Summer 8-12-2011

Essays on the Western Labor Markets

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Abstract

In Chapter 2, "Accounting for Cross-Country Differences in Intergenerational Earnings Persistence: The Impact of Taxation and Public Education Expenditure," I study the determinants of cross-country differences in intergenerational earnings persistence between fathers and sons. Western economies exhibit substantial differences in the degree of intergenerational earnings persistence between fathers and sons. Earnings persistence is relatively low in Northern Europe and relatively high in the US, Britain, and Southern Europe. In this chapter I first document that there is a strong negative cross-country correlation between intergenerational earnings persistence and tax progressivity, and intergenerational earnings persistence and public expenditure on tertiary education. I then develop an intergenerational life-cycle model of human capital accumulation and earnings, which features progressive taxation, public education expenditure, and borrowing constraints among the determinants of earnings persistence. I calibrate the model to US data and use it to quantify how earnings persistence in the US changes as I introduce policies from Denmark. Denmark is an interesting example because it is the country in my sample with the highest and most progressive taxes and the greatest expenditure on tertiary education, as well as the lowest earnings persistence. I find that the Danish policies would reduce earnings persistence in the US by reducing parental/individual incentives for investing in human capital, thereby creating a weaker relationship between the parent's financial resources and the child's earnings. Quantitatively, taxation is more important than education expenditure. Introducing a Danish tax policy in the US reduces the intergenerational elasticity of earnings from 0.47 to 0.35, or about 40% of the difference between the US and the Scandinavian countries, which have the lowest earnings persistence among the countries in my sample. I also find that borrowing constraints have a very limited impact on earnings persistence.

In Chapter 3, "Marriage Stability, Taxation, and Aggregate Labor Supply in the US vs. Europe," which is joint work with Indraneel Chakraborty (SMU, Finance) and Serhiy Stepanchuk (UPenn, Economics), we study the determinants of cross-country differences in aggregate labor supply. Aggregate labor supply is higher in America than in Europe, and there is also substantial variation within Europe. Using micro data from the US and eight European countries, we document that the difference between the US and Europe is mainly driven by the labor supply of women. European women work less than American women, whether it is single women, married women, or women with and without children. Using a larger number of countries, we also document that there is a strong correlation between divorce rates and female employment rates across countries and across time. A recent literature, including Prescott (2004), and Rogerson (2005), argues that differences in labor supply between the US and Europe can largely be explained by differences in tax rates. We use tax data from the OECD to develop tax schedules for a sample of 17 countries. The empirical correlation between hours worked and different measures of tax levels and progressivity is negative, however, weak. Motivated by these observations, we develop a life-cycle model with heterogeneous agents, marriage, and divorce and use it to study the impact of two mechanisms: 1) differences in marriage stability and 2) differences in tax systems on labor supply. There are three types of households; single males, single females and married households. Divorces and marriages occur stochastically. The main channel through which individual divorce and singlehood rates impact labor supply is by reducing the implicit insurance of marriage, and thereby providing incentives for individuals to invest in experience. We calibrate our model to US data and study how labor supply in the US changes as we introduce European tax systems, and as we replace the US divorce and marriage rates with their European equivalents. We find that the divorce and tax mechanisms combined on average explains 28% of the difference between the US and 11 European countries. This finding is sensitive to the use of tax revenues.

Degree Type
Dissertation

Degree Name
Doctor of Philosophy (PhD)

Graduate Group
Economics

First Advisor
Dirk Krueger

Second Advisor
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Third Advisor
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Keywords
Intergenerational Mobility, Earnings Persistence, Labor Supply, Taxation, Redistribution, Marriage and Divorce

Subject Categories
Labor Economics | Macroeconomics | Public Economics

ESSAYS ON THE WESTERN LABOR MARKETS

Hans Aasnes Holter

A DISSERTATION

in

Economics

Presented to the Faculties of the University of Pennsylvania

in

Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

2011

Supervisor of Dissertation

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Dirk Krueger, Professor of Economics

Graduate Group Chairperson

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Dirk Krueger, Professor of Economics

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To my Parents, Jofrid and Oskar.

Acknowledgements

I am very grateful to my thesis advisor, Dirk Krueger. I also thank Iourii Manovskii, Petra Todd, Alexander Bick, Se Kyu Choi, Andrew Clausen, Flavio Cunha, Jesus Fernandez-Villaverde, Jeremy Greenwood, John Knowles, Kei Muraki, Serdar Ozkan, Serhiy Stephanchuk, Panos Stavrinides, and seminar participants at the University of Pennsylvania, Uppsala University, Hunter College CUNY, Kansas State University, New Economic School, and the University of Alicante for helpful discussions and comments. I acknowledge financial support from the Research Council of Norway.

ABSTRACT

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Hans Aasnes Holter

Dirk Krueger

In Chapter 2, "Accounting for Cross-Country Differences in Intergenerational Earnings Persistence: The Impact of Taxation and Public Education Expenditure," I study the determinants of cross-country differences in intergenerational earnings persistence between fathers and sons. Western economies exhibit substantial differences in the degree of intergenerational earnings persistence between fathers and sons. Earnings persistence is relatively low in Northern Europe and relatively high in the US, Britain, and Southern Europe. In this chapter I first document that there is a strong negative cross-country correlation between intergenerational earnings persistence and tax progressivity, and intergenerational earnings persistence and public expenditure on tertiary education. I then develop an intergenerational life-cycle model of human capital accumulation and earnings, which features progressive taxation, public education expenditure, and borrowing constraints among the determinants of earnings persistence. I calibrate the model to US data and use it to quantify how earnings persistence in the US changes as I introduce policies from Denmark. Denmark is an interesting example because it is the country in my sample with the highest and most progressive taxes and the greatest expenditure on tertiary education, as well as the lowest earnings persistence. I find that the Danish policies would reduce earnings persistence in the US by reducing parental/individual incentives for investing in human capital, thereby creating a weaker relationship between the parent's financial resources and the child's earnings. Quantitatively, taxation is more important than education expenditure. Introducing a Danish tax policy in the US reduces the intergenerational elasticity of earnings from 0.47 to 0.35, or about

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Chapter 1

Introduction

The labor markets of the developed world are characterized by differences in intergenerational mobility and hours worked, as well as in public policies. My dissertation consists of two separate papers, each trying to uncover the determinants of cross-country patterns in the Western labor market outcomes. In Chapter 2, I study the determinants of cross-country differences in intergenerational earnings persistence between fathers and sons. In Chapter 3, I investigate the determinants of cross-country differences in aggregate labor supply.

Chapter 2: "Accounting for Cross Country Differences in Intergenerational Earnings Persistence: The Impact of Taxation and Public Education Expenditure" Western economies exhibit substantial differences in the degree of intergenerational earnings persistence between fathers and sons. Earnings persistence is relatively low in Northern Europe, and relatively high in the US, Britain, and Southern Europe. In this paper I first document that there is a strong negative cross-country correlation between earnings persistence and tax progressivity, and earnings persistence and public expenditure on tertiary education. I then provide an intergenerational life-cycle model of human capital accumulation and earnings to separate and quantify the determinants of earnings persistence. The model contains key elements which has been proposed as determinants of earnings persistence in the literature, namely: progressive taxation, the efficiency of human capital investments, public education expenditure, borrowing constraints, partially inheritable abilities, inter vivos transfers from parent to child, and idiosyncratic wage shocks. I calibrate the model to US data, and decompose the contributions of the different model elements. Next I study how earnings persistence in the US changes as I introduce policies from Denmark into the model. Denmark is an interesting example because it is the country in my sample with the highest and most progressive taxes and greatest expenditure on tertiary education, as well as the lowest earnings persistence. I find that taxation and public education expenditure have a significant impact on earnings persistence and therefore are important contributors to the cross country patterns which empirical researchers have found. More government expenditure on education and higher taxes reduce earnings persistence by reducing parental/individual incentives for investing in human capital, which leads to a weaker relationship between the financial resources of the parent and the earnings of the child. The impact of taxation is quantitatively greater than the impact of education expenditure. Introducing a Danish tax system in the US, reduces the intergenerational elasticity of earnings by 0.12, or about 40% of the difference between the US and the Scandinavian countries, which have the lowest earnings persistence among the countries in my sample. I also study the quantitative importance of borrowing constraints in the model and conclude that they have very little impact on earnings persistence.

Chapter 3: "Marriage Stability, Taxation, and Aggregate Labor Supply in the US vs. Europe," joint with Indraneel Chakraborty (SMU, Finance) and Serhiy Stepanchuk (UPenn, Economics). Aggregate labor supply is higher in America than in Europe, and there is also substantial variation within Europe. Using micro data from the US and eight European countries, we document that the difference between the US and Europe is mainly driven by the labor supply of women. European women work less than American women, whether it is single women, married women, or women with and without children. Using a larger number of countries, we also document that there is a strong correlation between divorce rates and female employment rates across countries and across time. A recent literature, including Prescott (2004), and Rogerson (2005), argues that differences in labor supply between the US and Europe can largely be explained by differences in tax rates. We use tax data from the OECD to develop tax schedules for a sample of 17 countries. The empirical correlation between hours worked and different measures of tax levels and progressivity is negative, however, weak. Motivated by these observations, we develop a life-cycle model with heterogeneous agents, marriage, and divorce and use it to study the impact of two mechanisms: 1) differences in marriage stability and 2) differences in tax systems on labor supply. There are three types of households; single males, single females and married households. Divorces and marriages occur stochastically. The main channel through which individual divorce and singlehood rates impact labor supply is by reducing the implicit insurance of marriage, and thereby providing incentives for individuals to invest in experience. We calibrate our model to US data and study how labor supply in the US changes as we introduce European tax systems, and as we replace the US divorce and marriage rates with their European equivalents. We find that the divorce and tax mechanisms combined on average explains 28% of the difference between the US and 11 European countries. This finding is sensitive to the use of tax revenues.

Chapter 2

Accounting for Cross-Country Differences in Intergenerational Earnings Persistence: The Impact of Taxation and Public Education Expenditure

2.1 Introduction

In recent years, several empirical studies have been concerned with estimating and comparing the intergenerational persistence of earnings between fathers and sons in Western economies. The main finding of this literature is that intergenerational persistence is relatively high in the US, Britain, and Southern Europe, and relatively low in Northern Europe and in Canada. Table 2.1 below displays the results from a meta study of intergenerational earnings persistence across countries by Corak (2006)

Table 2.1: Intergenerational Earnings Elasticity Across Countries

Country	Estimated Earnings Elasticity
Denmark	0.15
Norway	0.17
Finland	0.18
Canada	0.19
Sweden	0.27
Germany	0.32
Spain**	0.40
France	0.41
Italy*	0.43
USA	0.47
UK	0.50

This table displays the results from a meta study by Heinz Corak (2006). *Taken from Piraino (2007). **Taken from Pla (2009). Pla estimates one earnings elasticity using sons aged 30-40, and one earnings elasticity using sons aged 40-50. The number listed is the average of the two.

[1], supplemented with two recent studies from Italy and Spain[2]. The next question follows naturally: What are the reasons for these differences? Western economies differ greatly with respect to public expenditure on education and with respect to tax schemes. Does the cross-country variation in public institutions explain the variation in earnings persistence? Understanding why earnings mobility differs across countries is interesting, even if only for positive reasons. However, the question of whether economic fate is predetermined or whether it is influenced by public institutions may also have important policy implications. For instance, if the pattern we observe occurs because poor parents in some countries are borrowing constrained and cannot invest optimally in their children's human capital, it may call for policy intervention.

Several explanations that could contribute to the observed cross-country pattern in intergenerational earnings persistence have been proposed in the economic literature, but there is little quantitative work in the area. To the best of my knowledge there are no previous papers studying the impact of cross-country differences in poli-

[1] See also Blanden (2009) for an extensive summary of the empirical literature.

[2] There are many difficulties with comparing different studies of earnings persistence; see Appendix 2.10.1. Table 2.1 is to be interpreted as a stylized fact.

cies on earnings persistence. I start by documenting that there is a strong negative cross-country correlation between earnings persistence and tax progressivity, and earnings persistence and public expenditure on tertiary education. I then provide an intergenerational life-cycle model of human capital accumulation and earnings to separate and quantify the determinants of earnings persistence. The model contains key elements that have been proposed as determinants of earnings persistence in the literature, namely, progressive taxation, the efficiency of human capital investments, public education expenditure, borrowing constraints, partially inheritable abilities, inter vivos transfers from parents to children, and idiosyncratic wage shocks. I calibrate the model to US data and decompose the contributions of the different model elements.

Next I study how earnings persistence in the US changes as I introduce policies from Denmark into the model. Denmark is an interesting example because it is the country in my sample with the highest and most progressive taxes and greatest expenditure on tertiary education, as well as the lowest earnings persistence. I find that taxation and public education expenditure have a significant impact on earnings persistence and therefore are important contributors to the cross-country patterns that empirical researchers have found. More government expenditure on education and higher taxes reduce earnings persistence by reducing parental/individual incentives for investing in human capital, which leads to a weaker relationship between the parents financial resources and the childs earnings. The impact of taxation is quantitatively greater than the impact of education expenditure. Introducing a Danish tax system in the US reduces the intergenerational elasticity of earnings from 0.47 to 0.35, or about 40% of the difference between the US and the Scandinavian countries, which have the lowest earnings persistence among the countries in my sample. I also study the quantitative importance of borrowing constraints in the model and conclude that they have very little impact on earnings persistence.

Determinants of Earnings Persistence

In classical human capital theory, it is usually assumed that the earnings of individuals depend on their level of human capital and on market luck, or random shocks. Two factors go into human capital formation. One is a fixed endowment, imperfectly inherited by children from parents, and the other is investments in human capital, which can be made both by the parents and by the government; see Becker and Tomes (1979), Becker and Tomes (1986), and Solon (2004). Endowments here refer to everything from genetically inherited ability to knowledge acquired from the parents, family culture, and the parents social connections. In my model below I will refer to the family endowment as ability. The narrowest definition of human capital investment is investment in education, but many authors use broader definitions. It is also commonly assumed that parents care about their childrens utility and that utility depends only on the consumption of goods that cannot be considered as investments in human capital; see, for instance, Becker and Tomes (1986). This way, the only reason to invest in childrens human capital is to increase their future consumption through higher earnings. If there are diminishing returns to investment, there will be an optimal level of investment for each child.

From this theory, several explanations for cross-country differences in earnings persistence emerge. One possibility is that the inheritability of family endowments is stronger in some countries. There could be many underlying reasons for this. The degree of assortative mating does, for instance, differ across countries. In some countries, couples are more similar with respect to their education and family background, and since almost all research studies the correlation between fathers and sons, this will cause the sons to be more similar to their fathers. Indeed, there seems to be a somewhat higher correlation in spousal education in the US and Italy than in Northern Europe, but Britain, which has relatively high earnings persistence, has a relatively low correlation in spousal education.[3]

Another possibility is that countries just differ in the returns to human capital or the cost of acquiring it. In standard intergenerational models of earnings formation, earnings persistence increases with the returns to human capital investments; see, for instance, Restuccia and Urrutia (2004). Depending on modeling choices, there are several channels through which this may work, but I will mention just a common one: Optimal human capital investments are usually increasing in parental financial resources, as altruistic parents face a tradeoff between their own consumption today and their children's future consumption. If human capital investments become more efficient, then for a given inequality of investments in children of high and low earners, the inequality of earnings outcomes will increase. This results in higher intergenerational earnings persistence. In Section 2.3 below, I illustrate this mechanism with a simple model. Tax codes are also plausible explanations for the cross-country differences in earnings persistence, as they affect the incentives to invest in human capital. If taxes are progressive, it will have the effect that human capital investments become less attractive, particularly for someone with high ability. This will shrink the dispersion of human capital investments and cause smaller earnings persistence. In Section 2.2, I document a negative correlation between tax progressivity and earnings persistence.

If there are diminishing returns to human capital investments, and investments made by parents and the government are substitutes, then a parent's incentive to invest will be falling as the government invests more. As the government invests more, the difference between how much is invested in rich and poor children becomes smaller and earnings persistence will fall. Western economies differ with respect to public education expenditure. As I document in Section 2.2, the countries with low earnings persistence tend to spend more on public investments in education relative

[3]See Fernandez, Guner, and Knowles (2005)

to GDP per capita. The difference is particularly large when it comes to spending on tertiary education.

Finally, one potential cause of earnings persistence that has received much attention in the literature is the presence of credit constraints. As mentioned above, there will usually be a direct relationship between parents' and childrens earnings. This will be true even if the parents are not credit-constrained with respect to their own resources, and if human capital investments are risky it may also be true even if they are not credit constrained with respect to their children's future earnings. A stronger relationship may, however, occur if low earners with high ability/endowment children face binding credit-constraints with respect to investing in their childrens human capital. One potential source of cross-country differences in earnings persistence is the degree of credit market completeness. I do not have any good measure of credit market completeness across countries, but if the government heavily subsidizes education, it should reduce the number of credit-constrained parents. In my structural model below, I do, however, find that increasing or decreasing borrowing limits has very little quantitative impact on earnings persistence in the US.

Empirical Literature

The most commonly used measure of earnings persistence is the coefficient, often denoted , from the regression of the logarithm of the sons earnings on the logarithm of the fathers earnings and a constant, also called the intergenerational elasticity of earnings:

$$\log(y_{son}) = \alpha + \beta \log(y_{father}) + \epsilon \quad (2.1)$$

The relevant measure of earnings is lifetime or permanent earnings, but as this measure is rarely available, the best a researcher can do is often to average several years of earnings and control for the age at which the earnings were observed. What β tells us, in a purely statistical sense, is what percentage of a fathers earnings advantage, relative to the mean in his generation, that is on average transferred to the son. A β of 0 would represent the case in which the earnings of fathers and sons are completely unrelated, while a β of 1 would represent the case in which the earnings advantage of the father is perfectly transferred to the son. Hypothetically, one can also imagine β smaller than 0 or greater than 1. In practice, however, empirical studies have found β between 0 and 1, which implies that earnings tend to revert to the mean over generations.

The statistical literature, which estimates and compares the intergenerational elasticity of earnings for different countries, is by now quite large. Blanden (2009) provides a thorough discussion. There are some difficulties related to methodology and data, which makes it harder to compare different studies (see Appendix 2.10.1). It is, however, clear that there are substantial differences between countries. Corak (2006) provides a meta study based on previous empirical studies of earnings persistence in different countries and current knowledge of data and methodological issues. Table 2.1 reproduces the main findings of his study, supplemented with two recent studies from Italy and Spain. It documents the pattern with relatively high earnings persistence in the US, Britain, and Southern Europe, and relatively low earnings persistence in Northern Europe and in Canada.

Quantitative Literature

In addition to the empirical work, there is also a theoretical literature, pioneered by Becker and Tomes, which gives us a framework for understanding the factors that may affect the correlation of childrens and parents earnings. The quantitative/structural literature, which takes models to the data, is, however, very sparse. I will briefly mention the two papers that are closest in spirit to the work I am undertaking.

Han and Mulligan (2001) develop a very simple two-period/two-generation model in which parents care about their children and have the opportunity to invest in their human capital and to give them monetary bequests. They calibrate their model to fit characteristics of the US economy, including the intergenerational elasticity of earnings, β, which they take to be 0.4. They then study how β changes as they eliminate intergenerational borrowing constraints and increase the variance of shocks to ability. The authors conclude that eliminating borrowing constraints reduces β by up to 0.1, but they also find that β increases as the heterogeneity of family endowments increases. They suggest that if there is a greater variance of family endowments in the US and Britain, perhaps because those countries are more racially and culturally diverse, then this result could be used to explain higher earnings persistence in those countries. However, it is not an obvious result or theoretical implication that a larger variance of family endowments should lead to larger and not smaller persistence. This is something that comes out of their specific model for specific parameter values. It should also be noted that in their model agents experience the same shocks to human capital and financial assets. It is therefore no insurance in holding both assets. An individual will invest in human capital until the return equals the return on financial assets, and if needed borrow financial assets to achieve this level of human capital investment. This may increase the importance of borrowing constraints.

Restuccia and Urrutia (2004) develop a model with infinite dynasties in which agents live for four periods: two as children and two as adults. Parents decide how much to invest in their childrens elementary education and whether to send them to college. There is also a government that imposes taxes, runs a balanced budget, and invests the tax revenues in education. The focus of the paper is to determine whether investments in early or college education are quantitatively more important for earnings persistence. They find that early education matters more and that government investments in early education have a much greater impact than government investments in college education.

My paper is the first to study the impact of cross-country differences in policies on β. It turns out that across countries there is greater variation in spending on tertiary education than on early education. Tertiary education spending therefore seems like a more likely explanation for cross-country differences in β. My paper also offers a richer, more realistic model, combining some elements that are present in each of the two papers above. In Section 2.5, I discuss the different model elements in detail and why they are important in a study of earnings persistence.

The remainder of the paper is organized as follows: In Section 2.2, I document the correlation between and tax progressivity and between and spending on tertiary education. Section 2.3 studies the impact of taxation and public investment in education on in a simple analytical model. Section 2.4 presents the quantitative model. In Section 2.5, I discuss and justify some of the modeling choices. Section 2.6 discusses data and calibration. Section 2.7 decomposes the contributions to earnings persistence from the different model elements. Section 2.8 presents results from policy experiments. Section 2.9 concludes.

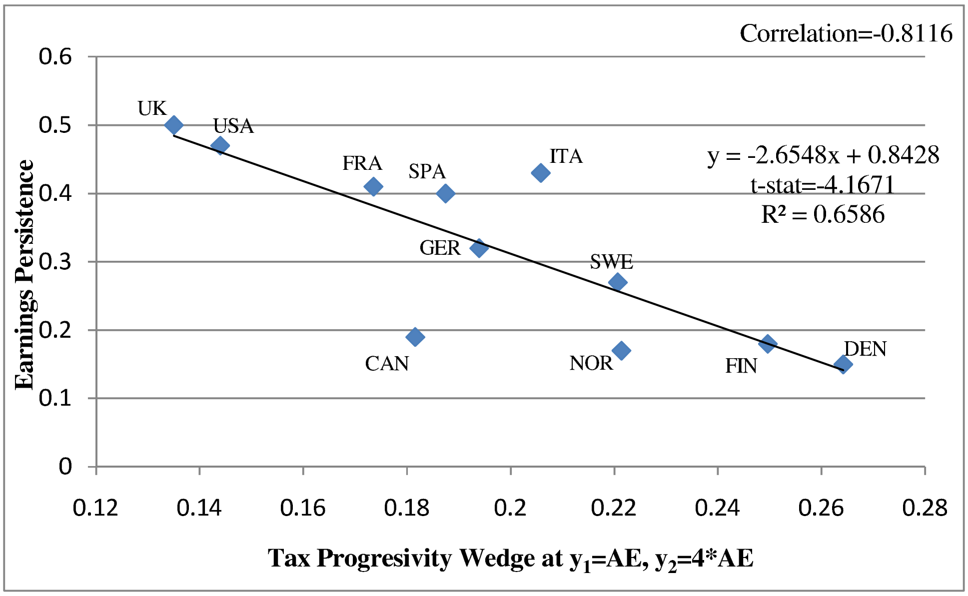
2.2 Correlations Between Earnings Persistence and Tax Progressivity and Earnings Persistence and Public Spending on Tertiary Education

It is difficult to summarize the tax system in a country with just one number. A commonly used measure of tax progressivity is so-called progressivity wedges; see, for instance, Guvenen, Kuruscu, and Ozkan (2009):

$$PW(y_1, y_2) = 1 - \frac{1 - \tau(y_2)}{1 - \tau(y_1)} \tag{2.2}$$

This measure says something about how fast the tax rate increases as earnings increase from y_1 to y_2. If there is a flat tax, then the progressivity wedge would be

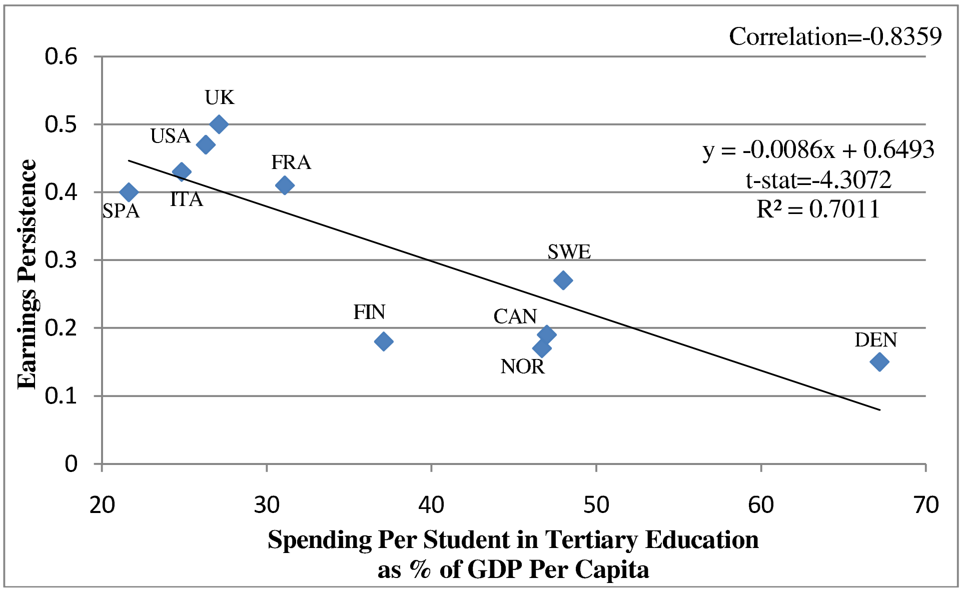
Figure 2.1: Correlation Between Tax Progressivity and Earnings Persistence



Earnings persistence from Table 2.1. The tax data is an average of the years 2001-2005, taken from the OECD Tax and Benefit Calculator and the OECD Tax Database. The regression coefficient is significant at the 1% level.

zero for all levels of y_1 and y_2. For each country in Table 2.1, I use labor income tax data from the OECD tax database to fit a tax function; see Appendix 2.10.2 for a detailed description. I then construct progressivity wedges using the average tax rate. I use the average earnings, AE, in each country for y_1 and four times average earnings for y_1. In Figure 2.1, I plot earnings persistence on the y-axis against this measure of tax progressivity on the x-axis. The correlation between the two quantities is -0.81 and the regression coefficient is highly significant when earnings persistence is regressed on the progressivity wedges. A strong correlation between two variables need not imply, of course, that one has a causal effect on the other. However, this empirical observation motivates a further investigation of the impact of taxes on earnings persistence in a structural model with careful modeling of the tax systems. In Figure 2.2, I plot the correlation between earnings persistence and public expenditure per student in tertiary education as a fraction of GDP per capita. The correlation between the two variables is -0.84, and the regression coefficient is

Figure 2.2: Correlation Between Public Expenditure on Tertiary Education and Earnings Persistence



Earnings persistence from Table 2.1. The education spending data are an average of the years 1999-2005, taken from the UNESCO Institute for Statistics. The regression coefficient is significant at the 1% level.

highly significant when earnings persistence is regressed on education expenditure.

2.3 Gaining Intuition: The Impact of Taxation and Public Education Expenditure on Intergenerational Earnings Persistence in a Simple Model

To obtain an intuitive understanding of how taxation and public education expenditure qualitatively affect earnings persistence, it may be helpful to start with a simple model. The model is a slight modification of Solon (2004), where I have changed the wage function and the process for inheritance of abilities to be similar to the wage function and the process for inheritance of abilities in the quantitative model of Section 2.4. Assume that there is a continuum of infinitely lived single individual dynasties. Each individual lives for two periods: one as a child and one as an adult. Parents decide how much to consume and how much to invest in their children's human capital, while children do not make any economic decisions. A parent's utility is a function of today's consumption, c_t , and his child's future earnings, y_{t+1}:

$$U_t(c_t, y_{t+1}) = \log(c_t) + \alpha \log(y_{t+1}) \tag{2.3}$$

The parameter α measures how altruistic parents are with respect to their children. The earnings of the child are determined by his level of human capital. Human capital is a function of investments made by the parents, I_t, investments made by the government, I_g, and of the childs ability or family endowment, A_t:

$$y_{t+1} = \gamma h_{t+1} \tag{2.4}$$

$$h_{t+1} = A_{t+1}(I_t + I_g)^{\psi} \tag{2.5}$$

Abilities are imperfectly transmitted from parent to child. I assume them to be log-normally distributed, and follow an AR(1)-process:

$$\log(A_{t+1}) = \theta \log(A_t) + \nu, \qquad \nu \sim N(0, \sigma_\nu^2) \tag{2.6}$$

Assuming that labor income is taxed at rate τ, the utility maximization problem of a parent can now be written as:

$$\begin{aligned} \max_{c_t>0, I_t \geq 0} \log(c_t) \quad &+ \quad \alpha \log(y_{t+1}) \\ s.t.: \quad c_t + I_t \quad &= \quad y_t(1-\tau) \\ y_{t+1} \quad &= \quad \gamma A_{t+1}(I_t + I_g)^{\psi} \end{aligned} \tag{2.7}$$

Substituting for c_t, and y_{t+1}, gives a maximization problem in I_t:

$$\max_{0 \le I_t < y_t} \log(y_t(1-\tau) - I_t) + \alpha\psi \log(I_t + I_g) + \alpha \log(A_{t+1}) + \alpha \log(\gamma) \tag{2.8}$$

The first-order condition is:

$$\begin{aligned} \frac{-1}{y_t(1-\tau) - I_t} + \frac{\alpha\psi}{I_t + I_g} &\le 0 \\ \frac{-1}{y_t(1-\tau) - I_t} + \frac{\alpha\psi}{I_t + I_g} &= 0, \quad if \quad I_t > 0 \end{aligned} \tag{2.9}$$

Rearranging this expression we get the following solution for I_t:

$$I_t = \begin{cases} \frac{\alpha\psi}{1+\alpha\psi} y_t(1-\tau) - \frac{1}{1+\alpha\psi} I_g, & if \quad y_t > \frac{I_g}{\alpha\psi(1-\tau)} \\ 0, & else \end{cases} \tag{2.10}$$

As long as there is an interior solution, I_t is decreasing in the tax rate, τ, decreasing in government investment, I_g, increasing with the altruism parameter, α, and increasing in the human capital production function parameter, ψ. Substituting for I_t in 2.5 and taking the log of 2.4, we get an equation relating the log of the earnings of children to the earnings of their parents:

$$\begin{aligned} &\log(y_{t+1}) \\ &= \begin{cases} \psi \log(y_t(1-\tau) + I_g) + \log(\theta A_t + \nu) + \log\left(\gamma(\frac{\alpha\psi}{1+\alpha\psi})^{\psi}\right), & if \quad y_t > \frac{I_g}{\alpha\psi(1-\tau)} \\ \psi \log(I_g) + \log(\theta A_t + \nu) + \log\left(\gamma(\frac{\alpha\psi}{1+\alpha\psi})^{\psi}\right), & else \end{cases} \end{aligned} \tag{2.11}$$

Proposition 2.3.1.

$$\begin{gathered} If \quad y_t > \frac{I_g}{\alpha\psi(1-\tau)} \quad and \quad I_g > 0 \quad then \\ \frac{\partial^2 \log(y_{t+1})}{\partial \log(y_t) \partial \tau} < 0, \quad \frac{\partial^2 \log(y_{t+1})}{\partial \log(y_t) \partial I_g} < 0, \quad \frac{\partial^2 \log(y_{t+1})}{\partial \log(y_t) \partial \psi} > 0 \end{gathered} \tag{2.12}$$

Proof: See Appendix 2.10.3

Proposition 2.3.1 states that as long as both the parental investment and the government investment are positive, the impact of the parent's earnings on the child's earnings become smaller when there is a higher tax level or more government investment, or when human capital production is more efficient. In the case of the tax, this happens because a smaller share of the parent's earnings can be devoted to investing in human capital when the tax is higher. Government investment, which is equal for all children, then accounts for a larger share of the total human capital investment, and a given percentage change, or a change in the log, of parental earnings will have a smaller impact on the log of the child's earnings. However, if government investments were zero, then the flat tax could be separated out as a constant term. When government investment increases, it has the same effect as when the tax increases. The relative importance of parental earnings is decreasing when I_g increases. The impact of parental earnings on the child's earnings is increasing in the human capital production function parameter, ψ. This is simply because an increase in ψ increases the effect of parental investments. The equation usually estimated by empirical researchers studying intergenerational earnings persistence is:

$$\log(y_{it+1}) = \alpha + \beta \log(y_{it}) + \epsilon_{it+1} \tag{2.13}$$

where i denotes the family or dynasty. If we assume that the government invests a constant fraction of average earnings in education, $I_g = \tilde{I}_g \bar{y}$, and that $y_{it} > \frac{I_g}{\alpha\psi(1-\tau)}$ $\forall\ i$, which implies that all parents invest a positive amount in their child's human capital, we only have to consider the first part of equation 2.11. Let us also assume that the economy is in steady state; i.e., the cross-sectional distributions of $\log(y_{it+1})$ and $\log(y_{it})$ are identical. With the purpose of obtaining an analytical solution for the regression coefficient, β, we can log-linearize the first part of 2.11

around average earnings, $\bar{y}$, and average ability, $\bar{A}$:

$$\log(y_{it+1}) = \alpha^* + \frac{\psi(1-\tau)}{(1-\tau)+\tilde{I}_g}\log(y_{it}) + \log(A_{it+1})$$
$$where \;\; \alpha^* = \psi\log\Big(\bar{y}\big((1-\tau)+\tilde{I}_g\big)\Big) + \log\left(\gamma(\frac{\alpha\psi}{1+\alpha\psi})^{\psi}\right) - \frac{\psi(1-\tau)}{(1-\tau)+\tilde{I}_g}\bar{y} \quad (2.14)$$

Equation 2.14 now resembles the classical linear regression equation in 2.13, except that the error term, $\log(A_{it+1})$, is correlated with the explanatory variable, $\log(y_{it})$. This is because both $\log(A_{it+1})$ and $\log(y_{it})$ depend on $\log(A_{it})$. OLS estimates of the slope will therefore be biased. Equation 2.14 is a first-order autoregression where the error term follows the AR(1)-process as in 2.6. It is shown in Greene (2000), pp. 534-535, that when $Var\big(\log(y_{it+1})\big) = Var\big(\log(y_{it})\big)$ the probability limit of the OLS-estimator for the slope coefficient in this equation is given by the sum of the true slope coefficient and the autoregressive parameter of the error term divided by one plus their product. Using this result we get that in the population regression where 2.14 is estimated by OLS:

$$\beta = \frac{(\psi+\theta)(1-\tau)+\theta\tilde{I}_g}{(1+\psi\theta)(1-\tau)+\tilde{I}_g} \quad (2.15)$$

Proposition 2.3.2.

$$\frac{\partial\beta}{\partial\tau} < 0, \quad \frac{\partial\beta}{\partial\tilde{I}_g} < 0, \quad \frac{\partial\beta}{\partial\psi} > 0, \quad \frac{\partial\beta}{\partial\theta} > 0 \quad (2.16)$$

Proof: See Appendix 2.10.3

Thus, in this simple model, we have seen that an increase in the level of taxes and/or government investment in education reduces earnings persistence by reducing the direct impact of parental earnings on the child's earnings (Proposition 2.3.1). The intuition behind the result is that the relative importance of parental investments compared to government investments decreases. The difference between how much is invested in rich and poor children becomes smaller in percent/log terms as taxes or government investments increase, and this leads to a fall in earnings persistence. β is, not surprisingly, increasing in the correlation of parent's and child's ability, θ. It is also increasing in the human capital production function parameter, ψ. It should be noted that the relationship between the market return to human capital, γ, and β generally is sensitive to the specification of the wage function. I have specified a constant return to a unit of human capital, and γ does not enter the expression for β. In Solons original model, an exponential return to human capital was specified and γ would then be present in the expression for β.

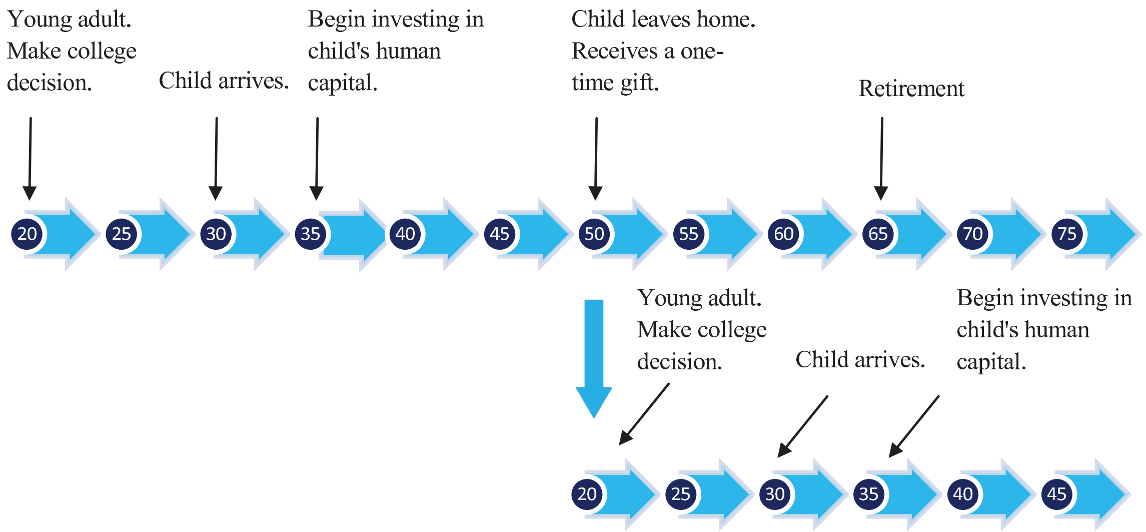
As long as the tax is flat in this model, there is a linear relationship between human capital investments and parental earnings. The percentage variation of private investments is the same when all parents invest a positive amount and the tax level increases; however, the percentage variation in total investments decreases because private investments are smaller compared to public investments. Introducing a progressive tax may have had the effect of decreasing the percentage variation in private investments, and this would also reduce earnings persistence. We will now turn to the study of a more realistic model with the purpose of quantifying the determinants of earnings persistence.

2.4 Model

Economic Environment

The economy is populated by single-individual dynasties, where each individual lives for at least 70 years and at most 100 years. A model period is five years. For the first four periods, or 20 years, of his life, an individual is part of the parents household and does not make any economic decisions. At age 20, a young individual moves out of his parent's house and forms his own household. At age 30, he has a child,

Figure 2.3: Household's Life Cycle



and at age 65 he retires. The first decision a young adult must make is whether or not to enroll in college. All working age households, including college students, decide how much to work, consume, and save at a risk-free rate. College students also decide how much to invest in human capital production. There is a fixed time cost of attending college, and college students have to work at a low fixed wage, which is independent of their human capital. There is a probability of failing college, depending on the student's ability and prior level of human capital. Households are altruistic and care about their childrens utility. Households with a child, ages 5 to 19, decide how much to invest in the childs human capital. At the moment a child leaves home and begins his own household, the parent has the option of giving him a one-time gift of liquid assets to ensure that he gets a good start in life. This is, of course, a simplifying assumption, but it greatly reduces the complexity of the model. Empirically, the fact that the child receives a one-time gift at the beginning of his adult life can be motivated by the observation that many parents help their child with paying for college or with buying a first home. Figure 2.3 illustrates the life cycle of a household.

Wages and Human Capital

Worker productivity in this economy depends on human capital, college completion, labor market experience, and labor market luck. Since there is no unemployment in the model, experience is equal to potential experience and is fully determined by age and whether a person attended college. Letting x denote the individual's experience level and h denote his level of human capital, his wage can be written:

$$w = h\gamma_0 e^{\gamma_1^j x + \gamma_2^j x^2 + \gamma_3^j x^3 + u} \tag{2.17}$$

$$u \sim N(0, \sigma_u^2) \tag{2.18}$$

Where u is an idiosyncratic productivity shock, and $j \in \{0, 1\}$ is an indicator for whether the individual is college educated. There are different age/experience paths for the wages of college- and high-school-educated workers. The human capital of a person must be built up during his childhood and during college. How much human capital a person accumulates depends on his ability, A, and how much is invested in his human capital in each time period by the parents, I_p, by the individual himself in college, I_s, and by the government, I_g:

$$\begin{aligned} h' &= h + A\big[h(I_p + I_g)\big]^{\psi_0} \\ h' &= h + A\big[h(I_s + I_g)\big]^{\psi_1} \end{aligned} \tag{2.19}$$

Here h' denotes human capital in the next time period. I follow the tradition in the literature on intergenerational earnings persistence (see Becker and Tomes (1979), Becker and Tomes (1986), and Solon (2004)) and think of human capital investments as investments of money or goods. However, while many definitions of what should be considered human capital investments have been suggested, I will think of it as investment in education. The ability or family endowment of the child is broadly defined to include things that do not have to be bought, like genetics, family culture, motivation, and knowledge acquired from the parents. Abilities are assumed to be log-normally distributed and imperfectly inherited from parent to child according to an AR(1) process:

$$\log (A_c) = \theta \log (A_p) + \nu, \qquad \nu \sim N(0, \sigma_\nu^2) \tag{2.20}$$

2.19 is the same functional form as in Ben-Porath (1967), except that Ben-Porath allowed for different exponentials on the human capital and goods inputs. The same production function has been used in some recent studies involving human capital accumulation; see, for instance, Huggett, Ventura, and Yaron (2007), or Ionescu (2009). These studies do, however, ignore the input of goods in the production of human capital and focus on the human capital input, which is modeled as the product of previous human capital and time. They are also different in that they focus on human capital accumulation during work-life and/or college. In my model the input of time is kept constant, and human capital accumulation starts at age 5. It is known that the efficiency of human capital investments varies by age (see Cunha and Heckman (2007)), and this is the rationale for specifying different technologies before college and in college. One could have used a different technology at every age but this would complicate the model.

Preferences

The momentary utility is a function of consumption in adult equivalents, $\frac{c}{e(t)}$, where $e(t)$ varies depending on whether there is a child in the household, and work hours, n:

$$u(c, n) = \frac{\left(\frac{c}{e(t)}\right)^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta} \tag{2.21}$$

A household discounts the future by a factor, δ. When the child leaves home, the parent cares about the child's utility, U^c, but discounts it by, α. Thus a household's lifetime utility, U, is given by:

$$U = \sum_{t=1}^{death} \delta^{t-1} u(c, n) + \delta^6 \alpha U^c \tag{2.22}$$

Borrowing for College and Probability of College Completion

Individuals who attend college are allowed to borrow up to an amount, z, while in college. I require that they do not retire in debt, and in subsequent periods, I let the borrowing constraint, $\phi(j, t)$, be linearly decreasing between college and retirement. High school graduates are not allowed to borrow:

$$\phi(j = 1, t) = max\big(0, z(9 - t)\big), \quad \phi(j = 0, t) = 0 \tag{2.23}$$

However, if someone took out a loan for college and failed to complete college, they will also be subject to the borrowing constraint for college graduates. The probability of success in college, $\pi(Ah)$, is a function of ability and acquired pre-college human capital:

$$\pi(Ah) = 1 - e^{\Omega Ah} \tag{2.24}$$

Recursive Formulation of the Household's Problem

A household can be in five different life stages, and therefore, there are five different household maximization problems. The first decision a young household must make is whether or not to go to college. This is done at age 20, or $t = 1$. In both cases he decides how much to consume, c, next period's capital, k', and how much to work, n. If he goes to college, he must also decide how much to invest in human capital, I_s. The state variables are age, t, capital, k, his level of human capital, h, his ability, A, and the productivity shock, u. In all time periods, experience, x, will be equal to the current model period minus 4 for high-school-educated workers and equal to the current model period minus 5 for college-educated workers. Formally, the individual solves the following Bellman problem:

$$
\begin{aligned}
W(k,h,t=1,A,u) &= \max\{V(j=0,\cdot),V(j=1,\cdot)\}, \quad where: \\
V(0,k,h,t,A,u) &= \max_{c,n,k'} u(c,n)+\delta E\big[V'(0,k',h,t',A,u')\big] \\
s.t.: \quad c(1+\tau_c)+k' &= k(1+r)+wn\big(1-\tau(wn)\big) \\
c>0,\ \ k' &\geq 0,\ \ 0\leq n\leq 1,\ \ t'=t+1 \\
w &= h\gamma_0 e^{\gamma_1^0 x+\gamma_2^0 x^2+\gamma_3^0 x^3+u},\ \ u\sim N(0,\sigma_u^2) \\
V(1,k,h,t,A,u) &= \max_{c,n,k',I_s} u(c,n+\varpi)+\delta\pi(h,A)E\big[V'(1,k',h',t',A,u')\big] \\
&\quad +\delta\big(1-\pi(h,A)\big)E\big[V'(0,k',h,t',A,u')\big] \\
s.t.: \quad c(1+\tau_c)+k' &= k(1+r)+wn\big(1-\tau(wn)\big)-I_s \\
c>0,\ \ I_s\geq 0,\ \ h' &= h+A\big[h(I_s+I_g)\big]^{\psi_1},\ \ k'\geq\phi(1,1),\ \ 0\leq n\leq 1-\varpi \\
w=w_c,\ \ w' &= h\gamma_0 e^{\gamma_1^j x+\gamma_2^j x^2+\gamma_3^j x^3+u},\ \ u\sim N(0,\sigma_u^2),\ \ t'=t+1 \qquad (2.25)
\end{aligned}
$$

ϖ is here the time cost of attending college, τ_c is a flat consumption tax, and $\tau(wn)$ is a non-linear labor income tax rate. Also note that while in college, an individual must work at the fixed wage, w_c, which is independent of his level of human capital. The problem of a working household without a child and at age 30 when no human capital investments are made is:

$$
\begin{aligned}
V(j,k,h,t,A,u) &= \max_{c,n,k'} u(c,n)+\delta E\big[V'(j,k',h,t',A,u')\big] \qquad (2.26) \\
s.t.: \quad c(1+\tau_c)+k' &= k(1+r)+w(j,t,h,u)n\big(1-\tau(w(j,t,h,u)n)\big) \\
k'\geq\phi(j,t),\ \ 0\leq n\leq 1,\ \ c &> 0,\ \ t'=t+1,\ \ for\ t=2,3,8,9\ (age=25,30,55,60)
\end{aligned}
$$

At age 30, (20) is also a constraint, as the ability of the child will be revealed in the next period, and the parent must have an expectation of his child's ability. Between ages 35 and 50 the parent must also decide on how much to invest in the child's human capital. He solves:

$$\begin{aligned} V(j,k,h_p,h_c,t,A,u) &= \max_{c,n,k',I_p} u(c,n) + \delta E\big[V'(j,k',h_p,h_c',t',A,u')\big] \\ s.t.: \quad c(1+\tau_c)+k'+I_p &= k(1+r)+w(j,t,h,u)n\big(1-\tau(w(j,t,h,u)n)\big) \\ I_p \geq 0, \;\; h_c' &= h_c + A\big[h_c(I_p+I_g)\big]^{\psi_0}, \;\; k' \geq \phi(j,t) \\ 0 \leq n \leq 1, \;\; c>0, \;\; t' &= t+1, \;\; for\ 4 \leq t \leq 6 \ (35 \leq age \leq 50) \end{aligned} \tag{2.27}$$

h_p here denotes the human capital of the parent, and h_c denotes the human capital of the child. The parent must keep track of both as state variables. A is now the ability of the child. There is no reason for the parent to know his own ability after the childs ability is revealed. When the parent is age 50 and the child is age 20, the child leaves the household and the parent has a one-time opportunity to give him a gift or an inter vivos transfer, b. The parent's problem is:

$$\begin{aligned} V(j,k,h_p,h_c,t=7,A,u) &= \max_{c,n,k',b} u(c,n) + \delta E\big[V_p'(j,k',h_p,h_c',t=8,u_p')\big] \\ &\quad +\alpha E\big[W_c(b,h_c,t=1,A,u_c)\big] \\ s.t.: \quad c(1+\tau_c)+k'+b &= k(1+r)+w(j,t,h,u)n\big(1-\tau(w(j,t,h,u)n)\big) \\ k' \geq \phi(j,t), \;\; c &> 0, \;\; 0 \leq n \leq 1, \;\; b \geq 0, \;\; t'=t+1 \end{aligned} \tag{2.28}$$

α here controls the parent's degree of altruism. I assume that the parent does not observe the child's idiosyncratic shock before the size of the gift is decided. He must, therefore, take the expectation of the child's value function with respect to the idiosyncratic shock. A household in retirement simply solves:

$$\begin{aligned} V(j,k,h,t,A,u) &= \max_{c>0,k'\geq 0} u(c,n=0) + \delta\Gamma(t)E\big[V'(k',t')\big] \\ s.t.: \quad c(1+\tau_c)+k' &= k(1+r)+T \\ for\ 10 \leq t &\leq 16 \;\; (65 \leq age \leq 95) \end{aligned} \tag{2.29}$$

T here is a constant amount of social security, and $\Gamma(t)$ is an age-dependent probability of survival to the next period.

2.5 Discussion of Modeling Choices

Life-Cycle Model with College Decision

Using a life-cycle model with college decision allows us to study government expenditure on different levels of education. We can separate the effects of spending on primary, secondary, and tertiary education. The cross-country variation in public education expenditure is largest for tertiary education. Another argument for using a life-cycle model is that when studying the impact of parents' earnings on the earnings of children, we are interested in the financial resources available to parents at the time when there are children in the household. There is a literature documenting that even after controlling for parents' lifetime income, the income of the parents during the childhood years matters for the children's income; see Cunha and Heckman (2007) for a survey.

Physical Capital, Inter Vivos Transfers, and Human Capital

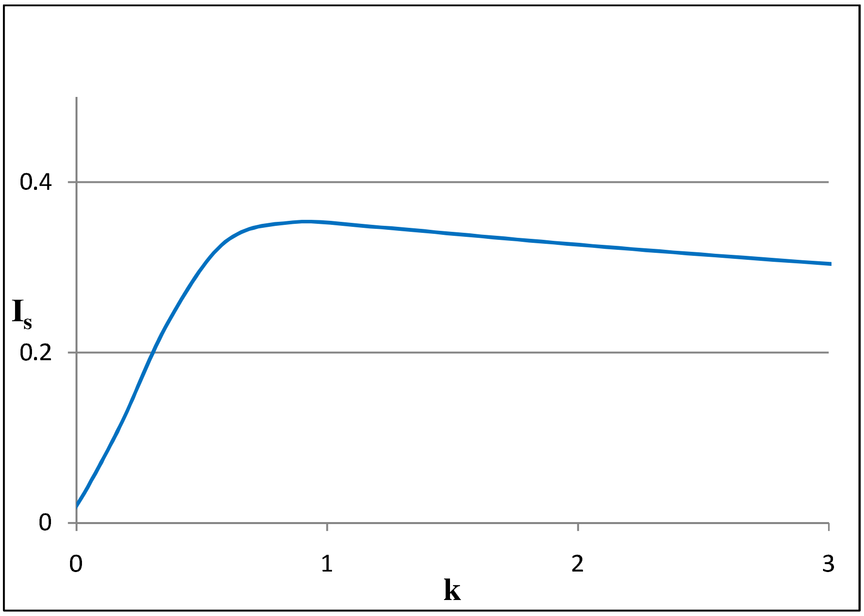
I will argue that in a realistic quantitative model developed to study intergenerational earnings persistence, it is important to have financial assets and a mechanism for transfers from parent to child, in addition to human capital. The existence of physical capital in the model affects how much is invested in a child's human capital in various ways. In a model without financial assets, parents will divide their resources between their own consumption today and their children's future consumption or, equivalently, their children's human capital. This may create a too strong correlation between the earnings of the parent and the child's human capital, as the optimal investment in the child will always be increasing in the earnings of the parent. If there is physical capital and diminishing returns to human capital investments, there will be a point at which the return on capital is strictly higher than the return on human capital, and this will put a cap on human capital investments. Children with low ability but rich parents will earn a lot more in a world with no financial assets, because the only way to help them is to invest in their human capital. With physical capital, their parents will rather give them some financial assets. Furthermore, since there is uncertainty in the model, parents would like to accumulate some physical capital to insure against negative shocks, even when the expected return on human capital investments is higher than the return on physical capital. This will take resources away from human capital investments. Finally, a popular explanation both for earnings persistence (see, for instance, Han and Mulligan (2001)), and for college enrollment in the literature is the existence of borrowing constraints. To study the impact of borrowing constraints, it is crucial that the model have financial assets.

Labor Supply

Allowing agents in the model to choose their work hours affects the returns to human capital investments and will be important for the shape of the optimal investment policy as a function of physical capital. In Figure 2.4, I illustrate this point by plotting the optimal investment in human capital for an individual in college. As can be seen from the figure, the optimal investment peaks at some point and starts sloping downwards. This is because, as the agent becomes wealthier, he will enjoy more leisure in the future and the returns to investing in human capital are falling. Some families accumulate a lot of physical capital, but the fact that they enjoy leisure and can control their labor supply will affect the shape of their optimal human capital investments.

Labor supply is also potentially important for college enrollment and for the importance of borrowing constraints with respect to human capital investments; see Garriga and Keightley (2007), and Keane and Wolpin (2001). If a poor person cannot borrow to invest in his child, he may choose to compensate by working a

Figure 2.4: Human Capital Investment for a Model College Student



bit more. Equivalently, if a college student cannot borrow, he may choose to take a part-time job. Having labor choice in the model reduces the importance of borrowing constraints. If a college student has no other way of raising money than borrowing, then borrowing constraints are more likely to be important.

2.6 Calibration

Many of the parameters can be obtained without solving the model. I calibrate 27 model parameters to their empirical counterparts. The remaining 11 parameters are estimated jointly using an exactly identified simulated method of moments approach. Tables 2.2 and 2.3 summarize the parameters calibrated outside and inside the model. The main source of data for the estimated parameters, 6 out of the 11 data moments, is employed males from the PSID (1999-2005). I use employed males because most of the literature on intergenerational earnings persistence is based on the relationship between father and son, and the analysis is carried out on working individuals. In addition there is no unemployment in my model. I use the years 1999-2005 because these are the years for which I also have data on education spending and taxes. Below I describe the data used in the calibration of each parameter as well as the estimation approach.

Preferences

The momentary utility function is the standard CRRA utility function in 2.21, with consumption measured in adult equivalents, $\left(\frac{c}{e(t)}\right)$. I use the so-called ÖECD-modifiedädult equivalence scale and set $e(t) = 1.3$ when there is a child in the household, and $e(t) = 1.0$ when there is not. Consistent with a survey of the empirical literature in Browning, Hansen, and Heckman (1999), I set the coefficient of relative risk aversion, σ, equal to 2, and the inverse of the Frisch elasticity of labor supply, η, equal to 3. The elasticity of substitution between consumption and labor, χ, the time discount factor, δ, and the altruism parameter, α, are among the estimated parameters. The corresponding data moments are average hours worked for employed males 25-64, asset holdings of employed males 50-54, and asset holdings of employed males 25-29 in the PSID (1999-2005). Consistent with the American Time Use Survey (2003), I assume that the day has 15 hours not needed for personal care and normalize hours so that working 15 hours per day is equivalent to a labor supply of 1 in the model.

Risk-Free Interest Rate

Given the partial equilibrium nature of the model, I take the risk-free rate as fixed and calibrate it using data. I set the risk-free rate equal to the average of 3-month T-bill rates minus inflation over the period 1947-2008 based on data from the Federal Reserve Bank of St. Louis.[4]

[4] Series TB3MS and GDPDEF

Table 2.2: Parameters Calibrated Outside of the Model

Parameter	Value	Description	Target
r	0.011	Risk free interest rate (annual)	3-mnth T-bill minus inflation (1947-2008)
σ	2	$u(c,n) = \frac{\left(\frac{c}{e(t)}\right)^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta}$	Browning et al. (1999)
η	3		
e	1.0 or 1.3		OECD-modified equivalence scale.
γ_1^0	0.221	$w = h\gamma_0 e^{\gamma_1^j x + \gamma_2^j x^2 + \gamma_3^j x^3 + u}$	PSID (1968-1997)
γ_2^0	-0.029		
γ_3^0	0.001		
γ_1^1	0.295		
γ_2^1	-0.052		
γ_3^1	0.003		
τ_1	-0.573	$\tau(wn) = \tau_1(wn/AE)^{0.2}$	OECD tax data (2001-2005)
τ_2	1.706	$+\tau_2(wn/AE)^{0.4} + \tau_3(wn/AE)^{0.6}$	
τ_3	-1.096	$+\tau_4(wn/AE)^{0.8}$	
τ_4	0.221		
τ_c	0.084	Consumption tax	Vertex Inc. (2002)
ϖ	0.110	Time spent studying in college	American Time Use Survey
w_c	\$11.14/h	Wage rate in college	CPS (1999-2005)
$I_g(t)$	Primary: \$4522	Public spending per student	UNESCO (1999-2005)
	Secondary: \$5295		
	Tertiary: \$10672		
z	\$24856	College borrowing limit	Lochner and Monge-Narajano (2008)
T	\$13094	Old age Social Security	Social Security Administration (1999-2005)
$\Gamma(t)$	Varies	Death probabilities	NCHS (1991-2001)

Dollar amounts in annual 2005 dollars.

Wages

I calibrate the life-cycle profile of wages exogenously, using the entire PSID from 1968-2005. I regress wages on model potential experience and control for the year of observation. I estimate different experience paths for college graduates and non-college graduates. For the data moments used in the structural estimation, I use only the years 1999-2005. I take the average wage of college graduates, the average wage of high school graduates, and the variance of log wages as the corresponding data moments to estimate the following parameters: the market return to human capital, γ_0, the starting level of human capital, h_0, and the standard deviation of the idiosyncratic earnings shock, σ_u. In the PSID, individuals are observed only every second year from 1999-2005, while they are observed every year until 1997. To get an estimate of the variance of five-year wages in the time period from 1999-2005, I assume that the ratio between the variance of five-year and one-year wages in this time period is the same as it was in the period 1991-1997.

Production of Human Capital/Investment in Education

The corresponding data moments to the parameters of the human capital production function, ψ_0, and ψ_1, are private spending on elementary and college education. In addition I must know public spending per student at each level of education, $I_g(t)$. I follow Restuccia and Urrutia (2004) and think of education spending by local governments in primary and secondary education as private spending, while I take state and federal education spending as public spending. The rationale behind this is that local government spending is financed by local taxes and that parents, when they choose which neighborhood to live in, choose the level of local government education spending. Public schools receive both local and state/federal funding, and schools in wealthier neighborhoods have larger budgets due to more local funding; see also Fernandez and Rogerson (1996), Fernandez and Rogerson (1998). In one way, counting all local government spending as parental investment in education may be

Table 2.3: Parameters Estimated Endogenously

Parameter	Value	Description	Data Moment
γ_0	0.372	$w = h\gamma_0 e^{\gamma_1^j x+\gamma_2^j x^2+\gamma_3^j x^3+u}$	$\bar{w}$, skilled workers
h_0	0.467	Starting level of human capital	$\bar{w}$, unskilled workers
ψ_0	0.300	$h' = h + A\big(hI\big)^{\psi_0}$, before college	$\bar{I}_p$, elementary school
ψ_1	0.881	$h' = h + A\big(hI\big)^{\psi_1}$, in college	$\bar{I}_s$, in college
σ_u	0.398	$u \sim N(0, \sigma_\nu^2)$	Std. dev. of $\log(w)$
θ	0.332	$log(A_c) = \theta \log(A_p) + \nu$	β
σ_v	0.259	$\nu \sim N(0, \sigma_\nu^2)$	College enrollment
Ω	-0.427	$pi(Ah) = 1 - e^{\Omega Ah}$	College failure rate
α	0.302	Parental altruism	$\bar{k}$, age 25-29
χ	171.2	$u(c,n) = \frac{\left(\frac{c}{e(t)}\right)^{1-\sigma}}{1-\sigma} - \chi\frac{n^{1+\eta}}{1+\eta}$	$\bar{n}$,
δ	1.016	Discount factor	$\bar{k}$, age 50-54

a strong assumption that leads to a high level of private education spending relative to public spending. On the other hand, defining education spending as the only form of monetary investment that parents make in human capital is very conservative. To construct the relevant calibration targets for each level of education under the above assumption, I use data on public expenditure per student as fraction of GDP per capita from the UNESCO Institute for Statistics (1999-2005), and data on private expenditure as a fraction of total expendiure, as well as local government's share of public expenditure from the OECD (1999-2005).

Intergenerational Correlation of Ability

The intergenerational correlation of ability, θ, obviously has an impact on the intergenerational persistence of earnings, and I use that as the calibration target for this parameter. I obtain the value of 0.47 for the intergenerational earnings persistence from a meta study by Corak (2006). This also happens to be the same value as found by Grawe (2004), the latest study, using data from the PSID.

Time Spent Studying in College, College Enrolment, Failure, and Borrowing

To calibrate the fixed time cost of attending college, ϖ, I use data from the American Time Use Survey (2004-2008). College students spend, on average, 3.3 hours per day on educational activities on weekdays. I assume that they attend two 13-week semesters per year and that they also study 3.3 hours per day on weekends. While this may be a bit optimistsic, many students also attend summer school. I use college enrollment as the data target for the standard deviation of abilities, σ_ν, and the college failure rate as the target for the parameter Ω, which determines the probability of failing college. I compute these targets from the fraction of males with college degrees in the PSID (1999-2005), and data on college survival probability from the OECD (2000, 2004). I get the college borrowing limit from Lochner and Monge-Narajano (2008). This is the borrowing limit for the federal loan program called Stafford loans, which is what most students are eligible for. There is another loan program called Perkins loans, which can provide further loans to the students with greatest financial need, but in practice, few students make use of this program. Below I study the effect of relaxing the borrowing constraint.

Taxes

The labor income tax schedule is a polynomial function of an individual's earnings relative to the average earnings, AE:

$$\tau(wn) = \tau_1 \left(\frac{wn}{AE}\right)^{0.2} + \tau_2 \left(\frac{wn}{AE}\right)^{0.4} + \tau_3 \left(\frac{wn}{AE}\right)^{0.6} + \tau_4 \left(\frac{wn}{AE}\right)^{0.8} \tag{2.30}$$

As described in more detail in Appendix 2.10.2 I fit this polynomial to labor income tax data from the OECD tax database (2001-2005). These data are constructed by the OECD based on tax laws from different countries. It is well suited for cross-country comparisons; see also Guvenen, Kuruscu, and Ozkan (2009). Coming up with an accurate estimate of consumption taxes in the US is complicated by the fact that there are local county-level taxes in addition to state taxes. Vertex Inc. (a consulting company) estimated that the average consumption tax in the US was 8.4% in 2002. I use that number. For simplicity, I abstract from capital taxes. I do this because different types of capital are taxed differently, and this also differs across countries. Households do, for instance, have about half of their wealth in their homes, wealth that may or may not be taxed. In the US, interest income is taxed as labor income, while dividends and capital gains are subject to capital gains tax. The return on capital is, however, set very conservatively in the calibration. It is set equal to the return on risk-free bonds, which was 1.1% over the past 60 years.

Death Probabilities and Social Security

I assume that all retirees receive the same constant Social Security benefit. I obtain the average benefit for males from the Annual Statistical Supplement to the Social Security Bulletin (1999-2005). I obtain the probability that a retiree will survive to the next period from the National Center for Health Statistics (1991-2001).

Estimation Method

Eleven model parameters are calibrated using an exactly identified simulated method of moments approach. I minimize the squared percentage deviation of simulated model statistics from the eleven data moments in Table 2.4. Let $\Sigma = \{\gamma_0, h_0, \psi_0, \psi_1, \sigma_u, \theta, \sigma_\nu, \Omega, \alpha, \chi, \delta\}$ and let $g(\Sigma) = (g_1(\Sigma), ..., g_{11}(\Sigma))'$ denote the vector where $g_i(\Sigma) = \frac{\bar{m}_i - \hat{m}_i(\Sigma)}{\bar{m}_i}$ is the percentage difference between empirical moments and simulated moments. Then:

$$\hat{\Sigma} = \min_{\Sigma} g(\Sigma)' g(\Sigma) \tag{2.31}$$

Table 2.3 summarizes the estimated parameter values. As can be seen from Table 2.4, I get close to matching all of the moments exactly.[5] Because five of the empirical moments have unknown variance, it is not possible to compute any standard errors

[5]The reason that the match is not exact is that the objective function which I minimize is not continuous. Following Tauchen (1986), I approximate the processes for the shocks to ability and productivity as finite state Markov processes. It turns out that the combination of ability and productivity shock has a non-negligible impact on the college decision. When the parameters are changed, almost everyone with the same combination of ability and productivity shock may change their college decision at the same time. As I increase the number of ability and shock states, the objective function becomes smoother and the estimation fit improves; however, the computational time also increases.

Table 2.4: Estimation Statistics

Statistic	Data	Model
Mean hours worked	0.417	0.417
Mean wages of workers without college degrees	1.000	1.002
Mean wages of workers with college degrees	1.757	1.757
Std. dev. of log(wage)	0.570	0.571
Investment in elementary school	0.038	0.037
Investment in college	0.121	0.120
Fraction of workers enrolling in college	0.588	0.590
Fraction failing college	0.400	0.399
Intergenerational earnings elasticity	0.470	0.470
Mean assets of people ages 25-29	0.092	0.092
Mean assets of people ages 50-54	0.525	0.525

in this exercise. I set the intergenerational persistence of earnings equal to 0.47 based on the meta study by Corak (2006). The moments on investment in early and college education are based on aggregate data from the UNESCO Institute for Statistics.

2.7 Decomposing Earnings Persistence

There are four main model elements that govern earnings persistence: the process by which abilities are inherited, the variance of idiosyncratic productivity shocks, inter vivos transfers from parent to child, and investments in human capital. Human capital investments are made by parents (individuals in college) and the government. Parental/individual investments and inter vivos transfers will be affected by the size of the government investment, returns to human capital investments, taxation, and borrowing constraints. To quantify how the different model elements affect earnings persistence, I shut them down and reintroduce them in the model one by one. We cannot set human capital investments to zero because everyone would get a zero wage, so we will keep government investments constant, relative to average earnings in the economy, and set parental investments to zero, inter vivos transfers to zero, the correlation of abilities to zero, and the variance of the idiosyncratic shock to zero.

Table 2.5: Earnings Persistence with Different Model Elements Present

Earnings persistence	Correlated abilities	Idiosyncratic shocks	Private investments	Inter vivos transfers
0.002				
0.314	X			
0.000		X		
0.256			X	
-0.017				X
0.180	X	X		
0.510	X		X	
0.304	X			X
0.222		X	X	
-0.030		X		X
0.249			X	X
0.428	X	X	X	
0.180	X	X		X
0.544	X		X	X
0.215		X	X	X
0.470	X	X	X	X

Then we will start reintroducing these elements in the model; see Table 2.5. I also keep the variance of the shocks to the log of abilities, σ_{ν}, constant in this exercise.

The main conclusion from Table 2.5 is that both parental/individual investments and correlation of abilities make significant positive contributions to intergenerational earnings persistence. The link between earnings persistence and private human capital investments comes from the fact that the optimal parental/individual human capital investment policy functions are usually upward sloping in financial resources; the exception is for very wealthy individuals.[6] The intergenerational earnings elasticity falls to approximately zero when all four model elements are left out. The reason it is not exactly zero is that I approximate the continuous AR(1)-process for abilities by finite state Markov processes, as proposed by Tauchen (1986), when simulating the model.[7] This leads to slight inaccuracies, which become smaller as one increases the number of states. Introducing correlated abilities leads to an intergenerational

[6]Figure 2.4 displays an example investment policy function for a model college student. In the simulated model, almost all individuals would be on the upward sloping part of the graph.

[7]See Appendix 2.10.4 for details on computation.

earnings elasticity of 0.314. One might have expected it to be equal to the correlation of the log of abilities, 0.332, but there is a nonlinear relationship between ability and earnings. Having parental/individual investments alone in the model gives an earnings elasticity of 0.256.

When all model elements are present, the effect of leaving out inter vivos transfers is to reduce the intergenerational earnings elasticity from 0.47 to 0.428. Inter vivos transfers affect intergenerational earnings persistence in three ways. The absence of transfers limits the ability of children with rich parents to invest in college education, and this would negatively impact earnings persistence. Another effect is that if there are no inter vivos transfers, the only way a wealthy parent with a low ability child can help the child is to invest more in human capital. This will reduce the dispersion of investments and reduce earnings persistence. However, introducing inter vivos transfers alone in the model yields a negative intergenerational earnings elasticity. This is because of the negative income effect on labor supply. Children of high earners get larger transfers and work less, which causes a negative correlation between the earnings of parents and children.

With all elements present in the model, removing the idiosyncratic shocks causes the intergenerational earnings elasticity to increase from 0.47 to 0.544. The effect of introducing idiosyncratic wage shocks in the model is generally to reduce earnings persistence. This is because the shocks are random and not correlated across generations, like abilities and investments in human capital. However, there is an exception when only inter vivos transfers are present in the model. Introducing shocks that are log-normally distributed around zero has the effect of making the society richer and causing parents to give larger transfers. In the case with only inter vivos transfers present, larger transfers lead to a stronger negative correlation between the earnings of parents and children.

The case when all model elements are present except private investments in human capital is particularly interesting. The intergenerational earnings elasticity is then 0.184, or about the same as in Scandinavian countries. In the context of the present model, we would need policy reforms that completely eliminate all private human capital investments to reach the same earnings persistence as in Scandinavia. This may imply that factors other than just policy impact cross-country differences in earnings persistence. Some of these factors may be captured by the correlation of abilities/family endowments. However, one shortcoming of the present model is that there is no explicit modeling of the supply of educational service. It may be realistic to assume that the human capital production function would change as the demand for education changes, and that this would impact the results.

2.8 Policy Experiments

In Section 2.2, I documented a strong cross-country correlation between intergenerational earnings persistence and tax progressivity and intergenerational earnings persistence and public spending on tertiary education. This motivates the study, in this section, of the contributions of differences in country policies to differences in earnings persistence. I also study the impact of relaxing and tightening the borrowing constraints. When I perform the policy experiments, I keep public education expenditure and taxes as functions of average earnings in the economy. In this way if the society becomes richer or poorer because of a policy change, education expenditure and taxes will adjust accordingly. Since there is no public good in the model, I do not keep a balanced government budget and excess tax revenues are assumed to finance bureaucracy.[8]

[8] In Appendix 2.10.6, I relax this assumption in the sense that when I perform the policy experiments I redistribute the net change in tax revenues relative to the benchmark model evenly to all households. Redistribution does not have a large impact on the results with respect to intergenerational earnings persistence. It does, however, have a significant impact on labor supply and therefore on average earnings.

Table 2.6: Policy Experiments

Statistic	Bench-mark	Danish taxes	Danish educ. subsidies	Danish subsidies + taxes	Tax w. US level, Dan. prg.
Average hours worked	0.417	0.446	0.408	0.440	0.413
Std. dev. of log wages	0.571	0.499	0.632	0.550	0.520
Fraction enrolling in college	0.590	0.511	0.890	0.832	0.507
Intergen. earnings elasticity	**0.470**	**0.350**	**0.434**	**0.351**	**0.423**
Average human capital inv. age 5-9	$3998	$868	$5710	$1547	$2287
Average human capital inv. age 10-14	$5127	$1310	$7165	$2144	$3002
Average human capital inv. age 14-19	$5752	$1492	$5055	$864	$3337
Average human capital inv. in college	$14692	$1780	$13513	$1881	$6070
Average human capital inv. (all ages)	$5016	$1041	$6200	$1288	$2596
Average gift from parent to child	$78714	$10333	$128269	$21193	$26581
$\frac{\textit{tax per worker} - \textit{educ. expenditure}}{\textit{benchmark average earnings}}$	0.343	0.546	0.379	0.599	0.318
Average Earnings	$61111	$53489	$71474	$60883	$53539
$\frac{\bar{I}_{private}}{\bar{I}_{total}}$	0.525	0.215	0.417	0.156	0.403
$Stdev\left(\frac{I_{private}-\bar{I}_{private}}{\bar{I}_{private}}\right)$	2.240	2.033	2.250	2.234	2.033
$Corr\big(college, \log\left(y_{parent}\right)\big)$	0.1939	0.1367	0.1572	0.1412	0.1705

Column 2 displays the results when introducing a Danish tax system into the model. Column 3 shows the resultswhen introducing Danish public education expenditure policies. Column 4 shows the results when introducing Danish taxes and education spending at the same time. Column 5 displays the results from introducing a tax system with the US average tax rate but with Danish progressivity. The dollar amounts are in annual 2005 dollars.

The Impact of Taxation and Public Education Expenditure

Out of the countries in Table 2.1, Denmark has the highest and most progressive taxes and they spend the most on tertiary education (see Figures 2.1 and 2.2). Denmark is also the country with the lowest earnings persistence. I therefore study how earnings persistence in my model economy, which is calibrated to US data, changes as I introduce Danish policies. I think of the change in earnings persistence due to the introduction of Danish policies as being in the upper range of how much of cross-country differences can be explained by policies, since the effect of introducing policies from any other country will be smaller. Table 2.6 displays how selected model statistics change in the policy experiments.

As can be seen from row 4 of Table 2.6, the greatest reduction in intergenerational earnings persistence comes from introducing a Danish tax system in the US. Introducing a Danish tax system in the US reduces the intergenerational earnings elasticity by 12 percentage points, to 0.35, or about 40% of the difference between the US and the Scandinavian countries; see Table 2.1. The higher and more progressive taxes greatly reduce the incentives for private investment in education, and this leads to lower earnings persistence. We observe that higher and more progressive taxes also lead to lower college enrollment and less cross-sectional inequality. A higher tax level has the effect of reducing the levels of private investments and private investments' share of total investments falls. Thus for a given percentage increase in private investments, the percentage increase in total investments is smaller. This weakens the relationship between the parents financial resources and the childs earnings and leads to lower earnings persistence. The effect of more progressive taxes is to disproportionally reduce the incentives for human capital investments for wealthy and/or high-ability individuals. This compresses the distribution of private human capital investments and leads to lower intergenerational earnings persistence.

To investigate the quantitative impact of tax progressivity versus tax levels on earnings persistence, I impose a tax system with the same average labor income tax rate as in the US but with the same progressivity as in Denmark, as measured by 2.2.[9] The right column of Table 2.6 displays the results from this experiment. The intergenerational persistence of earnings is now 0.423. We can interpret this as if about 40% of the difference in earnings persistence between the benchmark economy and the economy with a Danish tax system is due to increased tax progressivity and about 60% is due to the increased tax level. We observe that the percentage variation in private human capital investments is the same in the experiment with Danish taxes and in the experiment with US tax levels and Danish tax progressivity. The difference in earnings persistence between the two experiments is due to the level of private investments relative to public investments.

Introducing a Danish public education expenditure scheme lowers the intergen-

[9]See Appendix 2.10.5 for details.

Table 2.7: Public Education Expenditure Per Student as % of GDP Per Capita

Education level	US	Denmark
Primary	11.1	9.6
Secondary	13.0	19.5
Tertiary	26.3	0.671

Based on data from UNESCO (1999-2005) and OECD (1999-2005)

erational earnings elasticity by 3.6 percentage points, to 0.434. This is explained by increased public expenditure reducing the incentives for parental/individual expenditure on education in relative terms. Total private education expenditure actually increases in absolute terms but this is because the society has became richer, and average earnings have increased by about 17%. Private education expenditure's share of total education expenditure does, however, fall from 53% to 42%.

Secondary and tertiary private education spending decreases with Danish public expenditure, while private spending on elementary education increases. This is because the Danish public investments are very large for tertiary and secondary education (see Table 2.7) and at about the same level as in the US for elementary education. Therefore, parents move their investments from late to early education. Not surprisingly, greatly increasing public expenditure in tertiary education increases college enrollment. The correlation between college completion and parental earnings decreases.

Introducing both Danish public education expenditure and taxation at the same time actually increases earnings persistence by 0.01 percentage point, to 0.351, relative to the case with just a Danish tax. There are several competing effects here. On the one hand, private investment in education has become smaller relative to public investment and this should lead to lower earnings persistence, all else being equal. On the other hand, we observe that there has been an increase in the percentage variation in private investments in education. When public education spending increases, more people go to college and the private investment pattern changes.

Another effect pointing in the direction of higher earnings persistence is that the society has become richer, and therefore, people invest more in human capital, in addition to the government investing more. When total human capital investments increase, human capital becomes more important for the log of earnings relative to the idiosyncratic shocks.

It is interesting to note that in the experiment with Danish taxes and public education expenditure, average earnings are approximately the same as in the benchmark economy, as public human capital investments have taken on the role of private investments. The average gift from parent to child does, however, drop from $78,714 in the benchmark model to $21,193 in the model with Danish taxes and public education expenditure. A large part of the incentives to give the child a transfer lies in the increased earnings from investment in college. When the incentives for investing in college are reduced, the transfers from parents to children are also reduced.

We conclude that tax and education spending policies significantly impact earnings persistence. Taxation is quantitatively most important. Whether having low earnings persistence in the society is good or bad is naturally a different question. More high/progressive taxation as a stand-alone policy reduces human capital accumulation and leads to a poorer society, while increased public education expenditure has the opposite effect. Higher taxes may, however, be needed to finance education expenditure. When I introduced Danish education spending, the net change in tax revenues was actually positive. However, the society became richer, and the government only increased its spending on education. I did, for instance, let the Social Security payments stay at their old level. Yet another issue is, of course, general equilibrium effects. I will leave the study of optimal policies to future research.

The Impact of Borrowing Constraints

The importance of borrowing constraints both for intergenerational earnings persistence and college enrollment has received much attention in the literature. In this section, I study the effect of tightening and relaxing the college borrowing constraint, as well as relaxing the assumption that borrowing is allowed only if one attends college. Finally, I allow for negative inter vivos transfers; that is, the parents can pass on debt to their children. Table 2.8 displays the results from these experiments.

As can be seen from Table 2.8, relatively large changes to the borrowing constraint have relatively little impact on intergenerational earnings persistence. Completely eliminating borrowing for college reduces college enrollment by 18% and college completion by 14%; however, it is those who have the least to gain from college who drop out. Average earnings in the economy fall only by 1.7%, and intergenerational earnings persistence rises only by 0.4 percentage point. Letting people borrow more has little impact both on earnings persistence and on college enrollment. Human capital investments in college increase slightly and average earnings increase slightly when more borrowing is allowed. The obvious reason that relaxing the borrowing constraint has little effect on earnings persistence is simply that most individuals are not borrowing constrained from investing in human capital. Most individuals begin to accumulate positive asset holdings at a young age to save for retirement and for their children's college education. Thus, there are no binding constraints stopping them from investing more in human capital. It does, however, turn out that in the benchmark economy, the college borrowing constraint binds for about 30% of those who complete college. However, because it is also possible to work in college, tightening the borrowing constraint will not necessarily lead to large changes in human capital investments. Individuals in college can compensate by working more.

Columns 4 and 5 of Table 2.8 display the results from experiments in which everyone, not just those who attend college, can borrow up to twice the original college borrowing constraint in all time periods prior to retirement. In column 5, parents are also allowed to give their children negative inter vivos transfers. Allowing for borrowing against children's earnings leads to a very slight increase in intergenerational

Table 2.8: The Impact of Borrowing Constraints

Statistic	Bench-mark	0X BC	2X BC	2X BC w. o. college	Negative transfers
Fraction enrolling in college	0.590	0.483	0.619	0.611	0.418
Fraction completing college	0.355	0.306	0.371	0.368	0.262
Intergen. earnings elasticity	**0.470**	**0.474**	**0.466**	**0.468**	**0.472**
Average human capital inv. in college	$14692	$14914	$16874	$16715	$17819
Average gift from parent to child	$78714	$77168	$86709	$84367	$31390
Average Earnings	$61111	$60068	$63143	$62916	$60962

Columns 2 and 3 display the results when setting the college borrowing constraint to 0 and doubling the college borrowing constraint, to $49,712. The college borrowing constraint is linearly decreasing between college and retirement. Column 4 displays the results when people that do not attend college are also allowed to borrow up to twice the original college borrowing constraint, or $49,712, in all time periods before retirement. Column 5 displays the results when the borrowing constraint is 2 times the original college borrowing constraint in all time periods prior to retirement and parents are allowed to pass on debt to their children.

earnings elasticity, from 0.468 to 0.472, relative to the experiment in column 4 with identical borrowing constraints for parents but only positive transfers to children allowed. Allowing parents to pass on debt to their children is bad for children with poor parents. Many parents choose to borrow toward their children's earnings. The loan is not used for human capital investments but is rather added to the parents' retirement savings. This leads to a society in which the average holdings of capital are lower and the average transfer from parent to child falls by about $53,000 relative to the experiment in column 4 with identical borrowing constraints for parents but only positive transfers to children allowed. There is a significant drop in college enrollment; however, average earnings decrease only slightly. It is those who would get marginal gains from college who drop out, and those who have large gains from college are able to invest almost the same amount as before. The average human capital investment in college actually increases, but this is because college completion is lower and those who drop out were investing little.

2.9 Conclusion

In this paper I develop an intergenerational life-cycle model of human capital accumulation and earnings, which features taxation, public education expenditure, borrowing constraints, partially inheritable abilities, inter vivos transfers from parent to child, and idiosyncratic wage shocks as determinants of intergenerational earnings persistence. I calibrate the model to US data and use it to quantify how earnings persistence in the US changes as I introduce policies from Denmark. I find that taxation and public education expenditure have a significant impact on earnings persistence and are likely contributors to the cross-country patterns that empirical researchers have found. Taxation is quantitatively most important. As I introduce a Danish tax system in the US, intergenerational earnings elasticity falls from 0.47 to 0.35, or about 40% of the difference between the US and the Scandinavian countries, which have the lowest earnings persistence among the countries in my sample. I also find that borrowing constraints have a very limited impact on earnings persistence.

Future research in this area may include the study of optimal education expenditure and tax policies within an intergenerational general equilibrium framework. An extension is also to explicitly model the supply of educational services. In this paper I have assumed that the technology for human capital production stays the same as the demand for education changes.

2.10 Appendix

2.10.1 Discussion of Difficulties with Comparing Different Studies of Earnings Persistence

There are some difficulties related to comparing different studies of intergenerational earnings persistence. Solon (1992) and Blanden (2009) provide more in-depth discussions of some of the methodological issues. One problem in the estimation of 2.1 is the measure of earnings. Ideally the measure of earnings used in 2.1 should be permanent or lifetime earnings. Since this measure is rarely available, the econometrician will either use earnings observed in a single year or preferably take the average of several years of earnings. This will generally be an inaccurate measure of permanent earnings. It is easy to show that an inaccurate measure of the father's earnings in 2.1 will lead the estimate of β to be biased downward. A first step toward reducing this measurement error is controlling for age in 2.1, and this is done in pretty much every study. However, if more years of earnings are averaged, the measurement error is reduced, and this is a source of discrepancies between different studies. Another obvious source of discrepancies between studies is the quality of the data. If the sample is too homogeneous, i.e., the variance of earnings is too small, as is typical for unrepresentative data samples, the problem with measurement error is compounded; see Solon (1992).

A possible solution to the problem with measurement error in the father's earnings is the use of instrumental variables. The instruments must be uncorrelated with the measurement error and, in addition, uncorrelated to the son's earnings. The problem with the instrumental variable approach is that most variables related to father's earnings may also have an independent impact on the son's earnings. Solon (1992) shows that in this case, the estimate of β will be biased upward. The instrumental variables approach is nonetheless becoming more popular in the literature.

Finally, the age at which father's and son's earnings are observed may have a substantial impact on the estimates of β; see Haider and Solon (2006) and Grawe (2003). Controlling for age in the regression does not solve this problem, since high and low earners have different life-cycle earnings profiles. Often the earnings of young sons are regressed on the earnings of old fathers, which is found to cause a downward bias in the estimate of β. Haider and Solon (2006) find that the years around 40 will be the best proxies for lifetime earnings.

Corak (2006) provides a cross-country meta study of intergenerational earnings persistence that tries to take into account how many years of the father's earnings were used as a measure for permanent earnings, whether an IV approach was used, and the age of the father at the time of observation. Table 2.1 displays the results from this study supplemented with earnings persistence from Italy and Spain, which I take from Piraino (2007) and Pla (2009). I adjust the number for Italy using a formula provided in Corak (2006). I cannot do the same for Spain, because I do not know the average age of the fathers in that study. Given the many problems with comparing different studies of intergenerational earnings persistence, it is clear that Table 2.1 should be interpreted as a stylized fact.

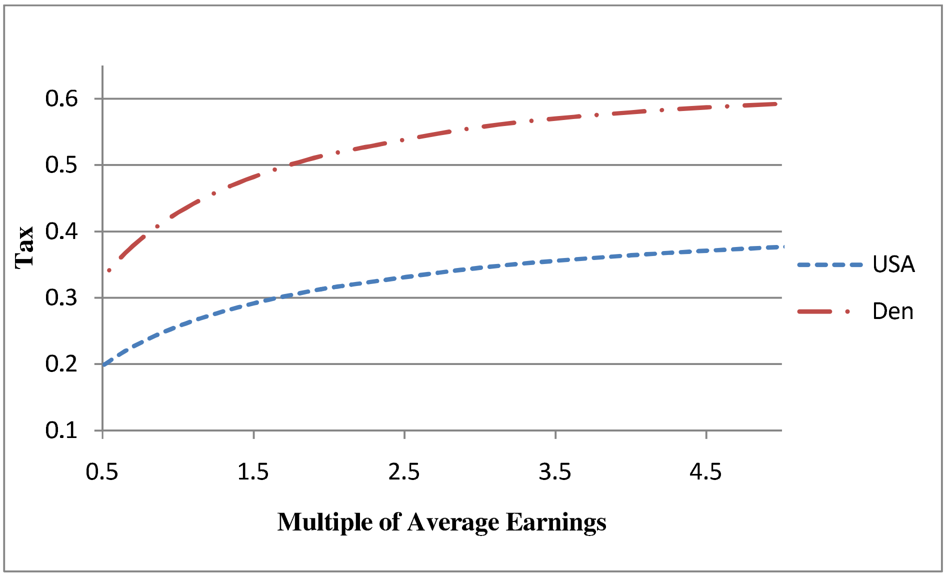
2.10.2 Fitting Tax Functions Based on Data from the OECD

For every country in Table 2.1, I fit the polynomial in 2.30. I use this functional form because it generally gives me a very good fit, R^2 above 99.9%, and because I get functions that are strictly increasing and well behaved on a relatively wide range of labor income. I use labor income tax data from the OECD tax-benefit calculator[10] and the OECD tax database[11]. These data are constructed by the OECD based on tax laws from different countries.

The OECD tax-benefit calculator gives the gross- and net (after taxes and ben-

[10] Available at: `www.oecd.org/document/18/0,3343,en_2649_34637_39717906_1_1_1_1,00.html`.
[11] Available at: `www.oecd.org/document/60/0,3343,en_2649_34533_1942460_1_1_1_1,00&&en-USS_01DBC.html`.

Figure 2.5: Labor Income Tax Functions for the US and Denmark



efits) labor income at every percentage of average labor income on a range between 50% and 200% of average labor income, by year and family type starting in 2001. I use the data at every fifth percentage point for single individuals without children and take an average of the years 2001-2005. The OECD tax catabase provides the top marginal tax rate in each country and the starting point for this tax rate. To get the tax at earnings above 200% of average labor income, I use this information and compute the tax at every multiple of 0.5 times average earnings between 2.5 and 15 times average earnings. For most countries the top marginal tax rate kicks in before 200% of average labor income, but in the US, for instance, the top marginal tax rate starts at about 9 times average earnings. I then assume that the marginal tax rate increases linearly between 2 times average earnings and the point at which the top marginal tax rate becomes effective.

Since I only have tax data starting at 50% of average earnings, I add a random positive point of close to zero tax for close to zero earnings, to get my tax functions well behaved for very small earnings. This, however, has almost no impact on the fit with the real data points. The alternative would have have been to require all

Table 2.9: Country Tax Functions

Country	τ_1	τ_2	τ_3	τ_4	R^2
Denmark	-1.242825	3.603493	-2.456365	0.5239973	0.9997
Norway	-0.6488133	1.818972	-1.023706	0.1670745	0.9999
Finland	-0.71829	1.895892	-1.004558	0.1465101	0.9996
Canada	-0.3056732	0.8059581	-0.2546371	-0.0145851	0.9997
Sweden	-0.6629891	1.966373	-1.183786	0.2152142	0.9997
Germany	-1.329006	4.017692	-2.947534	0.6809511	0.9998
Spain	-0.2001187	0.3728243	0.1407691	-0.1200151	0.9994
France	-0.5460613	1.651868	-1.011427	0.1903222	0.9998
Italy	-0.7060691	1.782236	-0.9431628	0.137171	0.9989
USA	-0.5730303	1.705866	-1.096482	0.2207298	0.9998
UK	-0.5907906	1.778369	-1.163281	0.2362276	0.9998

people to work enough to make a certain amount of income. I fit the tax functions by running OLS regressions. Table 2.9 displays the country tax functions, while Figure 2.5 plots the tax functions for the US and Denmark.

2.10.3 Proof of Propositions 2.3.1 and 2.3.1

Proposition 2.3.1

Since $\log(y_t)$ is a monotonic transformation of y_t, it will be sufficient to take the derivatives of the top part of 2.11 with respect to y_t. We have:

$$\frac{\partial \log(y_{t+1})}{\partial y_t} = \frac{\psi(1-\tau)}{y_t(1-\tau)+I_g} > 0 \tag{2.32}$$

$$\frac{\partial^2 \log(y_{t+1})}{\partial y_t \partial \tau} = \frac{-\psi I_g}{\left(y_t(1-\tau)+I_g\right)^2} < 0 \tag{2.33}$$

$$\frac{\partial^2 \log(y_{t+1})}{\partial y_t \partial I_g} = \frac{-\psi(1-\tau)}{\left(y_t(1-\tau)+I_g\right)^2} < 0 \tag{2.34}$$

$$\frac{\partial^2 \log(y_{t+1})}{\partial y_t \partial \psi} = \frac{y_t(1-\tau)^2+I_g(1-\tau)}{\left(y_t(1-\tau)+I_g\right)^2} > 0 \tag{2.35}$$

■

Proposition 2.3.2

Differentiating 2.16, we obtain:

$$\frac{\partial \beta}{\partial \tau} = \frac{-\psi(1-\theta^2)\tilde{I}_g}{\left((1+\psi\theta)(1-\tau)+\tilde{I}_g\right)^2} < 0 \tag{2.36}$$

$$\frac{\partial \beta}{\partial \tilde{I}_g} = \frac{-\psi(1-\theta^2)(1-\tau)}{\left((1+\psi\theta)(1-\tau)+\tilde{I}_g\right)^2} < 0 \tag{2.37}$$

$$\frac{\partial \beta}{\partial \psi} = \frac{(1-\theta^2)(1-\tau)^2+(1-\psi\theta-\theta^2)(1-\tau)\tilde{I}_g}{\left((1+\psi\theta)(1-\tau)+\tilde{I}_g\right)^2} > 0 \tag{2.38}$$

$$\frac{\partial \beta}{\partial \theta} = \frac{(1-\psi^2)(1-\tau)^2+2(1-\tau)\tilde{I}_g+\tilde{I}_g^2}{\left((1+\psi\theta)(1-\tau)+\tilde{I}_g\right)^2} > 0 \tag{2.39}$$

■

2.10.4 Computational Details

Computation of Optimal Policies

I put boundaries on the capital and human capital space and pick a grid in each dimension. I pick 40 grid points in $K = [k^{min}, k^{max}]$ and 16 grid points in $H = [h^{min}, h^{max}]$. The grid points for capital are taken to be the scaled zeros of a 40th order Chebyshev polynomial ,while the grid points for human capital are taken to be the scaled zeros of a 16th order Chebyshev polynomial. Following the method outlined by Tauchen (1986), I approximate the processes for the idiosyncratic productivity shock, u, and ability, A, as finite state Markov processes. I use 7 equally spaced states for u in $U = [-2\sigma_u, 2\sigma_u]$, and 13 equally spaced states for A in $\bar{A} = [-3\sigma_A, 3\sigma_A]$. Let $J = \{0, 1\}$ be the state space for whether an individual is college educated. The maximum size of the state space occurs in periods 5-7, or ages 40-50, when there are 6 state variables apart from time. The state space is then $J \times K \times H \times H \times \bar{A} \times U$, or 1,863,680 grid points. I compute the household's optimal policies for each grid point in each time period by iterating backwards. I start from age 100, the last period of life. In that period, the next period's value function is 0, and the optimal policy is to consume as much as possible. Knowing the value function at age 100, I can compute optimal policies and value functions for age 95, and so on. Reaching age 50, when the child leaves home, I need to know both the parent's value function at age 55 and the child's value function at age 20 to compute the optimal policies. The first time around, I use an educated guess for the child's value function at age 20. When I reach age 20, I get a new $V(age = 20, \cdot)$ and start over again from age 50. I continue this iteration until V converges.

To solve for the optimal policies in each time period, I use the routine called LCONF from the IMSL Fortran library. It is based on M. Powell's method for solving linearly constrained optimization problems; see IMSL documentation for details. To interpolate the value function outside of the grid, I use Chebyshev collocation; see Judd (1998), Heer and Maussner (2004). When there is a child in the household and the parent is investing in the child's human capital, the next period's value function must be interpolated in the $K \times H$-space. The value function is then represented as a polynomial with 40 X 16 = 640 coefficients. At one point in time, when the agent chooses whether or not to attend college, I am taking the max of two value functions. When these two value functions overlap, the value function considered by the parent, before the child makes the college decision, will generally not be concave. However, what the parent needs to consider is the expectation of the value function over the idiosyncratic shock. It turns out that the expectation of the value function is concave, although there is no theoretical guarantee for it. To be absolutely sure that I am finding a global max, I am multi starting the solver from points that are far apart.

Simulation

Knowing today's state, the policy functions, and drawing shocks, u and ν, I can find the next period's state. I make 200,000 draws from a random initial distribution of 20 year olds and run the simulation for 200 generations (enough to reach a stationary distribution). In the simulation, the policy functions must be interpolated on the $K \times H \times H$-space as both the child's and the parent's human capital may be outside of the grid. I use linear interpolation.

Hardware and Software

I use Intel Fortran, version 11.1 and a computer with a 2.93 GHz Core-i7 processor. To speed up the computation, I use OpenMP to parallelize the code on the 8 threads.

2.10.5 Introducing a Tax System with US Level and Danish Progressivity

We want to introduce a new tax function, $\tilde{\tau}(y)$, which has the same average tax rate as in the US but where progressivity, as defined in 2.2, is the same as the tax system in Denmark, $\tau_D(y)$. We must have:

$$1 - \frac{1-\tilde{\tau}(y_2)}{1-\tilde{\tau}(y_1)} = 1 - \frac{1-\tau_D(y_2)}{1-\tau_D(y_1)} \Rightarrow \frac{1-\tilde{\tau}(y_2)}{1-\tau_D(y_2)} = \frac{1-\tilde{\tau}(y_1)}{1-\tau_D(y_1)} \tag{2.40}$$

for all levels of y_1 and y_2. Letting the fraction $\frac{1-\tilde{\tau}(y)}{1-\tau_D(y)}$ be equal to a constant, Λ, for all levels of y, we can obtain a new tax system with the desired properties as follows:

$$1 - \tilde{\tau}(y) = \Lambda\big(1 - \tau_D(y)\big) \Rightarrow \tilde{\tau}(y) = 1 - \Lambda + \Lambda\tau_D(y) \tag{2.41}$$

We must solve for Λ in the context of the model to obtain the same average tax level as in the US.

2.10.6 Policy Experiments With Redistribution of Net Changes in Tax Revenues

Below I reproduce the first 4 columns of Table 6 but this time I redistribute the net change in tax revenues relative to the benchmark model evenly to all households.

Table 2.10: Policy Experiments with Redistribution of Δ Tax Revenue

Statistic	Bench-mark	Danish taxes	Danish educ. subsidies	Danish subsidies + taxes
Average hours worked	0.417	0.391	0.403	0.383
Std. dev. of log wages	0.571	0.491	0.628	0.533
Fraction enrolling in college	0.590	0.418	0.889	0.739
Intergen. earnings elasticity	**0.470**	**0.347**	**0.437**	**0.357**
Average human capital inv. age 5-9	\$3998	\$631	\$5501	\$1072
Average human capital inv. age 10-14	\$5127	\$957	\$6900	\$1493
Average human capital inv. age 14-19	\$5752	\$1042	\$4837	\$533
Average human capital inv. in college	\$14692	\$1570	\$12754	\$987
Average human capital inv. (all ages)	\$5016	\$750	\$5920	\$869
Average gift from parent to child	\$78714	\$4409	\$118617	\$8052
$\frac{\textit{tax per worker} - \textit{educ. expenditure}}{\textit{benchmark average earnings}}$	0.343	0.507	0.371	0.543
Average Earnings	\$61111	\$45265	\$69554	\$49448
$\frac{\bar{I}_{private}}{\bar{I}_{total}}$	0.525	0.193	0.413	0.138
$Stdev\left(\frac{I_{private}-\bar{I}_{private}}{\bar{I}_{private}}\right)$	2.240	2.118	2.263	2.202
$Corr\left(college, \log\left(y_{parent}\right)\right)$	0.1939	0.153	0.156	0.155

Column 2 displays the results when introducing a Danish tax system into the model. Column 3 shows the results when introducing Danish public education expenditure policies. Column 4 shows the results when introducing Danish taxes and education spending at the same time. The dollar amounts are in annual 2005 dollars.

Redistribution does not have a large impact on the results with respect to intergenerational earnings persistence. It does, however, greatly reduce labor supply and average earnings. The reduction in labor supply is the reason for why redistribution does not have a larger impact on earnings persistence. On one hand poorer households get more financial resources that could be invested in education but on the other hand poorer households tend to reduce their labor supply the most in response to the redistribution. this reduces their incentives to invest in education.

Chapter 3

Marriage Stability, Taxation and Aggregate Labor Supply in the US vs. Europe

3.1 Introduction

It is a well-known empirical finding that aggregate labor supply is higher in the United States than in Europe and that there is also substantial variation among European countries, see for instance Prescott (2004) and Rogerson (2006). Rogerson (2006) notes that these differences are an order of magnitude larger than the fluctuations at business cycle frequencies in post-WWII US data, and thus deserve serious attention. Are the differences in hours worked due to public policies or are they due to other fundamental differences between societies?

In this paper, we start by using micro level data to document the contribution of various demographic groups to the aggregate differences between the US and 8 European countries. We find that among the demographic groups that we consider, the largest contribution comes from women – in most European countries, women work substantially less than in the United States, while the difference in hours worked between European and American men is smaller, and in some cases practically non-existent. This is especially true for married women, but also holds for single women, and for women with and without children. We also document a negative cross-country correlation between tax level and labor supply, and a positive correlation between divorce rates and labor supply across countries and across time. Divorce rates are, however, in particular correlated with female labor supply. Motivated by these observations, we consider the following two potential driving forces for cross-country differences in labor supply: 1) cross-country differences in taxation; 2) cross-country differences in marriage stability.

To quantitatively assess the impact of taxes and marriage stability on labor supply we develop a life-cycle, overlapping-generations model with heterogeneous agents, marriage, and divorce. There are three types of households; single males, single females and married households. Divorces and marriages occur stochastically. The main channel through which individual divorce and singlehood rates impact labor supply is by reducing the implicit insurance of marriage, and thereby providing incentives for individuals to invest in experience accumulation. We calibrate our model to US data and study how labor supply in the US changes as we introduce divorce and marriage probabilities and tax systems from other countries. We find that the effect of making marriages more stable is a reduction in labor supply. This effect is particularly strong for female labor supply, because the woman is usually the lower earner in a married couple. Changing the US probabilities of marriage and divorce to their European equivalents accounts on average for 22% of the difference in hours worked between the US and 11 European countries. When we introduce European taxes and redistribute the increase in taxes evenly to all households, we can account for 19% of the difference in hours worked between the US and the average of the European countries. If the increased tax revenues from European taxation is not redistributed the average effect is an increase in labor supply. When using both the divorce and marriage probabilities and tax systems from the European countries, the model can on average account for 28% of the difference in hour worked between the US and Europe.

Cross-Country Differences in Labor Supply: Possible Explanations and Previous Literature

The economic literature has proposed several potential explanations for the observed cross-country differences in aggregate labor supply. Taxes have been suggested as a major contributor to the differences in labor supply by Prescott (2004) and Rogerson (2006), who used an infinite horizon, representative agent model to evaluate the impact of differences in average tax rates. We extend this argument, and use a life-cycle model with heterogeneous agents, who accumulate labor market experience, and reside in one- and two person households. This allows us to capture several dimensions of tax systems that cannot be captured in a representative agent model. We fit nonlinear income tax schedules that can capture the impact of both tax levels and tax progressivity on aggregate labor supply, as well as one the labor supply of various demographic groups. We are also able to capture the impact of joint versus separate taxation of married couples. As pointed out by Guner, Kaygusuz, and Ventura (2008), separate taxation of married couples leads to a lower marginal tax rate on the secondary earner in a couple, and therefore encourages female labor supply. In Section 3.7, we find this to be an important effect in our model.

To the best of our knowledge, the role of differences in marriage stability in accounting for cross-country differences in labor supply has not been analyzed in the literature. Yet, our finding in Section 3.2 below that the biggest contribution to the cross-cross country differences in average hours worked comes from women, and in particular from prime-aged married women, suggests that one may need to pay attention to the cross-country differences in family dynamics. There is ample anecdotal evidence that compared to the US, marriages are more stable in Europe, especially in “catholic” European countries such as Italy, Spain, Ireland, and Greece where divorces have traditionally carried more social stigma with them. Our hypothesis is that more stable marriages provide implicit income and consumption insurance to the spouse who is not the main income earner in the family (the role that for various reasons is traditionally played by the wife), thus giving her/him less incentive to accumulate market experience.

One may argue that divorce and marriage decisions are also affected by economic conditions and that therefore we should make them endogenous choices. However, then we would need a systematic cross-country pattern in economic conditions that could account for both the pattern in divorce rates and in labor supply at the same time. This type of condition could be for instance cross-country differences in the gender wage gap, in the female return to labor market experience, or in the cost of having children. These explanations have been proposed in the literature trying to explain changes in female labor supply over time, see for instance Olivetti (2006) and Attanasio, Low, and Sanchez-Marcos (2008). However, we have not been able to document a cross-country pattern in the gender wage gap or in the female return to labor market experience that would help us explain the observed patterns in aggregate labor supply and divorce rates. In Section 3.2, we argue that children are unlikely to be an important explanation, as the cross country differences in labor supply is not more pronounced for women with children. We therefore choose to study the economic implications of exogenous differences in marriage and divorce rates caused by ”cultural” and/or legal factors. Crouch and Beaulieu (2006) documents a correlation between different types of divorce laws and divorce rates in the US and 22 European countries. Generally divorce laws are stricter in Europe. For instance, they require a longer waiting period before a divorce can be obtained. Johnson and Skinner (1986) provides empirical support to our theory about the impact of exogenous changes in the probability of divorces on female labor supply. They estimate a simultaneous model of future divorce probability and current labor supply using US data, and conclude that their results support the hypothesis that higher divorce probabilities increase labor supply, while the reverse effect appears insignificant. Stevenson (2008) documents that the US states who adopted unilateral divorce in the 1970s experienced a spike in female labor supply compared to states who did not.

One pronounced difference between the US labor market and those in many European countries is the more rigid regulations and laws in Europe, often referred to in the literature as labor market frictions. These are possible contributors to the higher observed unemployment rates and lower labor force participation rates in Europe. Unions are also much more common in Europe. Alesina, Glaeser, and Sacerdote (2005) argues that regulations and unionization are more like explanations than taxes. We believe that they could also be contributing factors and that we should not hope for taxes and divorce rates to explain all of the cross country variation in labor supply. Out of all the above proposed explanations, however, differences in divorce rates stand out as a promising candidate for explaining why cross country differences is mainly driven by female labor supply.

The remainder of the paper is organized as follows: In Section 3.2, we study the contributions of different demographic groups to aggregate differences in labor supply between the US and 8 European countries. In section 3.3, we document a correlation between aggregate labor supply and taxation across countries and a correlation between aggregate labor supply and divorce rates across time and place. Section IV studies the impact of divorce rates on labor supply in a simple model. Section 3.5 develops the quantitative model. Section 3.6 discusses data and calibration. In Section 3.7, we study the quantitative implications from changing the US divorce and marriage probabilities to their European counterparts and from introducing European tax schemes in the US. Section 3.8 concludes.

3.2 Which Demographics Groups Contribute to Differences in Aggregate Labor Supply: US vs. Europe

In this section, we use data from the Luxembourg Income Study (LIS) and the OECD Employment Database to analyze the contribution of various demographic groups to cross-country differences in aggregate labor supply. We find that women is the biggest contributor to the cross-country differences in labor supply. American women work more than European women, whether it is single women, married women, women with and without children. The contribution of women is the largest in Spain, Italy, Greece and Ireland – the countries where, as we document in the next section, marriages tend to be more stable.

Next, we analyze the importance of the intensive and extensive margins in accounting for the cross-country differences in labor supply, and find that they are both important. However, the extensive margin is particularly important for Spain, Italy, Greece and Ireland (coincidentally, these are the countries where the contribution of women is also particularly large), while the intensive margin is particularly important in Germany and Netherlands.

Data Description

The LIS database that we use contains micro-level data from the United States and a large number of European countries. The advantage of using this database is that the LIS team harmonizes and standardizes the micro data from the different countries' surveys in order to facilitate comparative research.

The LIS database provides information about individual hours worked per week

Table 3.1: Annual Hours Worked, all Persons 15-64 Years of Age, 2000

Country	Annual Hours, LIS	% of the US, LIS	Number of obs, LIS	Annual Hours, OECD	% of the US, OECD
US	1375.46	100.0	84286	1360.69	100.0
Germany	1273.10	92.6	19845	965.91	70.99
Italy	1104.15	80.3	15354	1002.85	73.70
Spain	1127.14	81.9	9560	993.40	73.01
Ireland	1219.18	88.6	5992	1117.82	82.15
Austria	1375.30	100.0	4580	1132.39	83.22
Belgium	1344.42	97.7	4488	941.14	69.17
Netherlands	1240.23	90.2	8346	1117.82	72.76
Greece	1238.89	90.1	7309	1184.56	87.06

and weeks worked per year[1]. We construct annual hours worked as the product of these two variables. To make our data comparable to the OECD aggregate-level estimates used by Rogerson (2006) and Prescott (2004), we include in our sample all individuals between 15 and 64 years of age. We make two adjustments to the LIS data. First, for several European countries the LIS database does not provide information about the labor market outcomes for 15 and/or 16 year-olds[2]. In these instances, we replace the missing values with the appropriate group averages from the US sample.

Table 3.1 reports the average annual hours worked by individuals who are from 15 to 64 years old in the US and a number of European countries, computed using the LIS data for year 2000. For comparison, the last two columns of the table also show the corresponding averages computed using the OECD data.

Unfortunately, for several European countries the average annual hours worked computed from the LIS data differ substantially from those reported by the OECD. Further research is needed to understand what causes this discrepancy. One possible explanation is that the LIS data does not capture the differences between the countries in the number of holidays and paid vacations[3].

[1]Variables *phoursu* and *pweektl*.

[2]For instance, German data does not have labor market information for both 15 and 16 year-olds, while for Spain and Ireland, this information is missing only for 15 year-olds

[3]A vast majority of individuals in all countries in the LIS data report either 0 or 52 weeks worked per year. At the same time, Jorgensen (2002) documents that individuals in most European

Table 3.2: Annual Hours Worked, Men and Women, 15-64 yrs. old, LIS 2000

Country	Men		Women	
	Annual Hours	% of US	Annual Hours	% of US
US	1596.82	100.0	1164.64	100.0
Germany	1225.33	76.7	716.87	61.6
Italy	1351.31	84.6	658.78	56.6
Spain	1355.47	84.9	633.17	54.4
Ireland	1517.71	95.0	718.02	61.7
Austria	1425.27	89.3	844.41	72.5
Belgium	1192.77	74.7	711.24	61.1
Netherlands	1319.30	82.6	675.91	58.0
Greece	1671.21	104.7	738.49	63.4

Since most of the previous research on the cross-country differences in labor supply has relied on the OECD data, we use the OECD data to determine the average country-level annual hours worked, and use the LIS data mainly to compute the contributions of various demographic groups to the cross-country differences. To account for the discrepancy between the OECD and LIS data, we uniformly scale all individual observations in each country in the LIS data so that the aggregate country-level averages that we obtain from the LIS data are equal to those reported by the OECD. Such adjustment makes the contributions of various demographic groups to the cross-country differences in aggregate-level average hours worked more uniform (in other words, we obtain a conservative estimate of the contribution of women to the cross-country differences, since this adjustment makes the contribution of separate demographic groups less pronounced)[4].

Table 3.2 shows the average annual hours worked for men and women separately, computed using the LIS 2000 data (adjusted as explained above). The table shows that the difference between the hours worked by European women and American women is larger than the corresponding difference for men, both in percentage and

countries on average enjoy several more weeks of holidays compared to Americans.

[4]Our current adjustment is appropriate, for example, if the duration of vocations and holidays for each individual is a certain percent of his/her workdays. If, on the other hand, one assumes that the duration of vocations is the same for each individual, the differences in the contribution of various demographic groups would become more emphasized.

in absolute terms. This difference between genders is more pronounced in Italy, Spain, Ireland and Greece, and less pronounced in Germany, Belgium and Austria.

Table 3.14 in the appendix shows the average annual hours worked of individuals in 3 different age groups: 1) "young" (15-20 year-olds), 2) "prime-aged" (21-55 year-olds) and 3) "old" (56-64 year-olds). There is substantial heterogeneity in hours worked by the "young" across the countries in our data (part of this could reflect poorer quality of the data for this age group). The hours worked by the "prime-aged" and "old" individuals in Europe are uniformly lower compared to the US.

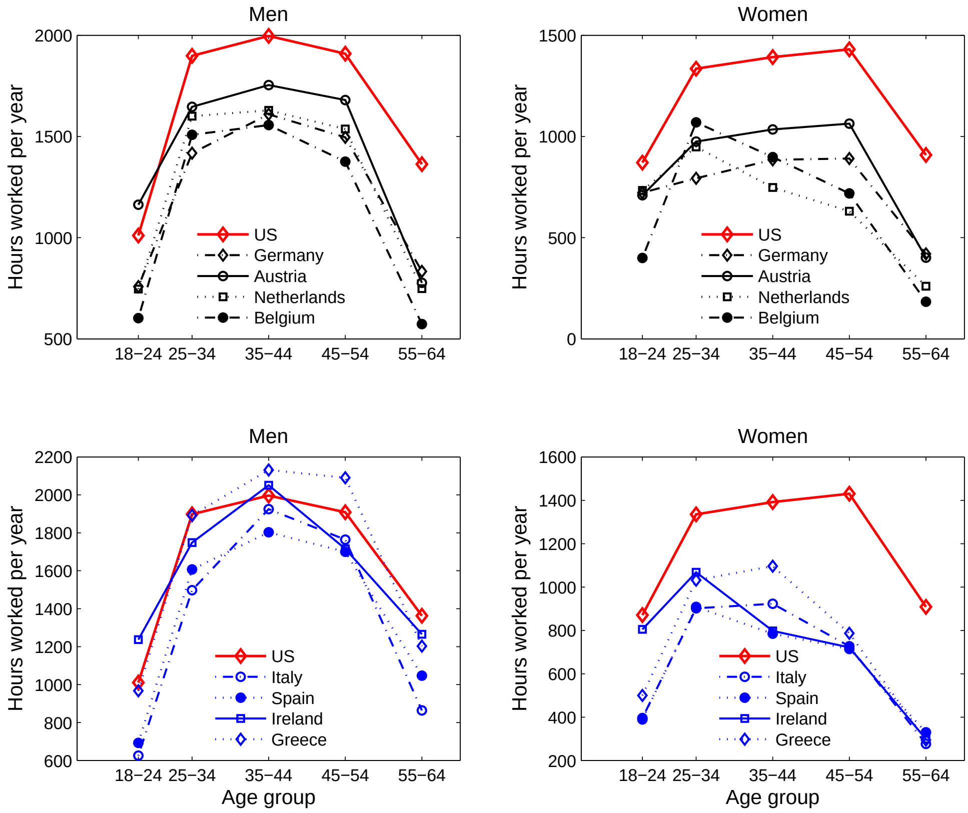
Figure 3.1 plots the age profiles, using more detailed data (5-year age groups), separately for men and women for the US and European countries. This figure illustrates that there is a larger difference in hours worked between the US and Europe for women than for men. It also suggests that while the age profiles for men appear to have similar shapre in the US and Europe (with hours worked peaking in the middle age group, 35-44 year-olds), in most European countries (with the exception of Germany and Austria) the age profiles for women look markedly different, with hours worked peaking earlier than in the US.

Table 3.3 compares the average annual hours worked by marital status and gender. It shows that in percentage terms married women in Europe display a bigger difference (work less) relative to their American counterparts than do single women. For men, the pattern is much less clear.

Given that we find that the difference in hours worked between the US and Europe is larger for women than for men, it is natural to ask whether this is related to women reducing their labor supply as a result of having children. Figure 3.13 in the appendix shows that in most of the countries where women worked the least compared to the US (Italy, Spain and Greece, but not in Ireland), women in fact tended to have fewer children than in the US.

Table 3.16 shows the hours worked by men and women split into three groups:

Figure 3.1: Average Hours Worked by Gender and Age Group



Averages are adjusted so that the total average across all subgroups is equal to the one reported by the OECD.

Table 3.3: Annual Hours Worked, by Gender and Marital Status, LIS 2000

Country	Men				Women			
	Married		Single		Married		Single	
	Annual Hours	% of US	Annual Hours	% of US	Annual Hours	% of US	Annual Hours	% of US
US	1965.87	100.0	1183.67	100.0	1207.27	100.0	1114.78	100.0
Germany	1398.72	71.2	1022.14	86.4	631.36	52.3	826.44	74.1
Italy	1620.99	82.5	982.29	83.0	651.98	54.0	669.62	60.1
Spain	1675.59	85.2	945.39	79.9	616.55	51.1	656.87	58.9
Ireland	1916.06	97.5	1107.74	93.6	692.64	57.4	747.04	67.0
Austria	1508.93	76.8	1324.17	111.9	807.33	66.9	891.72	80.0
Belgium	1328.43	67.6	971.42	82.1	713.24	59.1	708.17	63.5
Netherlands	1461.07	74.3	1134.34	95.8	553.21	45.8	856.81	76.9
Greece	1896.69	96.5	1276.75	107.9	748.15	62.0	719.60	64.6

1) "child 3", which includes the individuals who have a child under 3 years of age, 2) "child 6", which includes the individuals who have a child under 6 years of age, 3) "no child", which includes individuals with no small children. According to the table, it is only in Germany and Austria that mothers with small children reduce their labor supply further compared to the US. In the countries where women worked the least (Italy, Spain, Greece and Ireland), the percentage difference with the US in hours worked for mothers with small children is smaller than for women without small children.

These two observations: 1) that fertility in the US is relatively high; 2) women with small children in Europe do not reduce their labor supply relative to their American counterparts, suggest that having small children is not a major reason for the difference in women's labor supply between the US and Europe.

Group Contribution Decomposition

To analyze the contribution of various demographic groups to the difference between aggregate labor supply in the US and the European countries in our sample, we perform the following decomposition. Suppose we divide each country's sample into n different groups. Then the difference between the aggregate average annual hours worked in the US, H^{us}, and in country j, H^j, can be written as:

$$H^{us} - H^j = \sum_{i=1}^{n} \omega_i^{us} h_i^{us} - \sum_{i=1}^{n} \omega_i^j h_i^j$$
$$= \underbrace{\sum_{i=1}^{n} (h_i^{us} - h_i^j)\omega_i^{us}}_{\text{behavioral effect}} + \underbrace{\sum_{i=1}^{n} (\omega_i^{us} - \omega_i^j) h_i^j}_{\text{composition effect}} \tag{3.1}$$

where ω_i^j is the share of observations that come from group i in country j's sample, while h_i^j is the average annual hours worked by individuals in this group.

We divide the data into 12 demographic groups, according to gender, marital status and age (using 3 age groups). We are interested in analyzing the first summand in the expression above, which we call the behavioral effect, after removing the sample composition effect (which amounts to looking at a hypothetical case where the composition of the samples in different countries would be identical). Tables 3.20 and 3.21 in the appendix show the sample compositions in all our countries. It is worth noting that the total contribution of the compositional effects is quite small – in most cases, it is smaller than 5% of the total difference in average hours, except for Belgium (-8.717%), Greece (-7.176%) and Netherlands (-6.174%). Tables 3.17 and 3.18 show the contribution of different demographic groups to the aggregate difference in hours worked, weighted by the size of the appropriate group in the US sample, $\frac{h_i^{us} - h_i^j}{H^{us} - H^j} \omega_i^{us}$.

These tables show that women in general contribute more to the differences in labor supply than men. We find that in all countries, the contribution of women is larger than 50%. This difference between the contribution of the two genders is especially large in the four "catholic" countries – Spain, Italy, Ireland and Greece, where it ranges from 66% in Italy to 101% in Greece. In all countries except Belgium, married prime-aged women are the biggest contributing group. In Spain, Italy, Ireland and Greece single prime-aged women are the second-largest contributing group.

Intensive vs. Extensive Margin

Table 3.2 shows the contribution of intensive and extensive margins to the overall cross-country differences in labor supply, using the following decomposition formula:

$$\begin{aligned} H^{US} - H^{i} &= H^{US}_{\text{empl}} \cdot \text{Share}^{US}_{\text{empl}} - H^{i}_{\text{empl}} \cdot \text{Share}^{i}_{\text{empl}} \\ &= \underbrace{\left(H^{US}_{\text{empl}} - H^{i}_{\text{empl}}\right) \text{Share}^{US}_{\text{empl}}}_{\text{Intensive Margin}} + \underbrace{\left(\text{Share}^{US}_{\text{empl}} - \text{Share}^{i}_{\text{empl}}\right) H^{i}_{\text{empl}}}_{\text{Extensive Margin}} \end{aligned} \tag{3.2}$$

From the OECD data, one can compute the total average hours worked in country i, H^i, as the product of the hours worked by employed persons, H^i_{empl}, and the share of the population which is employed, $\text{Share}^i_{\text{empl}}$. Table 3.2 reports the contributions of intensive and extensive margins as a percentage of the total difference in hours worked between the US and country i, $H^{US} - H^i$. As can be seen from the table, both margins appear to be important. The contribution of the extensive margin is particularly large in Greece, Italy, Spain and Ireland. The intensive margin is more important in the Netherlands and Germany.

Table 3.4: Contribution of Intensive and Extensive Margins to Cross-Country Differences in Labor Supply

Country	Intensive Margin, %	Extensive Margin, %
Germany	68.21	31.79
Italy	-5.16	105.16
Spain	21.34	78.66
Ireland	35.82	64.18
Austria	57.87	42.13
Belgium	51.46	48.54
Netherlands	92.44	7.56
Greece	-119.62	219.62

3.3 Possible Determinants of Labor Supply: Taxes and Marriage Stability

In this section, we analyze the empirical relationship between hours worked in the US and Europe, and the following two candidate explanations for cross-country differences in labor supply: 1) differences in taxes; 2) differences in marriage stability. Taxes have been suggested as a major contributor to cross country differences in labor supply in the literature (see Prescott (2004) and Rogerson (2006)). Marriage stability is a new explanation in this context, motivated by our finding in section 3.2 that women are the biggest contributor to the cross-country differences in labor supply. Our hypothesis is that more stable marriages provide consumption insurance, thereby reducing the incentives to accumulate labor market experience, in particularly for women (who usually are secondary earners). Conversely, a higher probability of divorce can increase the value of market experience for the woman who has a higher probability of ending up as a single earner.

We first compare and discuss some features of the tax systems in the US and Europe with particular focus on the 9 countries in Table 1: the US, Germany, Italy, Spain, Ireland, Austria, Belgium, the Netherlands, and Greece. We then study the correlation between labor supply and various measures of tax levels, tax progressivity, and marriage stability in a larger sample of countries. We find that there is positive correlation between taxes and aggregate labor supply, and negative correlation between marriage stability and aggregate labor supply, but in both cases, the correlation is not very strong. In addition, when we regress average annual hours worked in each country on different measures of taxation and marriage stability separately, the regression coefficients have the expected sign, but are only marginally statistically significant (at 10% significance level), and the R^2 of the regressions are very low.

However, when we combine a measure of tax levels and divorce rates in the same regression, both regression coefficients become highly statistically significant, and the adjusted R^2 increases considerably (to 49.4%). We conjecture that the importance of these two mechanisms is different for different groups of countries within Europe. Finally, we document strong correlation between female employment rates and divorce rates[5]. These observations motivate us to more carefully study the impact of taxes and marriage stability on labor supply in a structural model.

Labor Income Taxes in the US and Europe

There are many issues to consider when comparing labor income taxes across countries. (i) Firstly, both the levels and progressivity of taxes may be of interest, when studying the impact of taxation on labor supply. (ii) Secondly, taxes differ with respect to marital status. In the US, Germany, Spain, and Ireland married couples are taxed jointly, while in Italy, Austria, Belgium, the Netherlands, and Greece they are taxed separately. In the whole OECD there are 19 countries practicing separate taxation of married couples and 11 countries practicing joint taxation. There may also be slightly different schemes for married households with 1 and 2 earners. (iii) Finally, taxes vary with the number of children in the household. In this section, we will focus on the taxes paid by single households without children[6].

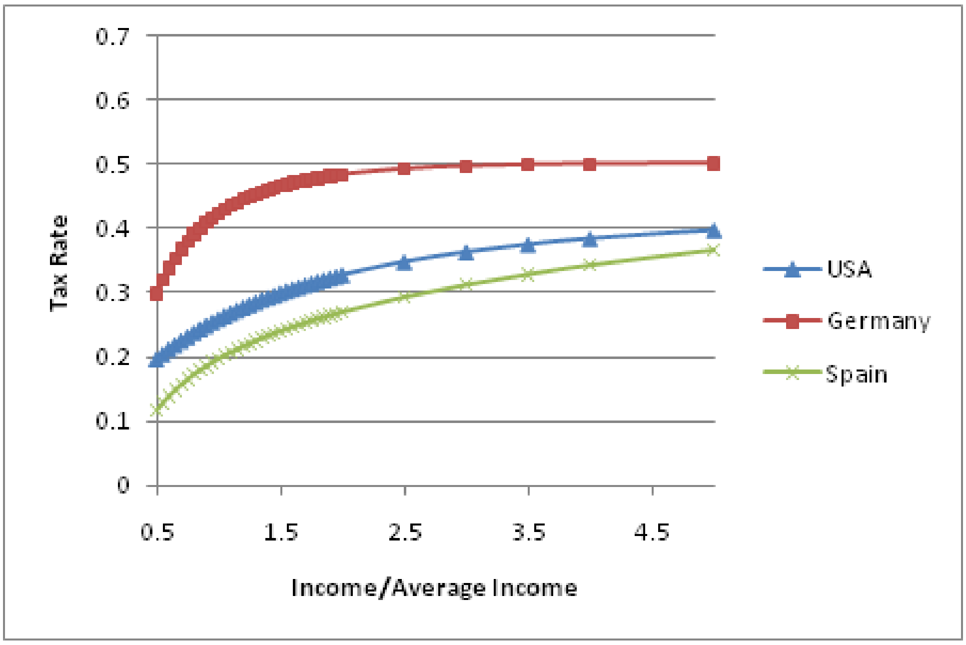
For each country in Table 3.19, we fit a polynomial tax function, based on tax data from the OECD[7]: Among our countries, labor income taxes are the lowest in Spain and Greece, moderate to low in the US, and highest in Germany and Belgium. In figure 3.2 we plot fitted labor income tax schedules for single individuals in Spain,

[5]Unfortunately, we are restricted to using the employment rates when we look at the labor supply by gender, since the OECD does not provide information for hours worked separately for men and women.

[6]Essentially, we abstract in this section from points (ii) and (iii) above. We do it here because taxes paid by an average single household without children is the measure that is most easily comparable between the countries. In sections 3.5-3.7, we differentiate between the taxes paid by single and married households within the structural model of labor supply.

[7]See Appendix

Figure 3.2: Country Labor Income Tax Functions (singles)

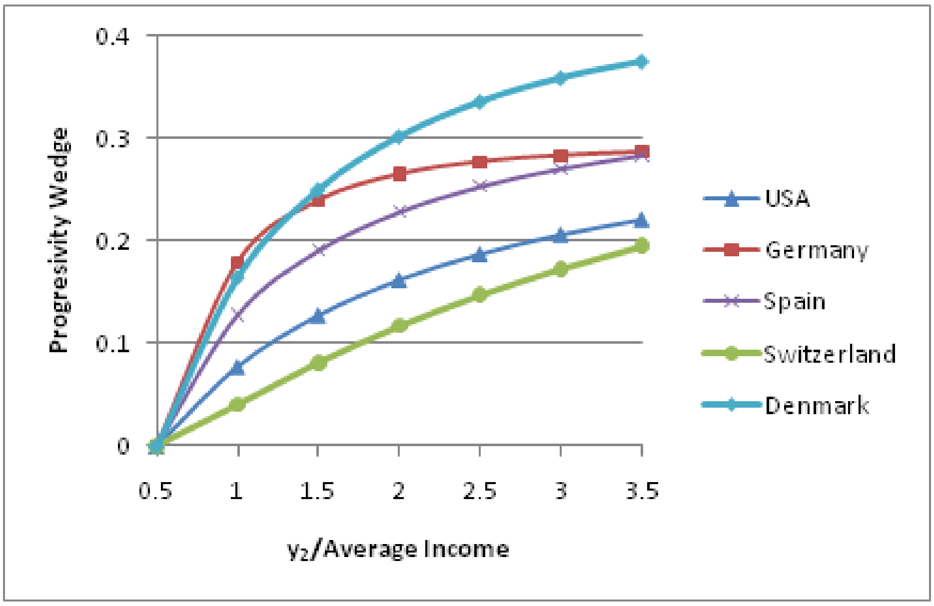


the US, and Germany.

Columns 1 and 2 of Table 3.19 display the top marginal tax rates and the income level where they become effective for single households in the US and many Western European countries. There are not always large differences in the maximum tax rates but the income level where they become effective also vary greatly. In Germany, for instance, the top tax rate becomes effective already at 1.5 times average earnings, while in the US the top marginal rate first becomes effective at 9 times average earnings. Column 4 of Table 1 displays the labor income tax paid by singles with average earnings across countries.

A person making labor supply decisions will care about his marginal tax rate in addition to his tax level. It is possible that tax progressivity, and not only the level of taxes are important for the cross country pattern in labor supply. A commonly used measure for tax progressivity is so-called progressivity wedges, see for instance

Figure 3.3: Country Tax Functions (Singles)



Guvenen, Kuruscu, and Ozkan (2009):

$$PW(y_1, y_2) = 1 - \frac{1 - \tau(y_2)}{1 - \tau(y_1)} \tag{3.3}$$

This measure says something about how fast the tax rate increases as earnings increase from y1 to y2. If there is a flat tax, then the progressivity wedge would be zero for all levels of y_1 and y_2. Figure 3.3 plots progressivity wedges for $y_1 = 0.5AE$ for the US, Germany, Spain, Denmark, and Switzerland. Among the 17 countries in Table 3.19, Denmark has the most progressive taxes and Switzerland the least progressive. The US is among the countries with the least progressive taxes, while Germany are among the countries with the most progressive taxes.

Consumption Taxes

Consumption taxes also have an impact on labor supply decisions. The second column of Table 2 reports these flat taxes in (2001). The consumption tax varies from 7.6% in Switzerland on the low end to 25% in Denmark and Sweden on the high end. Among our 9 countries, the US stands out with low consumption taxes.

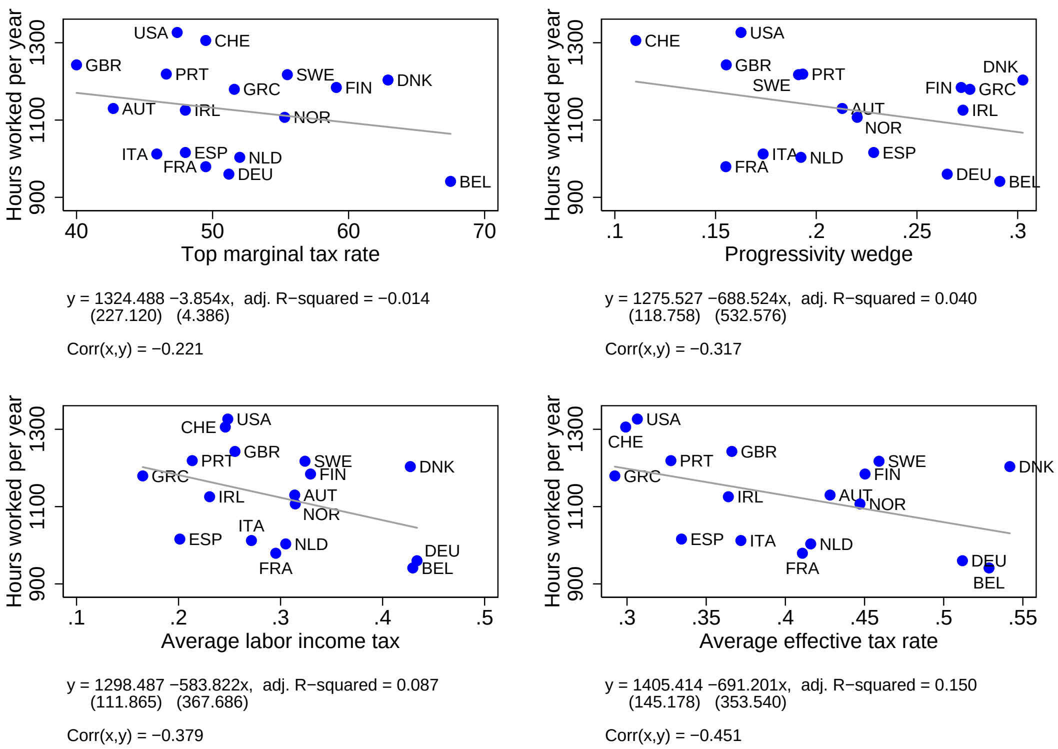
Correlation Between Labor Supply and Taxes and Labor Supply and Divorce Rates

In Figure 3.4, we plot the correlation between labor supply and four tax-related measures. They are: the average labor income tax rate at average earnings, the average effective tax rate on labor income at average earnings, the top marginal tax rate, and the tax progressivity wedge at $y_1 = 0.5AE$, $y_2 = 2AE$. The effective tax rate on labor income, τ, as defined in Prescott (2004) is:

$$\tau = 1 - \frac{1-\tau_l}{1+\tau_c} \tag{3.4}$$

It is the fraction of labor income that is taken in the form of taxes, holding investment fixed. In other words a measure that combines labor income tax and consumption tax into a single tax rate.

Figure 3.4: Relationship Between Annual Hours and Tax Measures by Country



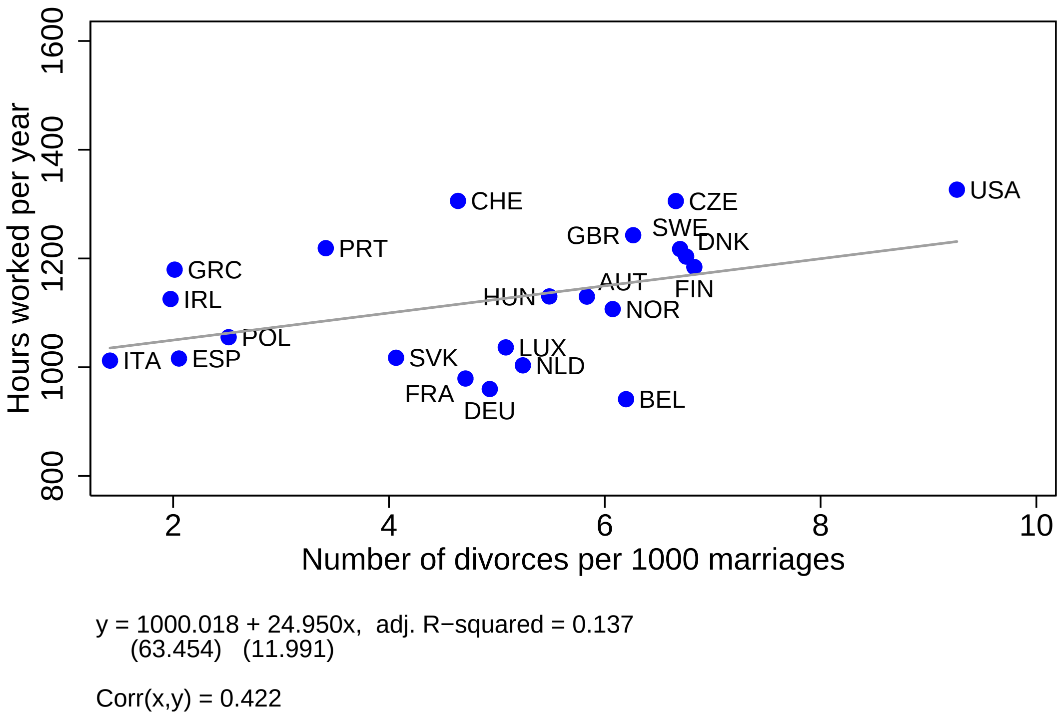
As can be seen from Figure 3.4, there is generally a negative but weak correlation between different measures of taxes and aggregate hours worked. The strongest correlation, -0.45, is with the effective tax rate at average earnings. There is a negative relationship between labor supply and all our tax measures, but only the regression coefficient for the effective tax rate at average earnings is marginally statistically significant at the 10% level. In addition, the largest adjusted R^2 in the regressions is 15%, so taxes alone do not explain much of the cross- country variation in labor supply.

In figure 3.5, we plot the correlation between divorce rates and aggregate labor supply. The data for divorce rates in European countries is constructed using Eurostat data, while for the US we use the National Vital Statistics data provided by the Centers for Decease Control and Prevention, and the US Census data. As can be seen from Figure 3.5, there is a positive relationship between average annual hours worked and divorce rates. The regression coefficient is almost statistically significant at the 5% level, and the adjusted R^2 is only 13.7%.

In Table 3.5 we present the results from a regression of labor supply on divorce rate and each of the different tax measures. In two cases (when using the average labor income tax and average effective tax rate), the coefficients for both the divorce rates and the tax measure that we use are statistically significant at any conventional significance level, and the adjusted R^2 improves substantially to 49.4%. Using both taxes and divorce rates together explains a significant share of the cross- country variation in labor supply.

Guner, Kaygusuz, and Ventura (2008) argue that one of the features of the tax system that can be particularly important for the labor supply of the married couples is whether the labor income of the couple is taxed jointly or separately. Table 3.25 in the appendix reports the regression results when we add a dummy variable equal to 1 for countries in our sample that practice separate taxation. Table 3.25 shows that

Figure 3.5: Relationship Between Annual Hours and Divorce Rates by Country



the coefficient for separate taxation in 3 out of 4 regressions reported in the table has the expected positive sign, but is not statistically significant.

Unfortunately, the OECD dataset does not provide data for hours worked separately for men and women, but it does provide data on employment rates by gender. Figure 3.6 shows the relationship between the divorce rates and employment ratios by country for men and women separately. It shows that for both men and women, this relationship is positive, but the magnitude of the coefficient is about three times as large for women as it is for men. In addition, the coefficient is statistically significant for women and not statistically significant for men.

Figures 3.14 and 3.15 in the appendix show the relationship between our tax measures and employment ratios for women and men respectively. None of the tax measures is statistically significant for either of the sexes, and in many cases the relationship appears to be negative. We conclude that our macro level data suggest

Table 3.5: Regressing Average Hours Worked on Divorce rate and Tax Measures

	(I)	(II)	(III)	(IV)
Const	1321.283***	1166.408***	1258.655***	1383.385***
	(207.819)	(137.197)	(83.996)	(112.1656)
Divorce rate	27.101*	19.428	42.036***	36.733***
	(13.694)	(13.418)	(11.627)	(10.968)
Top marginal tax rate	−6.409	–	–	–
	(4.215)			
Progressivity wedge	–	−629.513	–	–
		(515.734)		
Average labor income tax	–	–	−1156.867***	–
			(316.286)	
Average effective tax rate	–	–	–	−1088.327***
				(297.347)
adjusted R^2	0.151	0.106	0.494	0.494

Standard errors are in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

that while both tax measures and divorce rates appear to be related to annual hours worked, taxes appear to impact mostly the intensive margin (hours worked for those who are employed), while divorce rates appear to be related to the extensive margin – the employment ratios (see figure 3.16), and this relationship appears much stronger for women.

Finally, Table 3.6 shows the panel regression results, when regressing employment ratios on divorce rates for men and women separately, using the data from 1990 to 2009 (one obtains a qualitatively similar results when starting at an earlier date)[8]. The panel regression results provide further support to our finding that divorce rates appear to affect mostly the labor supply of women.

In this section, we have documented an empirical relationship between aggregate labor supply and taxes and aggregate labor supply and divorce rates. This motivates our study in the next three sections of the impact of taxes, divorce- and marriage

[8]Since the Eurostat data on the number of divorces that we use to construct the divorce rate measure spans different time periods for different countries, we have an unbalanced panel. The US data start in 2000. Also, the data here lacks observations for some European countries, such as Spain and Greece, altogether. In our previous cross-sectional plots for 2001, we used the Eurostat Census 2001 data on the number of married people for these countries, but this data is available only for one year, 2001.

Figure 3.6: Relationship Between Divorce Rates and Employment Ratios for Men and Women by Country

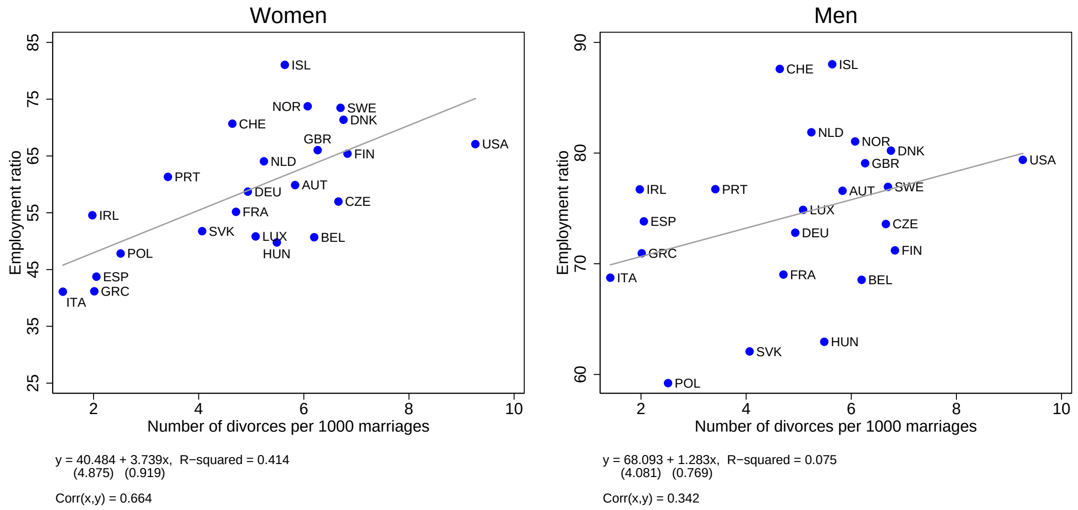


Table 3.6: Relationship Between Employment Ratios and Divorce Rates, Panel Regression Results

Employment rate	Women	Men
Constant	51.809***	72.681***
	(2.795)	(2.076)
Divorce rates	1.685***	0.323
	(0.398)	(0.283)
Standard errors are in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$		

probabilities on labor supply in a structural model.

3.4 Gaining Intuition: Labor Supply and Divorce in a Simple Two-Period Model

In this section, we outline the intuition for the effect of divorce rates on women's labor supply using a simplified two-period version of our model[9]. We describe our full model in the next section.

Consider a family that consists of a husband (a "man") and a wife (a "woman")

[9]The intuition concerning the effect of taxation is described very well in Rogerson (2007), Guner, Kaygusuz, and Ventura (2008) etc.

who live for 2 periods. Suppose that both members of the family have 1 unit of time at their disposal in each period. For simplicity, assume here that the husband always works full-time, while the wife has to decide how much time to spend working in period 1 and in period 2. Assume that the husband's wage in period 1 is $w_{1,m}$, while the wife's wage in the first period is $w_{1,f}$. Suppose that their wages in the second period increase linearly with the amount of time they spend working in period 1, with parameters k_m and k_f controlling the "returns to experience" for the husband and the wife. Thus, the husband's wage in period 2 is $w_{1,m} + k_m$ (since the husband always works full-time), while the wife's wage in period 2 is $w_{1,f} + k_f h_{1,f}$. Assume that with probability π_d, the couple divorces before the second period starts. Suppose that they cannot save or borrow in period 1.

At the start of period 1, the couple jointly solves:

$$
\begin{aligned}
\max_{\substack{c_1, c_2, c^s_{2,m}, c^s_{2,f}, \\ h_{1,f}, h_{2,f}, h^s_{2,f}}} \quad & \alpha \log(c_1/e) + (1-\alpha)\log(1-h_{1,f}) \\
& + \quad (1-\pi_d)\left(\alpha \log(c_2/e) + (1-\alpha)\log(1-h_{2,f})\right) \\
& + \quad \pi_d \left(\alpha \log(c^s_{2,m}) + \alpha \log(c^s_{2,f}) + (1-\alpha)\log(1-h^s_{2,f})\right) \\
s.t.: \quad c_1 &= w_{1,m} + w_{1,f} h_{1,f} \\
c_2 &= w_{1,m} + k_m + (w_{1,f} + k_f h_{1,f}) h_{2,f} \\
c^s_{2,m} &= w_{1,m} + k_m \\
c^s_{2,f} &= (w_{1,f} + k_f h_{1,f}) h^s_{2,f} \qquad (3.5)
\end{aligned}
$$

where $h_{2,f}$ is the woman's choice of work in period 2 in case she stays married, $h^s_{2,f}$ is her choice of work if she gets divorced, and e is the adult equivalence scale.

The solution is characterized by the following 3 first-order conditions:

$$\frac{1-\alpha}{1-h_{2,f}} = \frac{\alpha}{c_2}(w_{1,f} + k_f h_{1,f}) \tag{3.6}$$

$$\frac{1-\alpha}{1-h^s_{2,f}} = \frac{\alpha}{c^s_{2,f}}(w_{1,f} + k_f h_{1,f}) \tag{3.7}$$

$$\frac{1-\alpha}{1-h_{1,f}} = \frac{\alpha}{c^s_{1,f}} w_{1,f} + (1-\pi_d)\frac{\alpha}{c_2} k_f h_{2,f} + \pi_d \frac{\alpha}{c^s_{2,f}} k_f h^s_{2,f} \tag{3.8}$$

First, let us consider how a change in the probability of divorce, π_d, affects the woman's choice of labor supply in period 1, $h_{1,f}$. An increase in π_d will affect $h_{1,f}$ both directly through equation 3.8, and also indirectly through the effect of the change in $h_{1,f}$ on $h_{2,f}$ and $h^s_{2,f}$ in equations 3.6 and 3.7, which feeds back into c_2 and $c^s_{2,f}$ in equation 3.8. For simplicity, let us disregard the indirect effect, and concentrate on the direct effect in equation 3.8. On the right hand side of that equation, we have the marginal benefit of an increase in the wife's work in period 1, which includes both an immediate increase in consumption in period 1, and the increase in consumption in period 2 because of the accumulation of the woman's experience (and increased period 2 wages). An increase in π_d effectively decreases the weight put on the second period's marginal utility of consumption in case the couple stays married, and increases the weight on the second period's marginal utility of consumption of the divorced woman. Intuitively, because the income of the married couple also includes the income of the husband (which typically is larger than the income of the wife), we get $c_2 > c^s_{2,f}$. From equations 3.6 and 3.7, it also follows that $h^s_{2,f} > h_{2,f}$, so that $\frac{\alpha}{c^s_{2,f}} h^s_{2,f} > \frac{\alpha}{c_{2,f}} h_{2,f}$, and such re-weighting increases the marginal benefit from the woman's work in period 1. This increases the woman's incentive to work in period 1.

Given the utility function that we have assumed in this section, one can in fact show that an increase in divorce probability leads to an increase in the woman's labor supply:

Proposition 3.4.1.

$$\frac{\partial h_{1,f}}{\partial \pi_d} > 0, \quad \frac{\partial h_{2,f}}{\partial \pi_d} > 0, \quad \frac{\partial h^s_{2,f}}{\partial \pi_d} = 0 \tag{3.9}$$

Proof: See Appendix 3.9.3

It is clear from equation 3.8 that for the change in divorce probability to have an impact on the woman's labor supply, we need $k_f > 0$ (returns to experience must be positive). One can expect this impact to be larger, the bigger is the gender wage gap $(\frac{w_m}{w_f})$. One could also be tempted to conclude from equation 3.8 that the effect of the change in divorce probability is stronger, the bigger is the returns to experience. However, even though this is true for fixed c_2 and $c^s_{2,f}$, and we found it to be true for a variety of reasonable choices of parameters in this simple two-period model, this could be at least partially offset by the income effect of the increase in k_f, which could be larger for the single woman.

To see that the increased probability of divorce can also increase labor supply of single women, imagine that there are 3 periods of active life, all women are single in period 0, but they are certain to get married in period 1 (and periods 1 and 2 are the same as the above), and that the the wages the woman receives in period 2 increase both in experience accumulated in period 0 and 1.

3.5 Quantitative Model

The stationary economy is populated by three types of households: single males, single females, and married couples. Individuals start their life at age 20. They live for at least 65 years, and at most 95 years, but enter retirement at age 65. A model period is 1 year, so there are a total of 45 model periods of active work life. Single households face an age-dependent probability of becoming married, while married couples face an age dependent probability of divorce. One is more likely to be married to someone with the same level of education. We assume that marriage will always happen to a partner of the same age, and that married couples die together. Households decide whether to participate in the labor market, how much to consume, and how much to save, and they accumulate labor market experience.

Labor Income

The wage, w, of an individual depends on his level of education, $j \in \{\mathrm{hs}, \mathrm{c}\}$ (where "hs" stands for high school and "c" stands for college), gender, $g \in \{\mathrm{m}, \mathrm{f}\}$, and years of labor market experience, x:

$$w(j, g, x) = e^{\gamma_{0jg} + \gamma_{1jg} x + \gamma_{2jg} x^2 + \gamma_{3jg} x^3} \tag{3.10}$$

Given this wage function, the beginning wage levels as well as the returns to experience are allowed to differ by level of education and gender.

Preferences

The momentary utility function of single individuals, U^S, depends on labor market participation, $n \in 0, 1$, consumption, c, and on gender:

$$U^S(g, c, n) = \frac{c^{1-\sigma}}{1-\sigma} - F_g n \tag{3.11}$$

F_g is here a fixed, gender specific, disutility from working. Married couples have a joint utility function, U^M, with shared consumption, measured in adult equivalents:

$$U^M(c, n_m, n_f) = \frac{\left(\frac{c}{e}\right)^{1-\sigma}}{1-\sigma} - F_m n_m - F_f n_f \tag{3.12}$$

Household's Problem

Written recursively, a single household's problem can be formalized as follows:

$$\begin{aligned} V^S(g,j,k,x,t) &= \max_{c,n,k'} U^S(g,c,n) + \beta\Big((1-\bar{\omega}(t))V^S(g,j,k',x',t+1) \\ &\quad +\bar{\omega}(t)E_{j_p,k'_p,x'_p}\big[V^M(j,j_p,k'+k'_p,x',x'_p,t+1)\big]\Big) \\ \text{s.t.:}\quad c(1+\tau_c)+k' &= k(1+r)+nw(j,g,x)(1-\tau_S(w(j,g,x)n))+(1-n)T \\ x' &= x+n, \quad n\in\{0,1\}, \quad k'\geq 0, \quad c>0 \end{aligned} \tag{3.13}$$

k here is the level of asset holdings, r is the risk-free interest rate, and β the time discount factor. τ_c is a constant consumption tax, while τ_n is a nonlinear labor income tax. In the US and some European countries, the tax schedule is dependent on whether a person is single or married. T is an individual's income if he chooses not to participate in the labor market. The sources of such income would be unemployment benefits, social aid, transfers from relatives and charities and so on. $\bar{\omega}(t)$ is a time-dependent probability of becoming married in the next period. The subscript, p, stands for partner. In the case that an individual becomes married in the next period, the expectation of next period's utility must be taken with respect to the distribution over potential partners' education, experience, and asset holdings, $Q^{jgt}(j_p,x'_p,k'_p)$. An individual is more likely to find a partner of his own education group, and the distribution of partners naturally varies by gender and age. The distribution over x'_p and k'_p is derived from the individuals' optimal desicions.

Married couples maximize their joint utility and face a time-dependent probability, $\pi(t)$, of becoming divorced. When couples divorce, they split their assets evenly.

Their problem can be written as:

$$\begin{aligned}
V^M(j_m, j_f, k, x_m, x_f, t) &= \max_{c,k',n_m,n_f} U^M(c, n_m, n_f) \\
&\quad + \beta(1-\pi(t))V^M(j_m, j_f, k', x'_m, x'_f, t+1) \\
&\quad + \beta\pi(t)V^S(m, j_m, k'/2, x'_m, t+1) \\
&\quad + \beta\pi(t)V^S(f, j_f, k'/2, x'_f, t+1) \\
\text{s.t:} \quad c(1+\tau_c) + k' &= k(1+r) + (n_m w_m + n_f w_f)(1 - \tau_{n,M}(n_m w_m + n_f w_f)) \\
&\quad +(2 - (n_m + n_f))T \\
x'_m = x_m + n_m, \;\; x'_f &= x_f + n_f, \;\; n_f, n_m \in \{0,1\}, \;\; k' \geq 0, \;\; c > 0 \qquad (3.14)
\end{aligned}$$

Retired households make no labor supply decisions but receive an amount of social security, $\Phi(g)$, depending on their gender. We assume that retired households do not marry or get divorced, and that husband and wife die at the same time. Their problem, if single, is simply:

$$\begin{aligned}
V^S(g, k, t) &= \max_{c>0,k'\geq 0} U^S(g, c) + \Omega(t)\beta V^S(g, k', t+1) \\
\text{s.t.:} \quad c(1+\tau_c) &= k(1+r) + \Phi(g), \qquad (3.15)
\end{aligned}$$

where $\Omega(t)$ is the probability of survival until the next period. Married retirees solve:

$$\begin{aligned}
V^M(k, t) &= \max_{c>0,k'\geq 0} U^M(c) + \Omega(t)\beta V^M(g, k', t+1), \\
\text{s.t.:} \quad c(1+\tau_c) &= k(1+r) + \Phi(m) + \Phi(f), \qquad (3.16)
\end{aligned}$$

3.6 Calibration

This section describes the calibration of the model parameters. We calibrate our model to match the appropriate moments from the US data. We use data from different sources. We try to use data from 2000 or the year closest to 2000 that we can obtain. Many parameters can be calibrated to direct empirical counterparts without solving the model. They are listed in Table3.7. The 7 parameters in Table 2 below are, however, calibrated using an exactly identified simulated method of moments approach. We use the data from the European countries in our sample only to obtain the estimates of tax polynomials and age-specific marriage and divorce probabilities, which we use in section 3.7 in our counterfactual experiments.

Preferences

The momentary utility function is a standard CRRA utility function in equations 3.11 and , with consumption measured in adult equivalents, $\frac{c}{e}$. We use the OECD adult equivalence scale and set $e = 1.7$ for married couples, and $e = 1.0$ for singles. Consistent with a survey of the empirical literature in Browning et. al. (1999), we set the coefficient of relative risk aversion, σ, equal to 2. The discount factor, β, and fixed costs of working, F_m and F_f, are among the estimated parameters. The corresponding data moments are the mean asset holdings of households with head aged $20 - 64$, taken from the PSID (99-05), and the male- and female employment rates, taken from OECD 2000.

Risk Free Interest Rate

Given the partial equilibrium nature of the model, we take the risk free rate as fixed and calibrate it using the data. We set the risk free rate equal to the average of 3-month t-bill rates minus inflation over the period from 1947-2008 based on data from the Federal Reserve Bank of St. Louis[10].

Wages

We calibrate the experience profile of wages exogenously, using the PSID from 1968-1997. After 1997 it is not possible to get years of actual labor market experience

[10]Series TB3MS and GDPDEF.

from the PSID. We regress earnings on a 3rd order polynomial in years of labor market experience and control for the year of birth. We estimate different returns to experience for each gender/education group. To get levels of earnings that are in line with the asset holdings, we include a parameter controlling the average earnings of each gender/education group in the structural estimation. The corresponding data moments are the average wage of each group in the PSID 99-05.

Taxes

The labor income tax schedule is a polynomial function of an individual's earnings relative to the average earnings, AE, equation 3.20 in the appendix. As described in more detail in the appendix, we fit this polynomial to labor income tax data from the OECD tax database (2001). This data is constructed by the OECD based on tax laws from different countries. It is well suited for cross country comparisons, see also see Guvenen, Kuruscu, and Ozkan (2009). For those countries who practice joint taxation of married couples, we fit a different tax schedule for married and single individuals. Coming up with an accurate estimate of consumption taxes in the US is complicated by the fact that there are local county-level taxes in addition to state taxes. Vertex Inc. (a consulting company) estimated that the average consumption tax in the US was 8.4% in 2002. We use that number. For simplicity, we abstract from capital taxes. we do this because different types of capital is taxed differently, and this also differs across countries. Households do for instance have about half of their wealth in their homes which may or may not be taxed. In the US, interest income is taxed as labor income, while dividends and capital gains are subject to capital gains tax. The return on capital is, however, set very conservatively in our calibration. It is set equal to the returns on risk free bonds, which was 1.1% over the past 60 years.

Death Probabilities and Social Security

The probability that a retiree will survive to the next period, we obtain from the

Table 3.7: Parameters Calibrated Outside of the Model

Parameter	Value	Description	Target
r	0.011	Risk free interest rate (annual)	3-mnth T-bill minus inflation (1947-2008)
σ	2	$u(c,n) = \frac{(c/e)^{(1-\sigma)}}{(1-\sigma)}$	Browning et. al. (1999)
e	1.0 or 1.7		OECD equivalence scale.
$\gamma_{1hsm}, \gamma_{2hsm}, \gamma_{3hsm}$	0.066, -20(-4), 17(-6)	$w_{hsm} = e^{(\gamma_{0hsm}+\gamma_{1hsm}x+\gamma_{2hsm}x^2+\gamma_{3hsm}x^3)}$	PSID (1968-1997)
$\gamma_{1cm}, \gamma_{2cm}, \gamma_{3cm}$	0.109, -32(-4), 26(-6)	$w_{cm} = e^{(\gamma_{0cm}+\gamma_{1cm}x+\gamma_{2cm}x^2+\gamma_{3cm}x^3)}$	
$\gamma_{1hsf}, \gamma_{2hsf}, \gamma_{3hsf}$	0.069, -16(-4), 12(-6)	$w_{hsf} = e^{(\gamma_{0hsf}+\gamma_{1hsf}x+\gamma_{2hsf}x^2+\gamma_{3hsf}x^3)}$	
$\gamma_{1cf}, \gamma_{2cf}, \gamma_{3cf}$	0.064, -12(-4), 6(-6)	$w_{cf} = e^{(\gamma_{0cf}+\gamma_{1cf}x+\gamma_{2cf}x^2+\gamma_{3cf}x^3)}$	
τ_{s0}, τ_{s1}	1.727, -6.450	$\tau(y) = \tau_{s0} + \tau_{s1}(y/AE)^{0.2}$	OECD tax data (01)
τ_{s2}, τ_{s3}	8.995, -5.000	$+\tau_{s2}(y/AE)^{0.4} + \tau_{s3}(y/AE)^{0.6}$	
τ_{s4}	0.988	$+\tau_{s4}(y/AE)^{0.8}$	
τ_{m0}, τ_{m1}	2.162, -7.302	$\tau(y) = \tau_{m0} + \tau_{m1}(y/AE)^{0.2}$	OECD tax data (01)
τ_{m2}, τ_{m3}	9.222, -4.736	$+\tau_{m2}(y/AE)^{0.4} + \tau_{m3}(y/AE)^{0.6}$	
τ_{m4}	0.872	$+\tau_{m4}(y/AE)^{0.8}$	
τ_c	0.084	Consumption tax	Vertex Inc. (2002)
T	\$8440	income if not working	CEX 2000-2001
$\Phi(m), \Phi(f)$	\$12600, \$9680	Social security	S.S. Admin. (2000)
$\bar{\omega}(t)$	Varies	Prob. of marriage	CPS (1999-2001)
$\pi(t)$	Varies	Prob of divorce	CPS (1999-2001)
$\Gamma(t)$	Varies	Death probabilities	NCHS (1991-2001)
Fraction w. some college.	0.533		CPS (1999-2001)
Prob. intra ed. marriage	0.737		CPS (1999-2001)
k_0	8260	Savings at age 20	NLSY97
M_0	0.126	Share of married 20 year-olds	CPS (1999-2001)

Table 3.8: Parameters Calibrated Endogenously

Parameter	Description	Data Moment	Value
γ_{0hsm}	$w_{hsm} = e^{(\gamma_{0hsm}+\gamma_{1hsm}x+\gamma_{2hsm}x^2+\gamma_{3hsm}x^3)}$	Mean male hs-wages	-1.438
γ_{0cm}	$w_{cm} = e^{(\gamma_{0cm}+\gamma_{1cm}x+\gamma_{2cm}x^2+\gamma_{3cm}x^3)}$	Mean male c-wages	-1.464
γ_{0hsf}	$w_{hsf} = e^{(\gamma_{0hsf}+\gamma_{1hsf}x+\gamma_{2hsf}x^2+\gamma_{3hsf}x^3)}$	Mean female hs-wages	-2.081
γ_{0cf}	$w_{cf} = e^{(\gamma_{0cf}+\gamma_{1cf}x+\gamma_{2cf}x^2+\gamma_{3cf}x^3)}$	Mean female c-wages	-1.692
β	Discount factor	Mean assets	1.001
F_m	Fixed cost of working	Male employment rate	2.092
F_f	Fixed cost of working	Female employment rate	2.265

National Center for Health Statistics (1991-2001). We assume that all retirees receive the same constant Social Security benefit, only dependent on gender. We obtain the average benefit for males and females from the Annual Statistical Supplement to the Social Security Bulletin (2000).

Marriage and Divorce Probabilities

To compute the age-specific probabilities for marriage and divorce for the US, we use the data from the CPS March supplement from 1999-2001. For most European countries, we use the data from Eurostat on-line database[11]. For some European countries, we supplement it with the data from the IPUMS International.

We assume the stationary environment, where the probabilities of getting married and divorced don't change over time (we allow them to depend on the age of the person, but not on his/her cohort)[12]. We also assume that the probability of getting married is the same for those who get married for the first time, and those who were previously divorced. This allows us to compute the probabilities using the following approach. Let M_t and D_t be the share of the married and divorced persons respectively at age t[13]. Then the probability of getting married at age t, π_t^m, and the

[11]Available at `http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database`.

[12]Figure 3.17 in appendix shows the number of divorces per 1000 marriages for 3 countries – US, Italy and Netherlands over a span of 10 (in case of US) to 20 (in case of Netherlands and Italy) years. It shows that even though the number of divorces have been increasing in Italy and decreasing in the US, these changes over time were rather slow and small compared to the differences in levels.

[13]Figure 3.18 in appendix shows the share of married women in the countries in our sample.

probability of getting divorced at age t, π_t^d, is pinned down by:

$$M_{t+1} = (1 - M_t)\pi_t^m + M_t(1 - \pi_t^d) \quad (3.17)$$

$$D_{t+1} = D_t(1 - \pi_t^m) + M_t\pi_t^d \quad (3.18)$$

We smooth the resulting age-profiles for π_t^m and π_t^d by fitting a polynomial. Figure 3.7 shows the resulting probability profiles for the US, Germany and Italy[14].

Figure 3.7: Age-Dependent Probabilities of Marriage and Divorce

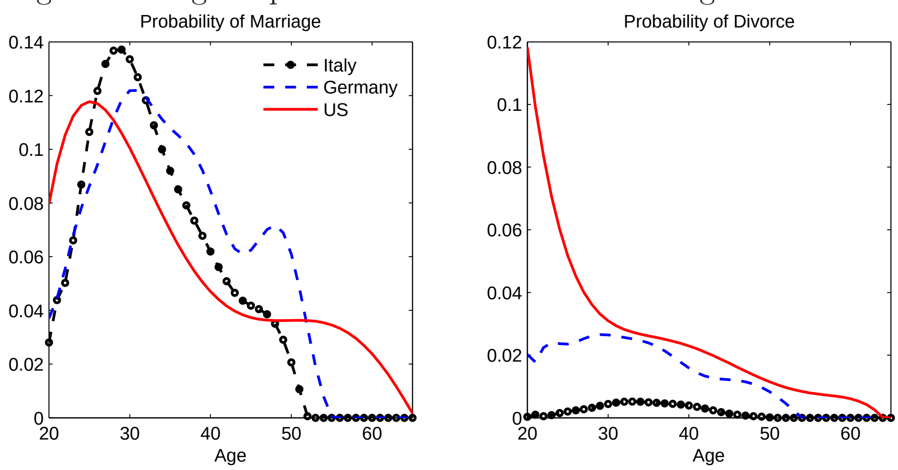


Figure 3.7 shows that the probability of getting divorced is noticeably higher in the US than Italy, and somewhat higher than in Germany. At the same time, the probability of getting married reaches its peak in the US somewhat earlier compared to the two European countries[15].

Fixed Cost of Working and Income if Not Working

The data moments for the fixed cost of working for men and women are the male and female employment rates in 2000, taken from the OECD. As an approximation for income when not working, we take the value of non-housing consumption of

[14]Countries like Spain, Ireland, Greece and Portugal have marriage and divorce probabilities similar to Italy, and countries like Netherlands and Belgium are similar in this respect to Germany.

[15]The computed probabilities use the data for women. We get a qualitatively similar picture when using the data for both men and women (with the exception that men in all countries tend to get married somewhat later than women).

Table 3.9: Calibration Fit

Moment	Data	Model
Mean wage of high school educated males	0.396	0.396
Mean wage of college educated males	0.594	0.594
Mean wage of high school educated females	0.255	0.255
Mean wage of college educated females	0.372	0.372
Mean assets	1.200	1.198
Male employment rate	0.841	0.841
Female employment rate	0.699	0.700

households with income less than $5000 per year from the 2000-2001 Consumer Expenditure Survey. The sources of such income would be unemployment benefits, social aid, gifts from relatives and charities etc.

Estimation Method

7 model parameters are calibrated using an exactly identified simulated method of moments approach. We minimize the squared percentage deviation of simulated model statistics from the 7 data moments in Table 3. Let $\Theta = \{\gamma_{0hsm}, \gamma_{0cm}, \gamma_{0hsf}, \gamma_{0cf}, \beta, F_m, F_f\}$ and let $V(\Theta) = (V_1(\Theta), \ldots, V_7(\Theta))'$ denote the vector where $V_i(\Theta) = (\bar{m} - \hat{m}(\Theta))/m$ is the percentage difference between empirical moments and simulated moments. Then:

$$\hat{V} = \min_{\Theta} V(\Theta)'V(\Theta) \tag{3.19}$$

Table3.8 summarizes the estimated parameter values. As can be seen from Table 3.9, we get close to match all the moments exactly.

3.7 Counterfactual Experiments

In Section 3.3, we have documented a correlation between labor supply and tax levels and labor supply and divorce rates across countries and across time. This motivates the study, in this section, of the quantitative impact of cross country differences in tax schemes and divorce rates on labor supply. When we perform the policy experiments, we keep taxes, old age social security, and income when not working as functions of average earnings in the economy. In this way if the society becomes richer or poorer because of a counterfactual experiment, taxes and social security payments will adjust accordingly. Since there is no public good in the model, we do not keep a balanced government budget and excess tax revenues are assumed to finance bureaucracy.

The Effect of Marriage and Divorce Probabilities on Labor Supply

In this subsection, we use our model that we described in Section 3.5, and calibrated to match the US economy in Section 3.6, to study the impact of marriage and divorce probabilities on labor supply. We do this by imposing the marriage and divorce probabilities that we computed for each of the European countries in our sample on the model. Figure 3.8 shows how it affects hours worked[16]. We obtain a positive correlation between the model's predictions and the data (equal to 0.467). As we expect, higher marriage stability reduces labor supply both in the model and in the data.

Ideally, if the model matched the data perfectly, all observations would be located somewhere on the diagonal line. The distance from the diagonal shows the discrepancy between the data and the model prediction.

Table 3.10 and figures 3.9 and 3.10 illustrate the impact on the employment rates for men and women. Unfortunately, we cannot perform the comparison by gender in terms of the hours worked because of the lack of the data. However, as we show in Section 3.3, marriage stability appears to affect mostly the extensive margin.

Figure 3.9 shows a rather high correlation (equal to 0.825) between our model's predictions and data for the individuals of both genders – higher marriage stability appears to reduce labor supply both in the model and in the data. Figure 3.10 shows

[16]Since we do not have the intensive margin in our model, we compute the predicted annual hours worked for all European countries in our sample as a product of employment rates predicted by our model and hours worked by employment persons in the data in the US.

Figure 3.8: The Impact of Marriage and Divorce Probabilities on Hours Worked, Both Genders

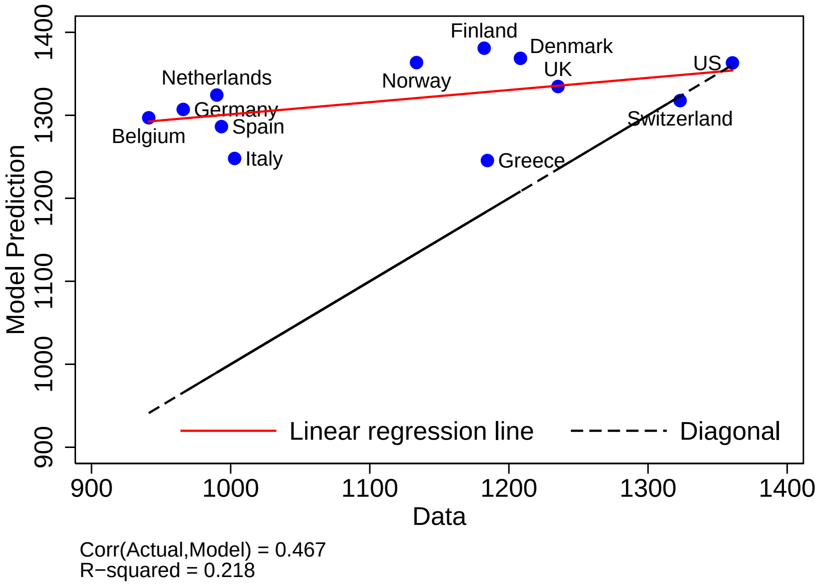
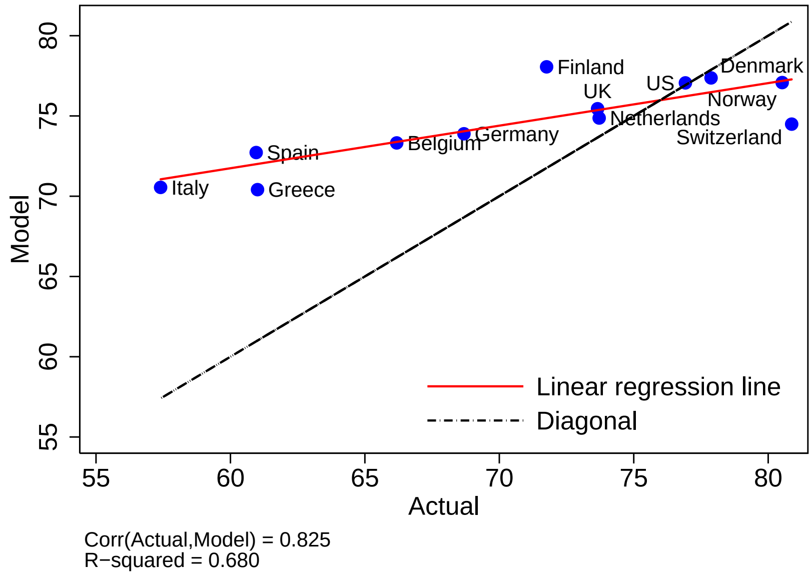


Table 3.10: The Impact of Marriage and Divorce Probabilities on Employment Rates

Country	Aggregate Employment Rates		Female Employment Rates		Male Employment Rates	
	Actual	Model	Actual	Model	Actual	Model
US	0.770	0.770	0.699	0.699	0.841	0.841
Greece	0.610	0.704	0.450	0.608	0.781	0.800
Italy	0.574	0.706	0.421	0.616	0.728	0.795
Spain	0.610	0.727	0.445	0.646	0.774	0.809
Belgium	0.662	0.733	0.564	0.649	0.759	0.817
Switzerland	0.809	0.745	0.715	0.669	0.903	0.821
Germany	0.687	0.739	0.610	0.659	0.762	0.819
Netherlands	0.737	0.749	0.637	0.668	0.835	0.829
UK	0.737	0.755	0.665	0.685	0.810	0.825
Norway	0.805	0.771	0.763	0.702	0.847	0.840
Denmark	0.779	0.774	0.733	0.703	0.823	0.844
Finland	0.718	0.781	0.684	0.720	0.751	0.841

that the correlation between the model predictions and the data is even higher for women (equal to 0.889). Figure 3.19 in appendix shows that the correlation between the model's predictions and the data is substantially worse for men (equal to 0.474). This is not surprising, as we expect the marriage stability mechanism to be able to better account for the behavior of women.

Figure 3.9: The Impact of Marriage and Divorce Probabilities on Employment Rates, Both Genders

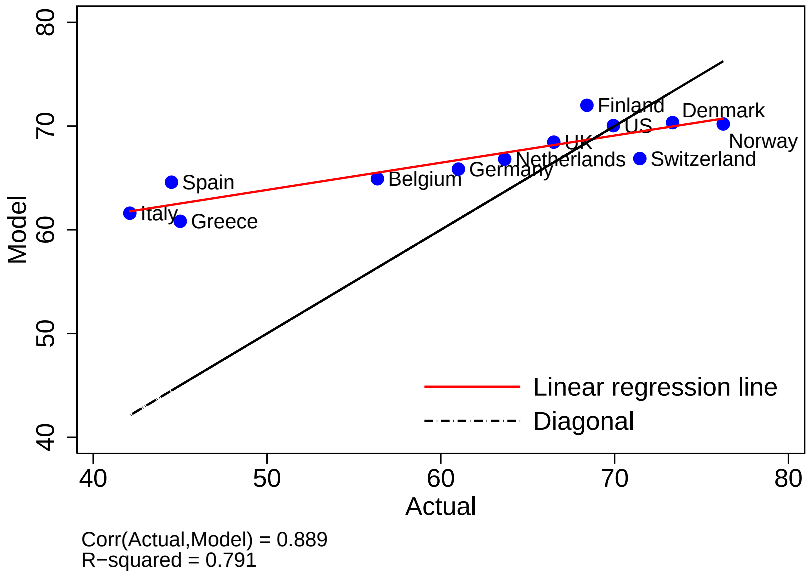


We conclude that the marriage stability mechanism works in the right direction in our model by reducing the labor supply in the countries with more stable marriages. As one would expect, this mechanism appears to be able to account better for the labor supply of women.

The Impact of Differences in Taxation on Labor Supply

Figure 3.20 compares the predictions of our model to the data when we assume that the divorce and marriage probabilities in all countries are the same as in the US, but replace the tax system in the model by the one computed for each country using the OECD data (as described in section 3.6), and furthermore assume that all the difference in tax revenues that result from the change of the tax system go to waistful

Figure 3.10: The Impact of Marriage and Divorce Probabilities on Employment Rates, Women



government spending. The figure shows that there is little impact on hours worked in our model in this case. We in fact obtain a negative correlation between our model's predictions and the data. Table 3.24 shows that one feature of the tax system that appears to be particularly important in our model is whether the married couples are taxed jointly or separately. In table 3.24, we see that our model predicts that labor supply is noticeably higher in the countries that practice separate taxation. Table 3.23 shows that this is primarily driven in the model by higher employment ratios of women.

Figure 3.21 shows that the predictions of our model improve when we assume that the additional tax revenues are redistributed to all the agents in the economy as a lump sum. This illustrates that the use of the tax revenues is crucial in our model for taxes to have a negative effect on labor supply.

The Combined Impact of Divorces and Taxation on Labor Supply

Figure 3.11 shows the impact of both the divorce and tax mechanisms combined in our model. When we include both mechanisms in the model, the correlation between the model's predictions and the data increase to 0.637, and we are able to explain 41% of the variation in hours worked in the data (as shown by the R^2).

On average, the experiment with changing only the divorce rates can account for 22% of the difference between the US and European countries in our sample, the experiment with changing only the tax system (and assuming redistribution of the additional tax revenues) can account for 19% of the difference, and in the experiment with both mechanisms included we account for 28% of the difference.

As can be seen from table 3.11, for Italy, Spain and Greece marriage stability appears to be a more important mechanism, while taxes is a relatively good predictor of labor supply in Germany, Belgium and Scandinavia. One interesting observation is that by a more careful modeling of the tax systems and introduction of the divorce mechanism we are able to resolve what Rogerson (2007) calls a puzzle, the fact that Scandinavian countries have among the highest taxes but still greater labor supply than a country like Germany. An important feature of the tax system in all Scandinavian countries (except Norway) is separate taxation of married couples. As was pointed out by Guner, Kaygusuz, and Ventura (2008), this can help explain higher labor supply in these countries. For Denmark and Finland, the average tax level mechanism cannot account for the higher labor supply in these countries compared with Germany, as average tax level is higher in Denmark and about the same in Finland. However, both of these countries have separate taxation of married couples.

We conclude that our counterfactual experiments suggest that both the divorce and the tax mechanisms are important for accounting for the differences in labor supply between the US and Europe. The significance of these two mechanisms appear to vary for different European countries. When combined, they on average allow us to account for 28% of the difference.

Figure 3.11: The Impact of Marriage and Divorce Probabilities on Hours Worked, Both Genders

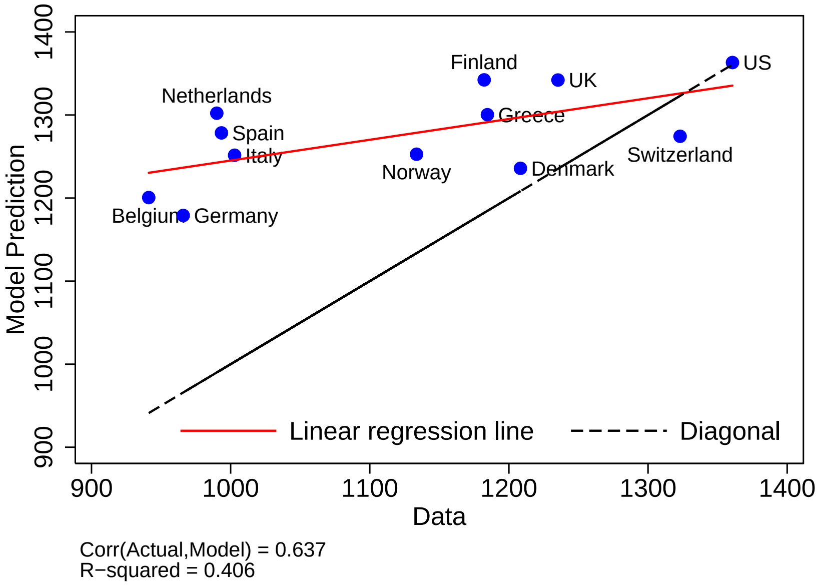


Table 3.11: Labor Supply, Taxation and Marriage and Divorce Rates

Country	Divorces	Taxation	Divorces and Taxation	Data
US	100.000	100.000	100.000	100.000
Greece	91.536	104.381	95.566	87.056
Italy	91.718	99.362	91.978	73.701
Spain	94.539	100.871	93.954	73.007
Belgium	95.319	91.562	88.234	69.167
Switzerland	96.840	99.869	93.655	97.234
Germany	96.060	88.782	86.648	70.987
Netherlands	97.334	97.685	95.696	72.762
UK	98.088	99.765	98.634	90.783
Norway	100.208	92.056	92.069	83.313
Denmark	100.585	89.287	90.821	88.802
Finland	101.482	97.282	98.647	86.886

The table shows hours worked (model predictions and data) as a percent of hours worked in the US.

3.8 Conclusion

In this paper we show that prime aged women is the largest contributor to differences in aggregate labor supply between the US and Europe. We document a negative cross-country correlation between tax levels and labor supply and a positive correlation between divorce rates and labor supply across time and place. The latter correlation is, however, driven by a strong correlation between female labor supply and divorce rates.

To quantify the impact of differences in tax schemes and divorce/marriage rates on labor supply, we develop a life-cycle, overlapping-generations model with heterogeneous agents, marriage, and divorce. We calibrate our model to US data and study how labor supply in the US change as we introduce European tax systems, and as we replace the US divorce and marriage rates with their European equivalents. Changing the US probabilities of marriage and divorce to their European counterparts on average accounts for 22% of the difference in hours worked between the US and the 11 European countries. When we also introduce European taxes and redistribute the increase in taxes evenly to all households, we can account for 28% of the difference in hours worked between the US and Europe.

3.9 Appendix

3.9.1 Fitting Tax Functions Based on Data from the OECD

For every country in Figure 3, we fit the below polynomial where an individuals average tax rate is a function of his earnings relative to the average earnings in the economy:

$$\tau(y) = \tau_0 + \tau_1 \left(\frac{y}{AE}\right)^{0.2} + \tau_2 \left(\frac{y}{AE}\right)^{0.4} + \tau_3 \left(\frac{y}{AE}\right)^{0.6} + \tau_4 \left(\frac{y}{AE}\right)^{0.8} \tag{3.20}$$

We use this functional form because it generally gives us a very good fit, R2, and because we get functions that are strictly increasing and well behaved on a relatively wide range of labor income. We use labor income tax data from the OECD Tax-Benefit Calculator[17] and the OECD Tax Database[18]. This data is constructed by the OECD based on tax laws from different countries. The OECD Tax-Benefit Calculator gives the gross- and net-, after taxes and benefits, labor income, by family type in 2001. For single individuals we can get tese data for every percentile of average labor income for a range between 50% and 200% of average labor income. For married couples, one spouse's earnings have to be fixed at either 0%, 67%, 100% or 167% of average labor income, while the other spouse's earnings can take any whole percent value between 50% and 200% of average labor income. For countries that practice joint taxation of married couples, we fit different polynomials for married and single. We use the data for single and married individuals without children. For married individuals, we let the couples be as symmetric as possible. In the US this is inconsequential, since the tax system is completely symmetric, i.e. it does not matter who makes the income. The OECD Tax Database provides the top marginal tax rate in each country and the starting point for this tax rate for single individuals. To get

[17]Available at: www.oecd.org/document/18/0,3343,en_2649_34637_39717906_1_1_1_1,00.html.

[18]Available at: www.oecd.org/document/60/0,3343,en_2649_34533_1942460_1_1_1_1,00&&en-USS_01DBC.html.

the tax at earnings above 200% of average labor income, we use this information. For many countries the top marginal tax rate kicks in before 200% of average labor income but in the US, for instance, the top marginal tax rate starts at about 9 times average earnings. We then assume that the marginal tax rate increases linearly between 2 times average earnings and the point where the top marginal tax rate becomes effective. For countries that practice joint taxation of married couples, we assume that the top marginal tax rate for married starts at twice the level for singles.

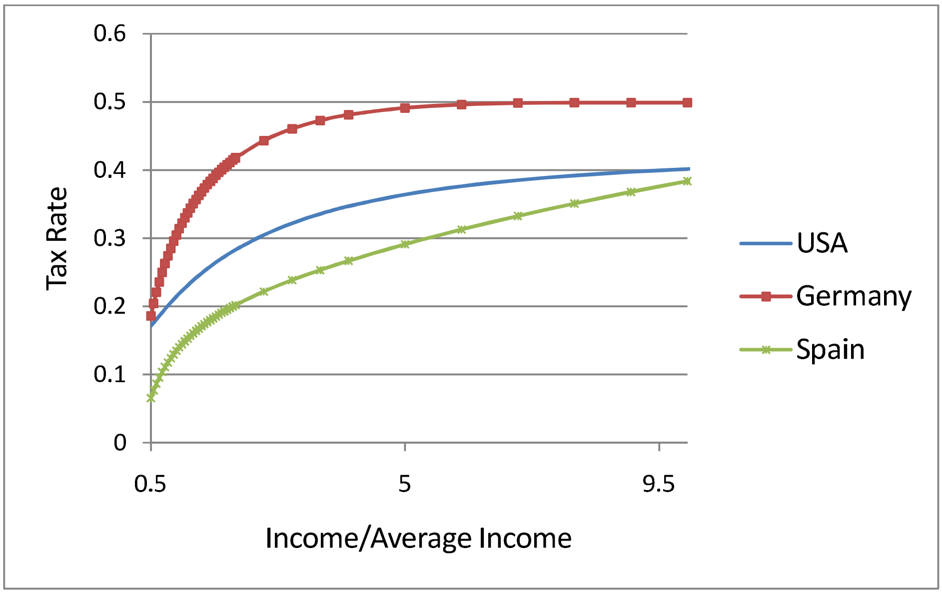
Table 3.12: Country Tax Functions for Married Couples

Country	τ_0	τ_1	τ_2	τ_3	τ_4	R^2
France	-0.4677592	2.062677	-2.743411	1.820481	-0.4305004	0.9989
Germany	-0.5409343	-0.9886915	4.474231	-3.421762	0.7909097	0.9962
Ireland	1.612143	-6.871639	9.391285	-4.898055	0.8901651	0.9940
Norway	-5.335858	14.96881	-15.43612	7.362051	-1.335945	0.9981
Portugal	3.907341	-12.23614	13.88106	-6.514196	1.101643	0.9995
Spain	-2.811092	8.034616	-8.401096	4.023208	-0.7058137	0.9959
Switzerland	-16.09581	48.2164	-53.35435	26.20165	-4.78368	0.9950
USA	2.16239	-7.301506	9.221961	-4.736035	0.8718943	0.9949

Table 3.13: Country Tax Functions for Singles

Country	τ_0	τ_1	τ_2	τ_3	τ_4	R^2
Austria	-5.626168	16.19854	-16.39948	7.397988	-1.250442	0.9937
Belgium	-4.587984	13.62661	-14.19084	6.823648	-1.24974	0.9959
Denmark	0.1422833	-2.357568	5.737164	-3.968169	0.8855884	0.9940
Finland	-1.387284	2.706099	-0.9767094	-0.0860593	0.0717587	0.9987
France	0.7157418	-2.514716	3.64648	-1.88936	0.3320441	0.9980
Germany	-6.582745	19.08046	-19.22463	8.580912	-1.430125	0.9964
Greece	-5.55185	14.76655	-14.7313	6.887032	-1.237959	0.9909
Ireland	-1.75284	2.625375	0.1463597	-1.13193	0.3456357	0.9983
Italy	-1.555522	2.965259	-0.9916236	-0.3076185	0.1599916	0.9992
Netherlands	1.126893	-4.322011	6.331867	-3.487033	0 .6651015	0.9899
Norway	2.335783	-8.6315	11.83152	-6.471281	1.25354	0.9988
Portugal	2.604929	-9.655736	12.78917	-6.821912	1.293703	0.9994
Spain	-2.640157	7.853874	-8.641411	4.527437	-0.9025463	0.9979
Sweden	5.645098	-18.75109	23.36599	-12.24517	2.322895	0.9968
Switzerland	-1.4185	5.181097	-6.488006	3.771889	-0.8035895	0.9985
UK	-0.3775787	0.2900424	1.07663	-0.9579886	0.2236049	0.9953
USA	1.727408	-6.44973	8.994808	-4.999817	0.9875019	0.9969

Figure 3.12: Country Tax Functions (Married)



3.9.2 Computational Details

Computation of Optimal Policies

We put boundaries on the capital space and pick a 16 point grid in $K = [k^m in, k^m ax]$. Capital is the only continuous state variable. Let $J = \{hs, c\}$ be the state space for whether an individual is high school or college educated, $X = \{0, , 44\}$ be the state space for the number of years of labor market experience, and $T = \{20, , 95\}$ be the state space for age. The state space for working age married individuals is then: $T \times J \times J \times X \times X \times K$, for working age single individuals it is: $T \times J \times X \times K$, and for retired individuals, both married and single it is: $T \times K$. We compute the household's optimal policies for each state by iterating backwards. We start from age 95, the last period of life. In that period, the next period's value function is 0, and the optimal policy is to consume as much as possible. Knowing the value function at age 95, we can compute optimal policies and value functions for age 94, and so on. The labor supply decisions are discrete, and so we compare the different options. For each choice of labor, we must solve for the optimal level of next period's capital. We find the optimal choice of capital by "golden search". To interpolate next period's value function outside of the grid, we use cubic splines.

Simulation

We simulate an over lapping generations economy with 100 000 men and 100 000 women in each identical generation. Knowing today's state, the policy functions, and next period's marital status, we can find the next period's state. To determine next period's marital status, we draw a random number, $\nu \in (0, 1)$, for every single individual and every married couple in each time period. We use the age dependent probabilities for divorce and marriage to determine whether a single individual is going to marry or a couple is going to split. We only let the random number drawn by the single men determine if they are going to get married. Then to find them a partner, we sort single men- and women by their random number and find a partner for each man that is going to change status. We also make sure that the right number of men marries someone with the same level of education.

Partial Equilibrium

When we calibrate the model we must have equilibrium in the marriage market, in the sense that single individuals must have rational expectations about their potential partners in the next period. This expectation must be taken with respect to education, experience, and asset holdings, $Q^{jgt}(j_p, x_p^{'}, k_p^{'})$. Given his own education, an individual knows the likelihood of marrying someone whit high school and college education in the next period. We keep track of the distribution of single individuals in each education group with respect to capital and experience at every age. We start out with an educated guess and then solve the model iteratively until we reach a fixed point.

When we perform the policy experiments we must also solve for a fixed point in terms of the average earnings in the economy because the tax functions, the social security payments, and the value of not working are kept as functions of average earnings. Finally when redistributing the increase in tax revenues, we must solve for a fixed point in terms of the lump sum redistribution.

3.9.3 Proof of Proposition 3.4.1

Given the choice of the utility function, one can solve for $h_{2,f}$ and $h^s_{2,f}$ in terms of $h_{1,f}$ from equations 3.6 and 3.7, and after plugging these solutions into 3.8, obtain that the dependence of $h_{1,f}$ on π_d is implicitly defined by:

$$\begin{aligned} & G(h_{1,f}, \pi_d) \\ = & \frac{\alpha w_{1,f}}{w_{1,m} + w_{1,f} h_{1,f}} - \frac{1-\alpha}{1-h_{1,f}} + \pi_d \left(\frac{\alpha k_f}{w_{1,f} + k_f h_{1,f}} \right) \\ & +(1-\pi_d) \left(\frac{k_f}{w_{1,f} + k_f h_{1,f} + w_{1,m} + k_m} \left(\alpha + (\alpha - 1) \left(\frac{w_{1,m} + k_m}{w_{1,f} + k_f h_{1,f}} \right) \right) \right) \\ = & 0 \end{aligned} \tag{3.21}$$

Using the implicit function theorem, one can show that:

$$\begin{aligned} \text{sign}\left(\frac{\partial h_{1,f}}{\partial \pi_d}\right) &= \text{sign}\left(\frac{\partial G}{\partial \pi_d}\right) \\ &= \text{sign}\left(\frac{\alpha}{w_{1,f} + k_f h_{1,f}} - \frac{1}{w_{1,f} + k_f h_{1,f} + w_{1,m} + k_m} \left(\alpha + (\alpha - 1) \left(\frac{w_{1,m} + k_m}{w_{1,f} + k_f h_{1,f}} \right) \right) \right) \end{aligned} \tag{3.22}$$

Since $\frac{w_{1,f}+k_f h_{1,f}+w_{1,m}+k_m}{w_{1,f}+k_f h_{1,f}} > 1 > 1 + \frac{\alpha-1}{\alpha} \left(\frac{w_{1,m}+k_m}{w_{1,f}+k_f h_{1,f}} \right)$, we get $\frac{\partial h_{1,f}}{\partial \pi_d} > 0$.

An increase in woman's labor supply in period 1 leads to accumulation of experience, and thus higher wages in period 2. On one hand, this gives both the married and the single woman an incentive to increase labor supply in period 2 through the substitution effect. However, there is also potentially an offsetting income effect. Intuitively, the income effect will be stronger for the divorced woman who does not have access to her spouse's income (and thus, its is more likely that the married woman will increase her labor supply in period 2). Given the utility function we have assumed in this section, we get $h^s_{2,f} = \alpha$ and $h_{2,f} = \frac{\alpha(w_{1,f}+k_f h_{1,f}+w_{1,m}+k_m)-(w_{1,m}+k_m)}{w_{1,f}+k_f h_{1,f}}$, so that $\frac{\partial h^s_{2,f}}{\partial \pi_d} = 0$ and $\frac{\partial h_{2,f}}{\partial \pi_d} = \frac{\partial h_{2,f}}{\partial h_{1,f}} \frac{\partial h_{1,f}}{\partial \pi_d} = \frac{k_f(w_{1,m}+k_m)(1-\alpha)}{(w_{1,f}+k_f h_{1,f})^2} \frac{\partial h_{1,f}}{\partial \pi_d} > 0$

■

3.9.4 Figures and Tables

Figure 3.13: Share of Persons With Children Younger Than 3 Years Old, by Age Group

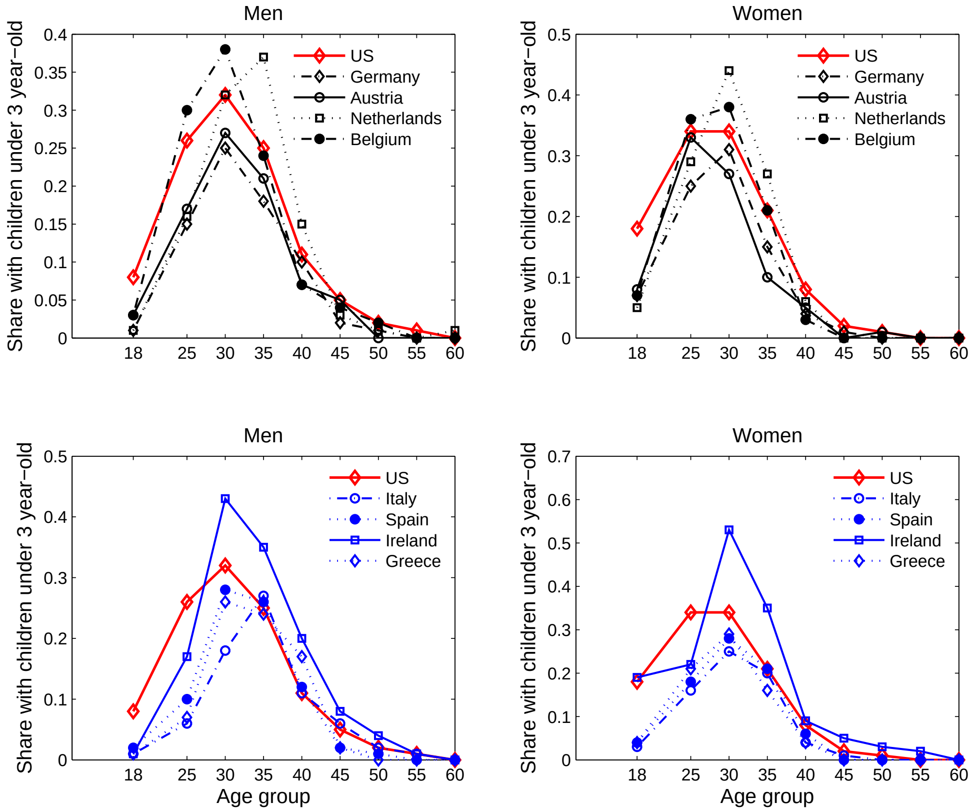


Figure 3.14: Relationship Between Tax Measures and Employment Ratios for Women

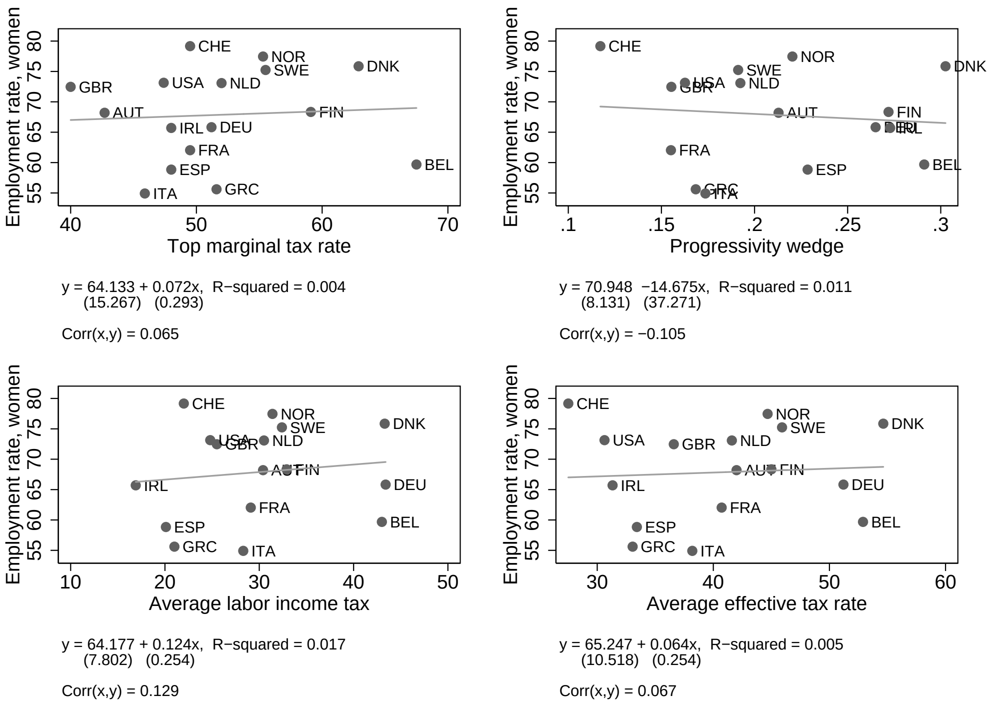


Figure 3.15: Relationship Between Tax Measures and Employment Ratios for Men

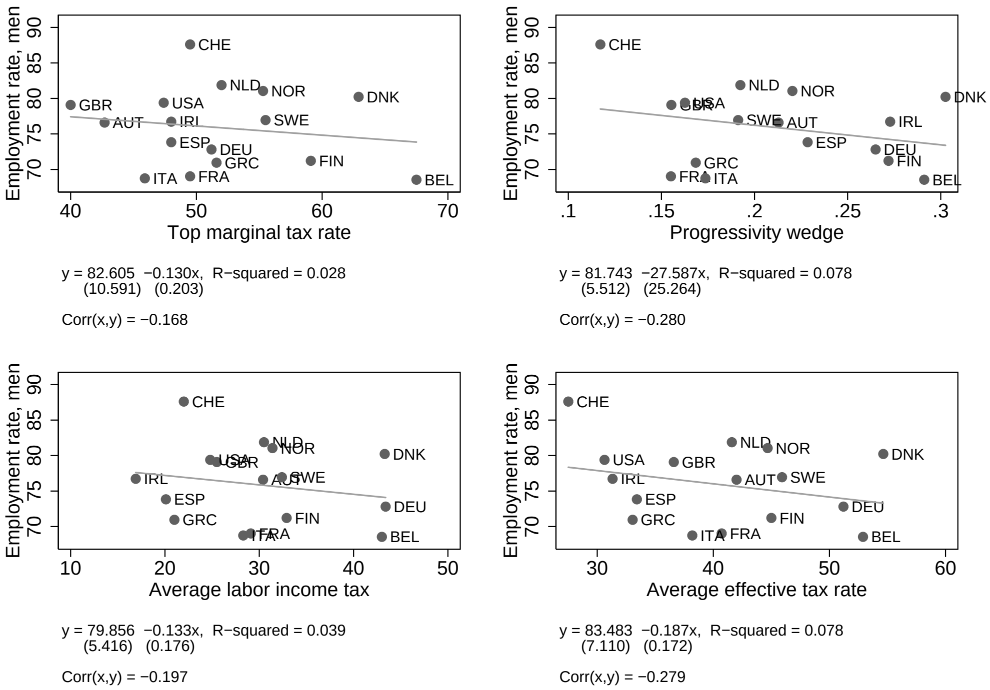
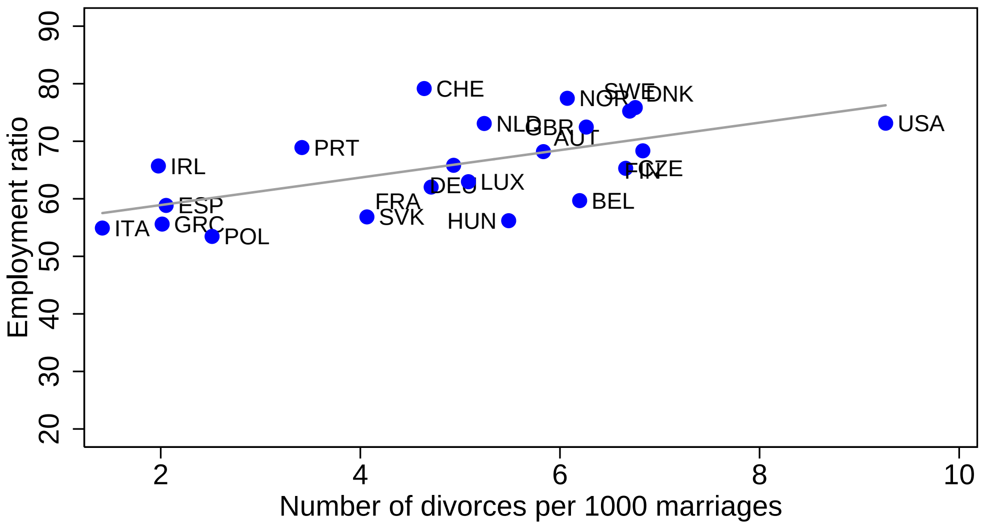


Figure 3.16: Relationship Between Divorce Rates and Employment Ratios for Both Genders



y = 54.144 + 2.387x, adj. R−squared = 0.330
(3.752) (0.709)

Corr(x,y) = 0.601

Figure 3.17: Trends in the Number of Divorces Over Time

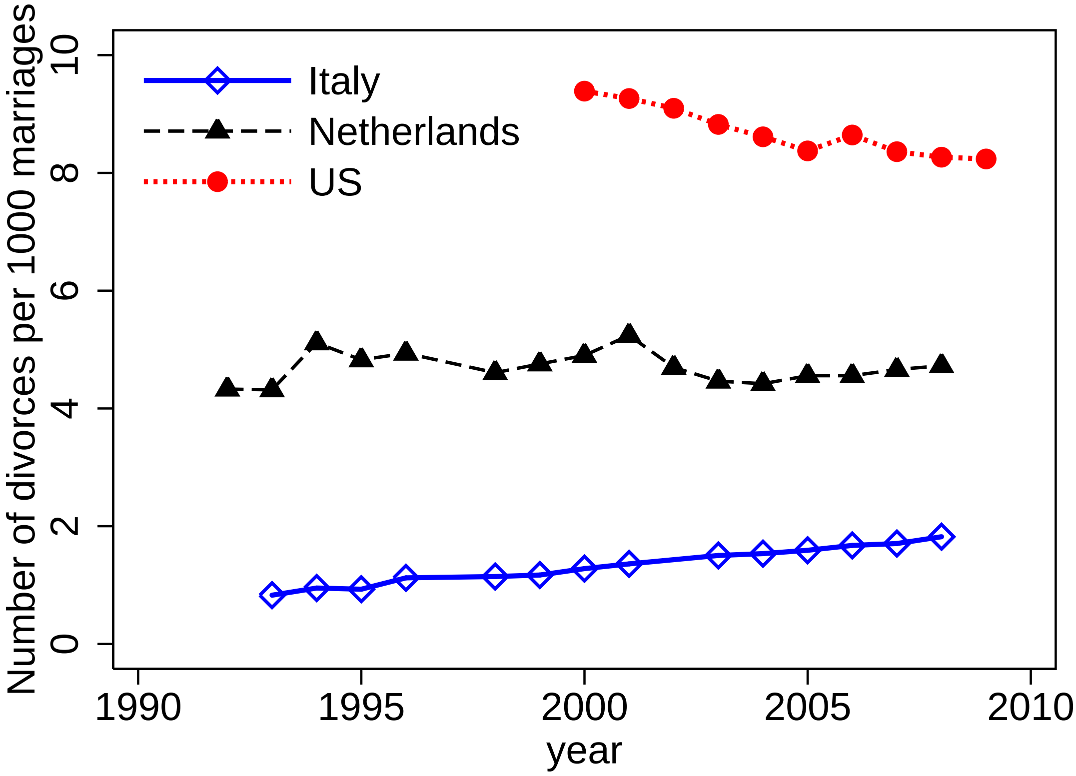


Table 3.14: Annual Hours Worked, by Age Group, LIS 2000

Country	15-20 yr	% of US	21-55 yr	% of US	56-64 yr	% of US
US	363.70	100.0	1600.89	100.0	1077.54	100.0
Germany	310.46	85.4	1154.65	72.1	582.38	54.0
Italy	102.50	28.2	1232.94	77.0	505.38	46.9
Spain	167.36	46.0	1177.30	73.5	644.34	59.8
Ireland	336.59	92.5	1309.16	81.8	782.43	72.6
Austria	571.16	157.0	1325.48	82.8	507.15	47.1
Belgium	90.54	24.9	1132.67	70.8	320.16	29.7
Netherlands	352.51	96.9	1152.01	72.0	446.21	41.4
Greece	173.91	47.8	1422.52	88.9	698.62	64.8

Figure 3.18: Share of Married and Divorced Women at Different Ages

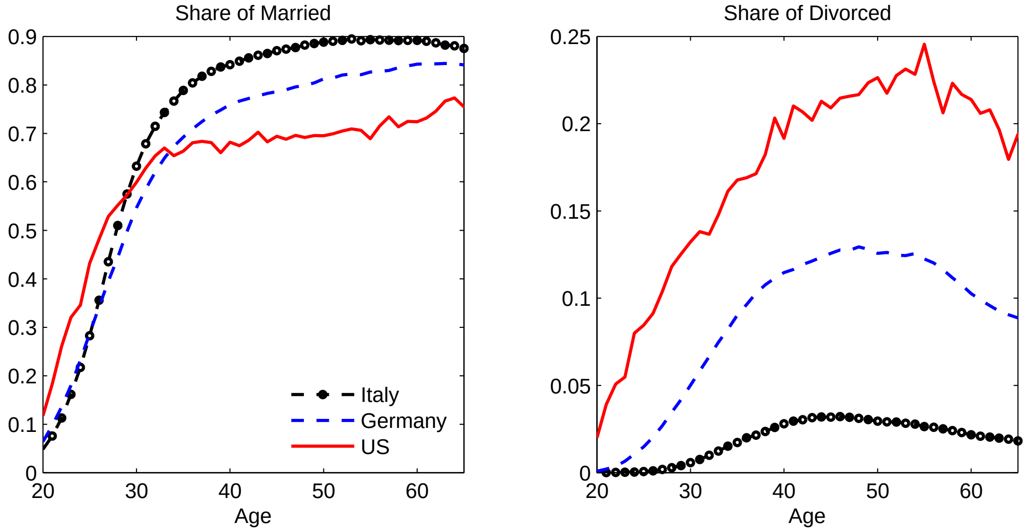


Table 3.15: Annual Hours Worked, by Age Group and Sex, LIS 2000

Country	Men						Women					
	15-20 yr	% of US	21-55 yr	% of US	56-64 yr	% of US	15-20 yr	% of US	21-55 yr	% of US	56-64 yr	% of US
US	380.80	100.0	1865.56	100.0	1309.24	100.0	345.88	100.0	1349.64	100.0	874.74	100.0
Germany	333.71	87.6	1464.09	78.5	779.80	59.6	287.22	83.0	857.98	63.6	395.93	45.3
Italy	130.80	34.3	1645.44	88.2	782.11	59.7	72.63	21.0	827.07	61.3	239.35	27.4
Spain	243.36	63.9	1587.55	85.1	992.96	75.8	85.96	24.9	768.40	56.9	321.42	36.7
Ireland	432.49	113.6	1761.80	94.4	1274.16	97.3	230.79	66.7	865.56	64.1	283.31	32.4
Austria	696.83	183.0	1649.07	88.4	725.37	55.4	452.59	130.9	1004.45	74.4	296.82	33.9
Belgium	155.56	40.9	1426.76	76.5	498.50	38.1	19.62	5.7	868.73	64.4	156.29	17.9
Netherlands	337.53	88.6	1530.10	82.0	679.06	51.9	366.06	105.8	788.86	58.4	225.45	25.8
Greece	261.82	68.8	1948.03	104.4	1169.27	89.3	101.26	29.3	931.88	69.0	277.77	31.8

Table 3.16: Annual Hours Worked, With and Without Children, LIS 2000

Country	Men						Women					
	child 3	% of US	child 6	% of US	no children	% of US	child 3	% of US	child 6	% of US	no children	% of US
US	2096.01	100.0	2093.84	100.0	1502.11	100.0	946.43	100.0	1021.13	100.0	1197.06	100.0
Germany	1604.33	76.5	1585.37	75.7	1170.99	78.0	196.58	20.8	304.35	29.8	786.22	65.7
Italy	2027.87	96.7	1976.34	94.4	1257.59	83.7	757.66	80.1	744.57	72.9	645.82	54.0
Spain	1883.10	89.8	1871.86	89.4	1273.15	84.8	676.93	71.5	642.64	62.9	631.69	52.8
Ireland	2045.85	97.6	2063.94	98.6	1390.88	92.6	680.39	71.9	639.05	62.6	740.95	61.9
Austria	1725.81	82.3	1751.53	83.7	1370.35	91.2	434.21	45.9	543.47	53.2	895.71	74.8
Belgium	1525.43	72.8	1540.27	73.6	1118.88	74.5	852.11	90.0	856.72	83.9	678.38	56.7
Netherlands	1668.32	79.6	1681.76	80.3	1232.26	82.0	583.29	61.6	568.38	55.7	702.31	58.7
Greece	2195.55	104.7	2218.34	105.9	1582.30	105.3	899.60	95.1	883.38	86.5	716.79	59.9

Table 3.17: Contribution of Different Demographic Groups to the Difference in Average Hours Worked Between the US and Europe

Germany

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.391	0.507	0.171	0.743
21-55:	25.379	10.538	33.299	14.594
56-64:	6.053	1.074	4.465	2.787
Total:	43.941		56.058	

Austria

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.422	-9.176	-0.720	-2.356
21-55:	27.700	3.199	34.182	20.023
56-64:	12.037	0.308	8.663	5.719
Total:	34.488		65.511	

Belgium

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	-0.103	3.025	0.362	4.172
21-55:	26.239	8.854	22.143	16.891
56-64:	7.473	1.789	5.763	3.393
Total:	47.276		52.723	

Netherlands

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.380	0.434	0.030	-0.379
21-55:	23.357	6.533	36.989	14.941
56-64:	6.649	1.690	6.215	3.160
Total:	39.043		60.956	

Table 3.18: Contribution of Different Demographic Groups to the Difference in Average Hours Worked Between the US and Europe, continued

Greece

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.760	3.320	0.698	7.129
21-55:	-6.865	-3.162	45.841	29.511
56-64:	4.366	0.271	10.115	8.016
Total:	-1.309		101.309	

Ireland

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.590	-1.744	0.648	2.452
21-55:	4.882	7.890	44.842	26.557
56-64:	-0.173	0.511	8.148	5.397
Total:	11.956		88.043	

Spain

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	-0.036	2.149	0.346	3.894
21-55:	12.859	12.912	33.838	21.756
56-64:	3.853	0.699	5.518	2.211
Total:	32.436		67.563	

Italy

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.407	4.092	0.395	4.285
21-55:	11.360	10.105	32.058	19.440
56-64:	6.371	1.376	5.980	4.132
Total:	33.710		66.289	

Table 3.19: Tax-Related Measures by Country (2001)

Country	Max marginal rate	Earnings level where the max marginal rate becomes effective	Consumption tax	Average labor income tax rate paid by the average worker
Austria	42.7%	2.2*AE	20.0	32.0%
Belgium	67.5%	1.2*AE	21.0	42.2%
Denmark	62.9%	1.0*AE	25.0	43.9%
Finland	59.1%	2.1*AE	22.0	32.8%
France	49.5%	1.8*AE	19.6	29.0%
Germany	51.2%	1.5*AE	16.0	42.4%
Greece	51.6%	3.8*AE	18.0	16.5%
Ireland	48.0%	1.1*AE	21.0	23.3%
Italy	45.9%	3.7*AE	20.0	27.0%
Netherlands	52.0%	1.4*AE	19.0	31.5%
Norway	55.3%	2.4*AE	24.0	31.8%
Portugal	46.6%	4.9*AE	17.0	21.3%
Spain	48.0%	4.2*AE	16.0	19.7%
Sweden	55.5%	1.5*AE	25.0	33.8%
Switzerland	49.5%	3.9*AE	7.6	23.8%
UK	40.0%	1.3*AE	17.5	25.5%
USA	47.4%	9.0*AE	8.4	26.0%

Table 3.20: Sample Compositions

United States

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.001	0.067	0.003	0.063
21-55:	0.215	0.151	0.234	0.151
56-64:	0.041	0.012	0.039	0.022

Germany

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.049	0.000	0.049
21-55:	0.195	0.156	0.219	0.146
56-64:	0.070	0.020	0.067	0.029
Total contribution of compositional effects = 2.798%				

Spain

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.057	0.001	0.053
21-55:	0.224	0.153	0.239	0.139
56-64:	0.056	0.008	0.055	0.015
Total contribution of compositional effects = -4.692%				

Italy

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.052	0.001	0.049
21-55:	0.219	0.149	0.248	0.125
56-64:	0.068	0.009	0.061	0.019
Total contribution of compositional effects = -2.597%				

Austria

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.001	0.043	0.001	0.045
21-55:	0.208	0.169	0.231	0.149
56-64:	0.063	0.012	0.050	0.028
Total contribution of compositional effects = -1.030%				

Table 3.21: Sample Compositions, continued

Belgium

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.039	0.000	0.036
21-55:	0.242	0.129	0.264	0.150
56-64:	0.054	0.014	0.053	0.020
Total contribution of compositional effects = -8.717%				

Greece

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.040	0.001	0.048
21-55:	0.227	0.129	0.269	0.112
56-64:	0.078	0.005	0.075	0.017
Total contribution of compositional effects = -7.176%				

Ireland

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.071	0.000	0.064
21-55:	0.211	0.160	0.223	0.156
56-64:	0.042	0.015	0.043	0.014
Total contribution of compositional effects = -2.310%				

Netherlands

	Men		Women	
Age:	Married	Single	Married	Single
15-20:	0.000	0.038	0.001	0.041
21-55:	0.223	0.160	0.251	0.147
56-64:	0.053	0.014	0.052	0.019
Total contribution of compositional effects = -6.174%				

Figure 3.19: The Impact of Marriage and Divorce Probabilities on Employment Rates, Men

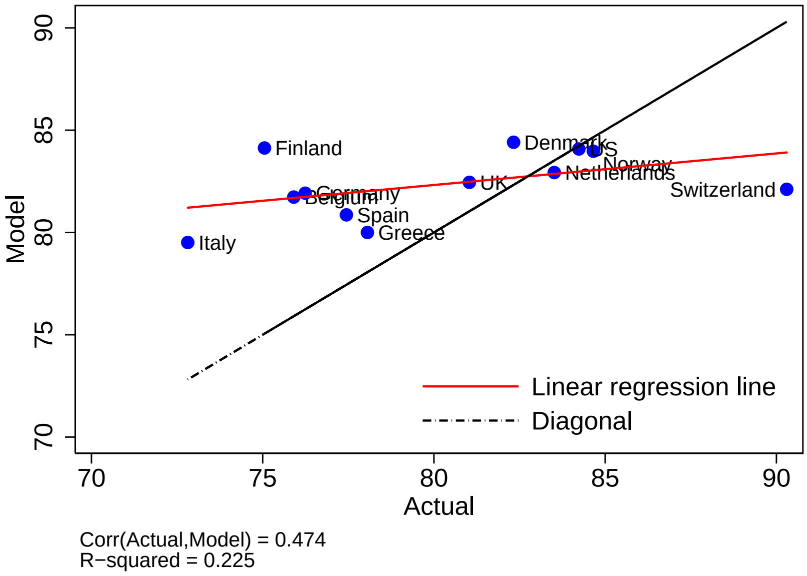


Table 3.22: The Impact of Taxation (Without Redistributiion) on Hours Worked

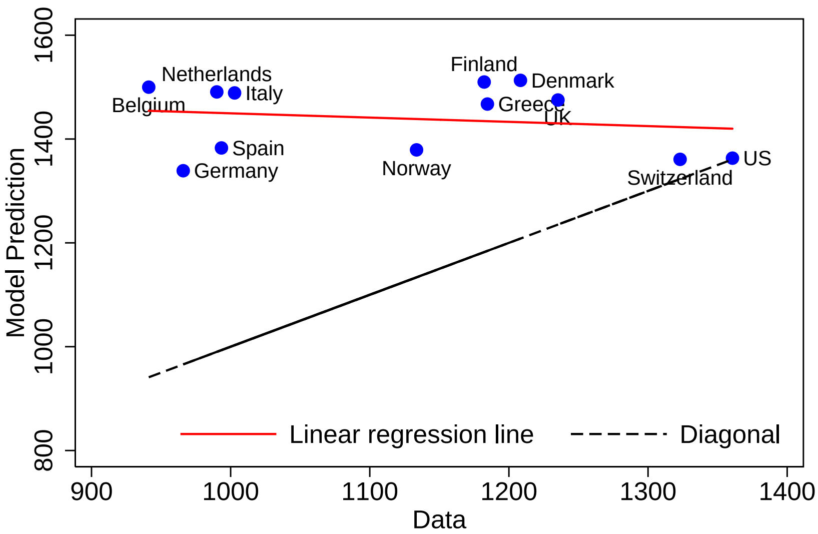
Country	Aggregate Employment Rates	
	Actual	Model
Countries with joint taxation of married couples:		
US	100.000	100.000
Germany	70.987	98.400
Norway	83.313	101.351
Spain	73.007	101.625
Switzerland	97.234	100.012
Countries with separate taxation of married couples:		
Greece	87.056	107.839
Italy	73.701	109.412
Belgium	69.167	110.231
Netherlands	72.762	109.555
UK	90.783	108.411
Denmark	88.802	111.193
Finland	86.886	110.959

The table shows hours worked (model predictions and data) as percent of the hours worked in the US

Table 3.23: The Impact of Taxation (Without Redistribution) on Employment Rates

Country	Aggregate Employment Rates		Female Employment Rates		Male Employment Rates	
	Actual	Model	Actual	Model	Actual	Model
Countries with joint taxation of married couples:						
US	0.771	0.771	0.699	0.700	0.841	0.841
Germany	0.687	0.757	0.610	0.693	0.762	0.821
Norway	0.805	0.780	0.763	0.710	0.847	0.850
Spain	0.610	0.782	0.445	0.716	0.774	0.857
Switzerland	0.809	0.769	0.715	0.699	0.903	0.840
Countries with separate taxation of married couples:						
Greece	0.610	0.830	0.450	0.779	0.781	0.880
Italy	0.574	0.842	0.421	0.800	0.728	0.883
Belgium	0.662	0.848	0.564	0.809	0.759	0.887
Netherlands	0.737	0.843	0.637	0.800	0.835	0.885
UK	0.737	0.834	0.665	0.783	0.810	0.885
Denmark	0.779	0.855	0.733	0.823	0.823	0.888
Finland	0.718	0.854	0.684	0.816	0.751	0.891

Figure 3.20: The Impact of Taxation Without Redistribution on Employment Rates, Both Genders



Corr(Actual,Model) = −0.176
R−squared = 0.031

Figure 3.21: The Impact of Taxation With Redistribution on Hours Worked, Both Genders

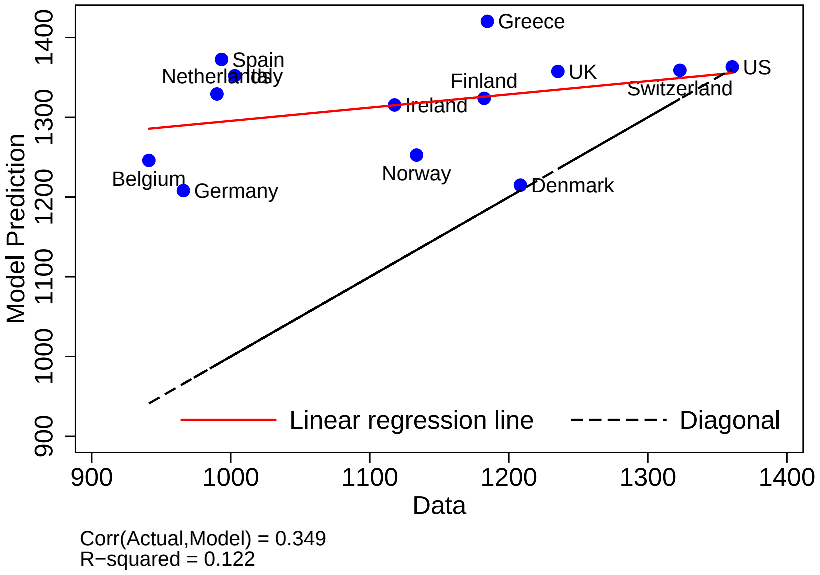


Table 3.24: The Impact of Taxation (With Redistributiion) on Hours Worked

Country	Aggregate Employment Rates		
	Actual	Model	
Countries with joint taxation of married couples:			
US	100.00	100.00	0.324
Germany	88.782	70.987	0.490
Norway	92.056	83.313	0.446
Spain	100.871	73.007	0.329
Switzerland	99.869	97.234	0.302
Countries with separate taxation of married couples:			
Greece	104.381	87.056	0.287
Italy	99.362	73.701	0.392
Belgium	91.562	69.167	0.551
Netherlands	97.685	72.762	0.445
UK	99.765	90.783	0.380
Denmark	89.287	88.802	0.585
Finland	97.282	86.886	0.476

The table shows hours worked (model predictions and data) as percent of the hours worked in the US

Table 3.25: Regressing Average Hours Worked on Divorce rate and Tax Measures (including joint versus separate taxation of married couples)

	(I)	(II)	(III)	(IV)
Const	1321.374***	1166.408***	1258.269***	1395.375***
	(217.377)	(142.989)	(86.756)	(115.362)
Divorce rate	27.097*	19.428	41.959***	36.638***
	(14.248)	(14.142)	(12.010)	(11.163)
Top marginal tax rate	−6.413	–	–	–
	(4.497)			
Progressivity wedge	–	−629.507	–	–
		(557.163)		
Average labor income tax	–	–	−1183.122***	–
			(334.931)	
Average effective tax rate	–	–	–	−1160.108***
				(318.644)
Separate Taxation	0.197	-0.002	16.046	32.918
	(59.042)	(61.365)	(45.244)	(45.770)
adjusted R^2	0.085	0.037	0.460	0.476

Standard errors are in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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