_M + s_H = 1$.

2.3 Changes in Income Skewness

Standard models of voting on redistribution predict that the extent of redistribution increases in the mean-to-median income ratio. The empirical evidence on this prediction is mixed (see Section 2.1). In this section, I analyze how changes in the mean-to-median income ratio affect election outcomes in this model.

Here, the mean-to-median income ratio can change due to two developments. Skewness can change because of rising polarization, i.e. by an income increase of the rich relative to the middle class (captured by an increase in the parameter α) or by upward mobility, i.e. by some agents catching up to richer ones (captured by an increase in s_M or s_H). While these two scenarios have similar impact on the skewness of the income distribution, their effect on the vote distribution differs. The reason is that while the first scenario simply moves earnings shares to the right of the distribution, the second also moves voting power.

2.3.1 Rising polarization

Consider first the case of rising polarization, i.e. an increase in the relative productivity of the upper class, and assume the parameter α rises from $\bar{\alpha}$ to α^{pol}, with $\alpha^{pol} > \bar{\alpha}$. Figure 2.5 illustrates the effects of rising polarization on income skewness. The left panel shows a symmetric distribution where mean and median income are identical. A symmetric distribution is chosen only for illustrational purposes in the figure, subsequent results do not require symmetry. The right part shows the income distribution after a rise in polarization. Due to income growth of the upper class, mean income (thick dashed line) has risen while median income (thin dashed line) has remained constant. The rise in polarization has thus led to an increased mean-to-median ratio.

The effects of this change on the implemented redistribution rate are illustrated graphically in Figure 2.6. The thin dashed line represents the initial vote distribution with $\alpha = \bar{\alpha}$ whereas the thick solid line stands for the new vote distribution associated with $\alpha = \alpha^{pol}$.

Since group sizes are constant, the median voter's quantile in the belief distribution remains unchanged. As the economy-wide mean belief shifts to α^{pol}, the median voter's belief, as given by equation (2.17),

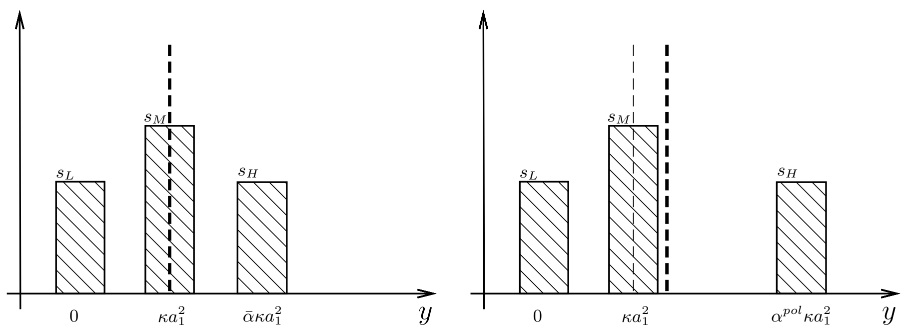

Figure 2.5: Income Distribution, mean (thick dashed line), and median (thin dashed line) income before and after polarization ($\alpha^{pol} > \bar{\alpha}$, $\kappa = \frac{1-\tau}{\phi}$).

increases as well,

$$\mu_m^{pol} = \alpha^{pol} + \frac{s_L - s_H}{s_M}\varepsilon > \bar{\mu}_m. \tag{2.20}$$

According to the belief-vote mapping in the middle class (2.12), the implemented redistribution rate is now

$$\tau_m^{pol} = \max\left[\frac{1 - \left(s_M + s_H\mu_m^{pol}\right)}{1 - 2\left(s_M + s_H\mu_m^{pol}\right)}, 0\right] \geq \bar{\tau}_m$$

and either larger or equal than with the lower difference in productivities, $\bar{\alpha}$.

The intuition behind this result is the following. Since the mean-to-median income ratio increases, the optimal rate of redistribution for the middle class rises. Group sizes are constant and thus the median voter misestimates income skewness by the same absolute deviation. The median voter's belief about the mean-to-median income ratio thus increases and so does her vote. Consequently, the winning tax rate rises.

Thus, the model predicts that, in reaction to an income increase for the rich, one observes indeed a positive correlation between the mean-to-median income ratio and redistribution. This prediction is equivalent to the standard model's one and corresponds to the Meltzer-Richard hypothesis.

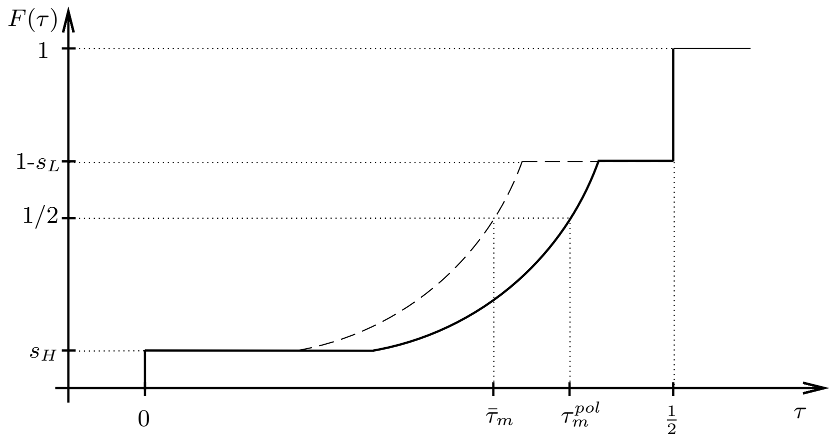

Figure 2.6: Vote distribution before (thin dashed line) and after (thick solid line) polarization ($\alpha^{pol} > \bar{\alpha}$).

2.3.2 Upward mobility

Effects are not as clear if the mean-to-median income ratio changes due to changes in relative group sizes. Consider a scenario where the upper class grows at the expense of the lower class (for simplicity with constant size of the middle class). Assume that group sizes change from $\bar{s}_L$, s_M, $\bar{s}_H$ to s_L^{um}, s_M, s_H^{um}, with $s_L^{um} < \bar{s}_L$ and $s_H^{um} > \bar{s}_H$. Figure 2.7 illustrates the effects of upward mobility on income skewness. Starting from a symmetric distribution (left panel), upward mobility increases mean income (thick dashed line) while median income (thin dashed line) is not affected since it lies still in group M. Thus the mean-to-median ratio is larger after upward mobility (right panel).

The consequences of this scenario on redistribution are illustrated in Figure 2.8. Again, the thin dashed line stands for the initial vote distribution and the thick solid line represents the vote distribution after upward mobility.

Since the compositional change affects the skewness of the income distribution, it alters the belief-vote mapping of the middle class. For a given belief about productivity differences, μ_i, the agent's expected mean-to-median income ratio, $s_M + s_H\mu_i$, increases with s_H and so does

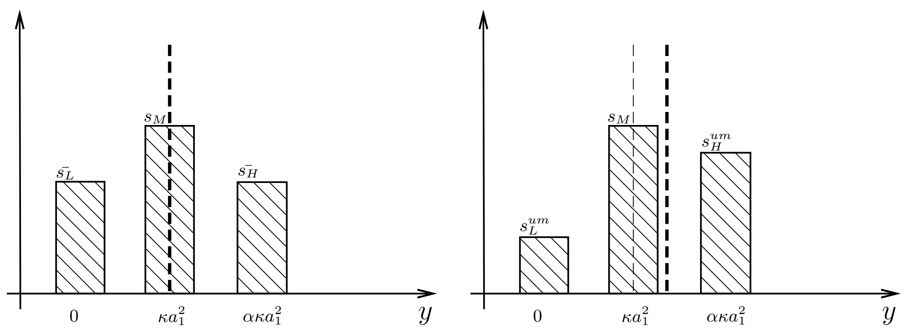

Figure 2.7: Income Distribution, mean (thick dashed line), and median (thin dashed line) income before and after upward mobility ($s_L^{um} < \bar{s}_L$, $s_H^{um} > \bar{s}_H$, $\kappa = \frac{1-\tau}{\phi}$).

her vote. Agent $i \in M$ with belief μ_i now votes for

$$\tau_i^{um} = \max\left[\frac{1-(s_M + s_H^{um}\mu_i)}{1-2\left(s_M + s_H^{um}\mu_i\right)}, 0\right] \geq \bar{\tau}_i.$$

In the figure, this effect is manifested in the movement of the non-degenerate part of the distribution to the right. This increase in redistribution sought by the middle class does, however, not imply that the winning tax rate necessarily increases as well.

When the upper class increases in size, voting power shifts towards this group as well. In the figure, this is associated with an upward movement of the non-degenerate part of the distribution, since more mass lies at zero redistribution. As a consequence, the position of the economy-wide median voter within the belief distribution moves to the left. The median voter's belief about productivity differences, as given by equation (2.17), is now

$$\mu_m^{um} = \alpha + \frac{s_L^{um} - s_H^{um}}{s_M}\varepsilon < \bar{\mu}_m.$$

These two developments result in an ambiguous effect on the implemented redistribution rate. While the increase in redistribution sought by the middle class tends to increase implemented redistribution, the shift in voting power has the opposite effect.

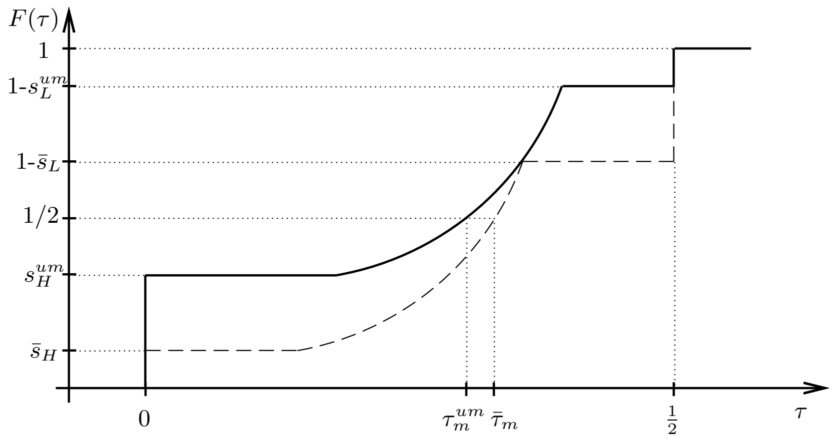

Figure 2.8: Vote distribution before (thin dashed line) and after (thick solid line) upward mobility ($s_L^{um} < \bar{s}_L$, $s_H^{um} > \bar{s}_H$).

Which effect is dominant depends on the degree of informational imperfections as measured by the dispersion of the signal, ε. To determine a threshold for ε, it is useful to consider the median voter's expected mean-to-median income ratio, $s_M + s_H \cdot \mu_m$, which is positively linked to implemented redistribution, see equation (2.18). Using the median voter's belief μ_m from equation (2.17) and eliminating the size of the lower class, the median voter's expected mean-to-median income ratio is

$$E_m y/y_m = s_M + s_H \left(\alpha + \frac{1 - s_M - 2s_H}{s_M} \cdot \varepsilon \right). \tag{2.21}$$

The effects of upward mobility can be studied by considering the marginal derivatives of (2.21) to group sizes. When some agents move from group L to group H, this leads to decreasing redistribution if $\varepsilon > \alpha \cdot \frac{s_M}{s_M + 4s_H - 1}$. Another, potentially more realistic, case of upward mobility is a movement of agents from group L to group M. Such development decreases redistribution if

$$\varepsilon > \frac{(s_M)^2}{s_H \cdot (1 - 2s_H)}, \tag{2.22}$$

i.e. if informational imperfections are pronounced enough.

In other words, upward mobility is more likely to cause decreasing redistribution the more people disagree in their beliefs about the income distribution in the economy. If condition (2.22) is fulfilled, an increase in s_M leads to the mean-to-median income ratio and redistribution moving into opposite directions. The Meltzer-Richard hypothesis is then turned upside-down.

How likely is it that condition (2.22) is fulfilled, i.e. that informational imperfections are strong enough for upward mobility to decrease redistribution? Suppose that group sizes are equal, i.e. $s_H = s_M = s_L = \frac{1}{3}$. Under this quantification, condition (2.22) gives a threshold value for ε of 1. To put this number into perspective, it is useful to calculate the variation coefficient of perceived average income for which an empirical counterpart is reported by Betts (1996). Doing this requires a quantification for α which I derive by matching the empirical US mean-to-median income ratio. In 2008, the mean-to-median income ratio among US households was 1.37.[6] With equal group sizes, this implies $\alpha = 3.12$ in this model, according to equation (2.8). Under the belief distribution (2.16), this quantification for α, ε, and group sizes gives a variation coefficient of perceived average income of $\sqrt{\int (E_i y - y)^2 \, di}/y \approx 14\%$. Since Betts (1996) finds that peoples' beliefs even about average wages in their own industry differ by a variation coefficient of roughly 30%, this magnitude does not seem implausibly high.

The model's prediction concerning the consequences of a rise in income skewness is in general not clear. If income skewness increases due to increased polarization, redistribution does unambiguously increase. If, however, an increase in income skewness is caused by upward mobility, redistribution may decrease. This ambiguity can be seen as a reason for why, in reality, one sometimes observes positive relationships between redistribution and income skewness and sometimes the opposite.

2.3.3 Evidence

In this section, I consider some empirical evidence on developments in income distributions in the time around the year 1980 which form a major anomaly to the Meltzer-Richard hypothesis. The Reagan administration in the US and the government of Thatcher in the UK were massively reducing redistributive spending although mean-to-median ratios of pre-

[6]Source: U.S. Census Bureau, 2008 American Community Survey.

tax income distributions were steadily increasing (see e.g. Rodríguez 1999). The model evaluation above proposes to determine the drivers of the increasing income skewness in that time. I will focus on the late 1970s, the time preceding Reagan's and Thatcher's first elections into office (1980 and 1979, respectively). Major reductions in redistribution occurred shortly after, e.g. in the first Reagan tax cut (1981) and in Thatcher's first budget (1979).

Esteban, Gradín, and Ray (2007) study developments in certain measures of income polarization for different countries including the US and the UK. They e.g. report the average income of certain population groups such as the top 20% or the bottom 40% of the distribution relative to mean income. These measures are suitable to distinguish between drivers of increasing income skewness. Rising polarization as discussed in Section 2.3.1 would increase top relative to medium incomes. Opposed to this, upward mobility as discussed in Section 2.3.2 would lead to a rise in the lowest relative incomes.

For the time period of interest, the results of Esteban, Gradín, and Ray (2007) point toward upward mobility as the source of increasing income skewness. The relative income of the top 20% of the distribution decreased from 1974 to 1979 while the relative income of the bottom 40% increased in both, the US and the UK.

A second source of useful information is the key figures of the Luxembourg Income Survey (LIS) which provide some summary statistics on the income distributions in the US and the UK for different waves of the survey. I will focus on two measures of the distribution, the 90/50 percentile ratio and the 50/10 percentile ratio, in the wave years 1974 and 1979.[7] The two developments discussed in this chapter, rising polarization and upward mobility, affect the mean-to-median ratio in the same way but the two percentile ratios are affected differently. Rising polarization would increase the 90/50 ratio but would have no effect on the 50/10 ratio while upward mobility could decrease the 50/10 ratio but not affect the 90/50 ratio.

Also the LIS data suggests that rising polarization did not take place between 1974 and 1979 since the 90/50 ratio actually decreased between these two years in both, the US and the UK. Concerning upward mobil-

[7] Data source: Luxembourg Income Study (LIS) Key Figures, http://www.lisproject.org/keyfigures.htm, data downloaded on May 31, 2010.

ity, the evidence is supportive. From 1974 to 1979, the 50/10 percentile income ratio indeed decreased in both countries.

This evidence suggests the view that increases in income skewness in the late 1970s have been caused by upward mobility rather than rising polarization. The succeeding cuts in redistribution can thus indeed be explained by the model presented in this chapter.

2.4 Conclusion

Despite a sharp theoretical prediction, empirical evidence on the relationship between the mean-to-median income ratio and redistribution is mixed. Some empirical studies find a positive relationship, some studies find a negative one. Changes in income skewness are often accompanied by developments in redistribution into the opposite direction.

I argued that it is important to distinguish between sources of changes in income skewness. In a model with imperfect information, rising polarization and upward mobility, though having the same effect on income skewness, affect redistribution in different ways.

I presented a model of direct democracy under imperfect information in which the relation between the mean-to-median income ratio and redistribution depends on the sources of changes in income skewness. While rising polarization generates a positive relation between income skewness and redistribution, upward mobility can have the opposite effect.

The mechanism leading to this non-standard result model works through the existence of extreme voter groups that can lead to a median voter with biased beliefs. Increases in income skewness lead to stronger redistribution sought by the middle class. However, if voting power is shifted to richer population groups, the position of the median voter moves towards voting for fewer redistribution. For informational imperfections pronounced enough, the second effect dominates. Then, the model generates a relationship between the mean-to-median income ratio and the extent of redistribution that would seem anomalous in light of standard voting models.

Appendix

Individual labor supply. At this stage, an agent i chooses consumption c_i and labor supply n_i to maximize utility (2.1) subject to the budget constraint

$$c_i = (1-\tau) \cdot a_i \cdot n_i + \tau \cdot y, \tag{2.23}$$

which is a combination of (2.2) and (2.3). Denoting the Lagrange multiplier on the budget constraint as λ_i, the first-order conditions are

$$\begin{aligned} 1 - \lambda_1 &= 0 \\ -\phi n_i + \lambda_1 \cdot (1-\tau) \cdot a_i &= 0, \end{aligned}$$

respectively. Combining the two conditions gives optimal labor supply $n_i = \phi^{-1} \cdot (1-\tau) \cdot a_i$ as in equation (2.6).

Aggregate income. To determine aggregate income (2.7), individual labor-supply decisions (2.6) are aggregated in the following way:

$$\begin{aligned} y &= \int a_i n_i \, \mathrm{d}i \\ &= \phi^{-1} \cdot (1-\tau) \cdot \int (a_i)^2 \, \mathrm{d}i \\ &= \phi^{-1} \cdot (1-\tau) \cdot \left[s_L \cdot 0^2 + s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2 \right] \\ &= (1-\tau) \cdot \frac{1}{\phi} \cdot \left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2 \right] \end{aligned}$$

Voting decision. At this stage, an agent i chooses a tax rate τ_i to maximize expected utility $E_i \left[c_i - \frac{\phi}{2} (n_i)^2 \right]$ subject to the buget constraint (2.23), equations (2.6) and (2.7) capturing optimal subsequent behavior of all agents, the condition $\tau = \tau_i$ capturing the sincerity of the voting decision, and $0 \leq \tau_i \leq 1$. Substituting the equality constraints into the problem, the Lagrangean reads as

$$\begin{aligned} \mathcal{L}_i = {} & (1-\tau_i)^2 \cdot (a_i)^2 \cdot \phi^{-1} + \tau_i \cdot (1-\tau_i) \cdot \phi^{-1} \cdot E_i \left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2 \right] \\ & - \frac{\phi}{2} \left(\phi^{-1} (1-\tau_i) \, a_i \right)^2 + \eta_i \cdot \tau_i + \nu_i \cdot [1-\tau_i] \, , \end{aligned}$$

where η_i and ν_i are the Lagrange multipliers on the inequality constraints. All agents know that the term $s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2$ is positive but less than $(a_2)^2$ since condition (2.4) and group sizes are common knowledge, i.e. $0 < E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] < (a_2)^2\ \forall i$. The derivative of the Lagrangean with respect to τ_i is

$$\begin{aligned}\frac{\partial \mathcal{L}_i}{\partial \tau_i} = & -2 \cdot (1-\tau_i) \cdot (a_i)^2 \cdot \phi^{-1} \\ & + (1-2\tau_i) \cdot \phi^{-1} \cdot E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] \\ & + \phi^{-1} \cdot (1-\tau_i) \cdot (a_i)^2 + \eta_i - \nu_i.\end{aligned}$$

First note that the inequality constraint $\tau_i \leq 1$ is never binding. If it were binding, $\tau_i = 1$ and $\nu_i > 0$, then the derivative of the Lagrangean would evaluate as $\partial \mathcal{L}_i / \partial \tau_i = -\phi^{-1} \cdot E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] - \nu_i < 0$, i.e. this can not be an optimizer. Therefore it holds for all agents that $\nu_i = 0$ and $\tau_i < 1$ in the optimum.

The second inequality constraint, $\tau_i \geq 0$, can be binding. If it is binding, $\tau_i = 0$ and $\eta_i > 0$, then the derivative of the Lagrangean evaluates as $-2 \cdot (a_i)^2 \cdot \phi^{-1} + \phi^{-1} \cdot E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] + \phi^{-1} \cdot (a_i)^2 + \eta_i = \phi^{-1}\left\{E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] - (a_i)^2\right\} + \eta_i$. With $\eta_i > 0$, this expression can only be zero when

$$E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right] < (a_i)^2. \tag{2.24}$$

Since it is sure that $(a_2)^2 > s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2$, this is fulfilled for agents in group H. Agents in this group therefore vote for zero redistribution as stated in equation (2.14).

Condition (2.24) is not fulfilled for agents in group L having zero productivity. These agents thus vote for positive redistribution. With $a_i = 0$ and $\nu_i = 0$, the derivative of the Lagrangean simplifies to

$$(1-2\tau_i) \cdot \phi^{-1} \cdot E_i\left[s_M \cdot (a_1)^2 + s_H \cdot (a_2)^2\right],$$

which is zero for $\tau_i = 1/2$. $\tau_i = 1/2$ is therefore the optimal vote for agents in this group as stated in equation (2.10).

For agents in group M having productivity a_1 and expectation $E_i (a_2)^2 = E_i\alpha \cdot a_1$, condition (2.24) is fulfilled if and only if $s_M + s_H E_i\alpha < 1$. If this is the case, agents in this group vote for zero redistribution, otherwise they vote for positive redistribution. Therefore the voting decision of agents in this group involves a case distinction. If $s_M + s_H E_i\alpha \geq 1$, the inequality constraint $\tau_i \geq 0$ is not binding for agents in group M.

Then, with $E_i\,(a_2)^2 = E_i\alpha{\cdot}a_1$, the derivative of the Lagrangean simplifies to

$$(a_i)^2\left\{(1-\tau_i)\cdot\phi^{-1}+(1-2\tau_i)\cdot\phi^{-1}\cdot[s_M+s_HE_i\alpha]\right\},$$

which is zero for $\tau_i = \frac{1-(s_M+s_HE_i\alpha)}{1-2(s_M+s_HE_i\alpha)}$. Since this expression is negative when the inequality constraint $\tau_i \geq 0$ is binding, the optimal vote for agents in group M can be expressed by $\tau_i = \max\left[\frac{1-(s_M+s_HE_i\alpha)}{1-2(s_M+s_HE_i\alpha)}, 0\right]$ as stated in equation (2.12).

Chapter 3

Inattentive Voters and Welfare-State Persistence

3.1 Introduction

It is a frequently expressed view that the political process features an asymmetry between the speed of implementations and the speed of removals of welfare-state arrangements. Reforms enhancing the size of the welfare state seem easily and quickly implemented while opposite reforms face stronger opposition. Welfare-state measures thus tend to persist. This chapter[1] offers an information-based explanation for such welfare-state persistence.

Many authors agree that the welfare state is persistent.[2] Lindbeck (2003, page 20) studies welfare-state dynamics and observes "certain asymmetries between the politics of expansion and retreat". Hassler, Rodríguez Mora, Storesletten, and Zilibotti (2003) describe welfare-state persistence after the great depression. They observe that the great depression led to increased public intervention in the US, the UK, France, and Italy. After the economies had recovered, however, public intervention did not diminish. Brooks and Manza (2004) find similar patterns in welfare-state dynamics of several OECD countries at the end of the

[1] The chapter is based on Bredemeier (2010b).

[2] See e.g. Gavin and Perotti (1997), Agell (2002), Lindbeck (2003), Hassler, Rodríguez Mora, Storesletten, and Zilibotti (2003), Hercowitz and Strawczynski (2004), Brooks and Manza (2004), Balassone, Francese, and Zotteri (2009), and Beetsma, Cukierman, and Giuliodori (2009).

twentieth century. They summarize that "welfare states within most developed democracies appear quite resilient in the face of profound shifts in their national settings" (page 1).

The contribution of this chapter is to offer a new explanation for welfare-state persistence which is based on the effects of the welfare state on attentiveness. Since the welfare state crowds out private financial precautions, it also reduces incentives to inform oneself about economic fundamentals such as life expectancy or invalidity risk. These fundamentals do not only influence private decisions on savings or insurance but also determine the optimal social choice regarding welfare-state arrangements.

The frequency with which people inform themselves about fundamentals depends on their level of private financial precaution and the incentives for private precaution depend on welfare-state arrangements. If the degree of social insurance is low (high), people engage much (little) in private financial activity such as savings. Therefore, they also inform themselves frequently (rarely) about fundamentals. Consequently, if initial welfare-state arrangements are low, a change in fundamentals is quickly noticed by a majority of society and translated into appropriate policies. By contrast, the political delay is long when welfare-state arrangements are pronounced.

This reasoning relies on the presence of information (or rationality) costs. Information costs can take the form of real resource costs, utility costs, or cognitive difficulties at any stage in the process between observing an information and the implementation of the appropriate response (Sims 2003; Mankiw and Reis 2010). Even with perfect information available, decisions may appear as if agents had imperfect information in the first place, for instance if agents choose not to use all information, have difficulties figuring out the appropriate response, or make mistakes while translating decisions into behavior.

The importance of informational imperfections in democratic decision making has been stressed by Downs (1957). Downs pointed out that even small information costs can lead voters to be rationally ignorant and cause pronounced uncertainty about issues important for the optimal vote. In political sciences, it is a common view that voters are usually poorly informed about relevant political measures, see e.g. Lupia (1994) and McDermott (1997). In economics, many papers have studied voting behavior under uncertainty, mostly theoretically.[3]

In the model presented in this chapter, optimal social choices depend on stochastic fundamentals. Voters have no incentive to inform themselves about these fundamentals for political purposes because the importance of any individual vote is negligible. But agents seek information about fundamentals in order to improve their private savings decision. The incentives to save and thus the incentives to inform oneself are, in turn, affected by social choices.

Agents have an exogenous and uncertain income stream and decide upon savings. Due to the absence of a private insurance market, there is a precautionary motive for savings. Agents face a risk of receiving no market income in future periods but the probability of this event is a random variable itself. Thus, the risk of receiving no market income is an unknown fundamental in the model which determines optimal savings.

In the political process, agents decide whether to vote in favor of a social insurance. Agents are ex ante identical such that there is no distributional motive of social insurance. However, there is potential demand for social insurance since agents have no access to a private insurance market. The stochastic income risk is also a determinant of the optimal social choice because it determines the future dependency ratio.

Next to the savings and voting choices, a third decision of agents is a costly and active choice whether to inform themselves about income risk. Doing so improves both the savings and the voting decision but agents only value the private benefit of improved savings and do not internalize the social benefit of their attentiveness. Thus, the information choice is only affected by the incentives for private savings which are weakened by social insurance.

There are two theoretical concepts for modelling costly and active information choice in a dynamic framework. In the theory of inattention (Sims 2003), agents decide on the precision of the information they acquire in any instant of time, while the theory of inattentiveness (Reis 2006a; Reis 2006b) models agents' decisions on the timing of their infrequent acquirement of perfect information. In the model presented in this chapter, the concept of inattentiveness is used.

[3] See e.g. Feddersen and Pesendorfer (1997), Myerson (1998), Shotts (2006), Gershkov and Szentes (2009), and Taylor and Yildirim (2010).

Empirical support for the inattentiveness hypothesis is provided by Lusardi (1999) and Ameriks, Caplin, and Leahy (2003) who report survey evidence that respondents only infrequently react to news and update plans. Carroll (2003) and Mankiw, Reis, and Wolfers (2004) analyze survey data on expectations and find that news disseminate slowly throughout the economy.[4] Alternatively, similar observations would be made if agents had full information but faced a cost of changing behavior. Mullainathan and Washington (2009) provide evidence that voters tend to process information in a biased way such as to confirm previous voting decisions. Experimental evidence suggests that such behavior is only given up when incentives are high enough (Festinger and Carlsmith 1959).

Agents in the model are rationally inattentive, i.e. they inform themselves infrequently about the state of the world but, if so, perfectly. When not informing themselves, agents remain completely inattentive and receive no new information at all. The model economy shifts between two aggregate states of the world with different levels of income risk. I consider a situation where social insurance is socially beneficial in only one of the two states. When agents believe this one to be the current state of the world, they vote in favor of social insurance. When social insurance is implemented, private savings are lower and, consequently, agents remain inattentive for longer periods of time. As a result, the removal of social insurance when a change in the state has made it suboptimal takes, in expectation, longer than the implementation of social insurance after a change in the state that makes the welfare state optimal.

Other papers have proposed explanations for welfare-state persistence under perfect information. One branch of the literature relates the phenomenon to changes in people's preferences. Lindbeck (1995) and Lindbeck and Weibull (1999) argue that welfare-state persistence is due to gradual changes in social norms regarding the perception of transfer recipients in society. In political sciences, welfare-state persistence is often attributed to changes in "policy preferences" (see e.g.

[4] Indirect empirical support for the inattentiveness hypothesis is provided by many papers showing that inattentiveness helps to explain seemingly anomalous aggregate phenomena on financial markets (DellaVigna 2009; DellaVigna and Pollet 2009) and regarding macroeconomic dynamics (Ball, Mankiw, and Reis 2005; Reis 2006a; Reis 2006b).

Brooks and Manza 2004). Another line of argument builds on changes in distributional conflicts. Agell (2002) argues that welfare states resist the pressures of globalization because globalization not only increases the efficiency costs of the welfare state but also increases the distributional conflict so that some voters' demand for welfare-state measures increases. Hassler, Rodríguez Mora, Storesletten, and Zilibotti (2003) offer an explanation based on the effects of redistribution on the future income distribution. In their paper, persistence arises from the fact that even temporary welfare-state measures affect incentives in a way generating a distributional conflict in the future. This in turn generates a sustained demand for the continuation of the welfare state. Beetsma, Cukierman, and Giuliodori (2009) present a framework where a median voter bargains with a richer politician. Their explanation for welfare-state persistence is that temporary increases in taxes increase the bargaining power of the median voter who afterwards enforces increased redistribution.

In my model, preferences are stable and there is no distributional conflict since agents are ex-ante identical. The persistence of the welfare state stems from the fact that it crowds out private financial precaution and with it attentiveness to changes in the environment. That a social-insurance system crowds out private financial precaution has been modeled by e.g. Rust and Phelan (1997). Empirical evidence supporting this hypothesis is provided by Bird (2001).

Some papers have studied voting on welfare-state measures under uncertainty about an underlying state of the world and a given information structure. For example, Dhami (2003) analyzes voting on redistribution in a model of representative democracy where voters have asymmetric but given information. Laslier, Trannoy, and van der Straeten (2003) and Hansen (2005) study majority-voting models of redistribution with imperfect information. In Dhami (2003) and Hansen (2005), the information structure is exogenously given, while, in Laslier, Trannoy, and van der Straeten (2003), it is endogenous but taken as given by agents. By contrast, in the model presented in this chapter, agents face an active information choice. Finally, the work presented in this chapter is related to the literature on the determination of social insurance in voting models, see Persson (1983) and Wright (1986).

The remainder of the chapter is organized as follows. Section 3.2 presents the model. In Section 3.3, the model is solved for individual decisions of agents. Section 3.4 describes the aggregate dynamics of the model. Section 3.5 concludes.

3.2 The Model

In the model, agents take intertemporal decisions under uncertainty. The economy is subject to two frictions. First, information is only available at a cost such that agents will rationalize on information. Second, there is a lack of a private insurance market such that there is a precautionary motive for savings and, in principle, demand for distortionary social insurance. In the political process, agents balance expected costs and benefits of social insurance based on their potentially imperfect information.

The model economy is an endowment economy which is populated by a mass-1 continuum of dynasties. A dynasty consists of an infinite stream of agents who live for two periods each. Each dynasty has one member in each generation. Generations overlap but do not interact with each other due to the absence of capital and factor markets. However, generations are linked through the transmission of information. Specifically, each agent receives all information her dynasty has at the beginning of her life.

Thus, each generation t consists of a mass-1 continuum of agents who live for two periods, t and $t+1$. Agents maximize

$$E_{i,t}\left[U_{i,t}\right] = E_{i,t}\left[u\left(c_{i,t,t}\right) + \beta \cdot u\left(c_{i,t,t+1}\right)\right] - \kappa \cdot d_{i,t}, \tag{3.1}$$

where $U_{i,t}$ is the lifetime utility of agent i in generation t, $c_{i,t,t}$ denotes this agent's consumption in period t, and $c_{i,t,t+1}$ is consumption of the agent in period $t+1$. $E_{i,t}$ denotes the statistical expectation operator conditional on information available to agent i of generation t. $d_{i,t}$ is an indicator variable describing the choice of the agent whether to be attentive to new information. κ is a fixed utility cost of acquiring new information.

This cost κ can be understood as the cost of obtaining information, processing and interpreting it. It may arise because agents find the process annoying or frustrating. Reis (2006a) argues that while some information may be observed at little cost, the costs of understanding it and determining the optimal response can be quite substantial. Likewise this cost could be modelled as a resource cost capturing e.g. payments to a financial advisor or as opportunity costs of time.

A rate of time preference, β, is included in equation (3.1) for convenience. To facilitate the exposition, I impose the parameter restriction $\beta = 1$. This restriction does not affect the qualitative results of the model because political choices do not apply to intertemporal transfers in this model.

For analytical tractability, I will use a specific functional form for period utility,

$$u\left(c_{i,t,t+h}\right) = 4 \cdot c_{i,t,t+h} - \left(c_{i,t,t+h}\right)^2 \tag{3.2}$$

where $h = 0, 1$.[5] This utility function exhibits linear marginal utility, $u'\left(c_{i,t,t+h}\right) = 4 - 2 \cdot c_{i,t,t+h}$, and constant curvature, $u''\left(c_{i,t,t+h}\right) = -2$. Under the model set-up described below, the maximal amount of consumption in a period is $c_{i,t,t+h} = 2$. Therefore, the utility function exhibits positive and decreasing marginal utility for all relevant levels of consumption.

In the first period of their life, agents receive a deterministic gross income $y_{i,t,t}$ normalized to one,

$$y_{i,t,t} = 1. \tag{3.3}$$

Income in the second period of life is stochastic. With probability $1-\pi_t$, a generation-t agent will receive a gross income of 1 also in period $t+1$. With probability π_t, agent i of generation t will receive an income of 0 in period $t+1$,

$$y_{i,t,t+1} = \begin{cases} 1, & \text{prob. } 1-\pi_t \\ 0, & \text{prob. } \pi_t \end{cases}. \tag{3.4}$$

In the following, I will refer to agents receiving a positive gross income in the second period as "lucky" while agents with zero income in the second period will be called "unlucky".

The risk of receiving no income in the second period of life, π_t, follows an exogenous stochastic process. In particular, π_t can take two values, π^h and π^l, $\pi^h > \pi^l$. Thus there are two states of the world, a "good" one with low income risk and a "bad" one where income risk is high.

State changes occur with an exogenous probability $\lambda < \frac{1}{2}$ at any period, i.e. they follow a Bernoulli process with Bernoulli parameter

[5] It is common to assume linear-quadratic (Hassler, Storesletten, and Zilibotti 2003; Chen and Song 2009) or quasi-linear (Tabellini 2000; Borck 2007) preferences in dynamic political-choice models in order to ensure tractability.

λ. Thus, the stochastic process for π can be described as a two-state Markov process with transition matrix Λ, given by

$$\Lambda = \begin{bmatrix} 1-\lambda & \lambda \\ \lambda & 1-\lambda \end{bmatrix}. \tag{3.5}$$

Income risk in period t is the same as k periods ago when the number of state changes between these two periods, denoted by $N(t-k,t)$, is even. Note that π_t is a generation-wide variable determining the risk for each member of generation t to receive no income in period $t+1$. This risk is the same for all members of the generation and is determined between periods $t-1$ and t.

For agents, there are two ways to cope with income risk, private (precautionary) savings and social insurance. There is no private insurance market. Agents have the possibility to save at a gross interest rate of 1, i.e. generation t agent i can store an amount $s_{i,t}$ of his income from period t to period $t+1$. Furthermore, each generation t can decide to implement social insurance. If so, the government evens out income differences perfectly. Specifically, it collects incomes from all lucky agents and redistributes incomes equally among the members of the generation. Thus, the contribution of the lucky agents is $\tau_t = 1$ when there is social insurance. It is assumed that the amount of total resources is lower in the presence of social insurance. This may capture disincentive effects or government inefficiency, which is modeled in a short-cut way for simplicity. From every unit of contributions collected, the government can only redistribute $e < 1$ units. If a generation decides against social insurance, I will capture this formally as a contribution of zero, $\tau_t = 0$.

The implementation of social insurance by a generation applies to both periods of the generation's life. In the first period, social insurance is a waste of resources since agents are still identical and thus pay the same contributions and receive the same transfer. However, in the second period, social insurance reduces income risk at the price of lower expected income. Formally, net income $x_{i,t,t}$ of an agent i of generation t in the first period of her life is given by

$$x_{i,t,t} = 1 - (1-e)\,\tau_t \tag{3.6}$$

and net income $x_{i,t,t+1}$ in the second period of her life is given by

$$x_{i,t,t+1} = \begin{cases} 1 - \tau_t + (1-\pi_t)\,e\tau_t, & \text{prob. } 1-\pi_t \\ (1-\pi_t)\,e\tau_t, & \text{prob. } \pi_t \end{cases}, \tag{3.7}$$

where τ_t is the contribution implemented by generation t and can be either one or zero. Equations (3.6) and (3.7) capture both political environments. When there is social insurance, $\tau_t = 1$, then first-period net income is $x_{i,t,t} = e$ and net income in the second period is $x_{i,t,t+1} = (1 - \pi_t)\, e$ independent of the agent's individual draw of gross income. In the absence of social insurance, $\tau_t = 0$, the agent receives net income $x_{i,t,t} = 1$ in period t and his second-period net income is either 0 or 1.

Agent i of generation t faces the following budget constraint in her first period of life:

$$c_{i,t,t} + s_{i,t} \leq x_{i,t,t}. \tag{3.8}$$

Thus, consumption and savings may not succeed her net income. In the second period consumption may not exceed net income plus savings,

$$c_{i,t,t+1} \leq x_{i,t,t+1} + s_{i,t}. \tag{3.9}$$

Political choices are decided by direct democracy. Each generation t decides upon whether to implement social insurance, i.e. $\tau_t = 1$, or not, i.e. $\tau_t = 0$, by a direct vote over these two opportunities. The vote takes place in a general, free, and secret ballot. All agents in generation t participate in this vote. Furthermore, I assume that agents vote truthfully in the sense that they vote for their individual expected-utility maximizing τ_t.[6] The vote of agent i of generation t is denoted by $\tau_{i,t} \in \{0, 1\}$.

Individual and public choices depend on income risk π_t. However, agents can not costlessly monitor the process determining π_t. In any period t, agents can decide to obtain perfect information about π_t and to accept a fixed utility cost κ. If an agent decides not to obtain the information, she will be said to be inattentive. Every agent transmits the information she has to the next member of her dynasty.

The time structure within periods is as follows. Prior to period t, income risk π_t for generation t is determined according to the transition matrix (3.5). In this period t, an agent of generation t first receives information from the member of her dynasty in generation $t - 1$. Second, she takes part in the referendum on the implementation of social insurance of her generation. Third, the agent decides whether or not

[6] Since any single voter has zero mass in this model, I abstain from analyzing strategic voting behavior and assume "sincere" (Bearse, Cardak, Glomm, and Ravikumar 2009) or "naive" (Feddersen and Pesendorfer 1997) voting instead.

to obtain complete information on income risk π_t. Fourth, the agent receives net income $x_{i,t,t}$, decides how much to save, and consumes the remaining part of her income.

In the second period of her life, the agent first bequeaths information to a member of generation $t+1$. After this, she observes and receives her net income $x_{i,t,t+1}$, and consumes. The timing of events is illustrated in Figure 3.1.

Agents' decisions are determined by (potentially perfect) beliefs about the state of the world. Since agents have the possibility to update their beliefs, one has to distinguish between prior and posterior beliefs. Posterior and prior beliefs are labeled by different time indices. The time index $t+$ refers to beliefs after the updating decision in period t, whereas the time index t refers to the time in period t before the updating decision. An agent's prior belief can be represented by the probabilities the agent assigns to the two possible states of the world, $p_{i,t}^h = prob_{i,t}\left[\pi_t = \pi^h\right]$ and $1 - p_{i,t}^h = prob_{i,t}\left[\pi_t = \pi^l\right]$, where $prob_{i,t}\left[\cdot\right]$ denotes the probability of the event in the brackets conditional on information available to agent i of generation t before the updating decision. Analogously, $p_{i,t+}^h = prob_{i,t+}\left[\pi_t = \pi^h\right]$ denotes the agent's posterior belief. When the agent decides to be attentive, she will know the state of the world for sure after updating, i.e. $p_{i,t+}^h = 1$ or $p_{i,t+}^h = 0$ then. By contrast, when the agent decides to be inattentive, then $p_{i,t+}^h = p_{i,t}^h$ and the posterior belief can take any value between zero and one. The timing of the belief formation can be seen from Figure 3.1.

To summarize, a formal description of the decision problem is as follows: Agent i of generation t chooses $\tau_{i,t} \in \{0,1\}$, $d_{i,t} \in \{0,1\}$, $s_{i,t} \in [0, x_{i,t}]$ sequentially such as to maximize (3.1) subject to (3.8), (3.9), the information constraints described above and as if $\tau_t = \tau_{i,t}$ capturing the sincerity of the voting decision.

Thus the decision problem of an individual agent includes three decision stages and a first stage where prior beliefs are determined. From stage to stage, the information set of the agent can change. Since I will solve the problem by backward induction, I summarize the different stages starting with the last one in the temporal ordering but the first one to be solved:

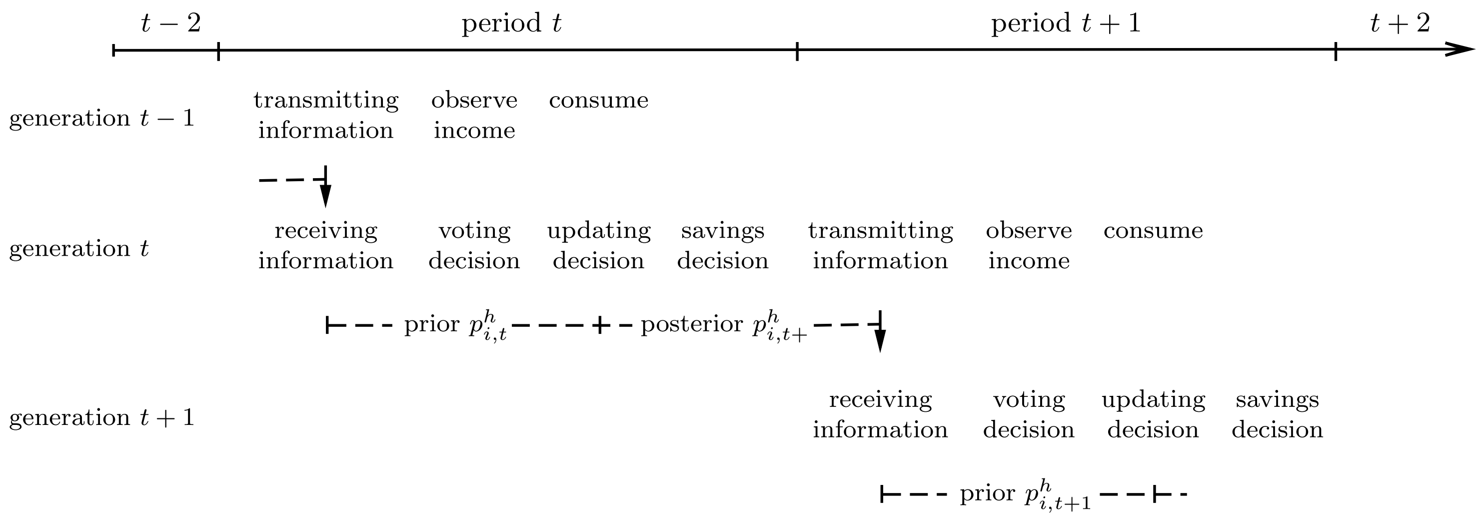

Figure 3.1: The timing of events and beliefs.

1. **Savings decision:** At the final stage, the agent chooses $s_{i,t}$ to maximize $E_{i,t}[U_{i,t}]$ based on (potentially perfect) *posterior beliefs* $p^h_{i,t+}$ about the state of the world and *knowing* whether there is social insurance or not. Potential updating costs are sunk at this stage.

2. **Updating decision:** At this stage, the agent chooses whether to update information in order to maximize expected indirect utility (taking into account optimal subsequent savings) having some *prior beliefs* $p^h_{i,t}$ about the state of the world and *knowing* whether there is social insurance. When the agents decides not to update, prior and posterior beliefs are identical, $p^h_{i,t+} = p^h_{i,t}$.

3. **Voting decision:** At this decision stage, the agent decides whether to vote in favor of social insurance in order to maximize expected indirect utility (taking into account optimal subsequent updating and savings) having some *prior beliefs* $p^h_{i,t}$ about the state of the world.

4. **Belief formation:** Prior to all decisions, the agent calculates subjective probabilities of the two states of the world, $p^h_{i,t}$ and $1 - p^h_{i,t}$, based on the received information.

3.3 Individual Decisions

In this section, I derive the decisions of an agent i of generation t, in short agent (i, t). Decisions of an agent depend only on her beliefs $p^h_{i,t}$ and $p^h_{i,t+}$. Thus agents with identical beliefs make identical decisions. This is the case because income in the second period of life, which is a source of heterogeneity, realizes after all decisions are taken.

3.3.1 Savings decision

When deciding upon individual savings, $s_{i,t}$, an agent i of generation t knows whether her generation has implemented social insurance. The agent furthermore has some belief about the current level of income risk. Since the updating decision has already taken place at this stage, the relevant belief is the posterior belief $p^h_{i,t+}$. If the agent has decided to be attentive, she knows the value of π_t for sure, i.e. $p^h_{i,h+} = 1$ or $p^h_{i,h+} = 0$. If the agent has decided to remain inattentive to news, the belief is uncertain and reflects the received information about past income risk and its precision as a signal about current income risk.

At this stage, updating costs are already sunk. The agent seeks to maximize

$$E_{i,t+}\widetilde{U}_{i,t} = E_{i,t+}\left[u\left(c_{i,t,t}\right) + u\left(c_{i,t,t+1}\right)\right], \tag{3.10}$$

which defines $\widetilde{U}_{i,t}$, based on the posterior belief $p^h_{i,t+}$ by choosing individual savings, $s_{i,t}$, subject to the two period budget constraints (3.8) and (3.9). Substituting constraints, the decision problem at this stage can be written as

$$\max_{s_{i,t}} E_{i,t+}\left[u\left(x_{i,t,t} - s_{i,t}\right) + u\left(x_{i,t,t+1} + s_{i,t}\right)\right].$$

In this expression, $x_{i,t,t+1}$ is stochastic and can take four values: If the state of the world is good, i.e. $\pi_t = \pi^l$, the agent can end up lucky and her net income in period $t+1$ is

$$x_{i,t,t+1} = x^{l,L} = 1 - \tau_t + \left(1 - \pi^l\right) e\tau_t. \tag{3.11}$$

However, the agent can end up unlucky even if the state of the world is good, then

$$x_{i,t,t+1} = x^{l,U} = \left(1 - \pi^l\right) e\tau_t. \tag{3.12}$$

If the state of the world is bad, i.e. $\pi_t = \pi^h$, lucky agents end up with a net income of

$$x^{h,L} = 1 - \tau_t + \left(1 - \pi^h\right) e\tau_t, \tag{3.13}$$

while unlucky agents receive

$$x^{h,U} = \left(1 - \pi^h\right) e\tau_t \tag{3.14}$$

in this case.[7]

Expected utility depends on the probabilities the agent assigns to these four scenarios. For instance, the agent believes to receive $x^{l,L}$ with the probability of having luck conditional on the state of the world being

[7]Equations (3.11) to (3.14) simplify in both political regimes. If there is social insurance, then $x^{l,L} = x^{l,U} = \left(1 - \pi^l\right) e$ and $x^{h,L} = x^{h,U} = \left(1 - \pi^h\right) e$. By contrast, in the absence of social insurance it holds that $x^{l,U} = x^{h,U} = 0$ and $x^{l,L} = x^{h,L} = 1$.

good multiplied with the probability the agent assigns to the good state of the world,

$$\begin{aligned} prob_{i,t+}\left[x_{i,t,t+1}=x^{l,L}\right] &= prob_{i,t+}\left[y_{i,t,t+1}=1|\pi_t=\pi^l\right]\cdot prob_{i,t+}\left[\pi_t=\pi^l\right] \\ &= \left(1-\pi^l\right)\cdot\left(1-p^h_{i,t+}\right). \end{aligned} \tag{3.15}$$

Analogously, we can calculate

$$prob_{i,t+}\left[x_{i,t,t+1}=x^{l,U}\right]=\pi^l\cdot\left(1-p^h_{i,t+}\right), \tag{3.16}$$

$$prob_{i,t+}\left[x_{i,t,t+1}=x^{h,L}\right]=\left(1-\pi^h\right)\cdot p^h_{i,t+}, \tag{3.17}$$

$$prob_{i,t+}\left[x_{i,t,t+1}=x^{h,U}\right]=\pi^h\cdot p^h_{i,t+}. \tag{3.18}$$

If the agent has chosen to be attentive, two of these probabilities (either (3.15) and (3.16) or (3.17) and (3.18)) are zero.

Using these subjective probabilities, the decision problem becomes

$$\max_{s_{i,t}} u\left(1-(1-e)\,\tau_t-s_{i,t}\right)+\begin{bmatrix}\left(1-\pi^l\right)\cdot\left(1-p^h_{i,t+}\right)\cdot u\left(x^{l,L}+s_{i,t}\right)\\ +\pi^l\cdot\left(1-p^h_{i,t+}\right)\cdot u\left(x^{l,U}+s_{i,t}\right)\\ +\left(1-\pi^h\right)\cdot p^h_{i,t+}\cdot u\left(x^{h,L}+s_{i,t}\right)\\ +\pi^h\cdot p^h_{i,t+}\cdot u\left(x^{h,U}+s_{i,t}\right)\end{bmatrix}.$$

The first-order condition for this problem is

$$u'\left(1-(1-e)\,\tau_t-s_{i,t}\right)=\begin{bmatrix}\left(1-\pi^l\right)\cdot\left(1-p^h_{i,t+}\right)\cdot u'\left(x^{l,L}+s_{i,t}\right)\\ +\pi^l\cdot\left(1-p^h_{i,t+}\right)\cdot u'\left(x^{l,U}+s_{i,t}\right)\\ +\left(1-\pi^h\right)\cdot p^h_{i,t+}\cdot u'\left(x^{h,L}+s_{i,t}\right)\\ +\pi^h\cdot p^h_{i,t+}\cdot u'\left(x^{h,U}+s_{i,t}\right)\end{bmatrix} \tag{3.19}$$

which is a consumption Euler equation for the case where the product of the rate of time preference and the gross interest rate is one. Marginal utility in the first period then equals expected marginal utility in the next period.

For the functional form of period utility (3.2), the consumption Euler equation can be solved analytically for savings. The optimal amount of savings for agent i of generation t equalizes expected consumption in the two periods.

In generations without social insurance, i.e. for $\tau_t=0$, optimal savings,

$$s_{i,t}|_{\tau_t=0}=\frac{\pi^e_{i,t+}}{2}, \tag{3.20}$$

depend only on expected income risk $\pi^e_{i,t+} = \left(1 - p^h_{i,t+}\right) \cdot \pi^l + p^h_{i,t+} \cdot \pi^h$. Savings increase with the expected income risk $\pi^e_{i,t+}$ which reflects the precautionary motive of savings. When generation t has decided in favor of social insurance, i.e. for $\tau_t = 1$, optimal savings are given by

$$s_{i,t}|_{\tau_t=1} = \frac{e \cdot \pi^e_{i,t+}}{2} \tag{3.21}$$

and depend on the level of government efficiency e. It is important that, since $e < 1$, savings are lower when there is social insurance. This implies that having better information when choosing savings has a smaller impact on lifetime utility in the presence of social insurance.[8]

At the updating decision, the agent takes into account the optimal subsequent savings behavior. Therefore it is useful to determine expected indirect lifetime utility net of updating costs which is determined by the solution to the optimization problem for savings. This expected indirect utility is a function of individual beliefs and the political regime. Individual beliefs are perfectly described by the probability assigned to the bad state, $p^h_{i,t+}$ and the political regime is perfectly described by the contribution rate τ_t. It is not necessary to distinguish between the states "attentive" and "inattentive" because the state "attentive" is a special case where $p^h_{i,t+}$ is either one or zero. I will denote expected indirect lifetime utility net of updating costs by $\widetilde{V}\left(p^h_{i,t+}\right) := E_{i,t+}\left[\widetilde{U}_{i,t} \mid \tau_t = 0\right]$ for the case of no social insurance and $\widetilde{W}\left(p^h_{i,t+}\right) := E_{i,t+}\left[\widetilde{U}_{i,t} \mid \tau_t = 1\right]$ for the case of social insurance.

Expected indirect lifetime utilities net of updating costs, $\widetilde{V}$ and $\widetilde{W}$, are derived in the following way. First, the optimal savings decision (3.20), or (3.21) respectively, together with the budget constraints (3.8) and (3.9) are used to determine the respective consumption levels in period t and the possible consumption levels in period $t+1$. Since consumption in period $t+1$ is stochastic, the subjective probabilities (3.15) to (3.18) are used to determine expected utility in period $t+1$. Finally, expected lifetime utility net of updating costs is given by the sum of the expected period utilities, according to equation (3.10).

When there is no social insurance, i.e. $\tau_t = 0$, expected indirect

[8] Equations (3.20) and (3.21) are derived in Appendix 3.A.

lifetime utility is given by

$$\widetilde{V}\left(p^h_{i,t+}\right) = 6 - 3\pi^e_{i,t+} + \frac{\left(\pi^e_{i,t+}\right)^2}{2} \tag{3.22}$$

and decreases in expected income risk. In the other political state, i.e. with social insurance, $\tau_t = 1$, expected indirect lifetime utility is

$$\widetilde{W}\left(p^h_{i,t+}\right) = 8e - 2e^2 - 2\pi^e_{i,t+}e + \frac{\left(\pi^e_{i,t+}\right)^2 e^2}{2} - e^2\left[E_{i,t+}\left(\pi_t\right)^2\right], \tag{3.23}$$

where $E_{i,t+}\left(\pi_t\right)^2 = \left(\pi^l\right)^2 + p^h_{i,t+}\left(\left(\pi^h\right)^2 - \left(\pi^l\right)^2\right)$. Here, expected indirect utility includes an expectation of the squared income risk because also net income in period $t+1$ depends on π_t, see equation (3.7).[9]

Three properties of the expected indirect utility functions are important for the subsequent analysis. First, both expected indirect utility functions (3.22) and (3.23) are convex in $p^h_{i,t+}$, which can take any value between zero and one,

$$\widetilde{V}''\left(p^h_{i,t+}\right) = \left(\pi^h - \pi^l\right)^2 > 0, \tag{3.24}$$

$$\widetilde{W}''\left(p^h_{i,t+}\right) = e^2\left(\pi^h - \pi^l\right)^2 > 0. \tag{3.25}$$

The convexity implies that there are potential gains from updating because, when knowing π_t for sure, i.e. $p^h_{i,t+} = 0$ or $p^h_{i,t+} = 1$, agents can choose the appropriate savings level and thus improve relative to uncertain income risk.

Second, (3.23) is less convex than (3.22), in the sense that $\widetilde{W}''\left(p^h_{i,t+}\right) < \widetilde{V}''\left(p^h_{i,t+}\right)$. In the presence of social insurance, agents save less and, consequently, the impact of an optimal savings decision on utility is lower. This implies that gains from updating are smaller when there is social insurance.

Third, there are constellations where agents would prefer social insurance only in one state of the world and not in the other, i.e.

$$\widetilde{V}(0) > \widetilde{W}(0), \quad \widetilde{V}(1) < \widetilde{W}(1) \tag{3.26}$$

or

$$\widetilde{V}(0) < \widetilde{W}(0), \quad \widetilde{V}(1) > \widetilde{W}(1). \tag{3.27}$$

[9] Equations (3.22) and (3.23) and their derivatives are derived in Appendix 3.B.

Since the focus of this chapter is on changes between political regimes, I will restrict the analysis to cases where either condition (3.26) or condition (3.27) is satisfied. It depends on the parameterization whether the agent is better off with social insurance when income risk is high or when it is low.[10] Increases in income risk have two counteracting effects on the attractiveness of social insurance. First, rising income risk increases the probability that the agent will be a beneficiary of the social-insurance system and thus makes this welfare-state measure more attractive. Second, rising income risk also affects the dependency ratio decreasing the benefits the agent receives if unlucky in the second period, this second effect makes social insurance less attractive. The results of the model do not depend on which of the two effects dominates. The following illustrations given in figures and examples will refer to the case where condition (3.27) is fulfilled. In this case, agents are better off with social insurance when income risk is low.

When condition (3.26) or (3.27) is fulfilled, there is a unique posterior belief p_+^* where the agent is in expectations equally off in both political regimes. Since $\widetilde{V}$ and $\widetilde{W}$ are strictly convex, there are at most two intersections between the two functions. When condition (3.26) or condition (3.27) is satisfied, the number of intersections between $\widetilde{V}$ and $\widetilde{W}$ on $(0,1)$ is odd. Together, this implies that the two functions intersect exactly once on $(0,1)$. Two expected utility functions (3.22) and (3.23) fulfilling condition (3.27) are illustrated graphically in Figure 3.2.

3.3.2 Updating decision

The agent will update her information whenever her expected indirect utility is higher when doing so. The agent enters this stage of the decision problem with knowledge about the political regime and a prior belief $p_{i,t}^h$ about income risk. In both political regimes, the decision whether to update will depend on the prior belief about income risk. When taking the updating decision, the agent takes into account optimal subsequent behavior.

Figure 3.3 illustrates the solution of the updating decision for the case of $\tau_t = 0$. The agent decides whether to update based on her prior beliefs about income risk, $p_{i,t}^h$. When the agent decides not to update, she

[10]In Appendix 3.B, I present examples for both, conditions (3.26) and (3.27), demonstrating that both these constellations exist.

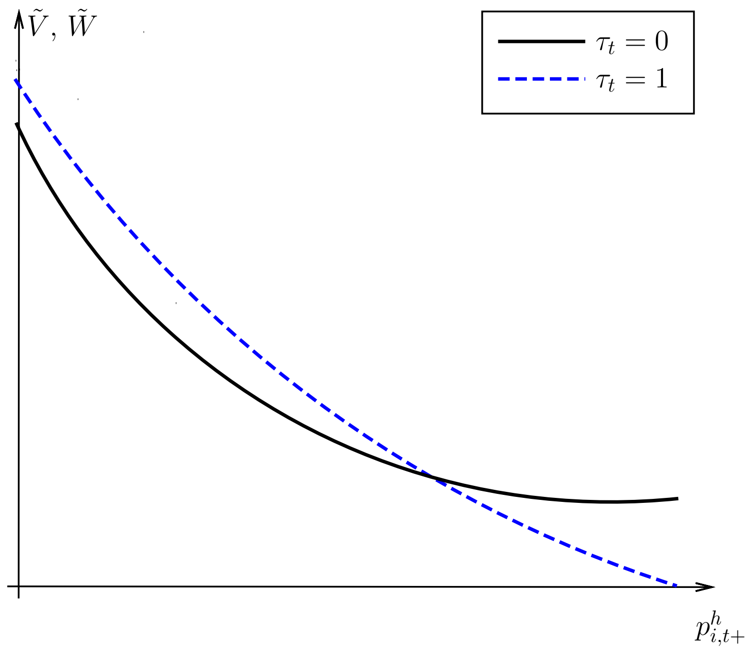

Figure 3.2: Expected indirect utilities net of updating costs from optimal savings in the two political regimes (satisfying condition (3.27)).

will choose a savings level according to her prior belief. Consequently, the agent will then expect to receive a lifetime utility of $\widetilde{V}\left(p^h_{i,t}\right)$ since $p^h_{i,t+} = p^h_{i,t}$ and $d_{i,t} = 0$.

When the agent decides to be attentive, she will know π_t for sure after updating, i.e. $p^h_{i,t+} = 0$ or $p^h_{i,t+} = 1$. The agent will then choose savings individually optimally according to the true income risk. However, in case the agent updates, her lifetime utility is reduced by the updating cost κ. She will then receive either $\widetilde{V}(0) - \kappa$ or $\widetilde{V}(1) - \kappa$. Prior to updating, the agent expects to observe $\pi_t = \pi^h$ with probability $p^h_{i,t}$ and $\pi_t = \pi^l$ with probability $1 - p^h_{i,t}$. Before updating, the agents thus expects a lifetime utility level of $\left(1 - p^h_{i,t}\right) \cdot \widetilde{V}(0) + p^h_{i,t} \cdot \widetilde{V}(1) - \kappa$ in case she updates.

Since $\widetilde{V}$ is convex in $p^h_{i,t+}$, there are potential gains from updating. The agent will decide to update whenever

$$\left(1 - p^h_{i,t}\right) \cdot \widetilde{V}(0) + p^h_{i,t} \cdot \widetilde{V}(1) - \widetilde{V}\left(p^h_{i,t}\right) > \kappa. \tag{3.28}$$

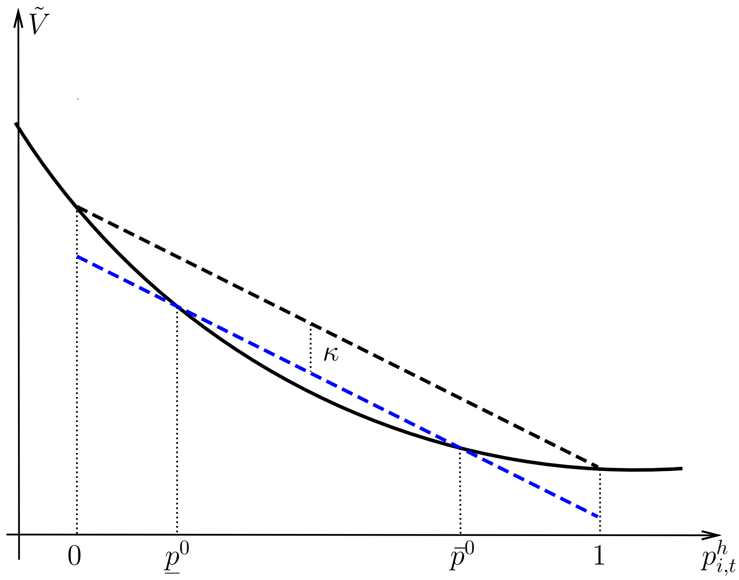

Figure 3.3: Updating decision in the absence of social insurance ($\tau_t = 0$).

Updating costs could be that large that condition (3.28) would never be fulfilled. However, if there is some $p_{i,t}^h \in (0,1)$ for which condition (3.28) is fulfilled, then there is a unique updating range between $\underline{p}^0$ and $\bar{p}^0$, due to the strict convexity of $\widetilde{V}$. Whenever $\tau_t = 0$ and $p_{i,t}^h \in \left(\underline{p}^0, \bar{p}^0\right)$, the agent decides to be attentive and to obtain perfect information about income risk.

In the other political regime, $\tau_t = 1$, the updating decision works equivalently. Here, the agent updates whenever

$$\left(1 - p_{i,t}^h\right) \cdot \widetilde{W}(0) + p_{i,t}^h \cdot \widetilde{W}(1) - \widetilde{W}\left(p_{i,t}^h\right) > \kappa. \tag{3.29}$$

If there is some $p_{i,t}^h \in (0,1)$ for which condition (3.29) is fulfilled, then there is a unique range $\left(\underline{p}^1, \bar{p}^1\right)$ for which (3.29) is fulfilled since also $\widetilde{W}$ is strictly convex.

Due to the constant second derivatives of both $\widetilde{V}$ and $\widetilde{W}$, both updating ranges, if they exist, are symmetric around 1/2. This implies that $\bar{p}^0 = 1- \underline{p}^0$ and $\bar{p}^1 = 1- \underline{p}^1$. This symmetry is the reason why it is not important whether agents prefer social insurance for high or low levels of income risk. The length of the range of beliefs for which the agent remains inattentive depends on the political regime but not on the specific end of the belief support. For instance, in the presence of social insurance, the agent chooses not to update for beliefs in $\left(0, \underline{p}^1\right)$ and for beliefs in $\left(1-\underline{p}^1, 1\right)$. Both ranges have length $\underline{p}^1$.

It is important that the updating range is smaller in the presence of social insurance which is crucial for the different information choices in the two political regimes. This results reflects that, when $\tau_t = 1$, savings are lower and thus choosing savings based on better information has a lower influence on lifetime utility. To show this result formally, note that also the difference function $\widetilde{V} - \widetilde{W}$ is convex in $p^h_{i,t}$ since $\widetilde{V}''\left(p^h_{i,t}\right) > \widetilde{W}''\left(p^h_{i,t}\right)$, see equations (3.24) and (3.25). Thus, the left hand side of (3.28) is always larger than the left hand side of (3.29). Therefore, whenever $p^h_{i,t}$ fulfills condition (3.29), condition (3.28) is also fulfilled. However, there are values of $p^h_{i,t}$ where condition (3.28) is fulfilled but not condition (3.29).

Furthermore, there a values of the information cost κ such that condition (3.28) has a solution on $(0, 1)$ but condition (3.29) has not. If this is the case, the agent would never update on income risk when social insurance is implemented but sometimes do so when there is no social insurance. When condition (3.28) is not fulfilled for any $p^h_{i,t} \in (0, 1)$, then also condition (3.29) is not fulfilled for any $p^h_{i,t}$.

At the voting stage of the decision problem, the agent takes into account optimal subsequent behavior including optimal updating. Therefore, it is useful to determine the expected indirect utility function which arises from optimal savings and optimal updating. I denote this function as $V\left(p^h_{i,t}\right) := E_{i,t}\left[U_{i,t} \mid \tau_t = 0\right]$ for the case of $\tau_t = 0$ and $W\left(p^h_{i,t}\right) := E_{i,t}\left[U_{i,t} \mid \tau_t = 1\right]$ for the case of $\tau_t = 1$. In the absence of social insurance, this function is

$$V\left(p^h_{i,t}\right) = \begin{cases} \widetilde{V}\left(p^h_{i,t}\right), & p^h_{i,t} \notin \left(\underline{p}^0, \bar{p}^0\right) \\ \left(1 - p^h_{i,t}\right) \cdot \widetilde{V}(0) + p^h_{i,t} \cdot \widetilde{V}(1) - \kappa, & p^h_{i,t} \in \left(\underline{p}^0, \bar{p}^0\right) \end{cases}.$$

Analogously, in the presence of social insurance, expected lifetime utility as a function of the agent's belief is

$$W\left(p^h_{i,t}\right) = \begin{cases} \widetilde{W}\left(p^h_{i,t}\right), & p^h_{i,t} \notin \left(\underline{p}^1, \bar{p}^1\right) \\ \left(1 - p^h_{i,t}\right) \cdot \widetilde{W}(0) + p^h_{i,t} \cdot \widetilde{W}(1) - \kappa, & p^h_{i,t} \in \left(\underline{p}^1, \bar{p}^1\right) \end{cases}.$$

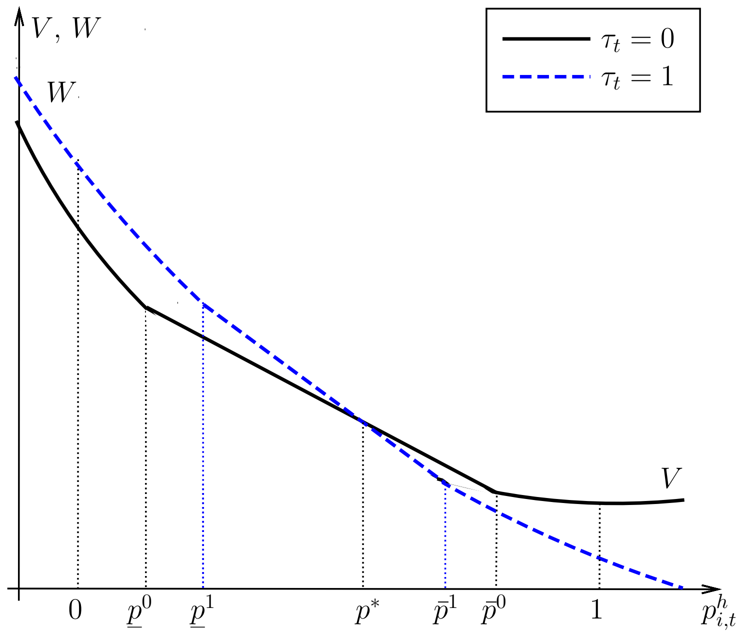

Figure 3.4: Indirect utility from optimal savings and optimal updating as a function of the prior belief in the two political regimes, $\tau_t = 0$ (solid line) and $\tau_t = 1$ (dashed line).

Two expected indirect utility functions V and W fulfilling condition (3.27) are illustrated graphically in Figure 3.4. V and W have a unique intersection p^* on $(0, 1)$. In the constellation chosen in the figure, this intersection lies in the updating range.[11]

3.3.3 Voting decision

At this stage, the agent decides whether to vote in favor of social insurance. She takes this choice such as to maximize expected indirect utility. She thereby takes into account optimal subsequent updating and savings. When entering this stage, the agent has some prior beliefs $p^h_{i,t}$ about the state of the world.

Since voting for one or the other alternative is costless, the voting decision is rather simple to determine. The agent votes for the political

[11] This does not necessarily have to hold but is possible which is illustrated in Appendix 3.B.

system under which expected indirect utility is higher depending on the agent's prior belief about the state of the world. Agent (i,t) votes in favor of social insurance whenever

$$W\left(p_{i,t}^{h}\right) > V\left(p_{i,t}^{h}\right)$$

and votes against it when $W\left(p_{i,t}^{h}\right) < V\left(p_{i,t}^{h}\right)$.

Revisiting the expected indirect utility functions V and W, it follows that there is a unique p^{*} for which the agent is indifferent between the two political regimes, see Figure 3.4. The voting decision is determined by whether the agent's prior belief $p_{i,t}^{h}$ is below or above p^{*}. Whether she votes in favor of social insurance when $p_{i,t}^{h} > p^{*}$ or when $p_{i,t}^{h} < p^{*}$ depends on the parametrization. However, the voting decision changes when the prior belief passes p^{*}.

3.3.4 Belief formation

The prior belief $p_{i,t}^{h}$ determines all decisions of the agent. Here I determine how this belief is formed given the information received from the previous generation. Agent (i,t) receives all information her ancestor $(i,t-1)$ had at the beginning of period t. Agent $(i,t-1)$ in turn received all information from agent $(i,t-2)$ and so on. Consequently, agent (i,t) knows the time of her dynasty's last update on income risk and knows what the respective member observed at that time.

Consider an agent (i,t) whose dynasty's last update on π was in period $t-j$. In period t, the probability that income risk is still the same as at the time of the last update equals the probability that the number of state changes between $t-j$ and t is even. This probability is given by

$$prob\left[\pi_t = \pi_{t-j}\right] = \begin{cases} j!\left(1-\lambda\right)^{j} \sum_{n=0}^{j/2} \frac{\left(\lambda^2\right)^n \left((1-\lambda)^{-2}\right)^n}{(j-2n)!(2n)!}, & j \text{ even} \\ j!\left(1-\lambda\right)^{j} \sum_{n=0}^{(j-1)/2} \frac{\left(\lambda^2\right)^n \left((1-\lambda)^{-2}\right)^n}{(j-2n)!(2n)!}, & j \text{ odd} \end{cases}, \tag{3.30}$$

which is derived in Appendix 3.C. This probability converges towards 1/2 and, since $\lambda < \frac{1}{2}$, it decreases monotonically in j. This means that the longer the time since the last update, the lower the probability that income risk is still the same.

When in the period of the dynasty's last update, $t-j$, the state of the world was bad, the dynasty's beliefs evolve according to

$$p_{i,t}^{h} = prob\left[\pi_t = \pi_{t-j}\right] \tag{3.31}$$

until the next update, with $prob\left[\pi_t = \pi_{t-j}\right]$ given by equation (3.30). In case the state of the world was good in $t-j$, beliefs evolve as

$$p_{i,t}^{h} = 1 - prob\left[\pi_t = \pi_{t-j}\right] \tag{3.32}$$

until the next update. Beliefs thus converge (from above or below) towards 1/2. The speed of convergence is the same for both, equations (3.31) and (3.32). Since $p_{i,t}^{h} = 1/2$ is always in the updating range if such range exists, beliefs reach the updating range in both political regimes.

Note that explicit updating is not the only source of complete information about income risk. Since agents vote truthfully, the outcome of the referendum in period t is a perfect signal about what agents who updated in period $t-1$ observed. When the agent observes an unexpected change in the result of the election, this can only be due to the fact that some agents have observed a change in the state of the world. This signal is observable for all agents and agents' beliefs will thus be identical afterwards. This way, the updating decision will be perfectly synchronized across the population. As a consequence, all agents within one generation have identical prior beliefs, $p_{i,t}^{h} = p_t^{h}\ \forall i$. Since the prior belief determines all decisions of an agent, also all decisions are taken in an identical way by all agents within one generation, $\tau_{i,t} = \tau_t$, $d_{i,t} = d_t$, $p_{i,t+}^{h} = p_{t+}^{h}$, $s_{i,t} = s_t\ \forall i$.

3.4 Aggregate Dynamics

In this section, I describe the dynamics of the model. First, I will develop two important concepts for the dynamics of the model, the duration of inattentiveness and the political delay. Then, I will present the responses to a change in the fundamental income risk. I will also explain the dynamics of the model for an example where no shifts in income risk occur.

3.4.1 Duration of inattentiveness and political delay

The duration of inattentiveness $I(\tau)$ is the time between two updates and depends on the current political regime described by τ. This time is only finite when, for some prior belief p_t^h, agents decide to update information or, technically, when an updating range exists for the current political regime. If an updating range exists, the duration of inattentiveness can be determined as follows. After an updating period $t-j$, agents' beliefs move into the direction of the updating range according to equations (3.31) or (3.32). The speed of this movement is independent of the state of the world in the previous updating period. In addition the distance to the updating range is independent of the state of the world in the previous updating period since this range is symmetric around 1/2, i.e. $\bar{p}^0 = 1 - \underline{p}^0$ and $\bar{p}^1 = 1 - \underline{p}^1$. However, the distance to the updating range does depend on the current political regime since $\underline{p}^0 < \underline{p}^1$.

In the absence of social insurance, the duration of inattentiveness $I(0)$ is the time between the last update and the first period in which prior beliefs are within $\left(\underline{p}^0, 1-\underline{p}^0\right)$,

$$I(0) = \min\left\{t \in \mathbb{N} \mid prob\left[\pi_t = \pi_{t-j}\right] < 1 - \underline{p}^0\right\}.$$

Analogously, in the presence of social insurance, the duration of inattentiveness is

$$I(1) = \min\left\{t \in \mathbb{N} \mid prob\left[\pi_t = \pi_{t-j}\right] < 1 - \underline{p}^1\right\}.$$

Since, if $\underline{p}^0$ and $\underline{p}^1$ exist, it holds that $\underline{p}^0 < \underline{p}^1$, the duration of inattentiveness is never longer without social insurance than with social insurance,

$$I(0) \leq I(1).$$

The political delay is the time between a change in the fundamental income risk and the implementation of the appropriate policy reform. The notion of a political delay implies that a certain policy reform is actually caused by a change in fundamentals. This is ensured when the expected indirect utility functions V and W intersect in the updating ranges. Then, a policy reform only takes place when agents actually observe that the true current state of the world is different from the state revealed by their last update.

The political delay then depends on the duration of inattentiveness and the timing of the change in the fundamental. The maximum delay is the duration of inattentiveness I and occurs when the change in the fundamental happens right after agents have updated. Due to the timing of events, the minimum delay is one period and occurs when income risk changes right before agents' next update. Since state changes occur with equal probability each period, all delays between the minimum and maximum delay are equally likely. The expected political delay is thus $D(\tau) = \frac{1}{2} \cdot (I(\tau) + 1)$, where τ indicates the initial political regime. Since $I(0) \leq I(1)$, the expected political delay is never longer in the absence of social insurance than in the presence of it,

$$D(0) \leq D(1).$$

This result relies on the disincentive effects of social insurance. In the presence of this welfare-state measure, agents save less and can thus gain less from information. As a consequence, agents remain inattentive for longer periods of time. Changes in income risk are then, in expectations, realized later and reforms have longer delays.

3.4.2 Welfare-state dynamics

In the following, I present three experiments to illustrate the dynamics of the model. In all experiments, I consider a constellation where the duration of inattentiveness is finite in both political regimes. Furthermore, the expected indirect utility functions V and W intersect in their updating ranges such that reforms only take place after actual changes in income risk. I consider a case where agents prefer social insurance for low levels of income risk. As discussed before, the duration of inattentiveness and the expected political delay are not affected by this assumption. An example for a parameter constellation yielding the above is $\pi^l = 0.5$, $\pi^h = 0.9$, $e = 0.92$, $\lambda = 0.1$, $\kappa = 0.001$.

In this parameter constellation, $V(0) < W(0)$ and $V(1) > W(1)$. The updating ranges are given by $\underline{p}^0 = 0.1471$, $\bar{p}^0 = 0.8529$, $\underline{p}^1 = 0.1802$ and $\bar{p}^1 = 0.8198$. V and W intersect at $p^* = 0.3095$ and thus in the updating ranges. The duration of inattentiveness is $I(0) = 2$ in the absence of social insurance and $I(1) = 3$ in the presence of social insurance. Figures 3.5 to 3.7 are qualitative sketches of the dynamics under this parameter constellation. The general insights regarding the duration of inattentiveness and political delays are also valid for other constellations of π^l, π^h, e and λ together with κ low enough for updating ranges to exist. For illustrational purposes, the sketches magnify certain areas while other areas are scaled down. The exact coordinates of belief-

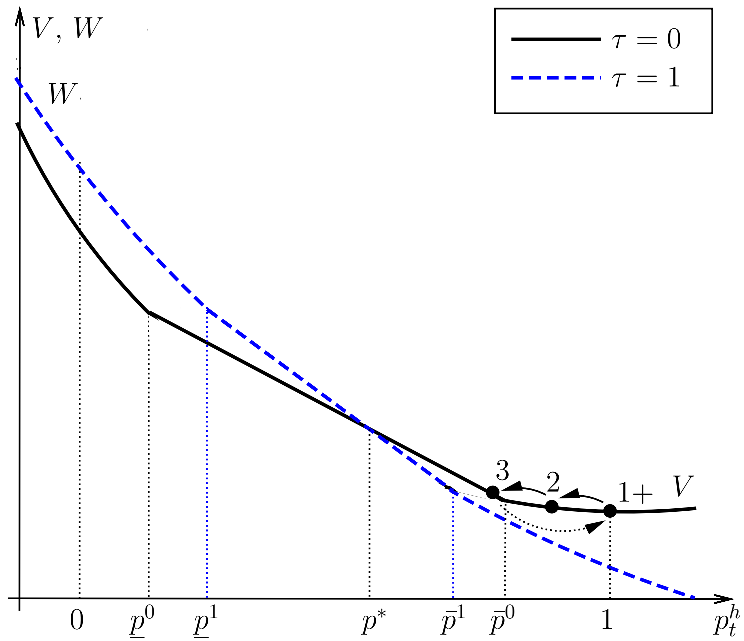

Figure 3.5: Model dynamics without a change in income risk ($\pi_1 = \pi_2 = \pi_3 = \pi^h$).

utility combinations sketched in the figures can be found in Appendix 3.D.

In the first experiment, I consider a scenario where income risk is constant and, consequently, no policy reform takes place. The second experiment describes the model dynamics in a scenario where a change in income risk justifies the implementation of social insurance whereas the third experiment deals with the removal of this welfare-state measure.

Scenario 1: Dynamics without changes in income risk. Consider a scenario where no state change realizes for a certain time such that income risk is constant at its higher level π^h, i.e. $\pi_1 = \pi_2 = ... = \pi^l$. For this scenario, the dynamics of the model are illustrated in Figure 3.5.

I begin the description of the dynamics in a period 1 where, for their prior belief p_1^h, agents find it optimal to update. Due to the information update, agents know for sure that the state of the world is bad, i.e. that $\pi_1 = \pi^h$. Their posterior belief is therefore $p_{1+}^h = 1$. This situation corresponds to the point labeled "1+" in Figure 3.5.

One period later, the state of the world has become uncertain since a state change may have taken place between periods 1 and 2. According to equation (3.31), the probability assigned to the bad state of the world is now lower, $p_2^h < 1$, due to the possibility of state change, $\lambda > 0$. In Figure 3.5, agents still prefer no social insurance, $V\left(p_2^h\right) > W\left(p_2^h\right)$, and vote accordingly. Furthermore, the information that $\pi_1 = \pi^h$ is still worth that much that agents find it optimal not yet to update since $p_2^h > \bar{p}^0$. Thus, prior and posterior beliefs are identical in the second period, $p_{2+}^h = p_2^h$. This situation corresponds to the point "2" in the figure.

In the third period, the value of the information that $\pi_1 = \pi^h$ has deteriorated further such that $p_3^h < p_2^h$ (point "3" in the figure). However, agents still find it optimal to have no social insurance, $V\left(p_3^h\right) > W\left(p_3^h\right)$. But agents are now so uncertain about income risk that they find it optimal to update since $p_3^h < \bar{p}^0$. Agents thus get informed about the true state of the world where income risk is still $\pi_3 = \pi^h$. Correspondingly, their posterior belief in period 3 is $p_{3+}^h = 1$ as in period 1.

Period 4 then begins with the same prior belief as period 2, $p_4^h = p_2^h$. Since behavior within periods is solely determined by the prior belief, all decisions in period 4 are identical to the ones in period 2. By the same logic, period 5 is identical to period 3 and so on.

Scenario 2: An implementation of social insurance. I will now present the dynamics of the model after a change in income risk which makes a social insurance beneficial to agents. I will again begin with a period "1" in which prior beliefs are such that agents decide to update. The change in income risk happens between periods 1 and 2 and income risk is constant afterwards, $\pi_1 = \pi^h$, $\pi_2 = \pi_3 = ... = \pi^l$. Suppose there is no social insurance in period 1, where it is socially suboptimal. The dynamics of the model in this scenario are illustrated in Figure 3.6.

Behavior in periods 1 and 2 is as in the previous experiment. In period 2, the state of the world is different than in the previous experiment but agents find it optimal not to update and therefore do not notice the change in fundamentals.

In period 3, the prior belief p_3^h is such that agents still vote against social insurance but now find it optimal to update. Agents thus observe the true state of the world and notice that it has changed since their

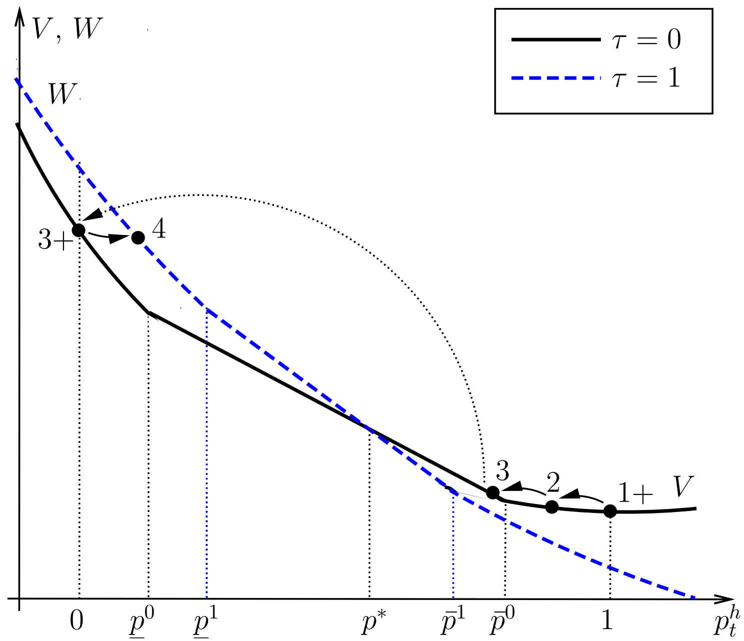

Figure 3.6: Model dynamics with an implementation of social insurance ($\pi_1 = \pi^h$, $\pi_2 = \pi_3 = ... = \pi^l$).

last update, $\pi_3 = \pi^l$. Accordingly, the posterior belief in this period is $p^h_{3+} = 0$. Agents would now prefer social insurance, $W(0) > V(0)$, but have already decided against its implementation.

At the beginning of period 4, the information that $\pi_3 = \pi^l$ has lost in value since it is possible that income risk has changed again between periods 3 and 4, therefore $p^h_4 > 0$. However, agents still believe income risk to be rather low due to $\lambda < 1/2$. Consequently, they prefer social insurance in this period, $W\left(p^h_4\right) > V\left(p^h_4\right)$, and implement it, $\tau_4 = 1$.

In this example, social insurance was implemented with a delay of 2 periods (periods 2 and 3) after the change in fundamentals which justified the implementation. This absolute delay of the implementation depends on the parameter constellation chosen and is thus rather uninformative. It is more informative to consider the relative delay compared to a scenario where income risk shifts into the opposite direction. In the next section, I will present this experiment using the same parameter constellation underlying Figures 3.5 to 3.7.

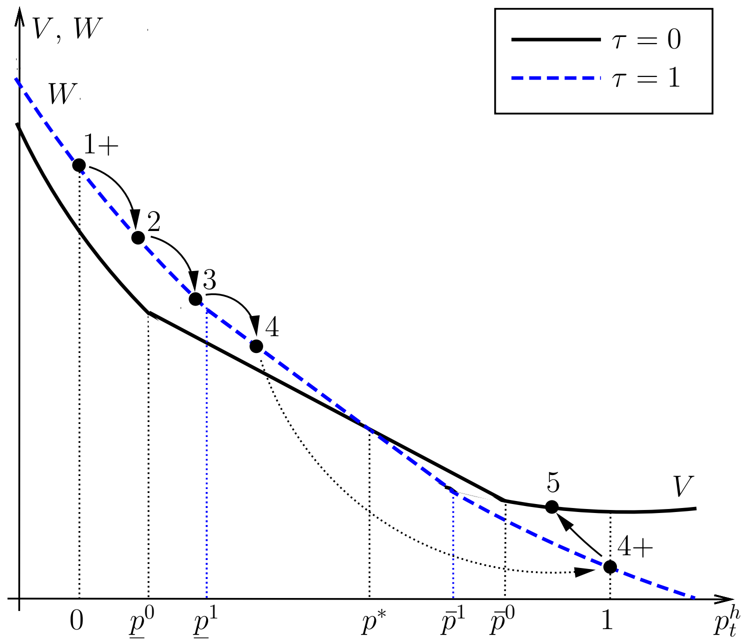

Figure 3.7: Model dynamics with a removal of social insurance ($\pi_1 = \pi^l$, $\pi_2 = \pi_3 = ... = \pi^h$).

Scenario 3: A removal of social insurance. This section presents the dynamics of the model when income risk changes into the opposite direction than in the previous experiment, i.e. I consider a change from low to high income risk between periods 1 and 2. After this single state change, income risk is constant, so that $\pi_1 = \pi^l$, $\pi_2 = \pi_3 = ... = \pi^h$. Suppose there is social insurance in period 1, where it is socially optimal. Figure 3.7 illustrates the dynamics of the model in this experiment.

Suppose again that, in period 1, prior beliefs are such that agents find updating optimal. Agents thus observe that the state of the world is good, i.e. $\pi_1 = \pi^l$. Since this piece of information is sure, agents' posterior beliefs in period 1 are characterized by $p^h_{1+} = 0$.

At the beginning of period 2, agents are aware of the possibility that the state of the world could have changed between periods 1 and 2. Consequently, they assign a positive (low) probability to the bad state of the world, $p^h_2 > 0$. However, agents still prefer social insurance, $W\left(p^h_2\right) > V\left(p^h_2\right)$. Furthermore, beliefs are still certain enough such that agents decide against updating their beliefs and thus do not notice the state change that occurred between periods 1 and 2.

At the beginning of period 3, the information $\pi_1 = \pi^l$ has further deteriorated in value, $p_3^h > p_2^h$, but the social insurance is still believed to be beneficial given agents' expectations and thus it is not removed. If there were no social insurance, agents would find it optimal to update their beliefs now, since $p_3^h > \underline{p}^0$. However, since there is social insurance, gains from updating are lower and agents decide not yet to update, $p_3^h < \underline{p}^1$.

Consequently, prior beliefs in period 4 still only reflect the possibility of a state change but not the fact that one state change has actually taken place. The probability agents assign to the bad state of the world has further increased, $p_4^h > p_3^h$, but not sufficiently to induce a change in policy. However, beliefs are now uncertain enough to cause agents update their beliefs. Observing the true state of the world, agents now realize that it has changed since their last update, $\pi_4 = \pi^h$. Thus posterior beliefs are now $p_{4+}^h = 1$. Agents would now like to change the political regime but can not do so before the next period.

In period 5, agents eventually change the political regime and remove social insurance which is no longer optimal. This political reform is implemented with a delay of 3 periods (periods 2, 3, and 4) after the change in fundamentals which justifies it. Again, this number alone is not very informative. But compared to the delay of 2 periods in the opposite experiment discussed previously, this model evaluation demonstrates that it takes longer to remove social insurance than to implement it.

The reason for this asymmetry is that informational incentives differ across political regimes. In the absence of social insurance, agents save more and update their information more frequently, in this example every 2 periods. When there is social insurance, private savings are crowded out and the duration of inattentiveness is longer (3 periods in this example). Without social insurance, changes in fundamentals are thus realized and political reforms carried out after two periods at the latest, while this can take three periods in the presence of social insurance.

3.4.3 Numerical evaluation

In this section, I evaluate the duration of inattentiveness and the expected political delay after changes in fundamentals numerically. Specifically, I analyze how the political delay depends on the information cost κ. It is clear from the theoretical considerations that higher updating costs make agents less attentive and increase both, the duration of inattentiveness and the political delay. However, it is not possible to quantify this effect analytically. This section present a numerical quantification of this effect. Furthermore, the numerical evaluation allows to analyze how the size of the information cost affects the relative duration of inattentiveness in the two political regimes, $I(1)/I(0)$.

In order to highlight the role of the information cost κ, I present results for different values of κ holding constant the other parameters of the model. Specifically, I consider the constellation $\pi^l = 0.25$, $\pi^h = 0.75$, and $e = 0.933$. These parameter values imply that the indirect utility functions V and W intersect at $p^* = 0.5$. Thus political reforms are only implemented after agents have updated beliefs. Furthermore, I set $\lambda = 0.1$ implying that the expected duration of a state of the world is ten periods. Table 3.1 presents the duration of inattentiveness and the expected political delay for different values of the information cost κ.

In order to put the absolute level of the information cost κ into perspective, the table also reports κ relative to full-information lifetime utility in the good state, $\kappa/\widetilde{V}(0)$. The third column expresses the utility cost in terms of consumption, the reported numbers are the relative reductions of income that would result in a utility loss of κ in the good state of the world without social insurance. The fourth column of the table reports the time between two updates in the absence of social insurance, $I(0)$, and the fifth column reports the duration of inattentiveness when there is social insurance, $I(1)$. The last two columns report the expected duration $D(\tau)$ between a change in income risk and the appropriate change in policy in the two political regimes, where τ indicates the initial political regime. $D(0)$ is the expected delay of an implementation of social insurance and $D(1)$ is the expected delay of a removal of social insurance.

In the first row of Table 3.1, information costs are rather small and amount to only 0.1% of lifetime utility. In this setting, agents find it optimal to update their beliefs in every period in both political regimes.

information costs			duration of inattentiveness		expected political delay	
κ	$\kappa/\widetilde{V}(0)$	cons. equ.	$I(0)$	$I(1)$	$D(0)$	$D(1)$
0.0053	0.10%	0.15%	1	1	1.0	1.0
0.0106	0.20%	0.30%	1	2	1.0	1.5
0.0158	0.30%	0.44%	2	2	1.5	1.5
0.0211	0.40%	0.59%	3	4	2.0	2.5
0.0264	0.50%	0.73%	5	8	3.0	4.5
0.0272	0.52%	0.76%	5	21	3.0	11.0
0.0290	0.55%	0.81%	6	∞	3.5	∞
0.0317	0.60%	0.89%	∞	∞	∞	∞

Table 3.1: Duration of Inattentiveness and Expected Political Delay for Different Informations Costs κ ($\pi^l = 0.25$, $\pi^h = 0.75$, $e = 0.933$, $\lambda = 0.1$)

Thus the time between two updates is 1. Consequently, we also observe the minimum political delay of one period between a change in fundamentals and the implementation of the appropriate policy reform.

With higher information costs of 0.2% of expected lifetime utility (second row of the table), agents still find it rational to update every period when there is no social insurance. However, in the presence of social insurance, gains from updating are lower and agents only update every second period. Consequently, a change in income risk justifying the implementation of social insurance is translated into a policy reform right in the next period. By contrast, removals of social insurance can have a delay of two periods.

Further increases in the information cost leads to longer durations of inattentiveness and, in consequence, to longer political delays. Since gains from updating are always lower in the presence of social insurance, the duration of inattentiveness and expected political delays are longer in this political regime.

The next to last row of Table 3.1 presents a scenario where information costs (0.029) are such that, without social insurance, agents find it optimal to update their beliefs every six periods but never update in the presence of social insurance. In this case, condition (3.29) is not fulfilled for any $p^h_{i,t} \in [0, 1]$. In this scenario, the society implements social insurance with an expected delay of 3.5 periods. Once this political regime is implemented, agents decide to be inattentive forever and thus the social insurance will never be removed independent of the underlying state of the world. Thus welfare-state persistence is eternal in this scenario.

The same holds in the last row of Table 3.1 where the information cost is set to 0.0317. Here, agents are also completely inattentive in the absence of social insurance. Political reforms thus never take place. The economy remains in its initial political regime forever.

Note that relatively low values for the information cost are sufficient to generate these extreme forms of political persistence. In the scenarios displayed in the last two rows of Table 3.1, information costs amount to 0.55% and 0.6% of expected lifetime utility under full information in the good state of the world, respectively, which is equivalent to a loss of less than 1% of consumption. Reis (2006a) discusses different parametrization of his inattentiveness modell with updating costs ranging from 0.2% to 0.8% of income. Zbaracki, Ritson, Levy, Dutta, and Bergen (2004) measure updating and planning costs of a firm and find that these costs are roughly 1% of total revenue.

3.5 Conclusion

This chapter has offered an information-based explanation for welfare-state persistence. The explanation is based on the effects of the welfare state on attentiveness. I argued that the welfare state crowds out private financial precautions and this way reduces incentives to be attentive to developments in economic fundamentals. Knowledge about fundamentals does not only influence private decisions on savings or insurance but is also important for optimal political choices.

When people face a cost of processing information, they will choose how often to inform themselves about fundamentals. The incentives to do so depend on their level of private financial precaution. In turn, the incentives for financial precaution depend on welfare-state arrangements. For instance, if the degree of social insurance is high, people engage little in private financial activity. Consequently, they remain inattentive to news for longer periods. As a result, it takes long until a change in fundamentals is noticed by a majority of society and translated into appropriate policies if initial welfare-state arrangements are pronounced.

I have presented a model where rationally inattentive agents face an unknown degree of income risk. Agents decide on private savings, attentiveness to news and whether to vote in favor of social insurance. When society has implemented social insurance, agents save less and are, consequently, less attentive to news since choosing savings based on better information has a lower impact on lifetime utility. This way, welfare-state persistence arises from the incentive effects of the welfare state on attentiveness.

Appendix

3.A Savings decision

Optimal savings when $\tau_t = 0$. Under $\tau_t = 0$, $x_{i,t,t+1}$ can take only two values: $x^{l,L} = x^{h,L} = x^L = 1$ and $x^{h,U} = x^{l,U} = x^U = 0$. From the perspective of agent (i,t) after the updating decision, the subjective probability of these two outcomes are

$$\begin{aligned} prob_{i,t+}\left[x_{i,t,t+1} = x^L\right] &= prob_{i,t+}\left[x_{i,t,t+1} = x^{h,L}\right] + prob_{i,t+}\left[x_{i,t,t+1} = x^{l,L}\right] \\ &= prob_{i,t+}\left[y_{i,t,t+1} = 1 \mid \pi_t = \pi^h\right] \cdot prob_{i,t+}\left[\pi_t = \pi^h\right] \\ &\quad + prob_{i,t+}\left[y_{i,t,t+1} = 1 \mid \pi_t = \pi^l\right] \cdot prob_{i,t+}\left[\pi_t = \pi^l\right] \\ &= \left(1 - \pi^h\right) \cdot p^h_{i,t+} + \left(1 - \pi^l\right) \cdot \left(1 - p^h_{i,t+}\right) \\ &= 1 - \pi^e_{i,t+} \end{aligned}$$

and

$$prob_{i,t+}\left[x_{i,t,t+1} = x^U\right] = \pi^e_{i,t+}.$$

Hence, the consumption Euler equation reads as

$$u'\left(1 - s_{i,t}\right) = \left(1 - \pi^e_{i,t+}\right) \cdot u'\left(1 + s_{i,t}\right) + \pi^e_{i,t+} \cdot u'\left(s_{i,t}\right).$$

Using the functional form of marginal utility, $u'\left(c_{i,t,t+h}\right) = 4 - 2c_{i,t,t+h}$, $h = 0, 1$, gives

$$4 - 2\left(1 - s_{i,t}\right) = \left(1 - \pi^e_{i,t+}\right) \cdot \left[4 - 2\left(1 + s_{i,t}\right)\right] + \pi^e_{i,t+} \cdot \left[4 - 2\left(s_{i,t}\right)\right].$$

This equation is solved by

$$s_{i,t} = \frac{\pi^e_{i,t+}}{2},$$

which is the expression for optimal savings in the absence of social insurance stated in equation (3.20).

Optimal savings when $\tau_t = 1$. Under $\tau_t = 1$, $x_{i,t,t+1}$ can take only two values: $x^{l,L} = x^{l,U} = x^l = \left(1 - \pi^l\right) e$ and $x^{h,L} = x^{h,U} = x^h = \left(1 - \pi^h\right) e$. From the perspective of agent (i,t) after the updating decision, the subjective probability of these two outcomes are

$$prob_{i,t+}\left[x_{i,t,t+1} = x^l\right] = 1 - p^h_{i,t+}$$

and

$$prob_{i,t+}\left[x_{i,t,t+1}=x^{h}\right]=p_{i,t+}^{h}.$$

Hence, the consumption Euler equation reads as

$$u'\left(e-s_{i,t}\right)=\left(1-p_{i,t+}^{h}\right)\cdot u'\left(\left(1-\pi^{l}\right)e+s_{i,t}\right)+p_{i,t+}^{h}\cdot u'\left(\left(1-\pi^{h}\right)e+s_{i,t}\right).$$

Using the functional form of marginal utility, $u'\left(c_{i,t,t+h}\right)=4-2c_{i,t,t+h}$, $h=0,1$, gives

$$\begin{aligned}
4-2\left(e-s_{i,t}\right) &= \left(1-p_{i,t+}^{h}\right)\cdot\left(4-2\left[\left(1-\pi^{l}\right)e+s_{i,t}\right]\right)\\
&\quad +p_{i,t+}^{h}\cdot\left(4-2\left[\left(1-\pi^{h}\right)e+s_{i,t}\right]\right)\\
&\Longleftrightarrow 2s_{i,t}=\left[\left(1-p_{i,t+}^{h}\right)\cdot\pi^{l}+p_{i,t+}^{h}\cdot\pi^{h}\right]e.
\end{aligned}$$

This can be simplified to

$$s_{i,t}=\frac{\pi_{i,t+}^{e}}{2}e,$$

which is equation (3.21).

3.B Expected indirect utility

Expected indirect utility when $\tau_t=0$. For a savings level $s_{i,t}$, consumption in period t and in the two possible realizations of net income in period $t+1$ are $c_{i,t,t}=1-s_{i,t}$, $c_{i,t,t+1}^{L}=1+s_{i,t}$, and $c_{i,t,t+1}^{U}=s_{i,t}$ when $\tau_t=0$. In the absence of social insurance, expected lifetime utility net of updating costs is thus

$$\widetilde{V}:=E_{i,t+}\widetilde{U}_{i,t}=u\left(1-s_{i,t}\right)+\left(1-\pi_{i,t+}^{e}\right)\cdot u\left(1+s_{i,t}\right)+\pi_{i,t+}^{e}\cdot u\left(s_{i,t}\right),$$

which, for (3.2), becomes

$$\widetilde{V}=4+4\left(1-\pi_{i,t+}^{e}\right)-\left(1-s_{i,t}\right)^{2}-\left(1-\pi_{i,t+}^{e}\right)\cdot\left(1+s_{i,t}\right)^{2}-\pi_{i,t+}^{e}\cdot\left(s_{i,t}\right)^{2}.$$

Using the optimal savings (3.20) gives

$$\widetilde{V}=4+4\left(1-\pi_{i,t+}^{e}\right)-\left(1-\frac{\pi_{i,t+}^{e}}{2}\right)^{2}-\left(1-\pi_{i,t+}^{e}\right)\cdot\left(1+\frac{\pi_{i,t+}^{e}}{2}\right)^{2}-\pi_{i,t}^{e}\cdot\left(\frac{\pi_{i,t+}^{e}}{2}\right)^{2}.$$

This evaluates as

$$\widetilde{V}=6-3\pi_{i,t+}^{e}+\frac{\left(\pi_{i,t+}^{e}\right)^{2}}{2},$$

which is equation (3.22). To derive the marginal derivatives of $\widetilde{V}$ with respect to $p^h_{i,t+}$, first take the derivatives with respect to perceived income risk $\pi^e_{i,t+}$:

$$\frac{\partial \widetilde{V}}{\partial \pi^e_{i,t+}} = -3 + \pi^e_{i,t+} < 0 \text{ since } \pi^e_{i,t} \leq 1$$
$$\frac{\partial^2 \widetilde{V}}{\partial \left(\pi^e_{i,t+}\right)^2} = 1 > 0$$

$\widetilde{V}$ is thus decreasing and convex in $\pi^e_{i,t+}$. As $\pi^e_{i,t+} = \pi^l + p^h_{i,t+} \cdot \left(\pi^h - \pi^l\right)$ is a linear and increasing function of $p^h_{i,t+}$, $\widetilde{V}$ is also decreasing and convex in $p^h_{i,t+}$:

$$\frac{\partial \widetilde{V}}{\partial p^h_{i,t+}} = \frac{\partial \widetilde{V}}{\partial \pi^e_{i,t+}} \cdot \frac{\partial \pi^e_{i,t+}}{\partial p^h_{i,t+}} = \left(-3 + \pi^e_{i,t+}\right) \cdot \left(\pi^h - \pi^l\right) < 0$$
$$\frac{\partial^2 \widetilde{V}}{\partial \left(p^h_{i,t+}\right)^2} = \left(\pi^h - \pi^l\right)^2 > 0$$

Expected indirect utility when $\tau_t = 1$. For a savings level $s_{i,t}$, consumption in period t and in the two possible realizations of net income in period $t+1$ are $c_{i,t,t} = e - s_{i,t}$, $c^l_{i,t,t+1} = \left(1 - \pi^l\right) e + s_{i,t}$, and $c^h_{i,t,t+1} = \left(1 - \pi^h\right) e + s_{i,t}$ when $\tau_t = 1$. In the presence of social insurance, expected lifetime utility net of updating costs is thus

$$\begin{aligned}\widetilde{W} := E_{i,t+}\widetilde{U}_{i,t} = u\left(e - s_{i,t}\right) + \left(1 - p^h_{i,t+}\right) \cdot u\left(\left(1 - \pi^l\right) e + s_{i,t}\right) \\ + p^h_{i,t+} \cdot u\left(\left(1 - \pi^h\right) e + s_{i,t}\right).\end{aligned}$$

which, for (3.2), becomes

$$\begin{aligned}\widetilde{W} =& 4e - \left(e - s_{i,t}\right)^2 + 4e\left[\left(1 - p^h_{i,t+}\right) \cdot \left(1 - \pi^l\right) + p^h_{i,t+} \cdot \left(1 - \pi^h\right)\right] \\ & - \left(1 - p^h_{i,t+}\right) \cdot \left(\left(1 - \pi^l\right) e + s_{i,t}\right)^2 - p^h_{i,t+} \cdot \left(\left(1 - \pi^h\right) e + s_{i,t}\right)^2 \\ =& 8e - \left(e - s_{i,t}\right)^2 - 4\pi^e_{i,t+} e - \left(1 - p^h_{i,t+}\right) \cdot \left(\left(1 - \pi^l\right) e + s_{i,t}\right)^2 \\ & - p^h_{i,t+} \cdot \left(\left(1 - \pi^h\right) e + s_{i,t}\right)^2.\end{aligned}$$

Using the optimal savings (3.21) gives

$$\widetilde{W} = 8e - \left(e - \frac{\pi^e_{i,t+}}{2}e\right)^2 - 4\pi^e_{i,t+}e - \left(1 - p^h_{i,t+}\right) \cdot \left(\left(1 - \pi^l\right) e + \frac{\pi^e_{i,t+}}{2}e\right)^2$$
$$-p^h_{i,t+} \cdot \left(\left(1 - \pi^h\right) e + \frac{\pi^e_{i,t+}}{2}e\right)^2,$$

which can be simplified to

$$\begin{aligned}
\widetilde{W} &= 8e - \left(1 - \pi^e_{i,t+}\right) e^2 - \frac{\left(\pi^e_{i,t+}\right)^2 e^2}{2} - 4e\pi^e_{i,t+} \\
&\quad -e^2 \left[\left(1 - p^h_{i,t+}\right) \cdot \left(1 - \pi^l\right)^2 + p^h_{i,t+} \cdot \left(1 - \pi^h\right)^2\right] \\
&\quad -e^2 \left[\left(1 - p^h_{i,t+}\right) \cdot \left(1 - \pi^l\right) + p^h_{i,t+} \cdot \left(1 - \pi^h\right)\right] \pi^e_{i,t+} \\
&= 8e - \left(1 - \pi^e_{i,t+}\right) e^2 - \frac{\left(\pi^e_{i,t+}\right)^2 e^2}{2} - 4\pi^e_{i,t+}e \\
&\quad -e^2 \left[E_{i,t+} \left(1 - \pi_t\right)^2\right] - e^2\pi^e_{i,t+} + e^2 \left(\pi^e_{i,t+}\right)^2 \\
&= 8e - e^2 - 4\pi^e_{i,t+}e + \frac{\left(\pi^e_{i,t+}\right)^2 e^2}{2} - e^2 \left[1 - 2\pi^e_{i,t+} + E_{i,t+} \left(\pi_t\right)^2\right] \\
&= 8e - 2e^2 - 2\pi^e_{i,t+}e + \frac{\left(\pi^e_{i,t+}\right)^2 e^2}{2} - e^2 \left[E_{i,t+} \left(\pi_t\right)^2\right],
\end{aligned}$$

which is the expression in equation (3.23). The marginal derivatives with respect to $p^h_{i,t+}$ are

$$\begin{aligned}
\frac{\partial \widetilde{W}}{\partial p^h_{i,t+}} &= \left(-2e + e^2\pi^e_{i,t+}\right) \cdot \frac{\partial \pi^e_{i,t+}}{\partial p^h_{i,t+}} - e^2 \frac{E_{i,t+} \left(\pi_t\right)^2}{\partial p^h_{i,t+}} \\
&= \left(-2e + e^2\pi^e_{i,t+}\right) \cdot \left(\pi^h - \pi^l\right) - e^2 \left(\left(\pi^h\right)^2 - \left(\pi^l\right)^2\right),
\end{aligned}$$

which is negative since $e < 1$, $\pi^e_{i,t+} \leq 1$, and $\pi^h > \pi^l$, and

$$\frac{\partial^2 \widetilde{W}}{\partial \left(p^h_{i,t+}\right)^2} = e^2 \cdot \left(\pi^h - \pi^l\right)^2 > 0.$$

$\widetilde{W}$ is thus decreasing and convex in $p^h_{i,t+}$.

Intersection of V and W. In this appendix, I present two examples of parameter constellations where the expected indirect utility functions V and W intersect on $(0,1)$. V cuts W from below in one example and from above in the other example. Furthermore, in these examples, V and W intersect at $p^* = 0.5$ which is always in the updating ranges (if they exist).

Consider first the parameter constellation $\pi^l = 0.7749$, $\pi^h = 0.9589$, and $e = 0.9355$. In this constellation, $V(0)$, $V(1)$, $W(0)$ and $W(1)$ evaluate as $V(0) = \widetilde{V}(0) = 3.9755$, $V(1) = \widetilde{V}(1) = 3.5830$, $W(0) = \widetilde{W}(0) = 4.0212$, and $W(1) = \widetilde{W}(1) = 3.5373$. I.e. it holds that $\widetilde{V}(0) < \widetilde{W}(0)$ and $\widetilde{V}(1) > \widetilde{W}(1)$. Thus V cuts W from below in this example.

Now consider the parameter constellation $\pi^l = 0.25$, $\pi^h = 0.75$, and $e = 0.9337$. In this constellation, $\widetilde{V}(0)$, $\widetilde{V}(1)$, $\widetilde{W}(0)$ and $\widetilde{W}(1)$ evaluate as $\widetilde{V}(0) = 5.2813$, $\widetilde{V}(1) = 4.0313$, $\widetilde{W}(0) = 5.2321$, and $\widetilde{W}(1) = 4.0804$. I.e. it holds that $\widetilde{V}(0) > \widetilde{W}(0)$ and $\widetilde{V}(1) < \widetilde{W}(1)$. Thus, in this example, V cuts W from above.

If V and W intersect in their updating ranges, then this intersection is at

$$p_{i,t}^h = \frac{\widetilde{V}(0) - \widetilde{W}(0)}{\widetilde{V}(0) - \widetilde{W}(0) - \widetilde{V}(1) + \widetilde{W}(1)}.$$

In both examples above this expression evaluates as $p_{i,t}^h = 0.5$. If an updating range exists, $p_{i,t}^h = 0.5$ is in this range. Provided that κ is small enough that V and W have updating ranges, the two functions intersect in their updating ranges in both examples.

3.C Belief formation

The probability that π is the same as j periods ago, i.e. $\pi_t = \pi_{t-j}$, is the probability that the number of regime shifts between $t-j$ and t is even. Using properties of the binomial distribution, this probability can be calculated as

$$\begin{aligned} p[\pi_t = \pi_{t-j}] = & \binom{j}{0} \cdot \lambda^0 (1-\lambda)^{j-0} + \binom{j}{2} \cdot \lambda^2 (1-\lambda)^{j-2} \\ & + \binom{j}{4} \cdot \lambda^4 (1-\lambda)^{j-4} + ... \end{aligned}$$

$$= \begin{cases} \sum_{n=0}^{j/2} \begin{pmatrix} 2n \\ j \end{pmatrix} \cdot \lambda^{2n} (1-\lambda)^{j-2n}, & j \text{ even} \\ \sum_{n=0}^{(j-1)/2} \begin{pmatrix} 2n \\ j \end{pmatrix} \cdot \lambda^{2n} (1-\lambda)^{j-2n}, & j \text{ odd} \end{cases}.$$

For the case of j being even, this probability can be simplified as follows:

$$\begin{aligned} \sum_{n=0}^{j/2} \begin{pmatrix} j \\ 2n \end{pmatrix} \cdot \lambda^{2n} (1-\lambda)^{j-2n} &= \sum_{n=0}^{j/2} \frac{j!}{(j-2n)!\,(2n)!} \cdot \left(\lambda^2\right)^n (1-\lambda)^j (1-\lambda)^{-2n} \\ &= j!\,(1-\lambda)^j \sum_{n=0}^{j/2} \frac{\left(\lambda^2\right)^n \left((1-\lambda)^{-2}\right)^n}{(j-2n)!\,(2n)!} \end{aligned}$$

Analogously, for the case that j is odd, the probability can be simplified to:

$$\sum_{n=0}^{(j-1)/2} \begin{pmatrix} j \\ 2n \end{pmatrix} \cdot \lambda^{2n} (1-\lambda)^{j-2n} = j!\,(1-\lambda)^j \sum_{n=0}^{(j-1)/2} \frac{\left(\lambda^2\right)^n \left((1-\lambda)^{-2}\right)^n}{(j-2n)!\,(2n)!}$$

such that

$$p\left[\pi_t = \pi_{t-j}\right] = \begin{cases} j!\,(1-\lambda)^j \sum_{n=0}^{j/2} \frac{\left(\lambda^2\right)^n \left((1-\lambda)^{-2}\right)^n}{(j-2n)!(2n)!}, & j \text{ even} \\ j!\,(1-\lambda)^j \sum_{n=0}^{(j-1)/2} \frac{\left(\lambda^2\right)^n \left((1-\lambda)^{-2}\right)^n}{(j-2n)!(2n)!}, & j \text{ odd} \end{cases},$$

which is equation (3.30).

3.D Welfare-state dynamics

This appendix presents the exact probabilities representing agents' beliefs and the exact associated values for expected indirect utility in the three scenarios in Section 3.4.2. The values can be found in Table 3.2.

	scenario 1			scenario 2			scenario 3		
time	belief	V	W	belief	V	W	belief	V	W
1+	1.000	3.705	3.668	1.000	3.705	3.668	0.000	4.625	4.641
2	0.900	3.790	3.760	0.900	3.790	3.760	0.100	4.526	4.538
2+	0.900	3.790	3.760	0.900	3.790	3.760	0.100	4.526	4.538
3	0.820	3.861	3.834	0.820	3.861	3.834	0.180	4.449	4.456
3+	1.000	3.705	3.668	0.000	4.625	4.641	0.180	4.449	4.456
4	0.900	3.790	3.760	0.100	4.526	4.538	0.244	4.390	4.394
4+	0.900	3.790	3.760	0.100	4.526	4.538	0.900	3.790	3.760
5	0.820	3.861	3.834	0.180	4.449	4.456	0.820	3.861	3.834

Table 3.2: Dynamics of beliefs and expected indirect utility in the scenarios from Section 3.4.2 ($\pi^l = 0.5$, $\pi^h = 0.9$, $e = 0.92$, $\lambda = 0.1$, $\kappa = 0.001$; scenario 1: $\pi_1 = \pi_2 = ... = \pi^h$, scenario 2: $\pi_1 = \pi^h$, $\pi_2 = \pi_3 = ... = \pi^l$, scenario 3: $\pi_1 = \pi^l$, $\pi_2 = \pi_3 = ... = \pi^h$).

Chapter 4

Household Labor Supply in a Heterogeneous-Agents Model with Tradable Home Labor

4.1 Introduction

This chapter[1] considers labor supply disaggregated by gender and marital status. Average weekly hours of market work in the US have increased steadily over the last 50 years. An aggregate view, however, hides a number of important subgroup-specific patterns in labor supply. In particular, there are pronounced differences in labor supply by gender and marital status. On average, married men work the most hours, followed by single men and single women. Married women work the fewest hours. Interestingly, group-specific levels of hours worked have changed substantially over time. Most striking is the sharp increase in married women's hours of market work over the last decades. By contrast, married men slightly decreased their working time, while singles of both genders increased their labor supply over time.

Traditional explanations for the developments in hours worked include overall productivity growth (Mincer 1962; Smith and Ward 1985), the rise in women's education levels (Olivetti 2006), the closure of the gender wage gap (Galor and Weil 1996; Jones, Manuelli, and McGrattan 2003; Knowles 2007; Attanasio, Low, and Sánchez-Marcos 2008), the fertility decline (Chiappori and Weiss 2006), and the decrease in

[1] The chapter is based on Bredemeier and Juessen (2009).

the marriage rate (Albanesi and Olivetti 2007). Yet, Eckstein and Lifshitz (2009) document that, in an extended version of the Eckstein and Wolpin (1989) model, a considerable portion of the increase in married women's labor supply remains unexplained by these traditional explanations. Eckstein and Lifshitz (2009) argue that the unexplained portion can be attributed to changes in preferences or the costs of childrearing and household maintenance.[2] More generally, the Eckstein and Lifshitz (2009) paper is a proposal to investigate more closely the set of unobservable determinants of family labor supply.

We pick up this general idea and propose a structural model where non-traditional factors influence group-specific labor supply, in addition to some of the traditional determinants mentioned before. Our household model of labor supply comprises four groups of agents—married women, married men, single women, and single men—and aims to generate the observed developments for married couples and simultaneously those for male and female single households, respectively. A key mechanism in our model relies on the possibility to outsource labor in home production. Examples for outsourcing home labor abound. For instance, when we think of home production being cleaning and washing, hiring housekeepers is an alternative to own labor. Considering child care or geriatric care, the assignment of babysitters or nannies and the use of outpatient care is not unusual. We propose that outsourcing home labor has become more attractive to households over time and that taking into account this development on the market for tradable home labor helps to understand the observed trends in labor supply at the subgroup level.

Outsourcing of home labor is related to the idea that home production has been replaced by the consumption of market-produced substitutes. Such marketization of home production has been shown to explain long-run trends (Ngai and Pissarides 2008; Rogerson 2008) as well as cross-country differences (Freeman and Schettkat 2005) in aggregate market hours. In this chapter, we develop a similar line of argument to explain the distinct subgroup-specific developments in labor supply by

[2] Further examples for what Eckstein and Lifshitz (2009) refer to as "other" explanations are provided by e.g. Greenwood, Seshadri, and Yorukoglu (2005) who show that technological improvements in home production affect female labor supply or by Attanasio, Low, and Sánchez-Marcos (2008) who analyze reductions in child care costs. Fernández, Fogli, and Olivetti (2004) and Fernández (2007) find that social norms are determinants of gender-specific labor supply.

gender and marital status.

Considering four groups of agents (couples and single households) simultaneously distinguishes our contribution from others that have also examined married women's labor supply in the framework of household decision making involving wife and husband but have not considered single households (Knowles 2007; Attanasio, Low, and Sánchez-Marcos 2008; Eckstein and Lifshitz 2009). Our model of labor supply is similar to the household model of Jones, Manuelli, and McGrattan (2003) who also consider all four groups of agents simultaneously. They primarily focus on explaining the substantial increase in married women's labor supply and find that the closure of the gender wage gap plays an important role for this development. However, the closure of the gender wage gap alone is not sufficient to explain the patterns in labor supply of married couples and single households simultaneously.

In our framework, the possibility to outsource home labor implies that households can take advantage of two forms of specialization: First, in marriages, spouses can decide to specialize on paid market work or home production, respectively. Second, couples as well as single households face the opportunity to hire labor used as an input in home production. In a heterogeneous-agents model of household labor supply, we show that the observed patterns in group-specific labor supply can be understood as optimal reactions to rising attractiveness of outsourcing home labor.

In our model, we distinguish between two labor markets. On a "first market", labor is used for the production of usual consumption goods, whereas on a "second market", labor is used as an input for home production. Since there are two markets, agents have the possibility to specialize. Some agents may supply home labor on the second market, while others find it more attractive to work on the first market solely, depending on the wages they can earn on each market. To address these relations, our model features another dimension of heterogeneity in addition to heterogeneity by gender and marital status. In particular, agents in our model differ with respect to the wages they can earn on the first labor market. The presence of wage heterogeneity implies that agents with relatively high wages will delegate home production either to their spouse or to other agents (i.e. outsource home labor) in order to realize an efficiency gain. The possibility to trade home labor explains level differences in hours worked among married men, married women, single men, and single women as the result of specialization decisions.

Yet, trading home labor differs from trade on other markets. Social norms, trust, and personal attachments to tasks play an important role when home labor is outsourced. For instance, parents may prefer self-supplied child care (Davis and Henrekson 2004). Outsourcing child care, or geriatric care, is also subject to social norms (Fernández 2007). Furthermore, employing a housekeeper requires trust because employers need to open their homes (Brück, Haisken-DeNew, and Zimmermann 2006). Another example for why trading home labor differs from trade on other markets is a lack of market transparency because a substantial part of the trade in home labor occurs in the shadow economy (Dortch 1996). Such aspects may prevent people from hiring home labor who could—in principle—afford it.

When modelling a market for home labor, we pick up the general idea by Chari, Kehoe, and McGrattan (2007) and capture these market particularities as a wedge that distorts the decision to outsource home labor. Specifically, we introduce costs of outsourcing home labor which add to wage costs. We label the difference between the price and the wage for home labor "home labor wedge". The existence of a home labor wedge implies that there are agents who do not outsource home labor although they could afford the wage costs. If the home labor wedge declines, outsourcing home labor becomes more attractive to households. In our model, a declining home labor wedge has the same qualitative effects as relative productivity growth on the market for home labor. Both developments make outsourcing home labor more attractive. This is similar to Eckstein and Lifshitz (2009) who do not distinguish between technological developments and changes in social norms as determinants of female labor supply.

A main result of our model is that rising attractiveness of outsourcing home labor (due to relative productivity growth or a declining home labor wedge) can explain the observed labor market trends at the subgroup level for all four population groups simultaneously. When outsourcing home labor becomes more attractive, more households decide to hire labor for home production instead of doing these tasks on their own. The respective singles and wives gain time to work on the first market. Being released of house work has a particularly strong impact on married women's labor supply because married women tend to work more in home production than singles due to intra-household specialization. Husbands, on the contrary, record a decrease in average market hours if the home labor wedge declines. Some husbands work more in the household and less on the market because they loose intra-household bargaining power due to increased earnings opportunities for their wives.

This effect in an important difference between our contribution and the ones by Greenwood, Seshadri, and Yorukoglu (2005) and Attanasio, Low, and Sánchez-Marcos (2008). In Greenwood, Seshadri, and Yorukoglu (2005) and Attanasio, Low, and Sánchez-Marcos (2008), agents also gain time for market work by substituting away from own time in home production. However, the supply of the substitute (home capital or child care, respectively) is not modeled. In our model, effects on the supply side of the market for home labor are important for subgroup-specific hours worked.

In the second part of the chapter we confront the model with US labor market data from the Current Population Survey (CPS). We calibrate the model to trace changes in hours worked by gender and marital status. We thereby take into account different channels affecting group-specific labor supply, such as the marriage decline, overall productivity growth, improvements in home capital, and the closure of the gender wage gap, as well as the channel emphasized in the theoretical part of the chapter, the rising attractiveness of trading home labor.

We find that the calibrated model is successful at matching the series of hours worked. Since our model is able to trace well the observed patterns in group-specific labor supply, we use it to assess the relative importance of different determinants of labor supply at the subgroup level. In line with Jones, Manuelli, and McGrattan (2003), we find that the closure of the gender wage gap plays an important role when accounting for the rise in hours. Our quantitative exercise also shows that, without taking into account developments that make outsourcing home labor more attractive, one can hardly account for the increases of hours worked by singles of both genders. In particular, the wage-gap closure cannot explain why the working time of single and married men evolved in different directions.

Accounting for an observed moderate relative productivity growth on the market for home labor (as documented by e.g. Ngai and Pissarides 2008) improves the model's predictions for all four population groups. However, to fully trace the patterns in hours, the rise in the attractiveness of this market needs to be more pronounced than reflected by productivity growth alone. Put differently, we can match the group-specific trends in hours worked when we allow for reductions in the home labor wedge. The decline in the home labor wedge may e.g. reflect developments in social norms which lead to rising acceptance of outsourcing home labor. Fernández (2007) has documented that such developments in social norms have actually occurred over the last decades. An empirical implication of the declining home labor wedge is that the market for household-related services has grown over time. Such sectoral shift in the composition of the US economy has been documented by e.g. Lee and Wolpin (2006), Ngai and Pissarides (2008), and Autor and Dorn (2009).

The remainder of the chapter is organized as follows. The next section briefly summarizes empirical facts on labor supply in the US over the last decades. Section 4.3 describes the theoretical model. Section 4.4 solves the model and analyzes the equilibrium response to a rising attractiveness of the market for home labor. The quantitative analysis is presented in Section 4.5. Section 4.6 concludes the chapter and an appendix follows.

4.2 Empirical Facts

To provide the empirical background of our analysis, we recapitulate the observed patterns in US labor market data to which we will compare our model. Figure 4.1 shows average hours of market work by gender and marital status. The data stems from the March Supplement of the CPS, from 1962 to 2007, in the format arranged by Unicon Research.[3] We define working age as 18 to 65 and restrict the sample to the civilian population of that age.

Over the last decades, labor supply of married women increased substantially. In the early 1960's, they worked on average just a little more than 10 hours per week. Until 2006, this number more than doubled to over 20 hours a week. At the same time, labor supply of married men slightly fell from somewhat below 40 hours per week to approximately 37.5 - a decrease of 6%. Both single men and women tended to work less than married men, but more than married women. On average, male singles worked slightly above, female singles slightly below 25 hours a week. Both time series showed an upward trend in the 1970's and 80's.

[3]Details are provided in Appendix 4.A.

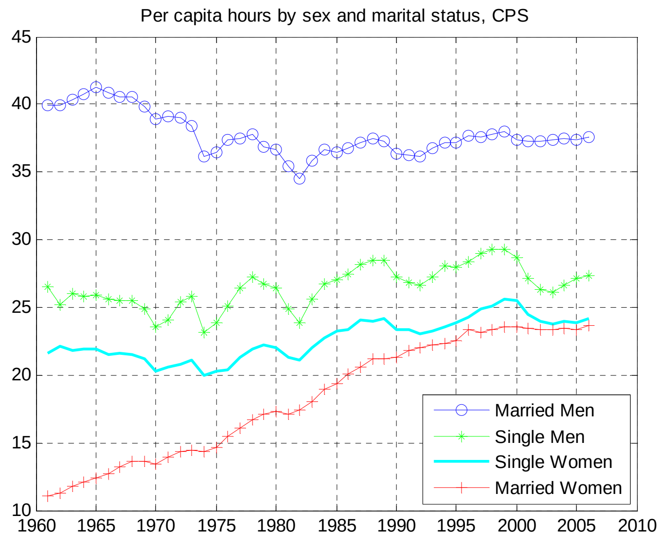

Figure 4.1: Average weekly market hours by gender and marital status in the US (March CPS, Persons aged 18-65)

Our model aims at replicating the ordering of hours worked by population groups, as well as the direction and magnitude of changes in hours over time. Specifically, we want to replicate the following three facts:[4]

1. **Levels of hours worked by groups:** On average, married men work the most hours of all four population groups, followed by single men and single women. Married women work the fewest hours on average.

2. **Directions of changes over time:** Over time, average market hours of married men decreased while all other population groups record increasing hours.

3. **Magnitude of changes over time:** The most pronounced change over time is the increase in married women's hours.

[4]These three results are highly significant (see Appendix 4.A).

4.3 Model Environment

In this section, we introduce a market for home labor into a collective model of household labor supply. We transfer the framework of Jones, Manuelli, and McGrattan (2003) into a heterogeneous-agents model where households differ with respect to their potential wages on the first market. The decision process within households is modeled using a stylized version of endogenous bargaining positions (Chiappori 1988; Chiappori 1992).

Our model aims at tracing developments in hours worked by gender and marital status. We therefore include different determinants of group-specific labor supply, such as the marriage rate, overall wages, gender differences in wages, home technology, and the home labor wedge. This means that from the list of traditional explanations we consider all but fertility. Changes in education appear as changes in wages in our model.

4.3.1 Population composition

The population consists of women (mass 1) and men (also mass 1). An exogenous fraction s of both genders are singles, the remaining fraction $(1-s)$ is married to an individual of the other gender. Households differ with respect to their wages on the "first market" where consumption goods are produced. Home goods are produced within households using own time and labor which can be traded at a "second market".

We incorporate heterogeneity with respect to first-market wages by assuming a continuum of agents with a continuous wage structure. In order to be able to derive results analytically, we first assume that wages on the first market (denoted by a) are distributed uniformly.[5] The wage distributions differ by gender and have supports $[0, 1]$ for men and $[0, \alpha]$ for women, respectively, $\alpha < 1$.[6] We assume that first-market wages are exogenous, thus we abstain from modelling an explicit education choice.

[5] In the quantitative part of the chapter, we relax this assumption and assume a more realistic log-normal distribution for first-market wages.

[6] Empirical evidence that wage distributions have gender-specific supports is provided by Albanesi and Olivetti (2006), who observe that among top-salary receivers men earn more than women. More generally, there is considerable empirical evidence that, even after controlling for a number of observable characteristics, women's wages are lower than men's, see e.g. Goldin (1990), Blau and Kahn (1997b), Blau (1998). Gender differences in wages can be due to various factors, such as discrimination (Jones, Manuelli, and McGrattan 2003).

This means that our model does not disentangle changes in education levels from the closure of the gender wage gap for given education. In our model, a rise in education levels appears as a rise in first-market wages.

Other than on the first market, all agents are assumed to earn the same wage on the second market. This simplifying assumption is motivated by the observation of Brück, Haisken-DeNew, and Zimmermann (2006) that household work typically requires only low skills and no formal qualifications. One may therefore argue that wages are determined by supply and demand rather than by individual characteristics.

We introduce subscripts to indicate an individual's gender, marital status, and her position in the wage distribution. Genders are coded by F (or f) for female and M (or m) for male. Capital letters indicate that the respective person is married, whereas lower-case letters stand for singles. For instance, the index $(M, 0.25)$ refers to a married man located at the lower .25 quantile of the wage distribution on the first market.

We assume that marital status and wages are independent and that mating occurs in a perfectly assortative way (Becker 1973).[7] As a consequence of assortative mating, first-market wages are perfectly correlated in marriages, i.e. a wife's wage is a constant fraction of her husband's one,

$$a_{F,i} = \alpha \cdot a_{M,i}, \tag{4.1}$$

such that we can use the subscript $i \in [0, 1]$ for the entire household, reflecting its position in the wage distribution. Given the assumption of assortative mating, the distribution parameter α determines intra-household wage differentials between husbands and wives. Equation (4.1) implies that there are households where both spouses earn high wages, but there are also households where both partners have rather low wages. Thus, not every woman is earning less than every man, but every wife is earning less than her husband (if both work on the first market).

[7]Becker (1973) shows that such sorting is the only stable outcome of a perfect marriage market when marital surpluses are supermodular (i.e. if there are marital complementarities). Fernández, Guner, and Knowles (2004) provide empirical evidence for marital sorting and find that the correlation of wife's and husband's education levels is remarkably high across Europe and both North and South America.

With the uniform distribution of wages on $[0,1]$ and $[0,\alpha]$ for men and women, respectively, we have:

$$a_{M,i} = i,\ a_{F,i} = \alpha i,\ a_{m,i} = i,\ a_{f,i} = \alpha i \tag{4.2}$$

4.3.2 Preferences and technology

We assume that preferences of agents are given by the individual utility function

$$U_{g,i} = \left(\left[\begin{array}{c} \left(\frac{\psi}{\psi+\nu}\right)^{1/\phi} (c_{g,i})^{\frac{\phi-1}{\phi}} \\ + \left(\frac{\nu}{\psi+\nu}\right)^{1/\phi} (d_{g,i})^{\frac{\phi-1}{\phi}} \end{array} \right]^{\frac{\phi}{\phi-1}} \right)^{(\psi+\nu)} \cdot (l_{g,i})^{(1-\psi-\nu)}, \tag{4.3}$$
$$g = F, M, f, m,$$

where $c_{g,i}$ denotes an individual's consumption of market goods, $d_{g,i}$ her consumption of home goods, and $l_{g,i}$ her time spent on leisure. The utility function is a Cobb-Douglas aggregator over consumption and leisure, where consumption is a CES aggregator over home and market consumption.

In the theoretical part of the chapter, we use the parameter restriction $\phi \to 1$ which results in log utility.[8] We do so to isolate the effects of outsourcing home labor. In the quantitative part of the chapter, we refrain from this parameter restriction.

First, we consider the decision problem for married couples. We assume that a couple i realizes an efficient intra-household bargaining solution. This is equivalent to assuming the household would maximize

$$U_i = \lambda_{F,i} \cdot u_{F,i} + \lambda_{M,i} \cdot u_{M,i}, \tag{4.4}$$

which is a weighted sum of the individual log utilities of the two spouses, $u_{G,i} = \ln U_{G,i}$. If the weights on individual utilities, $\lambda_{F,i}$ and $\lambda_{M,i}$, are endogenous, this is a version of the collective household model initially introduced by Chiappori (1988, 1992). In order to endogenize the weights, we assume that an individual's bargaining position depends on his or her outside options. As a simple specification of this idea, we assume that a

[8] With this parameter restriction, the utility function is decision-equivalent to $u_{g,i} = \psi \ln c_{g,i} + \nu \ln d_{g,i} + (1 - \psi - \nu) \ln l_{g,i}$.

spouse's weight is equal to her relative contribution to the household's full income:

$$\lambda_{F,i} = \frac{W_{F,i}}{W_{F,i} + W_{M,i}},\ \lambda_{M,i} = \frac{W_{M,i}}{W_{F,i} + W_{M,i}} \tag{4.5}$$

Full incomes, $W_{F,i}$ and $W_{M,i}$, should be understood as the amount of earnings on both markets if the entire time endowment was spent on paid labor and thus depend on wages and on the agent's choice of labor market. For the intra-household decision process it makes no difference whether the full incomes are actually earned or not, i.e. $W_{F,i}$ and $W_{M,i}$ are hypothetical incomes.[9]

A wife has a time endowment of one, which can be used for leisure $l_{F,i}$, first-market labor $n_{F,i}^{1,S}$, labor at home $h_{F,i}$, and labor at the second market $n_{F,i}^{2,S}$ (superscript S indicating supply). Husbands face an equivalent constraint:

$$l_{G,i} + n_{G,i}^{1,S} + n_{G,i}^{2,S} + h_{G,i} \leq 1, \quad G = M, F \tag{4.6}$$

Home goods have to be produced using capital k_i and labor as inputs. Labor in home production of a partnership is a weighted sum of husband's ($h_{M,i}$) and wife's labor ($h_{F,i}$) and the amount of hired labor ($n_i^{2,D}$):

$$d_{F,i} + d_{M,i} \leq A\left(k_i\right)^{\theta}\left(h_{F,i} + h_{M,i} + \eta \cdot n_i^{2,D}\right)^{1-\theta} \tag{4.7}$$

In this model, own and hired labor are perfect substitutes.[10] This is similar to the existence of market-produced substitutes to home-produced home goods as in Gronau (1977, 1980) and Ngai and Pissarides (2008). The parameter η measures the relative productivity of

[9] If utility weights were fixed, wives' leisure would decrease when the gender wage gap closes, which is counterfactual to what is observed, see Knowles (2007). Knowles argues that, when female wages rise, not only becomes her leisure more expensive to the household, but also improves her intra-household bargaining position due to better outside opportunities. Equation (4.5) is a stylized version of utility weights reflecting outside options. This decision rule allows us to solve the model in closed form. Other decision rules such as Nash Bargaining or Equal Surplus Splitting (Knowles 2007) lead to analytically non-tractable solutions of our model.

[10] Olivetti (2006) has also studied the effects of external services in home production (production of "child quality" in her case), but in her model these services are complements to own labor. We model hired home labor as substitutes to own labor, such that it can actually "free up" time to use for market labor.

hired home labor compared to own house work. For instance, for $\eta > 1$, one unit of hired time does replace more than one unit of own time, which would reflect that professional service providers produce home goods more efficiently than household members themselves.

The home production function (4.7) implies that replacing one unit of one's own time in home production costs w/η, where w is the wage rate for external home labor. A frictionless market for home labor would have a strong efficiency implication. Individuals whose opportunity cost of time is higher than w/η should not work at home at all. Since η is likely to be larger than 1, all individuals facing higher wage rates than the wage rate for home labor should employ personnel if the market for home labor was perfect. Furthermore, every individual would either supply or demand home labor at the market. Obviously, this is not how people behave.

There seem to be forces at play that distort the decision whether to outsource home labor. In the spirit of Chari, Kehoe, and McGrattan (2007), we capture such forces as a wedge. Specifically, we introduce a "home labor wedge" $1+\gamma$ into agents' budget constraints. This wedge implies that a household, that wishes to hire home labor for a certain amount $w \cdot n_i^{2,D}$, has to bear total costs of $(1+\gamma) \cdot w \cdot n_i^{2,D}$.

The budget constraint in terms of the market good for couple i then reads as:

$$c_{F,i}+c_{M,i}+q \cdot k_i+(1+\gamma) \cdot w \cdot n_i^{2,D} \leq a_{F,i} \cdot n_{F,i}^{1,S}+a_{M,i} \cdot n_{M,i}^{1,S}+w \cdot (n_{M,i}^{2,S}+n_{F,i}^{2,S}), \tag{4.8}$$

where q is the relative price of home capital.

The home labor wedge may be due to several reasons. One is disutility when outsourcing home labor. For instance, parents who outsource child care may suffer from being apart from their children (Davis and Henrekson 2004). Another form of utility costs is related to discrimination, for instance when child care or geriatric care are outsourced.[11] The need for mutual trust makes employing household personnel more difficult (Brück, Haisken-DeNew, and Zimmermann 2006). The home labor wedge can also be due to a lack of market transparency because a substantial part of the trade in home labor occurs in the shadow economy

[11] This point is emphasized by Fernández (2007), who argues that female labor supply "may depend on how a woman conceives of her role in the household, [...] or how she is treated as a result of her choice" (p. 6).

(Dortch 1996).

Our preferred interpretation of the home labor wedge is that outsourcing home labor involves utility costs. To provide a formal justification for this interpretation, we consider a version of the model (see Appendix 4.C) using a different utility function under which the equilibrium time allocation is the same as in our baseline model using the resource costs in the budget constraint (4.8).

The decision problem for couples is to maximize (4.4) by choosing consumption levels, time allocations, and demand for home capital and home labor subject to (4.6), (4.7), and (4.8) for given q, w, a_i. Singles face a similar decision problem as couples. They maximize individual utility (4.3) without the possibility of intra-household specialization subject to the following constraints (for $g = f, m$):

$$l_{g,i} + n_{g,i}^{1,S} + n_{g,i}^{2,S} + h_{g,i} \leq 1 \tag{4.9}$$

$$d_{g,i} \leq A \cdot (k_{g,i})^{\theta} \cdot (h_{g,i} + \eta \cdot n_{g,i}^{2,D})^{1-\theta} \tag{4.10}$$

$$c_{g,i} + q \cdot k_{g,i} + (1+\gamma) \cdot w \cdot n_{g,i}^{2,D} \leq a_{g,i} n_{g,i}^{1,S} + w \cdot n_{g,i}^{2,S} \tag{4.11}$$

4.4 Allocation of Time

In this section, we discuss how we derive group-specific hours. In Section 4.4.1, we discuss decisions at the household level for given prices exploiting information from optimality conditions. We aggregate these household-level decisions in Section 4.4.2 and determine the labor-market equilibrium in Section 4.4.3. In Section 4.4.4, we analyze comparative-static properties of the equilibrium.

4.4.1 Decisions at the household level

This section presents and discusses households' optimal decisions on time allocations and demand for home labor. All decisions presented in this section are derived formally in Appendix 4.B. In the appendix, decisions are derived for a general ϕ whereas, in this section, we present decisions for the special case $\phi \to 1$.

Depending on the relation between first and second market wages, households take discrete labor market choices, i.e. they decide on which market to work. Given the composition of the economy, couples split up into four groups of households regarding their behavior on the market for home labor. Households with high first-market wages demand home labor while, for those with low first-market wages, it is optimal to supply one or both spouses' labor on the second market. Other couples will not act on the market for home labor at all.

Individuals' potential first-market wages determine to which group an individual belongs. Agents with first-market wages lower than the wage on the second market, w, will decide to supply home labor.

The wage threshold for demanding home labor depends on the total costs of outsourcing one unit of home labor. When solving the model, it is convenient to explicitly distinguish between the price for outsourcing one unit of home labor and the wage received for supplying one unit. A household that wishes to replace one unit of its own time by hired home labor has to pay an effective price, p, given by

$$p = (1 + \tau) \cdot w, \tag{4.12}$$

where

$$1 + \tau = \frac{1 + \gamma}{\eta}. \tag{4.13}$$

Agents whose first-market wages exceed this price p will not work in home production themselves. For these agents, it is rational to outsource home labor and gain time for market work since their wages exceed the total costs of outsourcing. Agents with first-market wages between p and w will not act on the market for home labor at all.

Considering equation (4.12), it is apparent that the difference between the wage received for home labor and its effective price is equivalent to a distortionary tax on the second-market wage. When solving the model, we thus refer to the relative difference, τ, between price the p and wage w for home labor as an "as-if" tax. The "as-if" tax consists of the home labor wedge γ and the relative productivity of hired home labor η (see equation (4.13)) and measures the attractiveness of the market for home labor. It is also apparent that reductions in the home labor wedge γ and increases in relative productivity of hired home labor, η, respectively, have the same qualitative effects.

Table 4.1 summarizes optimal labor supply and demand decisions of the four groups of couples. Group sizes can be read from the first column. While we will derive the decisions of the first group of couples explicitly, we will sketch only briefly the mechanisms leading to the decisions of the other groups and those of singles.

(1)	(2)	(3)	(4)	(5)	(6)
	male hours		female hours		labor 2
	market 1	market 2	market 1	market 2	demand
	$n_{M,i}^{1,S}$	$n_{M,i}^{2,S}$	$n_{F,i}^{1,S}$	$n_{F,i}^{2,S}$	$n_i^{2,D}$
group 1 $i \in [\frac{p}{\alpha}, 1]$	$\psi + \nu$	0	$\psi + \nu$	0	$(1+\alpha)\cdot$ $(1-\theta)\nu\frac{i}{p}$
group 2 $i \in [\frac{w}{\alpha}, \frac{p}{\alpha}]$	$\psi + \nu$	0	$\psi + \theta\nu$ $-\alpha^{-1}(1-\theta)\nu$	0	0
group 3 $i \in [w, \frac{w}{\alpha}]$	$\psi + \nu$	0	0	$\psi + \theta\nu$ $-(1-\theta)\nu\frac{i}{w}$	0
group 4 $i \in [0, w]$	0	$\psi + \theta\nu$	0	$\psi + \theta\nu$	0

Table 4.1: Summary of couples' labor supply and demand decisions

Singles do not have the possibility of intra-household specialization and split up into three groups. For high-wage singles, it is rational to hire home labor in order to gain time to work on the first market. Singles with a medium first-market wage neither demand nor supply home labor. Low-wage singles supply home labor. Within the groups, decisions are the same for both men and women. The only difference is that for men, more individuals belong to the first two groups, due to the gender-specific wage distributions. Table 4.2 presents a summary of labor supply and demand decisions of singles.

Group 1: Top-wage couples. For households with $i > \frac{p}{\alpha}$ (see first row of Table 4.1), it is rational to hire home labor and to supply own labor only on the first market since both their wages (husband and wife) exceed the effective price for hired home labor, $\alpha i > p$. Consequently, both spouses neither supply labor on the second market ($n_{F,i}^2 = n_{M,i}^2 = 0$) nor work in home production themselves ($h_{F,i} = h_{M,i} = 0$). The remaining time-use decisions can be derived by considering the shares of wealth the household devotes to the goods which provide utility. The full (potential) income of a household of this type is the sum of the two wages, $W_i = a_{F,i} + a_{M,i} = (1+\alpha)i$. The expenditure shares for specific goods are determined by the corresponding utility weights.

For instance, husband's leisure multiplied with its opportunity costs is a constant fraction of full income in the optimum:

$$l_{M,i} \cdot a_{M,i} = \lambda_{M,i}(1 - \psi - \nu)W_i \tag{4.14}$$

Since $\lambda_{M,i} = \frac{W_{M,i}}{W_{F,i}+W_{M,i}} = \frac{a_{M,i}}{a_{F,i}+a_{M,i}}$, leisure of the husband is $l_{M,i} = 1 - \psi - \nu$ and, analogously, the wife spends $l_{F,i} = 1 - \psi - \nu$ on leisure time.

As both spouses do not work at home, they spend their remaining time working on the first market:

$$n^{1,S}_{M,i} = n^{1,S}_{F,i} = \psi + \nu \tag{4.15}$$

For the amount of hired home labor, total opportunity costs have to equal a constant fraction of total income that is determined by the corresponding utility weight and the efficient share of labor in the production of the home good, such that:

$$n^{2,D}_i = (1 + \alpha) \cdot (1 - \theta)\nu \frac{i}{p} \tag{4.16}$$

Group 2: High-wage couples. Couples with wages in the range $\frac{w}{\alpha} < i < \frac{p}{\alpha}$ do not act on the second labor market since it is neither rational to hire nor to supply home labor. Spouses consume equal amounts of leisure time, as all couples do. For non-leisure time, household optimization results in differences between spouses. Due to husband-wife wage differentials it is efficient to specialize. Married women in this group supply less labor on the first market than their husbands but spend more time on home production to provide their husbands with home goods as well, see the second row of Table 4.1.

Group 3: Low-wage couples. In households with $w < i < \frac{w}{\alpha}$, husbands work on the first labor market solely, whereas wives work on the second market and at home. As husbands in this group do not work at home, they spend their non-leisure time entirely on the first market. Women, however, spend some time in home production and devote only the remaining non-leisure time to paid second-market work. As before, the reason for intra-household differences in market hours is specialization.

(1)	(2)	(3)	(4)	(5)	(6)
	range for women	range for men	hours market 1 $n^{1,S}_{g,i}$	market 2 $n^{2,S}_{g,i}$	labor 2 demand $n^{2,D}_{g,i}$
group a	$i \in [\frac{p}{\alpha}, 1]$	$i \in [p, 1]$	$\psi + \nu$	0	$(1-\theta)\nu\frac{a_{g,i}}{p}$
group b	$i \in [\frac{w}{\alpha}, \frac{p}{\alpha}]$	$i \in [w, p]$	$\psi + \theta\nu$	0	0
group c	$i \in [0, \frac{w}{\alpha}]$	$i \in [0, w]$	0	$\psi + \theta\nu$	0

Table 4.2: Decisions of singles ($g = f, m$); $a_{f,i} = \alpha \cdot i$, $a_{m,i} = i$

Group 4: Bottom-wage couples. Households with $i < w$ have potential first-market wages which are so low that both, husband and wife, decide to work on the second market. Since wages are equal on this market, there is no incentive to specialize within the household for these couples and both spouses could engage in home production. As wages on the second market do not differ by gender, the allocation of working times across spouses is indetermined. We can only state how much they will supply together. In the following, we will assume that households in the bottom-wage group split both types of labor equally among wife and husband.[12]

Group a: High-wage singles. Singles earning higher first-market wages than the effective price for home labor, $a_{g,i} > p$, hire home labor. Equivalent to the decisions of couples discussed above, all singles consume a constant amount $1 - \psi - \nu$ of leisure time. Since singles in the high-wage group do not work at home themselves, they spend their remaining time on the first market. Similar to top-wage couples, demand for home labor depends positively on the ratio of a single's individual wage to the price for home labor, see the first row in Table 4.2.

Group b: Medium-wage singles. Singles with medium wages, $w < a_{g,i} < p$, neither demand nor supply home labor. They work on the first market and at home. They do not take advantage of any form of specialization, neither within nor among households. Singles in this group therefore work less on the market than singles in group a because

[12] For the following analysis, it is sufficient that households in this group split labor equally on average.

they work in home production on their own. Their time allocations solely reflect utility weights and production elasticities.

Group c: Low-wage singles. Singles whose potential wages on the first market fall short of the wage on the second market, $a_{g,i} < w$, decide to supply home labor. This group differs from the previous one only with respect to market choice. The allocation of time to leisure, home production, and market work is identical.

4.4.2 Average labor supply of population groups

We derive average market hours by gender and marital status by aggregating individual decisions. Market hours refer to total compensated work and consist of first- and second-market labor supply. Average market time of married men are derived by integrating columns (2) and (3) of Table 4.1:

$$N_M = \psi + \nu - (1-\theta)\nu \cdot w \tag{4.17}$$

When the wage for home labor increases, compensated male labor decreases since group 4 grows and, in this group, men do also work in the household and less on the market than men in other groups.

Average compensated hours of wives are calculated by integrating labor supply as given in columns (4) and (5) of Table 4.1:

$$\begin{aligned} N_F =& \psi + \left(1 - \frac{w}{\alpha}\right)\nu + \frac{w}{\alpha}\theta\nu \\ & - \left(\frac{p}{\alpha} - \frac{w}{\alpha}\right)\frac{1+\alpha}{\alpha}(1-\theta)\nu - \int_w^{w/\alpha}\left[(1-\theta)\nu\frac{i}{w}\right]\,\mathrm{d}i \\ =& \psi + \nu - (1-\theta)\nu\left[\alpha^{-2} + \alpha^{-1}\right]p + (1-\theta)\nu\left[\frac{\alpha^{-2}}{2} + \frac{1}{2}\right]w \end{aligned} \tag{4.18}$$

Wives' hours increase in the wage w for home labor but decrease in the price p. When w rises, more women receive male help in the household (group 4 grows) and some women (those in group 3) face rising opportunity costs of non-market time. When p rises, group 1 becomes smaller and, in this group, wives work the most.

Integrating total labor on both markets as given in columns (4) and (5) of Table 4.2, one can see that average compensated labor of female singles decreases in the second-market price p and is independent of the second-market wage w:

$$N_f = \psi + \nu - (1-\theta)\nu \cdot \frac{p}{\alpha} \tag{4.19}$$

The wage for home labor w does not affect hours of single women because changes in w only induce some women to change the market (women changing from group b to group c). But these women still keep working the same amount of time. However, decreases in p motivate some women to hire someone for doing house work and to increase their activity on the first market (women changing from group b to group a).

Analogously to female singles, we derive average market hours of single men by integrating total labor of both types, as given in columns (4) and (5) of Table 4.2, taking into account the group sizes for males reported in column (3):

$$N_m = \psi + \nu - (1-\theta)\nu \cdot p \tag{4.20}$$

Average hours of single men also decrease in p and are independent of w. The reasons are the same as for women. Men's response to a change in the second-market effective price p is weaker than that of women as $\alpha < 1$.

Considering individual decisions in Tables 4.1 and 4.2 and aggregated hours given by equations (4.17) to (4.20), it is apparent that time-use decisions neither depend on the price for home capital, q, nor on total factor productivity, A (see Jones, Manuelli, and McGrattan (2003) for a detailed discussion). These properties are an implication of Cobb-Douglas technology and preferences and they do not necessarily hold under different assumptions. In the quantitative part of the chapter, we relax the parameter restriction $\phi \to 1$ in the utility function (4.3), which allows q and A to affect hours decisions.

4.4.3 Equilibrium

We now analyze the equilibrium of the market for home labor and its dependency on the attractiveness of the market for home labor as measured by the "as-if" tax τ defined in (4.13). Having solved for equilibrium prices, p and w, we can analyze average market hours by gender and marital status as given by equations (4.17) to (4.20).

An equilibrium is an allocation of goods and time $\left\{c_{g,i}, d_{g,i}, k_{g,i}, l_{g,i}, n^1_{g,i}, n^{2,S}_{g,i}, h_{g,i}, n^{2,D}_{g,i}\right\}, g \in \{F, M, f, m\}, i \in [0,1]$

together with prices w and p which satisfy optimal decisions as discussed in Section 4.4.1. Furthermore, market clearing for goods requires $(1-s)\cdot\sum_{g=F,M}\int_0^1 a_{g,i}n_{g,i}^1 di + s\cdot\sum_{g=f,m}\int_0^1 a_{g,i}n_{g,i}^1 di = (1-s)\cdot\sum_{g=F,M}\int_0^1 (c_{g,i}+q\cdot k_{g,i})\,di + s\cdot\sum_{g=f,m}\int_0^1 (c_{g,i}+q\cdot k_{g,i})\,di$. The market for home labor is cleared when $(1-s)\cdot\sum_{g=F,M}\int_0^1 n_{g,i}^{2,S}di + s\cdot\sum_{g=f,m}\int_0^1 n_{g,i}^{2,S}di = (1-s)\cdot\sum_{g=F,M}\int_0^1 n_{g,i}^{2,D}di + s\cdot\sum_{g=f,m}\int_0^1 n_{g,i}^{2,D}di$.[13]

The market-clearing effective price and wage on the second market for a given $\tau\geq 0$ are:

$$p=(1+\tau)^{1/2}\cdot\left[\frac{(1+\alpha)D_1}{S_1+(1+\tau)D_1D_2}\right]^{1/2} \tag{4.21}$$

$$w=(1+\tau)^{-1/2}\cdot\left[\frac{(1+\alpha)D_1}{S_1+(1+\tau)D_1D_2}\right]^{1/2}, \tag{4.22}$$

where $D_1 := \frac{1}{2}(1-\theta)\nu$, $D_2 := \alpha^{-1}+\alpha^{-2}+s-\alpha^{-2}s$, and $S_1 := (\alpha^{-1}+1)(\psi+\theta\nu)-\frac{1}{2}(1-s)(\alpha^{-2}-1)(1-\theta)\nu$ are positive composite parameters. The effective price for home labor p is increasing in the "as-if" tax τ, while the respective wage w decreases in this measure of the attractiveness of the second market.[14]

4.4.4 Hours worked in equilibrium

The data suggests the following three observations with respect to market hours by gender and marital status (see Section 4.2): (i) Husbands work the most, followed by male singles and female singles. Married women work the fewest hours. (ii) Husbands' hours decreased and all other groups' hours increased over time. (iii) Comparing the magnitudes of the changes, wives' change was by far the strongest.

We now show that the model outlined in Section 4.3 is able to generate the ordering of hours, i.e. $N_M > N_m > N_f > N_F$. Moreover, the model generates the direction and relative magnitude of the changes over time as a (comparative-static) response to a decrease in the "as-if" tax on the market for home labor, τ. The "as-if" tax decreases when the relative productivity of hired home labor, η, increases or the home labor

[13] Note that we take q as given by technology.

[14] The derivation of equilibrium prices and their marginal derivatives with respect to τ can be found in Appendix 4.D.

wedge, γ, decreases, see (4.13). Thus, increases in η and reductions in γ have the same qualitative effects. These properties of the model follow from average market hours by gender and marital status as given by equations (4.17) to (4.20) and the reactions of price and wage for home labor to changes in the "as-if" tax τ, $\partial p/\partial \tau > 0$, $\partial w/\partial \tau < 0$. Analytical proofs of all statements can be found in Appendix 4.D.

1. Levels of hours worked by groups. In the labor-market equilibrium, average market hours by population groups fulfill $N_M > N_m > N_f > N_F$.

On average, married men work more hours on the market than single men because fewer married men have to work in home production due to intra-household specialization. On the other hand, male singles spend more time on market work than their female counterparts because more single men than single women can afford to outsource home labor. Finally, single women's average market time exceeds that of married women because some wives work more in home production providing this commodity also to their husbands. Thus, the ordering of average labor supply by groups is as in the data.

2. Directions of changes over time. If the market for home labor becomes more attractive, and thus the "as-if" tax τ declines, average hours of market work of married men decrease while all other groups' average hours increase.

When the "as-if" tax declines, the wage for home labor w increases and the effective price for this type of labor, p, decreases. Since outsourcing home labor is associated with lower costs, more households decide to use this opportunity. This is freeing up time for those agents who previously worked in home production. Therefore, average market hours by singles of both genders and by married women increase. Married men, by contrast, are affected in the opposite way. In households which decide to outsource home labor after the reduction in τ, the husband did not work in home production anyway. However, some other husbands begin to work in the household and reduce market hours because there are no longer intra-household market-wage differentials due to the increased earnings opportunities on the second market which favor their wives.

3. Magnitude of changes over time. The change in married women's market hours is the strongest one of all four population groups.

As before, we consider a decline in the "as-if" tax τ. In those households where husbands start to work in home production, wives at least compensate their husbands' market-hours decrease by own increases. Total market-labor supply of these households thus increases because opportunity costs of non-market time increase due to the wage rise on the second market. All other husbands record constant hours in this scenario, whereas there are some other wives who also increase their market time, e.g. because outsourcing is freeing up time. Thus the change in married women's market hours dominates the change in married men's hours in absolute terms.

The increase in hours for married women is also stronger than the induced increase for singles. When τ decreases, wives are affected stronger than single women because the married women involved did work more at home than singles as they provided their husbands with home goods as well. Female singles, on the other hand, are more strongly affected than male singles. Since the wage distribution for women is more compressed than the one for males, more female singles fall into the range of households that decide to outsource home labor after the decrease in τ.

4.5 Quantitative Analysis

We now calibrate our model to trace the developments in hours worked by gender and marital status. We then use the model to assess the relative importance of different explanations for the group-specific trends in hours. Group-specific labor supply depends on several developments, such as the fertility and marriage decline (Chiappori and Weiss 2006; Albanesi and Olivetti 2007), overall productivity growth (Mincer 1962; Smith and Ward 1985), technological improvements in home production (Greenwood, Seshadri, and Yorukoglu 2005), and the closure of the gender wage gap (Galor and Weil 1996; Jones, Manuelli, and McGrattan 2003; Knowles 2007; Attanasio, Low, and Sánchez-Marcos 2008). If trading home labor has become more attractive over time, this is an additional explanation for trends in hours, see Section 4.4.4.

In our model, trading home labor can become more attractive due to two developments: relative productivity growth of hired home labor and reductions in the home labor wedge. While the former development corresponds to increases in the parameter η in the home production function (4.7), the latter development is captured by reductions in the parameter γ in equations (4.8) and (4.11). The technology parameter

η can in principle be observed, while there is no directly observable counterpart for the home labor wedge γ.

As argued by Chari, Kehoe, and McGrattan (2007), wedges can represent several structural characteristics of markets. In our setting, the home labor wedge represents, for instance, disutility from outsourcing home labor and is thus not directly observable. Therefore, we use our model to quantify it. A second key point of Chari, Kehoe, and McGrattan (2007) is that wedges are time varying. In our setting, the home labor wedge is likely to have experienced changes over time due to changes in social norms. When quantifying the home labor wedge γ, we therefore allow for time variation in this parameter. We use our model to determine a sequence for γ under which the model generates the closest fit to the observed trends in hours. This means that, per point in time, we want to match four moments (hours worked by population groups) by choosing one free parameter (the home labor wedge) in a structural model, taking into account changes in other, observable variables.

We then use the calibrated model to quantify the relative contributions of the different channels when accounting for the group-specific trends in hours. First, we insert information on observables, such as demographic changes, the wage-gap closure, and technology changes, into our model one-by-one. Then, we assess the influence of the home labor wedge.

4.5.1 Wage distribution

For the quantitative analysis, we should make the specification of the wage distribution more realistic than the one used in the theoretical part of the chapter. So far, we have assumed a uniform distribution of wages, which allowed us to solve the model in closed form and to derive comparative-static properties analytically. For the quantitative analysis, we replace the uniform distribution by a log-normal one.

Analogously to our previous specification with a uniform distribution, we capture male-female wage differentials by assuming that the female wage distribution is a downward spread of the male one in the sense that

$$G(a) = F\left(\frac{a}{\alpha}\right), \tag{4.23}$$

where G is the female cumulative log-normal density and F the male one. Figure 4.2 illustrates the relation between F and G. For any particular

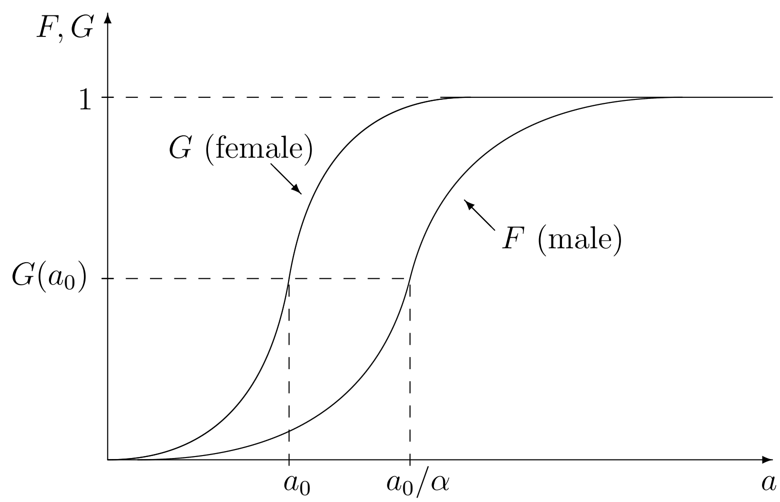

Figure 4.2: Relation between Male and Female Wage Distributions

wage a_0, more women than men fall short of this wage, which implies that $G \geq F \; \forall a$. Thus men are earning more than women in the sense of first-order dominance.

Under assumption (4.23), it holds that

$$\sigma_{female,t} = \sigma_{male,t} \tag{4.24}$$

$$\text{and } \mu_{female,t} = \mu_{male,t} + \ln \alpha_t, \tag{4.25}$$

where μ is the mean and σ the standard deviation of the respective normal distribution of log wages. Relation (4.24) is shown by Browning, Chiappori, and Weiss (2010) as a stylized empirical result and allows us to describe the wage structure in our model by just one variance. The entire wage structure at a specific point in time can thus be described by three parameters, mean and variance of the male wage distribution as well as the gender difference α. Under perfectly assortative mating, a husband with first-market wage a is paired with a woman earning $\alpha \cdot a$.

The choice of wage distribution does not affect individual decisions for given prices. By contrast, it does affect aggregation and equilibrium prices.

4.5.2 Calibration

We match our model to average hours by population groups in the five decades from the 1960's to now, i.e. $t = 1961\text{-}69, 1970\text{-}79, 1980\text{-}89, 1990\text{-}99, 2000\text{-}06$. By pooling the CPS data decade-wise, we are confident to filter out developments that occur at business-cycle frequency and we consider the five decades as separate equilibria. Table 4.3 presents a summary of the parameter choices.

Technology and demography. To quantify the fraction of singles in the economy, s, we compute the share of non-married individuals decade-wise from the CPS. Similarly to Jones, Manuelli, and McGrattan (2003), we calculate the relative price of home capital, q, as the ratio of the deflators for durable and non-durable goods in the National Income and Product Accounts.[15]

The capital share in home production, θ, is taken from Knowles (2007), who calibrates this number to 0.08 in order to match equipment spending as a share of total consumption. To quantify the parameters determining productivities in home production, we use the results of Ngai and Pissarides (2008) that productivity of marketized home production has grown at an annual rate of 0.4% while there has been no productivity growth in self-made home production. In our model, this implies that A is a constant (which we normalize to 1) and that η grows roughly with rate 4% per decade.

Preference parameters. We determine preference parameters by model calibration. In the theoretical part of the chapter, we have imposed the parameter restriction $\phi \rightarrow 1$ in order to isolate the effects of γ and η. In the quantitative part of the chapter, we relax this restriction and allow $\phi \neq 1$. The resulting labor supply and demand decisions are presented in Tables 4.6 and 4.7 in the appendix.

We calibrate the preference parameters ϕ, ψ, and ν to match mean levels of hours worked by groups. The chosen parameterization (see Table 4.3) implies that home and market consumption goods are complements. Furthermore, agents allocate roughly one half of their weekly time endowment (which we set to 80 hours) to leisure.

[15] The NIPA data are available online under www.bea.gov.

		1961-69	1970-79	1980-89	1990-99	2000-06
population composition						
s	fraction of singles	0.26	0.31	0.37	0.41	0.42
home production						
q	price of home capital	2.20	1.86	1.65	1.47	1.10
θ	capital share	0.08	0.08	0.08	0.08	0.08
A	TFP	1.00	1.00	1.00	1.00	1.00
η	rel. prod. of hired labor	1.00	1.04	1.08	1.13	1.17
γ	home labor wedge	5.50	2.69	1.70	1.67	1.92
preference parameters						
ϕ	substitution elasticity between c and d	0.25	0.25	0.25	0.25	0.25
ψ	weight on market good	0.42	0.42	0.42	0.42	0.42
ν	weight on home good	0.12	0.12	0.12	0.12	0.12
distribution parameters						
α	gender gap (full sample)	0.58	0.58	0.61	0.71	0.72
	gender gap (censored data)	0.61	0.60	0.61	0.70	0.71
μ	mean male wage (full sample)	2.35	2.43	2.36	2.36	2.45
	mean male wage (censored data)	2.39	2.46	2.35	2.33	2.43
σ^2	wage variance (full sample)	0.80	0.77	0.84	0.81	0.82
	wage variance (censored data)	0.78	0.77	0.88	0.90	0.92

Table 4.3: Choice of parameter values.

Finally, we need to determine the home labor wedge γ_t and a set of parameters characterizing the distribution of first-market wages, μ_t, σ_t^2, α_t. In order to ensure that our quantitative exercise is consistent with the underlying structural model, we have to take into account the model's predictions on labor market choices. For this reason, the distribution parameters are determined within the calibration procedure for γ_t described in the next paragraph.

Home labor wedge and wage distribution. Labor market choices determine whether first-market wages of agents are actually observable or not. According to our model, agents having lower first-market wages than w_t decide to work on the market for home labor and, consequently, their first-market wages should not be observable in year t. Since the equilibrium value for w_t depends on the home labor wedge γ_t, labor market choices and the observability of first-market wages depend on this parameter as well.

In order to ensure consistency, we determine γ_t and the wage-distribution parameters in an iterative way. The iterative procedure is performed separately for pooled decade data, $t = 1961\text{-}69, 1970\text{-}79, 1980\text{-}89, 1990\text{-}99, 2000\text{-}06$, and can be described as follows.

1. To obtain a first guess for the parameters of the wage distribution in a specific decade t, we fit log-normal distributions to all strictly positive hourly wages in our selected sample in this decade using Maximum Likelihood. We do so for both genders separately in order to obtain gender-specific means, $\mu_{female,t}$ and $\mu_{male,t}$, of log wages. The gender wage difference α_t is calculated as

   $$\alpha_t = \exp(\mu_{female,t} - \mu_{male,t}). \tag{4.26}$$

   Then, we use the parameters of the fitted male distribution and approximate the female one by $g(a) = f\left(\frac{a}{\alpha}\right)$. Since the entire wage structure in our model economy is described by the parameters referring to the male wage distribution along with α, we drop the index *male* and denote the wage distribution parameters by μ_t, σ_t, and α_t.

   We define a vector ρ_t containing the parameter values of our model (except for γ_t) for decade t:

   $$\rho_t = \left(s_t\, q_t\, \theta\, A\, \eta_t\, \phi\, \psi\, \nu\, \alpha_t\, \mu_t\, \sigma_t\right)' \tag{4.27}$$

2. Taking the values in ρ_t as given, we determine the value for γ_t that best enables the underlying structural model to match mean hours worked by gender and marital status in decade t. We choose that γ_t that minimizes a measure of the distance between the model and empirical moments, whereas the vector of moments comprises mean hours worked by gender and marital status. We calculate the theoretical moments for a given γ_t by aggregating household-level decisions in Tables 4.6 and 4.7 (multiplied with the respective densities of the wage distribution) as in Section 4.4.[16]

   Formally, let $N_{\rho_t}(\gamma_t)$ denote the vector of model moments for a given γ_t and a given parameter vector ρ_t, and let $\hat{\mathbf{N}}_t$ denote the corresponding empirical moments calculated from decade-t data. Our estimate $\widehat{\gamma}_t$ is the solution to the quadratic minimization problem

   $$\min_{\gamma_t} \Gamma(\gamma_t) = \left[\hat{\mathbf{N}}_t - \mathbf{N}_{\rho_t}(\gamma_t)\right]' \times \Omega_t^{-1} \times \left[\hat{\mathbf{N}}_t - \mathbf{N}_{\rho_t}(\gamma_t)\right], \quad (4.28)$$

   where Ω_t^{-1} is the inverse of a diagonal matrix with the sample variances of mean hours worked by gender and marital status along the diagonal. Thus, in each decade, we have an overidentified system with four moments to be matched and one parameter to be estimated. Minimization is carried out using a direct search method.

3. With the value for $\widehat{\gamma}_t$ resulting from step 2 and the current parameter vector ρ_t, we identify those agents who decide to work on the second market. Observed wages for those agents should not influence the identification of the distribution of first-market wages. For men, the fraction of individuals working on the second market evaluates as $F(w)$, for women as $F\left(\frac{w}{\alpha}\right)$. To update the parameters of the wage distribution we use a censoring routine. This censoring routine fits log-normal distributions to the upper $1-F(w)$ quantile of male wages and to the upper $1-F\left(\frac{w}{\alpha}\right)$ quantile of female wages. The Maximum-Likelihood estimation thereby takes into account that it deals with left-censored data. As in step 1, the

[16] When doing so, we need to determine the equilibrium second-market wage $w_t(\gamma_t)$. We determine the equilibrium wage numerically.

gender difference α_t is calculated as $\alpha_t = \exp(\mu_{female,t} - \mu_{male,t})$. The parameters μ_t and σ_t are again taken from the fitted male distribution (the one obtained using censored data).

As long as the new values for α_t, μ_t and σ_t are not sufficiently close to the ones in ρ_t, we update ρ_t with the new wage distribution parameters.[17] We then proceed with step 2 using the updated parameter vector ρ_t.

The final parameterization reflects a combination of wage-distribution parameters, α_t, μ_t, σ_t, and the home labor wedge, γ_t, for which the resulting labor market choices are consistent with the selection criterion to determine the parameters of the wage distribution. When the iterative procedure has converged, we proceed with the next decade.

The resulting sequence for γ_t (reported in Table 4.3) indicates that the home labor wedge has decreased substantially over time. This implies that outsourcing home labor has become more attractive to households, as non-wage costs of outsourcing home labor have declined.

Table 4.3 also reports the first guess for the gender wage gap α_t (which we derived from the entire data set without taking into account labor market choices) as well as the final parametrization for this parameter, which results from the iterative procedure described above. The sequence for α indicates that women are catching up to men in terms of first-market wages. Compared to the first guess, our final parameterization shows similar gender differences in wages. The developments of the distribution parameters μ and σ^2 reflect moderate average wage growth and rising inequality, respectively.

Calibration Results. Figure 4.3 displays the actual time series of hours worked by gender and marital status, together with the series of hours worked implied by our model under the calibration reported in Table 4.3. Empirical moments from the CPS are solid lines, while the dashed lines are their model counterparts. One can see that, under this calibration, the model is able to trace group-specific hours worked. The model does not only capture mean levels of hours worked by groups but, most importantly, it is able to predict the distinct changes in labor supply over time for all four groups. Since our model is successful at

[17] We stop the iteration if the Euclidian distance between ρ_t in the current and the previous iteration does not exceed a pre-specified (small) value.

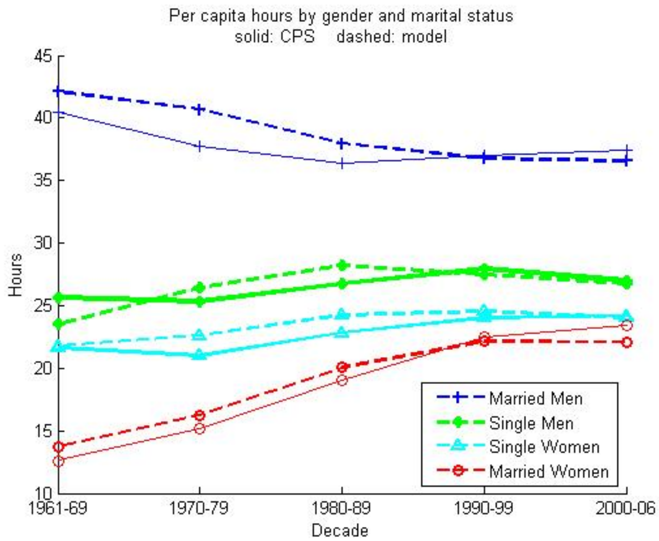

Figure 4.3: Per-capita hours under calibrated model versus empirical per-capita hours in the CPS

matching the series of hours worked, we use it to assess the relative importance of different determinants of labor supply at the subgroup level.

4.5.3 Accounting for the changes in hours

To assess the relative importance of different explanations for the group-specific trends in hours, we insert the time series for s_t, μ_t, σ_t^2, q_t, α_t, η_t, and γ_t reported in Table 4.3 into our model one after another, holding the other parameters at their 1960's level. This way, we first shut down all but the marriage-decline channel and then include the other channels in a cumulative way.[18]

The results of this accounting exercise are summarized in Table 4.4. The first row displays the observed changes in group-specific labor sup-

[18] Eckstein and Lifshitz (2009) also present an accounting exercise for labor supply but restrict their attention to female labor supply when comparing various explanations for the observed trend. Unlike Eckstein and Lifshitz (2009), we do not measure the effect of changes in fertility. Eckstein and Lifshitz (2009) find that the contribution of fertility to female employment is relatively small.

ply from the 1960's to the 2000's, i.e. a beginning-to-end-of-period comparison using CPS data. Rows 2 to 7 display group-specific changes predicted by our model when we incorporate parameter changes one by one.

In our model, the marriage decline can be captured by an exogenous increase in the parameter s. The second row in Table 4.4 refers to the case where we use the full time series for this parameter but fix the other variables at their 1960's levels. Under this scenario, average market hours do not change by much within groups formed by gender and marital status.[19]

If we additionally allow the parameters of the wage distribution to change over time, hours worked of married women and singles increase. Capital enhancing improvements in home technology, represented by reductions in the relative price for home capital q, result in further increases in hours.

In our model, the parameter α measures the gender wage gap.[20] The fifth row displays the changes in hours when we allow the wage gap to change over time, in addition to s, μ, σ, and q. In line with Jones, Manuelli, and McGrattan (2003) and Eckstein and Lifshitz (2009), the table shows that the closure of the gender wage gap plays an important role when accounting for the rise in hours at the subgroup level. Women increase their labor supply due to higher opportunity costs and, in the case of married women, also due to improved intra-household bargaining positions. Concerning married men, the increase in α leads to reduced labor supply.

The fifth line of the table also shows that, without taking into account developments that make outsourcing home labor more attractive, one can hardly account for the increases of hours worked by singles of both genders. In particular, the model does predict hardly any increase in labor supply of single men. The wage-gap closure cannot explain why the working time of single and married men evolved in different directions.

The finding that the traditional explanations are not sufficient to explain trends in hours is in line with Eckstein and Lifshitz (2009). They focus on the rise in female labor supply and find that a considerable

[19] This does not preclude compositional effects on groups formed by gender alone.

[20] Note that, in our model, we cannot study changes in wages and changes in education separately. Eckstein and Lifshitz (2009) make this distinction and find that both determinants are important and affect labor supply in the same direction.

		married women	married men	single women	single men
(1)	**CPS Data**	86.07%	-7.66%	11.68%	5.30%
(2)	marriage decline (s_t, $\bar{\mu}$, $\bar{\sigma}$, $\bar{q}$, $\bar{\alpha}$, $\bar{\eta}$, $\bar{\gamma}$)	-0.30%	-0.07%	-0.29%	-0.46%
(3)	+ wage growth (s_t, μ_t, σ_t, $\bar{q}$, $\bar{\alpha}$, $\bar{\eta}$, $\bar{\gamma}$)	10.39%	-2.05%	1.94%	2.25%
(4)	+ home capital improvements (s_t, μ_t, σ_t, q_t, $\bar{\alpha}$, $\bar{\eta}$, $\bar{\gamma}$)	16.53%	-1.81%	4.03%	4.15%
(5)	+ wage-gap closure (s_t, μ_t, σ_t, q_t, α_t, $\bar{\eta}$, $\bar{\gamma}$)	34.91%	-2.76%	2.31%	0.05%
(6)	+ prod. growth marketized home labor (s_t, μ_t, σ_t, q_t, α_t, η_t, $\bar{\gamma}$)	39.76%	-4.05%	4.01%	2.81%
(7)	+ changes in home labor wedge (s_t, μ_t, σ_t, q_t, α_t, η_t, $\hat{\gamma}_t$)	61.15%	-13.11%	10.30%	13.43%

Table 4.4: Accounting Exercise for the Rise in Hours (Overall Increase from the 1960's to the 2000's; Parameter Changes Incorporated in a Cumulative Way)

portion remains unexplained by the factors schooling, wages, fertility, and marital status. Eckstein and Lifshitz (2009) discuss developments in household technology and social norms as potential explanations for the remaining portion.

Our model encompasses two of such non-traditional determinants of labor supply: productivity of hired relative to own home labor and the home labor wedge. In our model, accounting for an observed moderate relative productivity growth on the market for home labor improves the predictions for all four population groups. This can be seen from the sixth line in the table, where we allow for changes in the relative productivity of hired home labor, η. Our model suggests that the increase in η is a source for a significant rise in hours worked by single men. At the same time, allowing for increases in η brings the model's predictions for the other three groups closer to what is observed in the data. However, to fully trace the patterns in hours for married couples and single women, the rise in the attractiveness of this market needs to be more pronounced than reflected by 4% relative productivity growth per decade.

The last row in Table 4.4 shows the results when we allow the home labor wedge γ to change over time. This parameter has been determined to provide the best fit of the model with respect to all four moments considered, given the other model parameters. It can be seen from Table 4.4 that the resulting sequence for γ explains a considerable part of the rise in hours by married and single women in our model. Concerning single men, however, our model overstates the increase in hours when we allow for time-variation in γ. Yet, the accounting exercise reported in Table 4.4 suggests that, to fully trace the group-specific trends in hours worked, we have to take into account that the home labor wedge has declined over time. Reductions in γ imply that non-wage costs of outsourcing home labor have declined. Thus, this decline reflects that outsourcing home labor has become more attractive to households.

The rising attractiveness of the market for home labor has two implications for the sectoral composition of the economy. With rising attractiveness of outsourcing home labor, the home-services sector increases in relative size. Furthermore, wages in this sector increase relative to average wages. Both implications are supported by empirical findings for the US. For instance, Blau (2001) documents that the market for child care arrangements has grown. Lee and Wolpin (2006) document growth in the service sector between 1950 and 2000. Similarly, Rogerson (2008) provides evidence on the sectoral composition of the US economy, reporting decreases in working time in the goods sector and increases in the services sector. Considering relative wages, Autor and Dorn (2009) investigate the growth of low-skill service jobs in the second half of the twentieth century. They find that wages exhibit above-average growth rates in this sector.

4.6 Conclusion

This chapter has investigated patterns in labor supply by gender and marital status in the US. We have shown that the observed group-specific trends in hours can be explained as optimal reactions to outsourcing labor in home production becoming more attractive to households over time.

To investigate the role of tradable home labor, we have introduced a market for home labor into a household model of labor supply. This model comprises four population groups: married women, married men, single women, and single men. Agents can decide whether to work in home production on their own or to hire someone for doing it. A prerequisite for such specialization is the presence of heterogeneity in wages. On the basis of individual households' labor supply and specialization decisions, we have solved for an aggregate equilibrium. The model is able to generate the ordering of hours at the subgroup level, and to generate the direction and relative magnitude of the changes in hours over time.

We have calibrated the model to trace the developments in hours worked by gender and marital status. Since our model is successful at matching the group-specific hours worked, we have used it to assess the relative importance of different determinants of labor supply at the subgroup level in an accounting exercise.

Our model has captured rising attractiveness of the market for home labor through two channels: first, by taking into account relative productivity growth on the market for home labor; second, by allowing for a time-varying home labor wedge. Our quantitative analysis has revealed that accounting for an observed moderate relative productivity growth on the market for home labor helps understanding the patterns in hours for all four population groups. To fully trace the patterns in hours for married couples and single women, the rise in the attractiveness of this market needs to be more pronounced than reflected by productivity growth alone.

The documented decline in the home labor wedge may be due to several developments. For instance, it may reflect rising social acceptance of outsourcing child care or geriatric care. Another reason for the decline of the home labor wedge may be an increase in market transparency due to government programs that aimed at pulling home services out of the shadow economy. We leave the task of assessing the relative merits of each of these interpretations for future research.

Overall, such developments reflect that non-wage costs associated with hiring home labor have declined over time and that the market for home labor has therefore become more attractive. The chapter has shown that taking the rising attractiveness of outsourcing home labor into account is important for understanding the trends in hours worked at the subgroup level.

Appendix

4.A CPS Data

Data description. We use data from the Current Population Survey (CPS) in the format arranged by Unicon Research.[21] The CPS is a monthly household survey conducted by the Bureau of the Census. In the CPS, respondents are interviewed to obtain information about the employment status of each member of the household 16 years of age and older. Survey questions covering hours of work, earnings, gender, and marital status are covered in the Annual Social Economic Supplement, the so-called March Supplement Files.

The sample of the CPS is representative of the civilian non-institutional population. Our selected sample comprises civilians aged 18 to 65, which is a standard definition of working-age population. The time period spanned by our data is 1962-2007. Data on hours and earnings is retrospective and refers to the previous year. In all our calculations, we use weights.

Our quantitative analysis is based on cross-sectional first moments measuring average hours per capita by gender and marital status. Figure

[21] See http://www.unicon.com/.

4.1 displays time series for these variables. The weekly hours variable is "hours worked last week at all jobs", which is the only information on hours worked which is available for all years and comparable across years. Other studies have documented that this variable yields similar results as the variable "usual weekly hours by number of weeks worked", which is not available for all years, see e.g. Knowles (2007) and Heathcote, Storesletten, and Violante (2008).

In the quantitative analysis presented in Section 4.5, we pool the CPS data decade-wise in order to filter out developments that occur at business-cycle frequency. Specifically, our empirical analysis considers the five decades from the 1960's to now, t = 1961-69, 1970-79, 1980-89, 1990-99, 2000-06.

We define a person as being married if the respondent answered the relevant question with "married, spouse present" (after Unicon recode). All other individuals are defined as being singles. The share of singles in our data is reported in Table 4.3.

We compute wages as annual earnings divided by annualized hours worked. In the CPS, gross annual earnings are defined as income from wages and salaries including pay for overtime. Nominal earnings are deflated with the CPI and expressed in 1992 dollars. Annual hours worked are calculated as the product of weeks worked last year and hours worked last week. When computing wage rates, we restrict the sample to people who worked at least 10 hours a week.

Significance of differences and trends in hours. Figure 4.4 shows a ± 2 standard deviations band around hours worked by gender and marital status on a yearly basis. The figure illustrates that hours worked differ significantly among subgroups. The bands of single women and married women come close to each other in the 2000's but p-values of tests of the hypothesis that average hours of single women are higher than average hours of married women are essentially zero in these years.

The upper part of Table 4.5 presents the time trends in log average hours by gender and marital status. $\hat{N}_{G,t}$ denotes average hours of group G in year t. Married men are captured by M, married women by F, single men by m, and single women by f. All four time series have a significant time trend, which is negative for married men and positive for the three other groups. The lower part of Table 4.5 presents empirical results on the differences in time trends. To test whether the

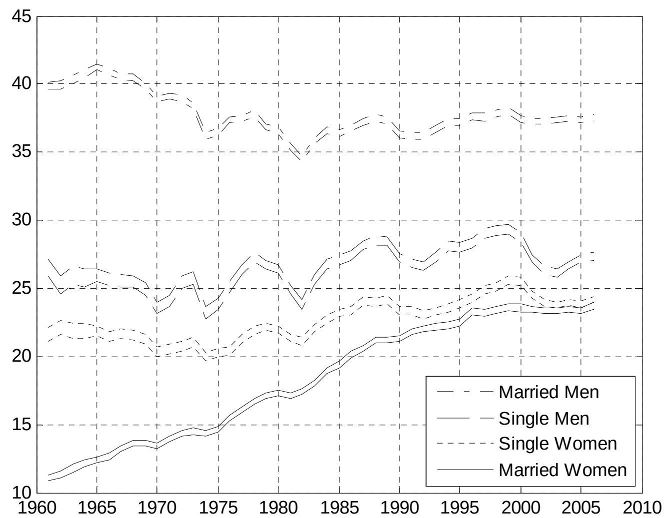

Figure 4.4: Average weekly market hours ± 2 standard deviations by gender and marital status in the US (March CPS, Persons aged 18-65)

estimated growth rates of hours worked by singles are significantly lower than the growth rate of married women' hours, we estimate the time trends in $\log\left(\hat{N}_{F,t}\right) - \log\left(\hat{N}_{f,t}\right)$ and $\log\left(\hat{N}_{F,t}\right) - \log\left(\hat{N}_{m,t}\right)$. To test whether the increase in hours of married women is significantly stronger than the decrease in hours of married men, we estimate the time trend of $\log\left(\hat{N}_{F,t}\right) + \log\left(\hat{N}_{m,t}\right)$. These three variables have significantly positive time trends documenting that the rise in married women's hours worked is significantly stronger than the developments in hours of all other groups.

4.B Formal derivation of optimal decisions

Couples. A couple i chooses $c_{F,i}$, $c_{M,i}$, $d_{F,i}$, $d_{M,i}$, $n^{1,S}_{F,i}$, $n^{2,S}_{F,i}$, $h_{F,i}$, $l_{F,i}$, $n^{1,S}_{M,i}$, $n^{2,S}_{M,i}$, $h_{M,i}$, $l_{M,i}$, $n^{2,D}_{i}$, and k_i in order to maximize (4.4) subject to (4.6), (4.7), (4.8), and non-negativity constraints for all decision variables. The concavity of the utility function ensures that consumption levels and leisure are always positive for both spouses. Positive leisure in turn ensures that the upper bound of 1 is never binding for any other

dependent variable	estimated time effect	standard deviation	t-value
$\log\left(\hat{N}_{M,t}\right)$	-0.18***	0.04	-4.75
$\log\left(\hat{N}_{F,t}\right)$	1.81***	0.06	30.79
$\log\left(\hat{N}_{m,t}\right)$	0.27***	0.05	5.40
$\log\left(\hat{N}_{f,t}\right)$	0.40***	0.04	9.33
$\log\left(\hat{N}_{F,t}\right)+\log\left(\hat{N}_{M,t}\right)$	1.64***	0.06	29.54
$\log\left(\hat{N}_{F,t}\right)-\log\left(\hat{N}_{m,t}\right)$	1.54***	0.06	26.94
$\log\left(\hat{N}_{F,t}\right)-\log\left(\hat{N}_{f,t}\right)$	1.41***	0.06	22.12

Table 4.5: Estimated time trends in hours worked by gender and marital status (estimated equation: dep. var. $= \beta_o + \beta_1 \cdot t + \varepsilon_t$, estimated time effects and standard deviations in percent per year, *** indicates that the estimated effect is statistically significant at the .99 significance level).

time use. Finally, $k_i \geq 0$ will never be binding since the home production function fulfills the Inada conditions. The Lagrangean of the couple's problem can thus be written as

$$\begin{aligned}
\mathcal{L} = {} & \lambda_{F,i} \cdot u_{F,i} + \lambda_{M,i} \cdot u_{M,i} \\
& + \varpi_{i,1} \left[A\left(k_i\right)^{\theta} \left(h_{F,i} + h_{M,i} + \eta \cdot n_i^{2,D} \right)^{1-\theta} - d_{F,i} - d_{M,i} \right] \\
& + \varpi_{i,2} \left[\begin{array}{c} a_{F,i} \cdot n_{F,i}^{1,S} + a_{M,i} \cdot n_{M,i}^{1,S} + w \cdot (n_{M,i}^{2,S} + n_{F,i}^{2,S}) \\ -c_{F,i} - c_{M,i} - q \cdot k_i - (1+\gamma) \cdot w \cdot n_i^{2,D} \end{array} \right] \\
& + \varpi_{i,3} \left[1 - l_{F,i} - n_{F,i}^{1,S} - n_{F,i}^{2,S} - h_{F,i} \right] \\
& + \varpi_{i,4} \left[1 - l_{M,i} - n_{M,i}^{1,S} - n_{M,i}^{2,S} - h_{M,i} \right] \\
& + \kappa_{i,1} \cdot n_{F,i}^{1,S} + \kappa_{i,2} \cdot n_{F,i}^{2,S} + \kappa_{i,3} \cdot h_{F,i} + \kappa_{i,4} \cdot n_{M,i}^{1,S} + \kappa_{i,5} \cdot n_{M,i}^{2,S} \\
& + \kappa_{i,6} \cdot h_{M,i} + \kappa_{i,7} \cdot n_i^{2,D},
\end{aligned}$$

where the ϖ's are Lagrange multiplier on the equality constraints and the κ's are Lagrange multipliers on the relevant inequality constraints.

The decision problem is solved sequentially in the following steps. We first determine the choice of the labor market for both agents. Then we determine the cost-minimal input combination to produce one unit of the home consumption good. Due to the constant-returns-to-scale property of the home consumption function, this yiels a couple-specific relative price of home consumption. In a third step, we determine the optimal combination of market and home consumption given the relative price of home consumption. Fourth, we determine the couple's demand for leisure and total consumption. Fifth, we deduce the relevant time-use and demand decisions.

1. Labor-market choice. The first-order conditions for $n_{F,i}^{1,S}$ and $n_{F,i}^{2,S}$ are

$$\begin{aligned} \varpi_{i,2}a_{F,i} - \varpi_{i,3} + \kappa_{i,1} &= 0 \\ \varpi_{i,2}w - \varpi_{i,3} + \kappa_{i,2} &= 0. \end{aligned}$$

Note that one of the two non-negativity constraints will always be binding when $a_{F,i} \neq w$. Assuming that only one non-negativity constraint is binding (i.e. that the wife will always supply some positive amount of labor), we get $\kappa_{i,1} > 0$ and $n_{F,i}^{1,S} = 0$ when $a_{F,i} < w$ and $\kappa_{i,2} > 0$ and $n_{F,i}^{2,S} = 0$ otherwise. Thus, the wife works only on the market where she can earn a higher wage. For the husband, we can analogously derive the equivalent result. With the wage structure expressed in the main text, we can state the following labor-market choices for couples: In couples with $a_{M,i} > w/\alpha$, both spouses work on the first market. In couples with $w < a_{M,i} < w/\alpha$, the husband works on the first market but the wife works on the second market. In couples with $a_{M,i} < w$, both spouses work on the second market.

2. Efficient home production. Having determined labor-market choice, we can denote an agent's effective wage as $\omega_{G,i}$ which is either w or $a_{G,i}$ depending on labor-market choice. Using this notation, we can merge time and budget constraints to

$$\begin{array}{c} c_{F,i} + c_{M,i} + q \cdot k_i + (1+\gamma) \cdot w \cdot n_i^{2,D} \\ +\omega_{F,i} \cdot (l_{F,i} + h_{F,i}) + \omega_{M,i} \cdot (l_{M,i} + h_{M,i}) \end{array} \leq \omega_{F,i} + \omega_{M,i}. \tag{4.29}$$

The decision problem at this stage is to maximize (4.4) subject to (4.7), (4.29) and the remaining non-negativity constraints, which is represented by

$$
\begin{aligned}
\mathcal{L} = {} & \lambda_{F,i} \cdot u_{F,i} + \lambda_{M,i} \cdot u_{M,i} \\
& + \varpi_{i,1} \left[A\left(k_i\right)^{\theta} \left(h_{F,i} + h_{M,i} + \eta \cdot n_i^{2,D} \right)^{1-\theta} - d_{F,i} - d_{M,i} \right] \\
& + \varpi_{i,5} \left[\begin{array}{c} \omega_{F,i} + \omega_{M,i} - c_{F,i} - c_{M,i} - q \cdot k_i - (1+\gamma) \cdot w \cdot n_i^{2,D} \\ - \omega_{F,i} \cdot \left(l_{F,i} + h_{F,i}\right) - \omega_{M,i} \cdot \left(l_{M,i} + h_{M,i}\right) \end{array} \right] \\
& + \kappa_{i,3} \cdot h_{F,i} + \kappa_{i,6} \cdot h_{M,i} + \kappa_{i,7} \cdot n_i^{2,D}.
\end{aligned}
$$

The first-order conditions for the three possible labor inputs into home productions read as

$$
\begin{aligned}
0 &= \varpi_{i,1} \cdot f_H - \varpi_{5,1} \cdot \omega_{F,i} + \kappa_{i,3} \\
0 &= \varpi_{i,1} \cdot f_H - \varpi_{5,1} \cdot \omega_{M,i} + \kappa_{i,6} \\
0 &= \varpi_{i,1} \cdot \eta \cdot f_H - \varpi_{5,1} \cdot (1+\gamma) \cdot w + \kappa_{i,7} \\
& \iff 0 = \varpi_{i,1} \cdot f_H - \varpi_{5,1} \cdot (1+\tau) \cdot w + \eta^{-1} \cdot \kappa_{i,7},
\end{aligned}
$$

where f_H is the marginal derivative of home production to effective labor input $H_i = h_{F,i} + h_{M,i} + \eta \cdot n_i^{2,D}$ and $1 + \tau = \eta^{-1}(1+\gamma)$. Due to the wage structure expressed in the main text, $\omega_{M,i}$ is never lower than $\omega_{F,i}$. Thus the non-negativity constraint on $n_i^{2,D}$ is only not binding when $\omega_{F,i} > (1+\tau) \cdot w$ which is the case for couples with $a_{G,i} > (1+\tau) \cdot w$ since we consider cases where $\tau > 0$. We can thus denote $p = (1+\tau) \cdot w$ as the effective price of hired home labor. Couples demand home labor when the wife's first-market wage is higher than this effective price. All other couples produce home consumption with own time input. In couples with $a_{M,i} > w$, the husband works on the first market and thus $\omega_{M,i} > \omega_{F,i}$. In these couples, the non-negativity constraint on $h_{M,i}$ is therefore always binding and $h_{M,i} = 0$. In couples with $a_{M,i} < w$, both spouses work on the second market and $\omega_{M,i} = \omega_{F,i} = w$. Opportunity costs of time spent in home production are therefore the same for both spouses and intra-household specialization is not efficient. As stated in Section 4.4.1, assume that spouses split labor equally in this situation. In the following, we express the effective costs of labor in home production (the cost of the chosen labor input) as π_i.

Summarizing the discrete decisions solved so far, couples split up into for groups:

1. Group 1 with $a_{M,i} > p$, where both spouses work on the first market and who demand marketized home labor ($\omega_{F,i} = a_{F,i}$, $\omega_{M,i} = a_{M,i}$, $\pi_i = p$, $H_i = n_i^{2,D}$).

2. Group 2 with $p > a_{M,i} > p/\alpha$, where both spouses work on the first market and the wife additionally in home production ($\omega_{F,i} = a_{F,i}$, $\omega_{M,i} = a_{M,i}$, $\pi_i = a_{F,i}$, $H_i = h_{F,i}$).

3. Group 3 with $p/\alpha > a_{M,i} > w/\alpha$, where the husband works on the first market and the wife works at the second market and at home ($\omega_{F,i} = w$, $\omega_{M,i} = a_{M,i}$, $\pi_i = w$, $H_i = h_{F,i}$).

4. Group 4 with $a_{M,i} < w$, where both spouses work on the second market and at home ($\omega_{F,i} = \omega_{M,i} = \pi_i = w$, $H_i = h_{F,i} + h_{M,i}$).

Efficient production of a level d_i of home consumption solves $\min_{k_i,H_i} q \cdot k_i + \pi_i \cdot H_i$ subject to $A\left(k_i\right)^{\theta}\left(H_i\right)^{1-\theta} = d_i$. Since the home production function is of Cobb-Douglas type, this yields the following cost function of home production in terms of market goods:

$$P_i^d = A^{-1} \cdot \left(\frac{q}{\theta}\right)^{\theta}\left(\frac{\pi_i}{1-\theta}\right)^{1-\theta}.$$

The efficient level of labor input is

$$H_i = (1-\theta)\frac{P_i^d}{\pi_i}d_i. \tag{4.30}$$

3. Efficient combination of home and market consumption. Consumption is a CES aggregate of market and home consumption $C_{G,i} = \left[\left(\frac{\psi}{\psi+\nu}\right)\left(c_{G,i}\right)^{\frac{\phi-1}{\phi}} + \left(\frac{\nu}{\psi+\nu}\right)\left(d_{G,i}\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}$. The price level for this CES aggregate is $P_i = \left[\left(\frac{\psi}{\psi+\nu}\right)\left(P^c\right)^{1-\phi} + \left(\frac{\nu}{\psi+\nu}\right)\left(P_i^d\right)^{1-\phi}\right]^{\frac{1}{1-\phi}}$, where P^c is the price of home consumption. Since the home consumption good is the numéraire, $P^c = 1$, the price level simplifies to $P_i = \left[\left(\frac{\psi}{\psi+\nu}\right) + \left(\frac{\nu}{\psi+\nu}\right)\left(P_i^d\right)^{1-\phi}\right]^{\frac{1}{1-\phi}}$. Given a total amount of consumption $C_{G,i}$, the demand for home consumption is

$$d_{G,i} = \left(\frac{\nu}{\psi+\nu}\right)\left(\frac{P_i^d}{P_i}\right)^{-\phi} C_{G,i}. \tag{4.31}$$

4. Demand for leisure and consumption. With the above results, the constraints of the decision problem can be merged to

$$\omega_{F,i} + \omega_{M,i} \geq P_i C_{F,i} + P_i C_{M,i} + \omega_{F,i} \cdot l_{F,i} + \omega_{M,i} \cdot h_{M,i}.$$

Futhermore, the utility weights can be expressed as $\lambda_{F,i} = \omega_{F,i} / (\omega_{F,i} + \omega_{M,i})$ and $\lambda_{M,i} = \omega_{M,i} / (\omega_{F,i} + \omega_{M,i})$. The outer utility function $U(C_{G,i}, l_{G,i})$ is of Cobb-Douglas type and its logarithm is $(\psi + \nu) \cdot \ln C_{G,i} + (1 - \psi - \nu) \cdot \ln l_{G,i}$. The decision problem can therefore be expressed by

$$\begin{aligned}
\mathcal{L} = & \frac{\omega_{F,i}}{\omega_{F,i} + \omega_{M,i}} \cdot \left[(\psi + \nu) \cdot \ln C_{F,i} + (1 - \psi - \nu) \cdot \ln (l_{F,i})^{1-\psi-\nu} \right] \\
& + \frac{\omega_{M,i}}{\omega_{F,i} + \omega_{M,i}} \cdot \left[(\psi + \nu) \cdot \ln C_{M,i} + (1 - \psi - \nu) \cdot \ln (l_{M,i})^{1-\psi-\nu} \right] \\
& + \varpi_{i,6} \left[\omega_{F,i} + \omega_{M,i} - P_i C_{F,i} - P_i C_{M,i} - \omega_{F,i} \cdot l_{F,i} - \omega_{M,i} \cdot h_{M,i} \right].
\end{aligned}$$

With log utility, optimization requires that the expenditure share on a certain good equals the respective utility weight. E.g.

$$\omega_{F,i} \cdot l_{F,i} / (\omega_{F,i} + \omega_{M,i}) = (1 - \psi - \nu) \cdot \frac{\omega_{F,i}}{\omega_{F,i} + \omega_{M,i}}$$

and equivalently for the husband. It follows that both spouses spent an equal amount of leisure time, $l_{F,i} = l_{M,i} = 1 - \psi - \nu$, independent of the couples' position in the wage distribution. Analogously, the couples' total amount is consumption

$$C_i = C_{F,i} + C_{M,i} = (\psi + \nu) \cdot (\omega_{F,i} + \omega_{M,i}) / P_i. \tag{4.32}$$

5. Time input to home production and labor supply. Couples demand home labor according to equations (4.30), (4.31), and (4.32), which results in

$$H_i = (1 - \theta) \cdot \nu \cdot (\psi + \nu) \cdot \frac{(\omega_{F,i} + \omega_{M,i})}{\nu \varphi_i + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta} \right)^{\theta} \left(\frac{1}{1-\theta} \right)^{1-\theta} (\pi_i)^{\frac{1-\theta}{\phi - 1}} \right)^{\phi - 1}}. \tag{4.33}$$

For couples in group 1, this is demand for marketized home labor, $n_i^{2,D} = H_i$ with $\pi_i = p$. For couples in groups 2, it holds $h_{F,i} = H_i$ with $\pi_i = a_{F,i}$. For couples in group 3, house work of the wife is $h_{F,i} = H_i$ with

$\pi_i = w$. Eventually, in group 4, spouses work in the household according to $h_{F,i} = h_{M,i} = H_i/2$ with $\pi_i = w$.

Market work can be determined as $1 - l_{G,i} - h_{G,i}$. For agents not working in home production (husbands in groups 1, 2, 3 and wives in group 1), this gives

$$h^{1,S}_{G,i} = \psi + \nu.$$

For wives in groups 2, working time is given by

$$h^{1,S}_{F,i} = \psi + \nu - (1-\theta) \cdot \nu \cdot (\psi + \nu) \cdot \frac{(\omega_{F,i} + \omega_{M,i})}{\nu a_{F,i} + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta}\right)^{\theta} \left(\frac{1}{1-\theta}\right)^{1-\theta} (a_{F,i})^{\frac{1-\theta}{\phi-1}} \right)^{\phi-1}}$$

and, for wives in group 3, labor supply is

$$h^{2,S}_{F,i} = \psi + \nu - (1-\theta) \cdot \nu \cdot (\psi + \nu) \cdot \frac{(\omega_{F,i} + \omega_{M,i})}{\nu w + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta}\right)^{\theta} \left(\frac{1}{1-\theta}\right)^{1-\theta} w^{\frac{1-\theta}{\phi-1}} \right)^{\phi-1}}.$$

Husbands and wives in group 4 both work on the second market, their hours are given by

$$h^{2,S}_{F,i} = h^{2,S}_{M,i} = \psi + \nu - (1-\theta) \cdot \nu \cdot (\psi + \nu) \cdot \frac{1}{\nu + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta}\right)^{\theta} \left(\frac{1}{1-\theta}\right)^{1-\theta} w^{1-\theta} \right)^{\phi-1}},$$

which uses that, in this group, $\omega_{F,i} + \omega_{M,i} = 2w$.

These time-use and demand decisions are summarized in Table 4.6, where $\omega_{F,i} + \omega_{M,i}$ is abbreviated by W_i. For the parameter restriction $\phi \to 1$, they simplify to the decisions expressed in Table 4.1.

Singles. A single (g, i) chooses $c_{g,i}$, $d_{g,i}$, $n^{1,S}_{g,i}$, $n^{2,S}_{g,i}$, $h_{g,i}$, $l_{g,i}$, $k_{g,i}$, and $n^{2,D}_{g,i}$ to maximize (4.3) subject to (4.9), (4.10), (4.11), and non-negativity constraints. The problem for a single can be solved analogously to that of couples with the exception that singles have no possibility of intra-household specialization. As married agents, singles work on the market where they can earn a higher wage. They demand marketized home labor when $a_{g,i} > p$. Singles thus split up into three groups:

1. Group a with $a_{g,i} > p$, who work on the first market and demand home labor ($\omega_{g,i} = a_{g,i}$, $\pi_{g,i} = p$, $H_{g,i} = n^{2,D}_{g,i}$).

2. Groub b with $p > a_{g,i} > w$, who work on the first market and at home ($\omega_{g,i} = \pi_{g,i} = a_{g,i}$, $H_{g,i} = h_{g,i}$).

3. Group c with $a_{g,i} < w$, who work on the second market and at home ($\omega_{g,i} = \pi_{g,i} = w$, $H_{g,i} = h_{g,i}$).

Then, all steps can be solved like in the problem of couples. Leisure is $l_{g,i} = 1 - \psi - \nu$ for all singles and the time input to home production is

$$H_{g,i} = (1-\theta) \cdot \nu \cdot (\psi + \nu) \cdot \frac{\omega_{g,i}}{\nu \varphi_{g,i} + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta}\right)^{\theta} \left(\frac{1}{1-\theta}\right)^{1-\theta} (\pi_{g,i})^{\frac{1-\theta}{\phi-1}} \right)^{\phi-1}}, \tag{4.34}$$

which is derived analogously to (4.33). Thus, singles in group a work

$$n_{g,i}^{1,S} = \psi + \nu$$

on the first market and demand home labor according to (4.34) with $\pi_{g,i} = p$ and $\omega_{g,i} = a_{g,i}$. Singles in groups b and c work $\psi + \nu - H_{g,i}$. For group b, this results in

$$n_{g,i}^{1,S} = \psi + \nu - (1-\theta) \cdot \nu \cdot (\psi + \nu) \cdot \left[\nu + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta}\right)^{\theta} \left(\frac{a_{g,i}}{1-\theta}\right)^{1-\theta} \right)^{\phi-1} \right]^{-1},$$

which uses $\omega_{g,i} = a_{g,i}$. For group c, labor supply is

$$n_{g,i}^{1,S} = \psi + \nu - (1-\theta) \cdot \nu \cdot (\psi + \nu) \cdot \left[\nu + \psi \left(\frac{1}{A} \cdot \left(\frac{q}{\theta}\right)^{\theta} \left(\frac{w}{1-\theta}\right)^{1-\theta} \right)^{\phi-1} \right]^{-1},$$

which uses $\omega_{g,i} = w$. These decisions of singles are summarized in Table 4.7. For $\phi \to 1$, they simplify to the decisions presented in Table 4.2.[22]

[22] To see that the decisions reported in Tables 4.6 and 4.7 simplify to the ones in Tables 4.1 and 4.2 when $\phi \to 1$, note that the terms in the square brackets Tables 4.6 and 4.7 are all $\psi + \nu$ for $\phi = 1$.

(1)	(2)	(3)	(4)	(5)	(6)
	male hours		female hours		labor 2
	market 1 $n_{M,i}^{1,S}$	market 2 $n_{M,i}^{2,S}$	market 1 $n_{F,i}^{1,S}$	market 2 $n_{F,i}^{2,S}$	demand $n_{i}^{2,D}$
group 1 $a_{M,i} \in \left[\frac{p}{\alpha}, \infty\right]$	$\psi+\nu$	0	$\psi+\nu$	0	$(1-\theta)\,\nu\,(\psi+\nu)\,W_i \cdot p^{-1} \cdot \left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{1}{1-\theta}\right)^{1-\theta} p^{1-\theta}}\right)^{\phi-1}\right]^{-1}$
group 2 $a_{M,i} \in \left[\frac{w}{\alpha}, \frac{p}{\alpha}\right]$	$\psi+\nu$	0	$\psi+\nu - (1-\theta)\,\nu\,(\psi+\nu)\,W_i \cdot a_{F,i}^{-1} \cdot \left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{1}{1-\theta}\right)^{1-\theta} a_{F,i}^{1-\theta}}\right)^{\phi-1}\right]^{-1}$	0	0
group 3 $a_{M,i} \in \left[w, \frac{w}{\alpha}\right]$	$\psi+\nu$	0	0	$\psi+\nu - (1-\theta)\,\nu\,(\psi+\nu)\,W_i \cdot w^{-1} \cdot \left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{1}{1-\theta}\right)^{1-\theta} w^{1-\theta}}\right)^{\phi-1}\right]^{-1}$	0
group 4 $a_{M,i} \in [0, w]$	0	$\psi+\nu - (1-\theta)\,\nu\,(\psi+\nu) \cdot \left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{1}{1-\theta}\right)^{1-\theta} w^{1-\theta}}\right)^{\phi-1}\right]^{-1}$	0	$\psi+\nu - (1-\theta)\,\nu\,(\psi+\nu) \cdot \left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{1}{1-\theta}\right)^{1-\theta} w^{1-\theta}}\right)^{\phi-1}\right]^{-1}$	0

Table 4.6: Summary of Couples' Labor Supply and Demand Decisions under $\phi \neq 1$

(1)	(2)	(3)	(4)	(5)
	wage range	hours		labor 2 demand
		market 1 $n_{g,i}^{1,S}$	market 2 $n_{g,i}^{2,S}$	$n_{g,i}^{2,D}$
group a	$[p, \infty]$	$\psi + \nu$	0	$(1-\theta)\,\nu\,(\psi+\nu)\,a_{g,i}\cdot$ $p^{-1}\cdot\left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{1}{1-\theta}\right)^{1-\theta}p^{1-\theta}}\right)^{\phi-1}\right]^{-1}$
group b	$[w, p]$	$\nu+\psi-$ $(1-\theta)\,\nu\,(\psi+\nu)\cdot$ $\left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{a_{g,i}}{1-\theta}\right)^{1-\theta}}\right)^{\phi-1}\right]^{-1}$	0	0
group c	$[0, w]$		$\nu+\psi-$ $(1-\theta)\,\nu\,(\psi+\nu)\cdot$ $\left[\nu+\psi\cdot\left(\frac{\frac{1}{A}\cdot\left(\frac{q}{\theta}\right)^{\theta}}{\left(\frac{w}{1-\theta}\right)^{1-\theta}}\right)^{\phi-1}\right]^{-1}$	0

Table 4.7: Summary of Singles' Labor Supply and Demand Decisions under $\phi \neq 1$

4.C A model version with utility costs of outsourcing home labor

In this appendix, we present a version of the model using a utility function which includes utility costs of outsourcing home labor. We show that, in this model version, the equilibrium time allocation is the same as in our baseline model using the utility function (4.3) and the resource costs in (4.8).

Without loss of generality, we consider the optimization problem for a non-married individual as described in Section 4.3. The proof for couples proceeds analogously. The Lagrangean for a single household reads as

$$\begin{aligned}\mathcal{L}_{g,i} =& U_{g,i}\left(c_{g,i}, d_{g,i}, l_{g,i}\right) \\ &+ \varpi_{g,i,1}\left[f\left(k_{g,i}, h_{g,i} + n_{g,i}^{2,D}\right) - d_{g,i}\right] \\ &+ \varpi_{g,i,2}\left[a_{g,i} n_{g,i}^{1,S} + w \cdot n_{g,i}^{2,S} - c_{g,i} - q \cdot k_{g,i} - (1+\gamma) \cdot w \cdot n_{g,i}^{2,D}\right] \\ &+ \varpi_{g,i,3}\left[1 - l_{g,i} - n_{g,i}^{1,S} - n_{g,i}^{2,S} - h_{g,i}\right] \\ &+ \kappa_{g,i,1} \cdot n_{g,i}^{1,S} + \kappa_{g,i,2} \cdot n_{g,i}^{2,S} + \kappa_{g,i,3} \cdot h_{g,i} + \kappa_{g,i,4} \cdot n_{g,i}^{2,D},\end{aligned}$$

where the ϖ's are Lagrange multiplier on the equality constraints and the κ's are Lagrange multipliers on the relevant inequality constraints. The first-order condition with respect to hired home labor $n_{g,i}^{2,D}$ is

$$\varpi_{g,i,1} f_H \eta - \varpi_{g,i,2}\left(1+\gamma\right) w + \kappa_{g,i,4} = 0, \tag{4.35}$$

where f_H is the marginal productivity of effective labor in home production.

Now consider a problem where individual utility is negatively affected by hiring home labor. Specifically, consider an otherwise identical model with the utility function

$$U_{g,i} = \left(\left[\begin{array}{c}\left(\frac{\psi}{\psi+\nu}\right)^{1/\phi}\left(c_{g,i} - \gamma w n_i^{2,D}\right)^{\frac{\phi-1}{\phi}} \\ + \left(\frac{\nu}{\psi+\nu}\right)^{1/\phi}\left(d_{g,i}\right)^{\frac{\phi-1}{\phi}}\end{array}\right]^{\frac{\phi}{\phi-1}}\right)^{(\psi+\nu)} \cdot \left(l_{g,i}\right)^{(1-\psi-\nu)} \tag{4.36}$$

instead of (4.3) and with no home labor wedge, $\gamma = 0$ in (4.11). The first-order condition with respect to $n_{g,i}^{2,D}$ is

$$-\frac{\partial U_{g,i}}{\partial\left(c_{g,i}-\gamma w n_{g,i}^{2,D}\right)}\cdot\gamma w+\varpi_{g,i,1}f_H\eta-\varpi_{g,i,2}w+\kappa_{g,i,4}=0. \tag{4.37}$$

Evaluating the derivatives, one obtains

$$\frac{\partial U_{g,i}}{\partial\left(c_{g,i}-\gamma w n_{g,i}^{2,D}\right)}=\frac{\partial U_{g,i}}{\partial c_{g,i}}.$$

In the optimum, marginal utility of market consumption has to equal the Lagrange multiplier on the budget constraint, $\varpi_{g,i,2}$:

$$\frac{\partial U_{g,i}}{\partial c_{g,i}}=\varpi_{g,i,2}$$

Replacing $\partial U_{g,i}/\partial\left(c_{g,i}-\gamma n_i^{2,D}\right)$ in (4.37) by $\varpi_{g,i,2}$ yields (4.35). Since all other derivatives of the Lagrangean are the same in the problem with the utility function (4.36) and the one with the home labor wedge in (4.11), the optimal time allocations are identical.[23]

4.D Proofs of Static and Comparative-Static Results

Equilibrium prices and marginal derivatives. Integrating the home-services supply and demand decisions of couples reported in Table 4.1 and those of singles reported in Table 4.2, and accounting for their respective masses ($(1-s)$ for couples, s for singles, respectively), yields total demand for and supply of home labor in the economy:

$$N^{2,D}=\frac{1}{2}(1-\theta)\nu\frac{1}{p}\cdot\left(1+\alpha-(\alpha^{-1}+\alpha^{-2}+s-\alpha^{-2}s)p^2\right) \tag{4.38}$$

$$N^{2,S}=\left[(\alpha^{-1}+1)(\psi+\theta\nu)-\frac{1}{2}(1-s)(\alpha^{-2}-1)(1-\theta)\nu\right]w \tag{4.39}$$

Using the definitions of D_1, D_2, and S_1 stated in Section 4.4.3, equalizing supply and demand for home services results in the expressions for

[23] To obtain identical systems of derivatives replace $\frac{\partial U_{g,i}}{\partial c_{g,i}}$ by $\varpi_{g,i,2}$ in the derivatives with respect to $c_{g,i}$.

p and w in equations (4.21) and (4.22). The effective price p for home labor is increasing in the "as-if" tax τ and the second-market wage w is decreasing in τ:

$$\frac{\partial p}{\partial \tau} = \frac{1}{2} \cdot (1+\tau)^{-1/2} \cdot S_1 \cdot \frac{((1+\alpha)D_1)^{1/2}}{(S_1 + (1+\tau)D_1 D_2)^{3/2}} > 0 \tag{4.40}$$

$$\frac{\partial w}{\partial \tau} = -\frac{1}{2} \cdot (1+\tau)^{-3/2} \cdot \frac{(S_1 + 2(1+\tau)D_1 D_2) \cdot ((1+\alpha)D_1)^{1/2}}{(S_1 + (1+\tau)D_1 D_2)^{3/2}} < 0 \tag{4.41}$$

Levels of hours worked by groups. Average market hours by gender and marital status are given by equations (4.17) to (4.20). Since $p > w$, it holds that $N_M > N_m$. One can also see that $N_m > N_f$ because $\frac{p}{\alpha} > p$. It remains to show that $N_f > N_F$, which can be simplified to:

$$\begin{aligned} & 0 > -(1-\theta)\nu\alpha^{-2}p + (1-\theta)\nu\left[\frac{\alpha^{-2}}{2} + \frac{1}{2}\right]w \\ \iff & 0 > -\frac{p}{\alpha^2} + \frac{w}{2\alpha^2} + \frac{w}{2} \\ \iff & 0 > \frac{1+\tau}{\alpha^2} + \frac{1}{2\alpha^2} + \frac{1}{2} \\ \iff & 0 > -\frac{1}{2} - \tau + \frac{\alpha^2}{2}, \end{aligned} \tag{4.42}$$

which is true for any non-negative τ since $\alpha < 1$. Therefore, the ordering of average market hours is $N_M > N_m > N_f > N_F$.

Directions and magnitudes of changes in hours. Average market hours by gender and marital status are given by equations (4.17) to (4.20). Taking derivatives of average hours by groups with respect to τ yields:

$$\frac{\partial N_M}{\partial \tau} = -(1-\theta)\nu \frac{\partial w}{\partial \tau} > 0 \tag{4.43}$$

$$\frac{\partial N_F}{\partial \tau} = (1-\theta)\nu \cdot \frac{\alpha^{-2}+1}{2} \cdot \frac{\partial w}{\partial \tau} - (1-\theta)\nu \cdot \left[\alpha^{-2} + \alpha^{-1}\right] \cdot \frac{\partial p}{\partial \tau} < 0 \tag{4.44}$$

$$\frac{\partial N_m}{\partial \tau} = -(1-\theta)\nu \frac{\partial p}{\partial \tau} < 0 \tag{4.45}$$

$$\frac{\partial N_f}{\partial \tau} = -(1-\theta)\nu \cdot \alpha^{-1} \cdot \frac{\partial p}{\partial \tau} < 0 \tag{4.46}$$

Since $\alpha^{-1} > 1$, we can state that $\left|\frac{\partial N_f}{\partial \tau}\right| > \left|\frac{\partial N_m}{\partial \tau}\right|$. Comparing the absolute value of the derivatives for husbands and wives reveals that $\left|\frac{\partial N_F}{\partial \tau}\right| > \left|\frac{\partial N_M}{\partial \tau}\right|$ because $\frac{\alpha^{-2}+1}{2} > 1$. Finally, since $\alpha^{-2} + \alpha^{-1} > \alpha^{-1}$, it also holds that $\left|\frac{\partial N_F}{\partial \tau}\right| > \left|\frac{\partial N_f}{\partial \tau}\right|$. Thus the change in married women's market hours is the strongest one of all groups.

Chapter 5

Assortative Mating and Female Labor Supply

5.1 Introduction

Hours worked of married women in the US increased substantially over the second half of the last century. The most prominent explanation for rising hours of wives is the closure of the gender wage gap, i.e. the catching-up of female wages relative to men's wages, see e.g. Galor and Weil (1996), Jones, Manuelli, and McGrattan (2003), Knowles (2007), and Attanasio, Low, and Sánchez-Marcos (2008). According to household models of labor supply (see Chiappori 1988; Apps and Rees 1997; Blundell, Chiappori, Magnac, and Meghir 2007), labor supply of a wife depends on both the wife's and the husband's characteristics. Many empirical studies estimate cross-wage elasticities of female labor supply and find a significant influence of husbands' wages on working hours of wives, see Blau and Kahn (1997a), Blundell, Duncan, and Meghir (1998), Devereux (2004, 2007), and Morissette and Hou (2008).

In this chapter[1], we investigate wives' hours disaggregated by the husband's wage decile. Juhn and Murphy (1997) have performed an empirical stratification of wives' hours by the husband's wage and document a clearly downward sloping relation for the late 1960s and for the 1970s. Juhn and Murphy (1997) also find that the increase in hours worked of wives over time has been strongly non-uniform among all groups of married women, with wives of middle- and high-wage men experiencing

[1] The chapter is based on Bredemeier and Juessen (2010).

more pronounced increases in hours than wives married to low-wage husbands. As a consequence, the pattern of wives' hours by the husband's wage has changed from negative to hump-shaped. Similar findings are reported by Morissette and Hou (2008) and Schwartz (2010).

Thus, a view on disaggregated labor supply of married women reveals the following two stylized observations. First, the pattern of wives' hours by the husband's wage has changed from downward-sloping to hump-shaped. Second, women married to men with high wages have experienced the strongest increases in hours worked. This chapter aims at explaining these two empirical observations.

We highlight the role of assortative mating for understanding the economy-wide pattern of wives' hours by the husband's wage decile. Assortative mating is the tendency of spouses with similar characteristics to marry each other. The relevance of assortative mating for spouses' labor-supply decisions has been emphasized by Pencavel (1998) and Devereux (2004) who stress that, when seeking to interpret the observed relation between husbands' characteristics and wives' work decision, one needs to take into account that husbands' and wives' characteristics are usually correlated.

In this chapter, we demonstrate that a standard household model of labor supply (Chiappori 1988; Apps and Rees 1997; Blundell, Chiappori, Magnac, and Meghir 2007) can generate the observed economy-wide pattern of wives' hours by the husband's wage when one takes into account trends in assortative mating. We measure assortative mating in terms of wage potentials. For a low degree of assortative mating (i.e. mating is almost random), our model generates a downward-sloping pattern of wives' hours by the husband's wage. By contrast, this pattern is hump-shaped for more pronounced assortative mating. Thus, when the degree of assortative mating increases, this induces a non-uniform change in wives' hours worked by the husband's wage decile. Specifically, the increase in hours is most pronounced for women married to top-wage husbands.

The economy-wide pattern of wives' hours by the husband's wage can change due to two reasons: first, changes in the relation between the husband's wage and the wife's labor supply at the household level and, second, compositional effects which may arise because the fractions of spouses marrying in different ways changes. In our model, the relation at the micro level is stable but the aggregated pattern of wives' hours by the husband's wage depends on assortative mating.

Specifically, patterns in hours in our model depend on the joint distribution of wages in marriages, i.e. on the marginal distributions of gender-specific wages and the association between spouses' wages. Couples face a specialization decision with respect to market work and home production. Within a couple, the efficient time allocation depends on the wage ratio of the two spouses. Only when the wife's relative wage is high enough, the couple opts for labor market participation of both spouses. Conditional on participation, hours of the wife are an increasing function of her relative wage.

To illustrate the effects of assortative mating, consider first the extreme cases of perfect sorting and random mating. Under random mating, every husband is on average married to the wife earning the average female wage independent of his own wage. Therefore, the relative wages are on average lowest for wives married to top-wage husbands. As a consequence, these wives work the fewest hours and the pattern of wives' hours by the husband's wage is downward-sloping.

Under perfect sorting, there exist only marriages where both wife and husband are from the same quantile in the respective gender-specific wage distribution. Husband's and wife's wages are thus perfectly correlated though not necessarily identical. The pattern of wives' hours by the husband's wage will then also depend on the marginal distributions of gender-specific wages. For example, with identical gender-specific distributions and perfect sorting, the wage ratio is one in each couple. Consequently, all wives work the same and the pattern of wives' hours by the husband's wage is flat. By contrast, when there is a gender wage gap, the wife's relative wage can also be increasing in the husband's wage. The reason is that an absolute wage gap is less important in relative terms when absolute wages of the two spouses are high. In couples where the husband's wage is relatively low, the wage gap translates into pronounced relative wage differences between husband and wife. Since the wife's relative wage can be increasing in the husband's wage, also hours worked of the wife can be increasing in the husband's wage.

We can imagine intermediate sorting as a combination of the two extreme cases, a fraction of the population marrying randomly and a fraction marrying in a perfectly assortative way. The resulting pattern of wives' hours worked by the husband's wage decile is therefore a weighted average of the patterns in the two extreme cases.

For the fraction of the population marrying in a random way, the pattern of wives' hours by the husband's wage decile is downward sloping independent of the wage gap. By contrast, for the fraction of the population marrying in a perfectly assortative way, the pattern can be upward sloping with the steepness depending on relative wage differences between husband and wife. The pattern is strongly increasing where wages are low and relative wage differences are thus pronounced. The pattern is almost flat for couples with high absolute wages and thus low relative wage differences. The resulting economy-wide pattern of wives' hours by the husband's wage decile can therefore be hump-shaped depending on the relative sizes of the two population groups marrying randomly and perfectly assortatively, respectively. Trends in assortative mating thus alter the pattern of wives' hours by the husband's wage decile observed in the aggregate and consequently lead to a non-uniform change in hours worked by wives.

From previous studies, there is much evidence that assortative mating in the US has indeed become stronger over time. Most studies have investigated assortative mating in terms of educational attainment and found that husband and wife have become more similar with respect to education over time, see Mare (1991), Kalmijn (1991a), Kalmijn (1991b), Qian and Preston (1993), Pencavel (1998), Qian (1998), Schwartz and Mare (2005), Sánchez-Marcos (2008), and Schwartz (2010). Cancian and Reed (1998) and Schwartz (2010) report increased assortative mating by income. Sweeney and Cancian (2004) provide evidence for an increasing correlation between wife's wage and husband's income. Herrnstein and Murray (1994) report increased sorting by academic ability in higher education and by intelligence. We use data from the Current Population Survey (CPS) to measure trends in assortative mating in terms of wage potentials. We find strong evidence that assortative mating in terms of wages has increased substantially over time.

To investigate whether empirically observed trends in the marginal and joint distributions of wages imply patterns in hours that are consistent with the empirical developments, we feed the observed distributions of wages into our model. We measure the association between spouses' wages in terms of the number of marriages that exist between different deciles of the gender-specific marginal wage distributions. By measuring assortative mating in terms of wage deciles, we can disentangle changes in the marginal distributions of husbands' and wives' wages from changes in the association between spousal wages.

The data shows a closure of the gender wage gap and a clear trend towards stronger assortative mating in terms of wages. Our empirical investigation suggests that trends in the marginal wage distributions are responsible for the overall increase in hours worked by wives. By contrast, the fact that wives married to high-wage men experienced the most pronounced increase is primarily a result of trends in assortative mating rather than being due to changes in the marginal wage distributions.

The remainder of this chapter is organized as follows. In Section 5.2, we present the empirical facts on married women's labor supply we aim to explain as well as empirical evidence for increasing marital sorting in terms of wages. Section 5.3 presents the theoretical model that uses as an input the association between spousal wages to predict optimal labor supply decisions. Section 5.4 provides an quantitative analysis where we use the empirically observed joint distributions of wages. Section 5.5 concludes.

5.2 Wives' hours by the husband's wage decile and trends in assortative mating

In this section, we present the empirical facts we aim to explain. The key observation we address is that the increase in married women's labor supply has not been uniform among all wives. We also illustrate in this section that assortative mating in terms of wages has increased substantially over time.

The non-uniform increase in women's hours has been documented by e.g. Juhn and Murphy (1997) and Schwartz (2010) and is illustrated in Figure 5.1. The data are from the Current Population Survey (CPS) in the US. The left panel shows average weekly hours worked of wives married to men in the 10 deciles of the male wage distribution. The figure compares two periods of time, 1975-1979 (darkly shaded bars) and 2000-2006 (white bars). We form subperiods of more than one year to control for business cycle effects. The sample consists of matched husband-wife pairs of ages 30-50. Details on the data employed can be found in Appendix 5.A.

During the 1970s, there has been a clear downward-sloping pattern of wives' hours by the husband's position in the wage distribution. Women married to high-wage men tended to work less hours. In the more recent period, this relationship has changed with wives of men in the middle of the wage distribution working the most. Thus, the pattern of wives' hours by the husband's wage has changed from downward-sloping to hump-shaped.[2]

The right panel in Figure 5.1 shows the change (between the two periods) in weekly hours worked by married women disaggregated by the husband's wage decile. One can see that hours worked of wives increased substantially among all groups of married women over time. However, the increase has been strongly non-uniform across husband's wage deciles. Increases in hours have been largest for wives of middle- and high-wage men. By contrast, the increase in labor supply was relatively weak among wives of men in the low wage deciles.

The empirical facts we aim to explain can thus be summarized as follows:

1. The aggregate pattern of wives' hours by the husband's wage has changed from downward-sloping to hump-shaped.

2. The increase in hours worked of wives has been strongly non-uniform among all groups of married women, with increases in hours of wives of middle- and high-wage men being more pronounced than for wives of men married to low-wage husbands.

In this chapter, we seek to explain these developments as a result of changes in the wage structure in the economy. Specifically, the aggregate pattern of wives' hours by the husband's wage predicted by our model will depend on the joint distribution of wages in marriages, i.e. on the marginal distributions of gender-specific wages together with the association between spouses' wages.

While most studies focused on assortative mating along education levels (see e.g. Mare 1991, Fernández, Guner, and Knowles 2005, Schwartz and Mare 2005, and Schwartz 2010), we consider sorting in terms of spousal wages. Thereby we face the problem that, in the data, we can observe an individual's wage only if the person is participating in the labor market. In our model, by contrast, wages are measures of earnings potentials. To measure assortative mating in terms of potential wages, we therefore have to impute wages for non-working individuals.

[2] A similar picture emerges when one considers changes in participation rates instead of changes in hours worked.

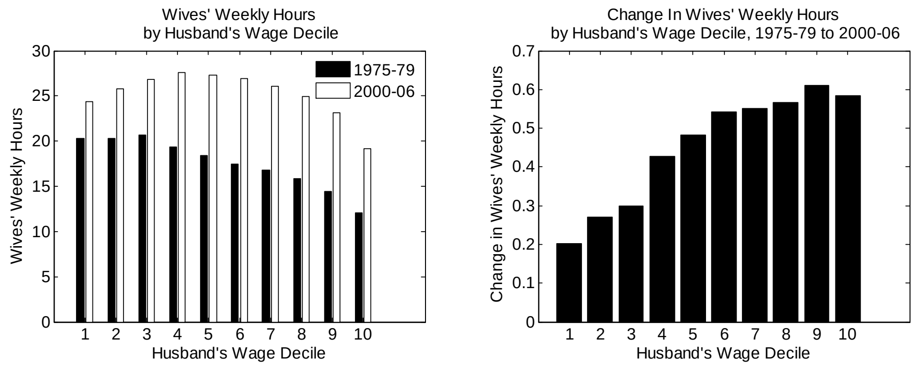

Figure 5.1: Wives' weekly hours by the husband's wage decile.

Our model implies that the participation decision is not random. We therefore need to predict wages for non-working wives that would be observed in the absence of non-participation. To do so, we use a Heckman (1976, 1979) selection model. The Heckman model is estimated separately for the periods 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, and 2000-2006.[3] Appendix 5.B presents details on the wage imputation.

When measuring assortative mating, one has to take into account that simple correlation coefficients between the absolute levels of the variable of interest can be poor measures for describing trends in assortative mating, see Mare (1991) and Hou and Myles (2007). The problem of correlation coefficients is their inability to distinguish changes in the marginal distributions of husbands' and wives' wages from changes in the association between spousal wages. For example, the correlation coefficient between absolute wages would change in response a change in the marginal distributions even when the association between spousal wages were unchanged.

We overcome this problem by calculating the correlation between husband's and wife's position in the respective gender-specific wage distribution, rather than between the absolute levels of their wages. Specif-

[3] To check for robustness, we also consider alternative ways to handle the missing-data problem. A first strategy is to delete the entire couple from the sample if one of the spouses' wages is not observed. We refer to this specification as 'listwise deletion'. A second strategy is to use wage predictions from simple OLS estimates.

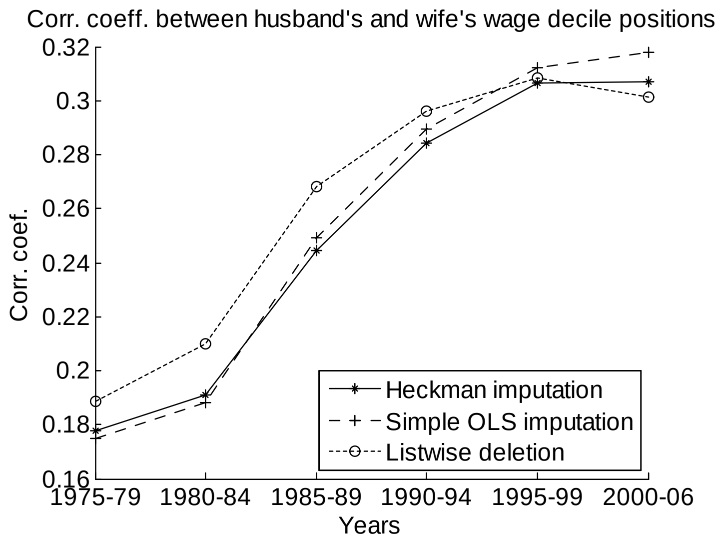

Figure 5.2: Correlation coefficient between spousal wage decile positions.

ically, we consider the association between spouses' decile positions in the gender-specific wage distributions. At each point in time, there are 10% of individuals of a given gender in each wage decile independent of the wages earned in the specific decile. Thus, the distribution of decile positions is by construction constant over time. Changes in the correlation between these relative positions of husband and wife therefore reflect changes in assortative mating.[4]

Figure 5.2 shows the change in the correlation coefficient between husband's and wife's wage decile positions over time for different approaches to handle the missing-data problem. Both for simple regression-based and Heckman-based imputation, respectively, there is a pronounced and steady increase in the correlation coefficient between spousal wage decile positions. In fact, the correlation coefficient almost doubles from 1975-79 to 2000-06. When we abstain from imputing

[4]An alternative approach to disentangle changes in the association from changes in the marginal wage distributions is to estimate a crossings model, see e.g. Mare (1991) and Schwartz (2010). An advantage of measuring assortative mating in terms of wage decile positions is that this association has a structural interpretation and can be used directly as an input in our model later on.

wages and restrict the sample to couples were both husband and wife are participating, we find a similar development with a marked increase in the wage correlation between 1975-79 and 1995-99.

It is instructive to investigate in more detail the joint distribution of spousal wage decile positions. This allows us to see in which areas of the distribution the association between husband's and wife's wage decile positions has become stronger over time. We summarize the association between spousal wages by a 10×10 association matrix S containing the observed frequencies of the 100 possible combinations of spouses' wage deciles. Entry s_{ij} in this matrix gives the fraction of marriages in which the husband belongs to the i'th decile of the male wage distribution while the wife is in the j'th decile of the female wage distribution.

To highlight changes over time, Table 5.1 shows the relative changes of the frequencies of the different combinations of wage deciles from 1975-79 to 2000-06, $\left(s_{ij}^{2000-06} - s_{ij}^{1975-79}\right)/s_{ij}^{1975-79}$, using the Heckman-imputed wages for non-working wives.[5] Positive values indicate that in 2000-06 the number of couples with the specific combination of wage deciles has increased relative to 1975-79. Tables 5.5 and 5.6 in Appendix 5.C show the association matrices separately for the two periods of time.

From Table 5.1 it can be seen that the number of couples where husband and wife differ by much with respect to their relative positions in the respective wage distributions has decreased substantially. For example, the number of couples where the husband is from the top decile of the male distribution and the wife is from the lowest decile of the female distribution has decreased by about 30%. In general, Table 5.1 shows a clear pattern that most entries distant from the main diagonal are negative. By contrast, decile combinations on and close to the main diagonal tend to be observed more often, highlighting that couples have become more similar in terms of gender-specific wage positions.

These results show that assortative mating in terms of wages has increased substantially over time. In the next section, we present a theoretical model that highlights the role of changes in the wage structure for explaining the non-uniform increase in hours worked by married women and the resulting change in wives' hours worked disaggregated by the husband's wage decile.

[5] Results using OLS-imputed wages and from listwise deletion are very similar.

husb.'s	wife's wage decile									
decile	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1st	46.0	11.5	**-12.7**	5.4	**-1.4**	1.0	**-23.8**	**-38.5**	**-20.8**	**-32.2**
2nd	27.0	16.7	**-6.0**	25.3	11.3	30.1	**-27.3**	**-46.7**	**-15.6**	**-33.0**
3rd	**-3.8**	5.9	1.4	19.6	17.8	50.6	**-16.0**	**-37.0**	**-7.5**	**-26.4**
4th	**-4.2**	1.7	1.2	22.1	**-1.4**	38.5	7.1	**-20.2**	**-13.1**	**-31.2**
5th	**-16.0**	1.1	6.5	9.6	2.5	9.7	3.2	**-6.2**	11.3	**-21.2**
6th	**-15.2**	**-9.1**	4.3	**-5.4**	5.2	3.8	8.6	**-0.4**	31.2	**-19.8**
7th	**-20.3**	**-10.0**	15.1	**-9.6**	**-5.1**	**-8.4**	13.1	1.9	27.6	**-3.4**
8th	**-17.7**	**-14.2**	**-1.2**	**-19.5**	**-12.2**	**-16.2**	11.6	23.2	20.4	18.7
9th	**-29.0**	**-21.7**	**-1.3**	**-19.1**	**-8.3**	**-34.5**	15.6	31.6	0.3	46.6
10th	**-29.6**	**-18.8**	5.9	**-26.6**	**-2.7**	**-39.4**	**-1.8**	69.0	**-33.8**	52.2

Table 5.1: Change in the Association Matrix between Spousal Wages (percentage changes in the density of the decile combinations from 1975-79 to 2000-06).

5.3 The model

5.3.1 Decision problem of a couple

We consider an economy populated by couples which differ by the wages of the two spouses. First, we will present the decision process for individual couples. Thereafter, we will aggregate their decisions.

A couple consists of two spouses. We denote spouses' wages by w_1 and w_2 and order spouses by these wages such that the index $i = 1$ refers to the primary earner and $i = 2$ to the secondary earner. Note that the index does not necessarily refer to the gender of the respective spouse. For the decisions at the couple level, gender is not relevant. For instance, labor-force participation of the secondary earner will depend on his or her relative wage independent of gender.

There are two commodities in the model, a private "market" consumption good and a "home" consumption good that is public to the couple. We assume that individuals' preferences over the two commodities are characterized by the additively separable utility function

$$u_i = \ln c_i + \psi \ln d \,, \tag{5.1}$$

where c_i denotes consumption of the market good and d stands for consumption of the home or domestic good. d does not wear an index indicating an individual since the home good is public.

Market goods can be earned through market labor by both spouses. We denote the time spent on market work by n_i. The couple's budget constraint is thus given by

$$c_1 + c_2 = w_1 \cdot n_1 + w_2 \cdot n_2. \tag{5.2}$$

Home goods are produced within the household using both spouses' labor (denoted by h_1 and h_2, respectively) as inputs with a production function $f(h_1, h_2) = (h_1)^{1/2} (h_2)^{1/2}$. Correspondingly, the home consumption constraint takes the form

$$d = (h_1)^{1/2} (h_2)^{1/2} \,. \tag{5.3}$$

We impose equal exponents on both labor inputs. A priori, there is therefore no difference between the two spouses' labor in home production. However, the household can decide to use the two inputs in different quantities depending on opportunity costs.

Both spouses have a time endowment of 1 which can be used for market work and home production, i.e.

$$n_i + h_i = 1, \ i = 1, 2. \tag{5.4}$$

The couple chooses the time allocations of both spouses and the distribution of the resulting consumption possibilities. Thus the couple chooses h_1, h_2, n_1, n_2, d, c_1, and c_2. Constraints are given by equations (5.2) to (5.4).

While the distribution of market consumption is subject to the specific process of household bargaining, we can determine the time allocations by efficiency considerations alone. Since the focus of this chapter is on labor-supply decisions, we do not need to specify a household bargaining process. For our purposes, it is sufficient to assume that the outcome of the bargaining process is efficient.

5.3.2 Decision making

In collective models of household behavior, households are assumed to allocate their resources efficiently (Chiappori 1988; Chiappori 1992). Consequently, given a desired amount of home consumption, the household will produce it with minimal opportunity costs. Given the desired level of home consumption, the cost minimization determines time spent in home production for both spouses. In our set-up, spouses spend their remaining time on paid market work. Accordingly, we proceed by solving for a family's optimal level of home consumption and then deduce labor-supply decisions.

For efficiency, the marginal costs to produce the public home good (in terms of foregone market consumption) has to be equal to the sum of both spouses marginal rates of substitution which corresponds to Samuelson's (1955) rule for efficient public-good provision,

$$MRS_1 (c_1, d) + MRS_2 (c_2, d) = MC (d), \tag{5.5}$$

where $MRS_i (c_i, d) = \frac{\partial u_i}{\partial c_i} / \frac{\partial u_i}{\partial d}$ is spouse i's marginal rate of substitution between home and market goods. $MC (d)$ denotes the marginal costs of home production for the couple in terms of market goods. In order to determine the optimal level of home consumption which satisfies (5.5), we need to consider the couples' marginal costs of producing the home good as well as spouses' marginal rates of substitution. Detailed derivations of decisions at the couple level can be found in Appendix 5.D.

Marginal costs of home consumption. The marginal cost function $MC(d)$ results from the production of d units of the home good with minimal costs. In this minimization problem, the household has to respect that no member can work more than one unit of time in home production:

$$h_1 \leq 1 \tag{5.6}$$

$$h_2 \leq 1 \tag{5.7}$$

In efficient allocations, total opportunity costs of home production as a function of the consumption level d are the value function of the minimization problem

$$\min_{h_1,h_2} w_1 h_1 + w_2 h_2$$

subject to the home production function (5.3) and the two time constraints (5.6) and (5.7). Technically, marginal costs are the derivative of this value function.

Due to the inequality restrictions (5.6) and (5.7), the marginal cost function is not globally differentiable. In the range where (5.6) and (5.7) do not bind, production of the home good exhibits constant marginal costs due to the constant returns to scale property of the production function. Marginal costs in this range are given by $2 \cdot (w_1)^{1/2} \cdot (w_2)^{1/2}$. The cost-minimal time inputs are $h_1 = \left(\frac{w_1}{w_2}\right)^{-1/2} \cdot d$ and $h_2 = \left(\frac{w_1}{w_2}\right)^{1/2} \cdot d$.

The couple can only produce with constant returns to scale and thus with constant marginal costs as long as both spouses can still increase their time spent in home production. From the point where one spouse spends her or his entire time endowment in home production, further increases in home production can only be realized by increases in the other spouse's time input. Since $w_1 > w_2$, the time constraint of the secondary earner (5.7) will be binding first. This is at the point where $d = \left(\frac{w_2}{w_1}\right)^{1/2}$. From there on, marginal costs are given by the inverse of the primary earner's marginal productivity multiplied by his or her wage. Since $h_2 = 1$ in this range, the marginal productivity of the primary earner is given by $\frac{1}{2}(h_1)^{-1/2}$. For $d > \left(\frac{w_2}{w_1}\right)^{1/2}$, the required amount of h_1 to produce d is $h_1 = d^2$. Marginal costs are therefore $2 \cdot w_1 \cdot d$ in this range. Since both spouses' time endowments are 1, the maximum quantity of home consumption is 1. The marginal cost function (in terms of foregone market consumption) is thus given by

$$MC(d) = \begin{cases} 2 \cdot (w_1)^{1/2} \cdot (w_2)^{1/2}, & d < \left(\frac{w_2}{w_1}\right)^{1/2} \\ 2 \cdot w_1 \cdot d, & \left(\frac{w_2}{w_1}\right)^{1/2} < d < 1 \\ \infty, & d > 1. \end{cases} \tag{5.8}$$

The corresponding total (opportunity) cost function is

$$C(d) = \begin{cases} 2 \cdot (w_1)^{1/2} \cdot (w_2)^{1/2} \cdot d, & d < \left(\frac{w_2}{w_1}\right)^{1/2} \\ w_2 + w_1 \cdot d^2, & \left(\frac{w_2}{w_1}\right)^{1/2} < d < 1 \\ \infty, & d > 1. \end{cases} \tag{5.9}$$

Sum of the marginal rates of substitution. We now turn to the spouses' marginal rates of substitution between market and home consumption. The marginal rates of substitution depend on spouses' individual marginal utility of market consumption. The couples's marginal willingness to pay will therefore in general depend on the intra-couple distribution of private consumption which is subject to bargaining. With log utility, however, intra-household bargaining does not affect the couple's willingness to pay for home consumption. Since the marginal rates of substitution are linear with this specific formulation of utility and the home good is public, marginal rates of substitution can be added up to a function of the couple's total consumption levels of the two goods independent of the distribution across spouses. In particular, it holds that

$$MRS_1(c_1, d) + MRS_2(c_2, d) = \psi \cdot \frac{c_1}{d} + \psi \cdot \frac{c_2}{d} = \psi \cdot \frac{c}{d}, \tag{5.10}$$

where $c = c_1 + c_2$. Redistributing private consumption lowers one spouses's marginal rate of substitution but increases the other spouse's one by the same amount. Changes in the distribution of private consumption within the couple therefore do not affect the sum of the two marginal rates of substitution.

With efficient production of the home good, the constraints (5.2), (5.3), and (5.4) can be combined to

$$w_1 + w_2 = c + C(d).$$

Thus, the choice of either c or d determines the other as well. The couple's total level of market consumption, c, can then be expressed as $c = w_1 + w_2 - C(d)$. We can therefore express the sum of the two marginal rates of substitution (5.10) as a function of the level of home consumption only:

$$\sum_{i=1}^{2} MRS_i = \begin{cases} \psi \frac{w_1+w_2}{d} - 2\psi (w_1)^{1/2} \cdot (w_2)^{1/2}, & d < \left(\frac{w_2}{w_1}\right)^{1/2} \\ \psi w_1 \left(d^{-1} - d\right), & \left(\frac{w_2}{w_1}\right)^{1/2} < d < 1 \\ -\infty, & d > 1 \end{cases} \tag{5.11}$$

5.3.3 Labor-supply decisions

By the condition for efficient provision of the public good (5.5), the optimal level of home consumption is at the intersection of (5.8) and (5.11). Labor-market participation of the secondary earner will depend on whether or not the couple wishes a level of home consumption that can be produced without using the entire time endowment of the secondary earner. Technically, the secondary earner will participate if (5.5) is solved by a d that falls below $\left(\frac{w_2}{w_1}\right)^{1/2}$. We can thus derive a participation condition on the secondary earner's wage relative to the primary earner's one. The participation threshold for the secondary earner is

$$w_2 > \frac{\psi}{2} \cdot w_1. \tag{5.12}$$

The secondary earner only participates in the labor market if his or her relative contribution to the couple's potential income exceeds some threshold value determined by the valuation of home consumption. The higher the wage of the primary earner, the higher the wage of the secondary earner has to be for participation of both spouses.

Conditional on participation of the secondary earner, her or his market hours are

$$n_2 = \frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \frac{w_1}{w_2} \tag{5.13}$$

and the primary earner's hours are

$$n_1 = \frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \frac{w_2}{w_1}. \tag{5.14}$$

If the secondary earner does not participate, the primary earner works constant hours on the market, given by

$$n_1 = \frac{2}{2+\psi}. \tag{5.15}$$

Note that none of the labor-supply decisions described by equations (5.12) to (5.15) depend on the absolute wage of one of the two spouses. Instead, all decisions depend on the wage ratio between the two spouses within the couple.

Now we consider a couple with a wife F and husband M, whose wages are denoted by w_F and w_M, respectively. The wife is the secondary earner if $w_F < w_M$ and vice versa. Summarizing labor-supply decisions at the couple level as described by equations (5.12) to (5.15), we can express hours worked by a wife F as a function of the wage ratio within the couple, $\omega = \frac{w_F}{w_M}$,

$$n_F(\omega) = \begin{cases} 0, & \omega < \frac{\psi}{2} \\ \frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \omega^{-1}, & \frac{\psi}{2} \leq \omega < \frac{2}{\psi} \\ \frac{2}{2+\psi}, & \omega \geq \frac{2}{\psi} \end{cases}. \tag{5.16}$$

We impose the parameter restriction

$$\psi < 2$$

such that there are wage ratios for which both, husband and wife, participate in the labor market, see equation (5.16).

5.3.4 The role of assortative mating

We now illustrate the influence of the mating structure on the aggregate pattern of wives' labor supply. In the next section, we aggregate individual decisions formally to obtain the aggregate pattern of wives' hours by the husband's wage predicted by our model.

Equation (5.16) describes the relation between the husband's wage and the wife's labor supply at the household level. This relation is negative and independent of the mating structure. By contrast, the aggregate pattern of wives' hours by the husband's wage also depends on assortative mating because assortative mating affects the aggregation of individual decisions.

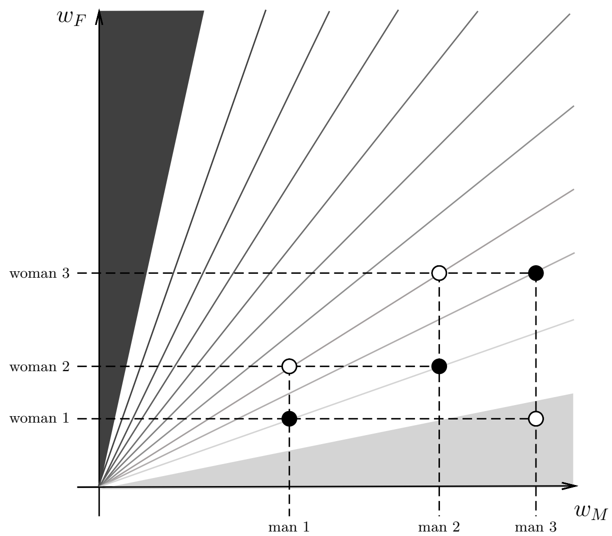

Figure 5.3: Wives' hours of market work for different husband-wife wage combinations (iso-hours lines and areas, resp.; the darker, the more hours) and two joint distributions of wages with identical marginal distributions (scenario 1: imperfect sorting (non-filled circles); scenario 2: perfect sorting (filled circles)).

Figure 5.3 illustrates the relation between wife's hours and the wages of the two spouses in the couple given by equation (5.16). The figure shows some selected iso-hours lines where darker colors correspond to more hours of the wife. The dark gray area in the upper left part of the figure contains couples who decide that only the wife works for pay. In the light gray area in the lower right corner of the figure, wives do not participate in the labor market. Between these two areas, hours of wives continuously decrease from the upper left to the lower right as the wife's relative wage decreases.

The circles in the figure indicate couples with different husband-wife wage combinations. We illustrate the role of assortative mating on the aggregate pattern of labor supply using these couples as examples. We consider three women and three men who are matched to each other in two different ways. Across scenarios, the gender-specific marginal distributions of wages are identical but the joint distribution of spousal wages differs. In scenario 1 (non-filled circles), marital sorting is imperfect while it is perfect in scenario 2 (filled circles). Marital sorting is perfect in the second scenario as the woman with the highest potential wage (woman 3) is married to the man with the highest wage (man 3), and so on.

First note that, in the example, the increase in assortative mating alters the aggregate participation rate. In scenario 1, the couple in the lower right of the figure (woman 1 and man 3) decides against labor-market participation of the wife. Intra-household wage differentials are sufficiently pronounced that it is rational to use the wife's time solely in home production. In the other two couples, both spouses participate on the labor market. The aggregate participation rate of wives is 2/3 in this scenario.

In scenario 2 (filled circles), although the marginal distributions of wages have not changed, the aggregate participation rate is 1. Sorting is perfect in this scenario, i.e. the top-wage wife is matched with the top-wage husband and so on. As a consequence, in the example, there is no more couple where intra-household wage differentials are sufficiently large for husband-only participation.

Changes in assortative mating affect the aggregate pattern of wives' hours worked by the husband's wage positions. In scenario 1, the wife married to the husband with the highest wage (man 3) works the fewest hours while the other two women work the same. In scenario 2, this pattern is flipped upside down with the wife married to the top-wage husband supplying the most labor and the other two women working the same.

5.3.5 Aggregate pattern of wives' hours by the husband's wage positions

We now use our model for a stratification analysis as performed in Section 2 for the CPS data. Specifically, we study the aggregate pattern of wives' hours by the husband's wage predicted by our model for different forms of assortative mating.

We can use the joint distribution of wages in marriages as an input to our model, i.e. the marginal distributions of gender-specific wages and the association between spouses' wages. We allow for the possibility that the marginal distributions are not the same across genders. Specifically, we allow for a gender wage gap. To highlight the role of changes in the association between husband's and wife's wages, we consider uniform marginal distributions in the theoretical part of the chapter. In the next section, we feed the empirically observed marginal and joint distributions of wages into our model.

In general, marginal distributions may differ by gender. With a gender wage gap, the wage of the representative man in the i'th decile of the male distribution, $W_M(i)$, is higher than the wage of the representative woman in the i'th decile of the female distribution, $W_F(i)$. We denote the absolute difference between gender-specific wages by α and assume here that this wage gap is constant across deciles.

We normalize the marginal distribution of female wages so that its support has length 1, i.e. female wages are distributed uniformly on $(w_{\min}, w_{\min}+1)$ with $w_{\min} \geq 0$. Correspondingly, male wages are distributed uniformly on $(w_{\min}+\alpha, w_{\min}+1+\alpha)$. We apply the parameter restriction

$$\frac{w_{\min}}{w_{\min}+\alpha} \geq \frac{\psi}{2},$$

which ensures that in a couple where both husband and wife earn the lowest gender-specific wages, respectively, the wife participates in the labor market. It furthermore implies that, whenever husband and wife are at the same quantile of the respective wage distributions, both spouses participate.

We model assortative mating similar as in Kremer (1997). It is assumed that a proportion ξ of agents marries a spouse from the same wage quantile whereas everyone else marries randomly. Perfect sorting and random mating are special cases where $\xi = 1$ or $\xi = 0$, respectively. For a husband with wage w_M, the probability of being married to a wife with wage $w_F = w_M - \alpha$ is ξ while all other wages of the wife are equally likely with a total probability of $1 - \xi$.

The economy-wide pattern of wives' hours by the husband's wage positions results from (i) the relation between the husband's wage and the wife's labor supply at the household level described by equation (5.16) and (ii) the mating structure in the economy. To determine the aggregate pattern, we calculate average hours of wives married to husbands earning a certain wage w_M. We do so by integrating individual decisions (5.16) taking into account the density function of wages,

$\overline{n}_F(w_M) = \int n_F\left(\frac{w_F}{w_M}\right) \cdot f(w_F \mid w_M)\, \mathrm{d}w_F$, where $\overline{n}_F(w_M)$ denotes average hours worked of wives married to husbands earning a wage w_M. The densities $f(w_F \mid w_M)$ depend on assortative mating. Given the marginal and joint distributions of wages, average hours of wives married to husbands earning a wage w_M are

$$\begin{aligned}
\overline{n}_F(w_M) = & \underbrace{(1-\xi)\cdot \int_{w_{\min}}^{\frac{\psi}{2}w_M} 0 \,\mathrm{d}w_F}_{\text{no participation of wife}} \\
& \underbrace{+(1-\xi)\cdot \int_{\frac{\psi}{2}w_M}^{\frac{2}{\psi}w_M} \left[\frac{2}{2+\psi} - \frac{\psi}{2+\psi}\cdot\frac{w_M}{w_F}\right] \mathrm{d}w_F}_{\text{both spouses participate}} \qquad (5.17) \\
& \underbrace{+(1-\xi)\cdot \int_{\frac{2}{\psi}w_M}^{w_{\min}+1} \frac{2}{2+\psi}\,\mathrm{d}w_F}_{\text{only wife participates}} \\
& + \underbrace{\xi\cdot\left[\frac{2}{2+\psi} - \frac{\psi}{2+\psi}\cdot\frac{w_M}{w_M-\alpha}\right]}_{\text{fraction marrying perfectly assortatively, both participate}}
\end{aligned}$$

which evaluates as (see Appendix 5.D)

$$\overline{n}_F(w_M) = \Psi + (1-\xi)\cdot g(w_M) + \xi \cdot k(w_M), \qquad (5.18)$$

where $\Psi = \frac{2}{2+\psi} + (1-\xi)\cdot\frac{2}{2+\psi}\cdot w_{\min}$ and

$$\begin{aligned}
g(w_M) &= -\frac{\psi}{2+\psi}\cdot\left(1+\ln\frac{4}{\psi^2}\right)\cdot w_M \\
k(w_M) &= -\frac{\psi}{2+\psi}\cdot\frac{w_M}{w_M-\alpha}.
\end{aligned}$$

Wives' hours by the husband's wage are thus a constant plus the weighted sum of two functions of the husband's wage. $g(w_M)$ is a downward sloping and linear function while $k(w_M)$ is an upward sloping and concave function for $\alpha > 0$ and a constant for $\alpha = 0$. The weights for $g(w_M)$ and $k(w_M)$ are determined by the parameter ξ measuring the degree of assortative mating. The pattern of wives' hours by the husband's wage decile thus depends on the degree of assortative mating and the gender wage gap.

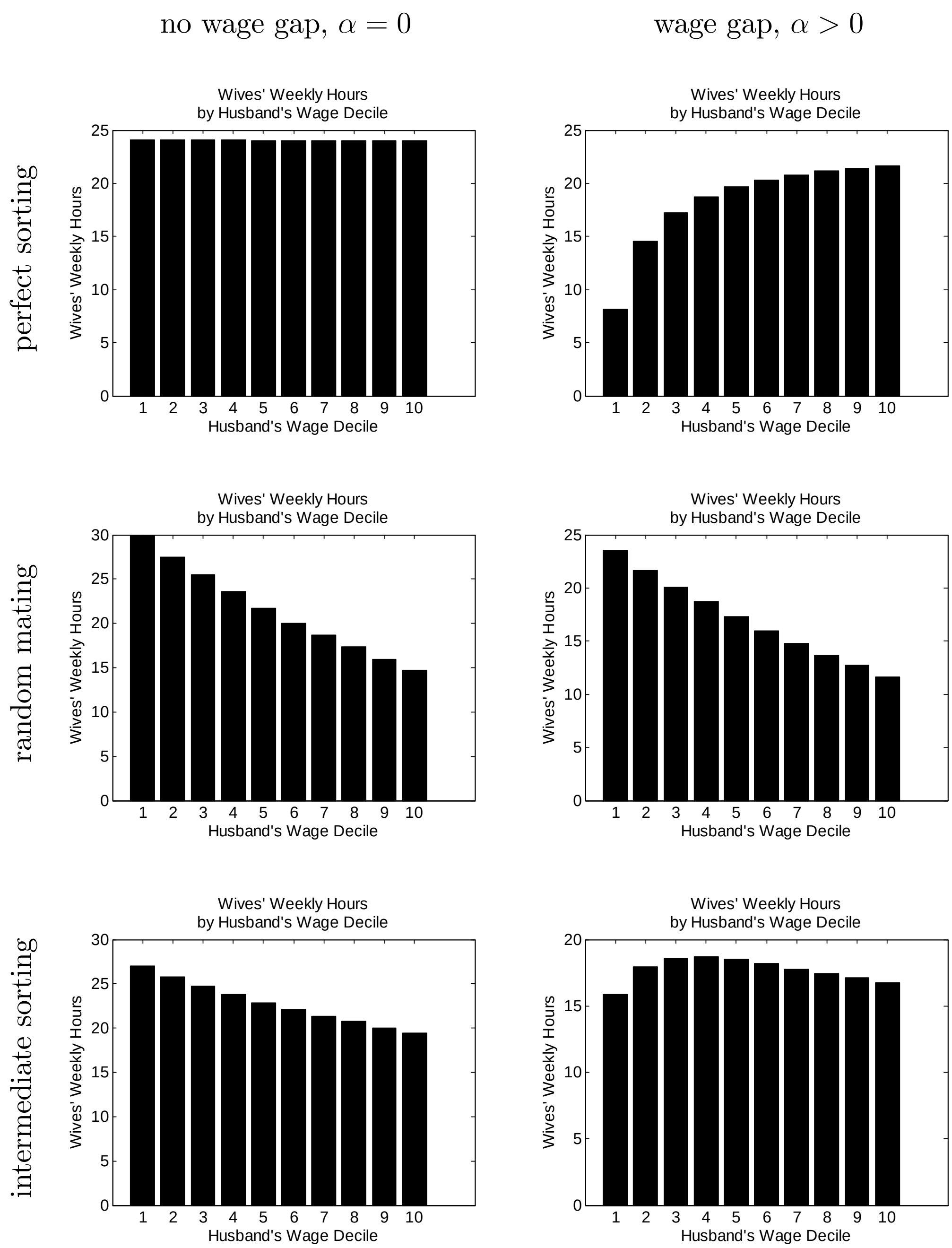

Figure 5.4: Patterns of wives' hours by husbands' wage deciles for different degrees of assortative mating (illustration using uniform marginal distributions).

Figure 5.4 illustrates the pattern of wives' hours by the husband's wage deciles for six different scenarios. To illustrate the possible patterns, we use example parameter values.[6] When we compare model predictions to empirical observations in the next section, we use the empirically observed marginal and joint distributions of wages.

Here, we distinguish between two cases concerning the wage gap ($\alpha = 0$, $\alpha > 0$) and three different degrees of assortative mating ($\xi = 1$, $\xi = 0$, $0 < \xi < 1$). The left column in Figure 5.4 refers to the case of no wage gap ($\alpha = 0$), while the right column shows the results when a wage gap is present ($\alpha > 0$). The rows in Figure 5.4 refer to the three cases of assortative mating (perfect sorting, random mating, intermediate sorting).

Consider the case of perfect assortative mating, $\xi = 1$, which is illustrated in the first row of Figure 5.4. In this situation, there exist only marriages where both wife and husband are from the same quantile in the respective gender-specific wage distribution.

Without a gender wage gap, $\alpha = 0$, this implies that the wage ratio in each couple is $\omega_j = 1$. Consequently, all wives work the same, which can be seen from equation (5.18) for $\xi = 1$ and $\alpha = 0$,

$$\overline{n}_F\left(w_M\right) = \Psi - \xi \cdot \frac{\psi}{2+\psi}.$$

This case is illustrated in the upper left panel of Figure 5.4.

By contrast, when there is a gender wage gap, $\alpha > 0$, the average wage ratio, $\left(w_M - \alpha\right)/w_M$, is increasing in the husband's wage. As a consequence, with a gender wage gap and perfect assortative mating, average hours worked by wives are increasing in the husband's wage. This is illustrated in the upper right panel of Figure 5.4 and can be seen from equation (5.18) for $\xi = 1$ and $\alpha > 0$:

$$\overline{n}_F\left(w_M\right) = \Psi - \xi \cdot \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_M - \alpha}.$$

[6] For the figure, the parameter ψ measuring the valuation of home consumption is set to 0.5 and the marginal distribution of female wages is uniform on $[0.1, 1.1]$, thus $w_{\min} = 0.1$. For the cases with a gender wage gap (right column), we set $\alpha = 0.3$, otherwise $\alpha = 0$. The parameter ξ measuring the degree of assortative mating is 1 (first row), 0 (second row), or 0.5 (third row), respectively. The weekly time endowment is set to 40 hours.

In the other extreme case, $\xi = 0$, mating is completely random. Here, all possible combinations of wages within a marriage exist with same frequency. Hence, every husband is on average married to the wife earning the average female wage $\overline{w}_F$ independent of his own wage position. Therefore, the average wage ratio $\overline{w}_F / w_M$ is decreasing across the male wage distribution. As can be seen from equation (5.18) for $\xi = 0$, this results in a downward-sloping pattern of wives' hours by the husband's wage, independent of the wage gap,

$$\overline{n}_F (w_M) = \Psi - \frac{\psi}{2+\psi} \cdot \left(1 + \ln \frac{4}{\psi^2}\right) \cdot w_M.$$

This case is illustrated in the second row of Figure 5.4.

The third row of Figure 5.4 represents an intermediate case of assortative mating where $\xi = 0.5$. In this intermediate case, both functions $g(w_M)$ and $k(w_M)$ are given non-zero weights in equation (5.18). For $\alpha = 0$, wives' hours by the husband's decile are then the sum of a downward sloping function and a constant,

$$\overline{n}_F (w_M) = \Psi - (1-\xi) \cdot \frac{\psi}{2+\psi} \cdot \left(1 + \ln \frac{4}{\psi^2}\right) \cdot w_M - \xi \cdot \frac{\psi}{2+\psi},$$

and thus downward sloping in the male wage, see the lower left panel of Figure 5.4. In the presence of a gender wage gap, $\alpha > 0$, female hours by male wage decile are the sum of a downward sloping linear function and a concave upward sloping function,

$$\overline{n}_F (w_M) = \Psi - (1-\xi) \cdot \frac{\psi}{2+\psi} \cdot \left(1 + \ln \frac{4}{\psi^2}\right) \cdot w_M - \xi \cdot \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_M - \alpha}. \tag{5.19}$$

The function $n_F(w_M)$ is thus concave and can be hump-shaped, depending on the specific value for ξ. In Appendix 5.D, we show that for any combination of the parameters ψ, $w_{\min}$, and $\alpha > 0$, there exists a degree of assortative mating, ξ, such that the pattern of wives' hours by the husband's wage is hump-shaped.

The role of assortative mating for the pattern of wives' hours by the husband's wage becomes apparent when comparing the three panels in the right column of Figure 5.4. In all three scenarios, the marginal distributions of gender-specific wages are identical. However, the patterns in wives' hours differ depending on the association between spouses' wages.

5.4 Quantitative analysis

The analysis in the previous section has shown that our model is able to generate the empirical patterns documented in Section 5.2: The aggregate pattern of wives' hours by the husband's wage has been downward-sloping in 1975-79 like in the middle row of Figure 5.4. In 2000-06 this pattern has changed to being hump-shaped as in the lower right panel of Figure 5.4.

The patterns in hours predicted by the model depend on the joint distribution of wages in marriages, i.e. on the marginal distributions of gender-specific wages and the association between spouses' wages. We now feed the empirically observed joint distributions of wages into our model and investigate whether observed trends in these distributions imply patterns in hours that are consistent with the empirical developments.

As in Section 5.2, we measure the association in terms of the number of marriages that exist between different deciles of the gender-specific marginal wage distributions. The 10×10 association matrix S introduced in Section 5.2 contains the relative frequencies of the 100 possible combinations of deciles in a marriage. As discussed in Section 5.2, the association between husband's and wife's wage has changed towards more pronounced assortative mating.

Since we consider deciles, all columns (and all rows) in S contain 10 percent of the overall population. By construction, our analysis in terms of wage deciles controls for changes in the marginal gender-specific wage distributions that could otherwise distort the measurement of changes in assortative mating. Put differently, by measuring assortative mating in terms of wage deciles, we can disentangle changes in the marginal distributions of husband's and wife's wages from changes in the association between spousal wages.

The gender-specific mean wage levels associated with the deciles are denoted by $W_F(i)$ and $W_M(i)$, respectively, where i is a decile number. Table 5.2 shows the marginal distributions of spousal wages for the two periods of time we consider, 1975-79 and 2000-06. For both genders, wages have increased over time whereas the increase has been stronger for women. The gender wage gap closed by 12 percentage points on average over all deciles. The table also shows that changes in wages and the gender wage gap have not been uniform across wage deciles. For

	mean	deciles									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
male wages 1975-79	15.48	4.54	8.56	10.46	12.09	13.69	15.31	17.08	19.29	22.66	31.10
female wages 1975-79	8.52	3.35	6.04	6.74	7.18	7.69	7.93	8.40	9.53	11.21	17.18
wage gap 1975-79	0.55	0.74	0.71	0.64	0.59	0.56	0.52	0.49	0.49	0.49	0.55
male wages 2000-06	17.19	4.43	7.72	9.62	11.36	13.18	15.18	17.65	21.04	26.54	45.15
female wages 2000-06	11.54	3.51	5.64	6.98	7.77	8.89	10.20	12.17	13.53	17.00	29.75
wage gap 2000-06	0.67	0.79	0.73	0.73	0.68	0.67	0.67	0.69	0.64	0.64	0.66
wage-gap closure	0.12	0.06	0.02	0.08	0.09	0.11	0.15	0.20	0.15	0.15	0.11

Table 5.2: Marginal Distributions of Spousal Wages 1975-79 and 2000-06.

both genders, wages in the upper deciles have grown stronger than wages in the lower deciles. Similarly, the closure of the gender wage gap has been strongest in the upper half of the wage distribution.

Finally, we have to choose a value for the parameter ψ measuring the valuation of home consumption and a value for the weekly time endowment. We set the relative valuation of home consumption to $\psi = 0.5$, a value in the range commonly used in the literature for comparable utility functions, see e.g. Jones, Manuelli, and McGrattan (2003). This value implies that the ratio of time spent on home production and time spent on market work is about 60%, which is in line with empirical findings. For instance, McGrattan, Rogerson, and Wright (1997) estimate a household utility function with home production and their results imply that the ratio of home to market hours is 15/27. The weekly time endowment has a pure scaling effect on labor supply and is set to 40 hours. The weekly time endowment is the total working time of agents in our model since leisure is absent from the model.

To calculate the economy-wide pattern of wives' hours by the husband's wage decile predicted by our model for a given joint distribution of wages $\{W_F, W_M, S\}$, we proceed as follows. We first determine female labor supply for all 100 possible combinations of decile positions in a 10×10 matrix H. To determine hours worked by the wife h_{ij} in a specific cell ij we plug the ratio of gender-specific average wages in this cell, $\omega_{ij} = W_F(j) / W_M(i)$, into equation (5.16). Average hours worked by wives married to men in decile i are then given by $(h_i \cdot s_i') / \sum_{j=1}^{10} s_{ij}$, where h_i is the i'th row of the female hours matrix H and s_i is the corresponding row in the association matrix S.

Figure 5.5 shows wives' hours by the husband's wage decile predicted by our model when we use the empirically observed marginal and joint distributions of spousal wages in 1975-79 and 2000-06, respectively. The right panel shows the relative change in married women's hours by the husband's wage decile between the two periods. Thus, the figure is the model's counterpart to the stratification analysis performed using CPS hours displayed in Figure 5.1.

For 1975-79, the model predicts a decreasing pattern of wives' hours by the husband's wage decile as observed in the data. For 2000-06, the model predicts a higher level of hours worked by wives. From the right panel of the figure, one can see that the predicted increase in hours is not uniform across husband's wage deciles. As in the data, wives

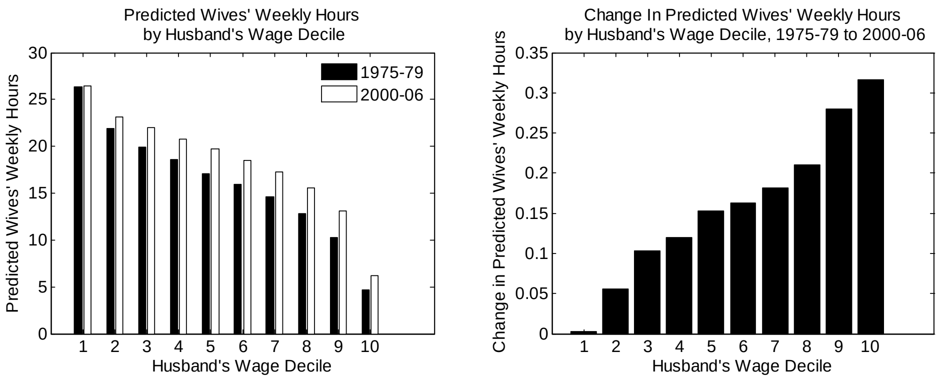

Figure 5.5: Predicted wife's weekly hours by husband's wage decile.

married to high-wage men experience the strongest increases. However, the increase is not sufficiently non-uniform to change the pattern in the left panel from downward sloping to hump-shaped.

The patterns in Figure 5.5 result from effects of changes in the marginal distributions of gender-specific wages as well as from effects due to changes in the association of spousal wages. To disentangle these effects, we perform a series of counterfactual experiments. Figure 5.6 summarizes the results. Each panel in the figure corresponds to a different counterfactual setting and shows the change in wives' hours by the husband's decile (the figures are thus the analogs to the right panel in Figure 5.5).

In a first experiment, we hold constant the association matrix S at its 1975-79 level but allow the marginal distributions to change over time. This way, we shut down effects of trends in assortative mating. From the upper left panel in Figure 5.6 it can be seen that, when we do not allow for change in assortative mating, the model does predict an increase in hours for all groups of wives. Yet, in this scenario, the increase is strongest for wives married to medium-wage men. By contrast, the data show that wives married to high-wage men have experienced the strongest increases in hours worked.

The upper right panel in Figure 5.6 refers to the other extreme case where we allow for changes in the association between spousal wages but hold constant the gender-specific marginal wage distributions. In this

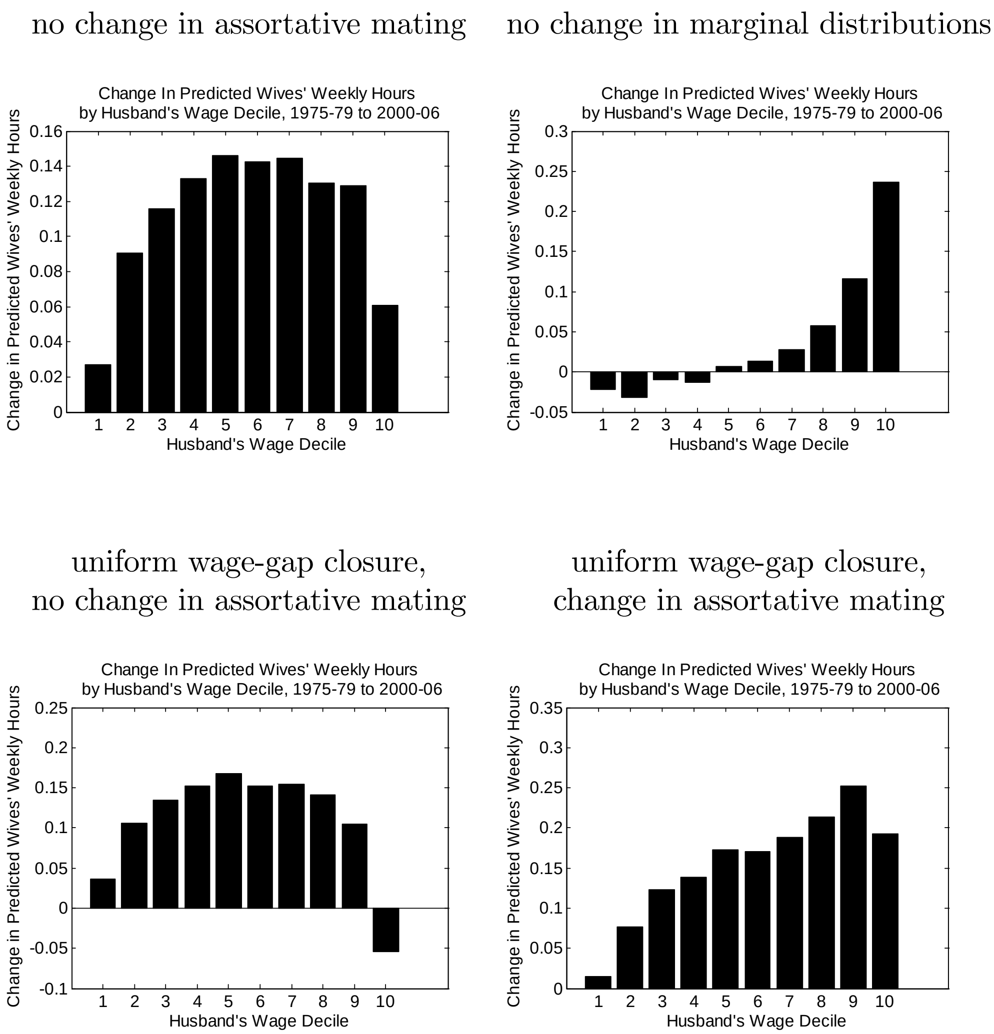

Figure 5.6: Counterfactual experiments.

scenario, changes in wives' hours are increasing in the husband's decile position. Yet, not all groups of wives experience increasing hours in this scenario.

This evaluation of our model suggests that changes in the marginal wage distributions are responsible for the overall increase in hours worked by wives. By contrast, the fact that wives married to high-wage men experienced the most pronounced increase is a result of trends in assortative mating rather than being due to changes in the marginal distributions.

A potential source of the non-uniform increase in hours is that the gender wage gap has closed in a non-uniform way. As we used the empirically observed marginal gender-specific wage distributions, our benchmark results reported in Figure 5.5 include the effects of the non-uniform wage-gap closure. In order to study the role of this development, we perform two additional counterfactual experiments. In these experiments, we impose a uniform closure of the wage gap, i.e. we impose that the wage gap has closed by the same amount (measured in percentage points) across all deciles.

The lower left panel in Figure 5.6 refers to the case where the wage gap closes in such uniform way and the association is held constant at its 1975-79 level. The lower right panel also imposes a neutral wage-gap closure but additionally allows for changes in assortative mating over time. The effects of the non-neutrality of the wage gap closure become apparent when comparing the upper left and the lower left panels in the figure. With a uniform closure of the wage gap, the model predicts decreasing hours for wives of top-wage men, opposed to what is observed in the data. However, one can see that accounting for trends in assortative mating is key for understanding the non-uniform increase in wive's hours. Only when we allow the association matrix to change over time, our model predicts an increasing pattern in the change of hours worked by women as observed in the data.

5.5 Conclusion

This chapter has investigated wives' hours disaggregated by the husband's wage decile. Specifically, we have addressed two empirical observations that have been documented for the US. First, the aggregate pattern of wives' hours by the husband's wage has changed from downward-sloping to hump-shaped. Second, over time, the increase in hours worked of wives has been strongly non-uniform among all groups of married women, with increases in hours of wives of middle- and high-wage men being more pronounced than for wives of men married to low-wage husbands.

We have presented a theoretical model that explicitly considers the role of assortative mating in terms of wages for understanding these developments. Assortative mating determines the wage ratios within individual couples. In our model, the intra-couple wage ratio determines the efficient time allocation of the two spouses. Only when the wife's relative wage is high enough, the couple opts for labor-market participation of both spouses.

Under random mating, every husband is on average married to the wife earning the average female wage independent of his own wage. Therefore, the relative wages are lowest for wives married to top-wage husbands. As a consequence, these wives work the fewest hours. Under random mating, the pattern of wives' hours by the husband's wage decile is therefore negative.

Under perfect sorting, by contrast, there exist only marriages where both wife and husband are from the same quantile in the respective gender-specific wage distribution. The pattern of wives' hours by the husband's wage will then also depend on the marginal distributions of gender-specific wages. When there is a gender wage gap, the wife's relative wage can be increasing in the husband's wage. As a consequence, hours worked by the wife can be increasing in the husband's wage.

For intermediate sorting, the resulting pattern of wives' hours worked by the husband's wage decile is a weighted average of the patterns in the two extreme cases of random and perfect mating, respectively. The resulting economy-wide pattern of wive's hours by the husband's wage decile can therefore be hump-shaped depending on the relative weights of population groups marrying randomly and perfectly assortatively, respectively. Changes in assortative mating thus alter the pattern of wives' hours worked by the husband's wage decile and consequently lead to a non-uniform change in hours worked by wives.

The patterns in hours predicted by our model depend on the joint distribution of wages in marriages. In a quantitative analysis, we have fed the empirically observed joint distributions of wages into our model and have investigated whether observed changes in these distributions imply patterns in hours that are consistent with the empirical developments.

The data shows a closure of the gender wage gap and a clear trend towards stronger assortative mating in terms of wages. For 1975-79, the model predicts a decreasing pattern of wives' hours by the husband's wage decile as observed in the data. For 2000-06, the model predicts a higher overall level of hours worked by wives. In accordance with empirical developments, the model-predicted increase in hours is not uniform across husband's wage deciles. As in the data, wives married to high-wage men experience the strongest increases. However, the increase is not sufficiently non-uniform to change the pattern of wives' hours by the husband's wage from downward sloping to hump-shaped.

A series of counterfactual experiments has shown that changes in the marginal wage distributions are responsible for the overall increase in hours worked by wives. By contrast, the fact that wives married to high-wage men experienced the most pronounced increase is a result of trends in assortative mating rather than being due to changes in the marginal wage distributions. Thus, accounting for trends in assortative mating is key for understanding the non-uniform increase in wives' hours. Only when we take into account trends in assortative mating, our model predicts an increasing pattern in the change of hours worked by women as observed in the data.

Appendix

5.A CPS data

The CPS data we use are in the format arranged by Unicon Research.[7] The CPS is a monthly household survey conducted by the Bureau of the Census. Respondents are interviewed to obtain information about the employment status of each member of the household 16 years of age and older. Survey questions covering hours of work, earnings, gender, and marital status are covered in the Annual Social Economic Supplement, the so-called March Supplement Files. The sample of the CPS is representative of the civilian non-institutional population.

Data on hours and earnings is retrospective and refers to the previous year. The CPS data we use covers the period 1975-2006. While the CPS provides data on hours and earnings from 1963 onwards, the number of children in family under age six is not available before 1975. Since the latter variable is used as an instrument for imputing wages for non-working individuals, our analysis starts in 1975.

Our selected sample comprises civilians aged 30 to 50. In a set of robustness tests, we checked that our results are robust with respect to the specific age range. We drop people who derive their main income from self-employment and consider only couples where both husband and wife are present in the sample. We identify spouses by the household identification number. To control for outliers, we drop couples where either husband or wife fall in the top 1% percentile of observed wages.

In 1992, the educational-attainment question in the CPS changed from years of education to degree receipt. Following Jaeger (1997), we harmonized both series and created a measure of educational attainment that takes on four categories: dropouts, high-school graduates, some college, and college graduates.[8]

5.B Wage imputation

Since our dataset is very large, we use Heckman's (1979) two-step efficient estimator instead of Maximum likelihood estimation (see Wooldridge 2002 for technical details). The Heckman two-step model

[7] See http://www.unicon.com/.

[8] This education variable has been created from the CPS variables _educ (1964-1991, 19 categories, Unicon recoded) and grdatn (1992-2007, 17 categories).

	1975-1979		2000-2006	
Wage equation	estimate	std. err.	estimate	std. err.
log(age wife/17)	-0.054	0.149	1.182	0.116
log(age wife/17) squared	0.038	0.103	-0.592	0.077
education level 2 wife	0.156	0.011	0.385	0.014
education level 3 wife	0.257	0.013	0.600	0.014
education level 4 wife	0.495	0.014	0.975	0.014
intercept	1.938	0.056	1.035	0.047
year dummies included				
Participation equation				
log(age wife/17)	0.105	0.280	0.338	0.235
log(age wife/17) squared	-0.390	0.193	-0.172	0.157
log(age husband/17)	-1.493	0.301	-0.797	0.256
log(age husband/17) squared	0.843	0.198	0.416	0.164
education level 2 wife	0.306	0.015	0.501	0.019
education level 3 wife	0.451	0.020	0.712	0.019
education level 4 wife	0.769	0.022	0.928	0.021
education level 2 husband	-0.051	0.015	0.190	0.018
education level 3 husband	-0.070	0.019	0.181	0.019
education level 4 husband	-0.232	0.019	-0.111	0.020
2 kids younger than age 6	-0.655	0.013	-0.443	0.011
3 kids younger than age 6	-1.041	0.020	-0.733	0.015
4 kids younger than age 6	-1.332	0.051	-1.131	0.037
5 kids younger than age 6	-1.765	0.173	-1.392	0.131
intercept	0.626	0.090	0.215	0.088
year dummies included				
λ (inv. Mills ratio)	-0.017	0.018	0.295	0.018

Table 5.3: Two-step Estimates of Heckman Selection Model

	Method	Obs.	Mean	Std. Dev.	Min	Max
1975-1979	Heckman	64090	2.070	0.158	1.790	2.419
	OLS	64090	2.057	0.159	1.774	2.408
2000-2006	Heckman	94352	2.183	0.307	1.376	2.618
	OLS	94352	2.334	0.277	1.665	2.729

Table 5.4: Predictions of Heckman Selection Model vs. OLS imputation

can be described as follows. First, we estimate a binomial probit model that predicts the individual's probability of participation in the labor market (selection equation). Second, we use the estimated selection model to construct the hazard rate for sample inclusion. Third, we include the hazard rate as a regressor in the wage equation. When the error term in the selection equation is correlated with the error term in the wage equation, standard regression techniques yield inconsistent estimates while the two-step Heckman procedure yields consistent estimates.

To identify the Heckman model, we need to find factors that determine whether a wife participates in the labor market but are unrelated to a wife's wage. We assume that the likelihood of working is a function of the number of preschool children at home (we code the number of kids as dummy variables). Moreover, we include in the selection equation quadratic terms in age of wife and husband and the levels of education of both partners. The number of preschool children and the characteristics of the husband are only included in the participation equation but are omitted from the wage equation. We also control for time effects. In the wage equation, we include a quadratic term in the wife's age and dummy variables for the wife's level of education. By including all variables that determine the wage also in the participation equation, we allow the participation decision to depend implicitly on the wage.

We fit the Heckman model separately for the periods 1975-1979 and 2000-2006. Table 5.3 summarizes the two-step estimates of the Heckman selection model. The upper part of the table displays the estimates for the parameters in the wage equation while the lower part shows the results for the participation equation. In both equations, we have included time dummies but their point estimates are omitted from the table to save on space.

From the selection equation, it can be seen that more preschool children in the household significantly decrease the probability of participation. The coefficient of the selection term is reported at the bottom of Table 5.3. While the selection term is found to be insignificant in 1975-1979 it turns highly significant in the more recent period. This means that a standard regression not taking into account selection will produce inconsistent wage predictions for non-working women, which shows the relevance of incorporating selectivity in the estimation of the wage equation.

Table 5.4 compares predicted values from the Heckman model with an ordinary regression model without selection adjustment. In the period where the selection term has been found to be insignificant (1975-1979), wage predictions from the Heckman model and uncorrected OLS are fairly similar on average. During 2000-2006, by contrast, simple regression yields predictions that are on average higher than the Heckman-corrected estimates. Specifically, wage predictions of the Heckman model are on average about 6.87% lower than the regression-based ones. One can also see that the regression prediction shows less variation than the prediction based on the selection model.

5.C Association matrices

Table 5.5 shows the association matrix S between spouses' wage decile positions for the period 1975-79. The association matrix for the period 2000-06 is presented in Table 5.6. The relative changes of the frequencies of the different combinations of the wage deciles, $\left(s_{ij}^{2000-06} - s_{ij}^{1975-79}\right)/s_{ij}^{1975-79}$, can be found in Table 5.1 in the main text.

husb.'s	wife's wage decile									
decile	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1st	1.61	1.64	1.46	0.96	0.84	0.74	0.75	0.73	0.65	0.62
2nd	1.26	1.39	1.43	0.98	0.90	0.72	0.92	1.02	0.69	0.68
3rd	1.24	1.22	1.20	0.96	0.92	0.82	0.96	1.03	0.87	0.78
4th	1.04	1.06	1.10	0.96	0.98	0.95	0.96	0.97	1.03	0.93
5th	0.99	0.95	1.01	1.00	0.97	1.07	0.99	1.03	0.96	1.04
6th	0.92	0.92	0.94	1.08	0.98	1.07	0.97	0.96	0.97	1.18
7th	0.84	0.87	0.81	1.09	1.04	1.14	0.96	1.05	1.02	1.18
8th	0.77	0.77	0.80	1.13	1.13	1.10	1.03	0.97	1.15	1.15
9th	0.72	0.66	0.70	0.97	1.11	1.25	1.14	1.06	1.20	1.19
10th	0.61	0.53	0.56	0.87	1.12	1.13	1.31	1.19	1.45	1.25

Table 5.5: Association Matrix S between Spousal Wages in 1975-79. (Entries give percentage frequencies of different decile comibations.)

husb.'s decile	wife's wage decile									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1st	2.36	1.83	1.28	1.02	0.83	0.75	0.57	0.45	0.51	0.42
2nd	1.61	1.62	1.34	1.23	1.00	0.94	0.67	0.54	0.58	0.45
3rd	1.19	1.29	1.22	1.15	1.08	1.23	0.81	0.65	0.81	0.58
4th	1.00	1.08	1.12	1.17	0.96	1.32	1.03	0.78	0.90	0.64
5th	0.83	0.96	1.07	1.09	1.00	1.17	1.03	0.96	1.07	0.82
6th	0.78	0.84	0.98	1.02	1.03	1.11	1.05	0.96	1.28	0.95
7th	0.67	0.78	0.93	0.99	0.99	1.05	1.09	1.07	1.31	1.14
8th	0.64	0.66	0.79	0.91	0.99	0.92	1.15	1.20	1.38	1.37
9th	0.51	0.52	0.69	0.78	1.02	0.82	1.32	1.40	1.20	1.74
10th	0.43	0.43	0.59	0.64	1.09	0.69	1.28	2.00	0.96	1.90

Table 5.6: Association Matrix S between Spousal Wages in 2000-06. (Entries give percentage frequencies of different decile comibations.)

5.D Derivations and proofs

Decisions at the couple level

Marginal costs of home consumption To find the marginal cost function of home consumption, we determine the cost function first. Total opportunity costs are given by $C = w_1 h_1 + w_2 h_2$ (home production involves labor only but each spouse faces opportunity costs of not working for pay). For the cost function, we determine the quantities h_1 and h_2 to produce d units of the home good with minimal costs. This cost minimization problem yields equivalent input combinations as the maximization of output for given costs. The optimization problem involves the home production function $f(h_1, h_2) = (h_1)^{1/2} (h_2)^{1/2}$, time constraints $h_1 \leq 1$, $h_2 \leq 1$, and the total cost function $C = h_1 w_1 + h_2 w_2$. When solving the problem, one has to distinguish whether the time constraints are binding or not.

1. If time constraints are not binding, the Lagrangean reads as

$$\mathcal{L} = (h_1)^{1/2} (h_2)^{1/2} + \lambda [h_1 w_1 + h_2 w_2 - C].$$

The first-order conditions are

$$\frac{\partial L}{\partial h_1} = \frac{1}{2} (h_1)^{-1/2} (h_2)^{1/2} + \lambda w_1 = 0$$
$$\frac{\partial L}{\partial h_2} = \frac{1}{2} (h_1)^{1/2} (h_2)^{-1/2} + \lambda w_2 = 0$$

which can be simplified to

$$h_2 = \frac{w_1}{w_2} h_1. \tag{5.20}$$

This gives a relation between both spouses' cost-minimal labor inputs in home production. To determine each spouse's time in home production for a given level of home consumption d, substitute (5.20) into the home production function:

$$d = (h_1)^{1/2} \left(\frac{w_1}{w_2} h_1 \right)^{1/2} \iff h_1 = d \left(\frac{w_1}{w_2} \right)^{-1/2}.$$

For the secondary earner, one obtains

$$h_2 = \frac{w_1}{w_2} d \left(\frac{w_1}{w_2} \right)^{-1/2} = d \left(\frac{w_1}{w_2} \right)^{1/2}.$$

When time constraints are not binding, total opportunity costs of home production are thus given by

$$\begin{aligned} C(d) &= h_1 w_1 + h_2 w_2 = d \left(\frac{w_1}{w_2} \right)^{-1/2} w_1 + d \left(\frac{w_1}{w_2} \right)^{1/2} w_2 \\ &= 2 (w_1)^{1/2} (w_2)^{1/2} d . \end{aligned}$$

Marginal costs in this case are

$$MC(d) = 2 (w_1)^{1/2} (w_2)^{1/2} .$$

2. Now we consider the case where the time constraint for the secondary earner is binding. This is at the point where

$$h_2 = d \left(\frac{w_1}{w_2} \right)^{1/2} = 1 \iff d = \left(\frac{w_2}{w_1} \right)^{1/2}.$$

The production function in this case is

$$f(h_1, 1) = d = (h_1)^{1/2} .$$

In this range, to produce d units of the home good, the primary earner's time in home production has to be

$$h_1 = d^2.$$

Total opportunity costs in this case are thus

$$C(d) = h_1 w_1 + h_2 w_2 = w_1 d^2 + w_2$$

and marginal costs are

$$MC(d) = 2 w_1 d.$$

3. When both time constraints are binding, the household can not achieve a higher level of home consumption. The maximum level of home consumption is

$$d = 1^{1/2} \cdot 1^{1/2} = 1$$

In summary, the marginal cost function is defined piecewise, see equation (5.8) in the main text. If time constraints are not binding, marginal costs are constant. If the time constraint of the secondary earner binds, marginal costs are increasing linearly. If both time constraints bind, home production cannot be increased further.

Sum of the marginal rates of substitution In general, the sum of the marginal rates of substitution will depend on the intra-household distribution of private consumption, since the individual MRS depend on both consumption goods. However, with log utility (and thus linear marginal utility), the MRS can be simply added up,

$$MRS_1(c_1, d) + MRS_2(c_2, d) = \frac{\psi c_1}{d} + \frac{\psi c_2}{d} = \frac{\psi c}{d},$$

where $c = c_1 + c_2$. The sum of husband's and wife's MRS involves the couple's total level of market consumption c, which is given by the difference between the couple's full income and its expenditures for home production

$$c = w_1 + w_2 - C(d).$$

Using total costs of home consumption (5.9), this can be written as

$$c = \begin{cases} w_1 + w_2 - 2 \cdot (w_1)^{1/2} \cdot (w_2)^{1/2} \cdot d, & d < \left(\frac{w_2}{w_1}\right)^{1/2} \\ w_1 \cdot (1 - d^2), & \left(\frac{w_2}{w_1}\right)^{1/2} < d < 1 \\ -\infty, & d > 1. \end{cases}$$

Using this expression for c, the sum of the MRS can be written as in equation (5.11) in the main text.

Labor-supply decisions To determine labor-supply decisions, we derive the household's efficient level of home consumption which is determined by the intersection of equations (5.8) and (5.11). Since (5.8) and (5.11) are piecewise defined functions, one has to solve for the intersections of the different parts and check whether the intersection lies within the respective range.

1. The intersection of the first parts of (5.8) and (5.11) satisfies:

$$\begin{aligned} 2\,(w_1)^{1/2}\,(w_2)^{1/2} &= \psi \frac{w_1 + w_2 - 2 \cdot (w_1)^{1/2} \cdot (w_2)^{1/2} \cdot d}{d} \\ &\iff d = \frac{\psi}{2+\psi} \cdot \frac{[w_1 + w_2]}{(w_1)^{1/2} \cdot (w_2)^{1/2}} \end{aligned}$$

This level of d lies in the interval $\left(0, \left(\frac{w_2}{w_1}\right)^{1/2}\right)$ if

$$\frac{\psi}{2+\psi} \cdot \frac{[w_1 + w_{i,2}]}{(w_1)^{1/2} \cdot (w_2)^{1/2}} < \left(\frac{w_2}{w_1}\right)^{1/2} \iff w_2 > \frac{\psi}{2} w_1,$$

which is condition (5.12) from the main text. If this condition is fulfilled, the couple wishes a level of home consumption which can be produced with both spouses working less than their full time endowment in home production. Then, both spouses also participate in the labor market. If the condition is fulfilled, the efficient level of home consumption determines the two spouses' time inputs in home production:

$$\begin{aligned} h_1 = d \cdot \left(\frac{w_1}{w_2}\right)^{-1/2} &= \frac{\psi}{2+\psi} \cdot \frac{[w_1 + w_2]}{(w_1)^{1/2} \cdot (w_2)^{1/2}} \cdot \left(\frac{w_1}{w_2}\right)^{-1/2} \\ = \frac{\psi}{2+\psi} \cdot \frac{w_1 + w_2}{w_1} & \\ h_2 = d \cdot \left(\frac{w_1}{w_2}\right)^{1/2} &= \frac{\psi}{2+\psi} \cdot \frac{[w_1 + w_2]}{(w_1)^{1/2} \cdot (w_2)^{1/2}} \cdot \left(\frac{w_1}{w_2}\right)^{1/2} \\ = \frac{\psi}{2+\psi} \cdot \frac{w_1 + w_2}{w_2} & \end{aligned}$$

The remaining time is spent on market work:

$$n_1 = 1 - h_1 = \frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \frac{w_2}{w_1}$$

$$n_2 = 1 - h_2 = \frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \frac{w_1}{w_2}$$

2. If the participation condition (5.12) is not fulfilled, (5.8) and (5.11) intersect in the second part of their piecewise definitions:

$$2w_1 d = \psi \frac{w_1 \cdot (1-d^2)}{d} \iff d = \left(\frac{\psi}{2+\psi}\right)^{1/2}$$

The time inputs in home production of the two spouses are

$$h_1 = d^2 = \frac{\psi}{2+\psi}$$
$$h_2 = 1.$$

Again, the remaining time is spent on paid market work:

$$n_1 = 1 - h_1 = \frac{2}{2+\psi}$$
$$n_2 = 1 - h_2 = 0$$

Derivation of wives' hours by the husband's wage

The integrals in equation (5.17) evaluate as follows, yielding equation (5.18):

$$\begin{aligned}
n_F(w_M) = {} & (1-\xi) \cdot \int_{w_{\min}}^{\frac{\psi}{2}w_M} 0 \, \mathrm{d}w_F + (1-\xi) \cdot \int_{\frac{\psi}{2}w_M}^{\frac{2}{\psi}w_M} \left[\frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_F}\right] \mathrm{d}w_F \\
& + (1-\xi) \cdot \int_{\frac{2}{\psi}w_M}^{w_{\min}+1} \frac{2}{2+\psi} \, \mathrm{d}w_F + \xi \cdot \left[\frac{2}{2+\psi} - \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_M - \alpha}\right] \\
= {} & \frac{2}{2+\psi} + (1-\xi) \cdot \frac{2}{2+\psi} \cdot \left(w_{\min} - \frac{\psi}{2}w_M\right) \\
& - (1-\xi) \cdot \frac{\psi}{2+\psi} \cdot w_M \cdot \int_{\frac{\psi}{2}w_M}^{\frac{2}{\psi}w_M} \left[\frac{1}{w_F}\right] \mathrm{d}w_F - \xi \cdot \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_M - \alpha} \\
= {} & \frac{2}{2+\psi} + (1-\xi) \cdot \frac{2}{2+\psi} \cdot \left(w_{\min} - \frac{\psi}{2}w_M\right) \\
& - (1-\xi) \cdot \frac{\psi}{2+\psi} \cdot w_M \cdot [\ln w_F]_{\frac{\psi}{2}w_M}^{\frac{2}{\psi}w_M} - \xi \cdot \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_M - \alpha}
\end{aligned}$$

$$= \frac{2}{2+\psi} + (1-\xi) \cdot \frac{2}{2+\psi} \cdot w_{\min}$$
$$- (1-\xi) \cdot \frac{\psi}{2+\psi} \cdot \left(1 + \ln \frac{4}{\psi^2}\right) \cdot w_M - \xi \cdot \frac{\psi}{2+\psi} \cdot \frac{w_M}{w_M - \alpha}$$

Hump-shaped pattern of wives' hours by the husband's wage

For $0 < \xi < 1$, the right hand side of equation (5.19) is a strictly concave function of w_M. Thus, when there is a local extremum, it is a maximum. In this appendix, we show that for any combination of ψ, $w_{\min}$, and α, there is a ξ such that $n_F(w_M)$ has a local extremum in the interior of the support of male wages. This is equivalent to the statement that, for all marginal distributions of wages, there is a degree of assortative mating such the pattern of wives' hours by the husband's wage is hump-shaped.

The first derivative of equation (5.19) is

$$n_F'(w_M) = -(1-\xi) \cdot \frac{\psi}{2+\psi} \cdot \left(1 + \ln \frac{4}{\psi^2}\right) + \xi \cdot \frac{\psi}{2+\psi} \cdot \frac{\alpha}{(w_M - \alpha)^2}. \quad (5.21)$$

Since $n_F(w_M)$ is concave, it is sufficient to show that there is a ξ^* such that $n_F'(w_M)$ has a root on $(w_{\min} + \alpha, w_{\min} + \alpha + 1)$. A root w_M^* satisfies

$$(1-\xi^*) \cdot \left(1 + \ln \frac{4}{\psi^2}\right) = \xi^* \cdot \frac{\alpha}{(w_M^* - \alpha)^2}$$
$$\iff (w_M^* - \alpha) = \sqrt{\frac{\xi^*}{1-\xi^*}} \cdot \sqrt{\frac{\alpha}{1 + \ln \frac{4}{\psi^2}}}.$$

The root lies in the support of the male wage distribution when

$$w_{\min} < \sqrt{\frac{\xi^*}{1-\xi^*}} \cdot \sqrt{\frac{\alpha}{1 + \ln \frac{4}{\psi^2}}} < w_{\min} + 1. \quad (5.22)$$

Since $\sqrt{\frac{\alpha}{1+\ln \frac{4}{\psi^2}}} > 0$ due to the restriction $\psi < 2$ and

$$\lim_{\xi \longrightarrow 0} \sqrt{\frac{\xi}{1-\xi}} = 0,$$

$$\lim_{\xi \longrightarrow 1} \sqrt{\frac{\xi}{1-\xi}} = \infty,$$

there is always a $\xi^* \in (0,1)$ such that (5.22) is fulfilled.

Chapter 6

Concluding Remarks

This thesis has presented four applications of heterogeneous-agents models to the fields of political economy and labor markets. The essays presented in the thesis have explicitly considered of heterogeneity by income potentials, expectations, gender and marital status. Such heterogeneity is key to understand certain phenomena on both the aggregate and the subgroup level.

Chapters 2 and 3 have presented essays on the political economy in presence of income heterogeneity. Both chapters have explained puzzling observations in voting behavior within simple models of majority voting by incorporating imperfect information. The model presented in Chapter 2 can generate a negative relation between income skewness and redistribution as a result of heterogeneous expectations. The model presented in Chapter 3 generates welfare-state persistence as a results of the incentive effects of the welfare state on attentiveness.

Chapters 4 and 5 have presented essays on heterogenous-agents models which address empirically observed differences in labor supply by gender, marital status, and wage potentials. Chapter 4 has demonstrated that the distinct trends in hours worked by gender and marital status can be better understood when one incorporates trade in home labor between heterogeneous households into a household model of labor supply. Chapter 5 has focussed on the pattern of hours worked by married women disaggregated by the husband's wage. It has been shown that the observed that the observed change in this pattern can be generated within a standard model of household specialization when taking into account trends in assortative mating.

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