ABSTRACT

Title of dissertation: ESSAYS ON TRANSATLANTIC DIFFERENCES IN TAXATION, REDISTRIBUTION AND PROVISION OF PUBLIC GOODS

Orhan Torul, Doctor of Philosophy, 2013

Dissertation directed by: Professor Allan Drazen
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This dissertation investigates differences between the U.S. and Europe in the levels of taxation, redistribution, provision of public goods, and perception of fairness in income inequality. The first chapter concentrates on the differences between the U.S. and Scandinavia in higher education, and asks how it is possible that the U.S. has considerably more unequal higher educational attainment, higher reliance on private education and lower taxes than Nordic Europe, given similar political institutions. To address this question, I develop a parsimonious overlapping generations model in which agents can choose between public and private education. I first show that for a given tax rate difference of 7 percent, the model can deliver the observed educational Transatlantic differences, without having to rely on cross-country differences in preferences, parameters or other unorthodox elements. Next, I show the model can provide insight into how either the U.S. or the Nordic tax regimes could receive political consent. My explanation is due to the fact that per-capita output and other macroeconomic variables are U-shaped in taxes, both in the model

and in the cross-country data. The economic intuition behind this finding is that while at low tax rates an increase in taxes and public education provision dampen human capital accumulation due to marked drops in private education attainment, at high tax rates public education provision gets sufficiently large that a majority of the population prefers public over private education, and further increases in taxes boost public education attainment more than they reduce private one.

The second chapter incorporates the Transatlantic differences in perceptions into the picture and asks how the fact that a majority of Europeans believe income differences are primarily due to luck while a majority of Americans attribute such differences to the role of effort and skill reconciles with Transatlantic macroeconomic differences. I extend the model from the first chapter to include two sources of individual income differences: an inborn competence shock which affects labor supply choice and education decisions, and a luck shock on income, which is orthogonal to decision rules and inborn abilities. I find that low taxes coupled with low public education provision, as in the U.S. case, induce a large impact of inborn competence on schooling and labor supply, which in turn implies that a large share of the U.S. income differences are due to skill, education and effort. By contrast, a combination of high taxes and high public education, as in Europe, minimizes total income inequality and differences due to effort and inborn competence, and magnifies the impact of luck on inequality, in accordance with the existing beliefs. I also show that the U-shaped behavior of macro variables and welfare gains in taxes, as documented in the first chapter, carries over to this model, thereby providing insight into the political sustainability of macroeconomic variables and perceptions.

ESSAYS ON TRANSATLANTIC DIFFERENCES IN TAXATION, REDISTRIBUTION AND PROVISION OF PUBLIC GOODS

by

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Dedication

To my parents, Leyla and Oktay Torul

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I owe my gratitude to all the people who have made this thesis possible, because of whom my graduate experience has been one that I will cherish forever.

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List of Abbreviations

GDP	Gross Domestic Product
ISCED	International Standard Classification of Education
OECD	Organisation for Economic Co-operation and Development
OLG	Overlapping Generations
PPP	Purchasing Power Parity
RBC	Real Business Cycle
USD	United States Dollar
WVS	World Values Survey

Chapter 1

Higher Education in a Heterogeneous-Agent Economy: Revisiting the Transatlantic Differences

1.1 Introduction

Education plays a seminal role in a modern economy by serving as a fundamental determinant of economic growth and income inequality through the human capital channel.[1] While the importance of education is well-acknowledged, ideal and sustainable system-design for education, especially at the tertiary level and above has been a controversial subject among researchers.[2,3]

Lack of consensus on ideal higher education design is present among policy-makers, as well. Sources of financing and public versus private education choices are two of the most central and controversial issues, and countries show considerable degree of disparities in these dimensions. Figure 1.1 displays one of the major accounts on expenditure, average tuition fees for tertiary public education across most

[1] For a detailed literature review on the role of human capital in macroeconomics, see Romer (1986), Lucas (1988), Benabou (1996), and Glomm and Ravikumar (1992), among others.

[2] While there is a reasonable degree of consensus in the literature on some fundamentals, such as that public education alleviates income inequality in the long-run (Glomm and Ravikumar, 2003; Benabou, 2005) for example, differing results have been documented on other issues such as on the role of provision of public vs private education on output growth.) For instance, whereas Glomm and Ravikumar (2003) claim private education fuels output growth more than public education, many claim otherwise (Benabou, 2000, 2002, 2005; Zhang, 2005).

[3] Among others, Mankiw (1997) argues later stages of education contribute more to human capital accumulation (as it can be inferred from opportunity cost of schooling or college premium), and are more influential in determining the level of knowledge-based externalities. This chapter takes a similar stance, and concentrates on higher education, which displays more variation across countries compared to primary and secondary education.

of the OECD countries. Noticeably, the average tuition fee of the U.S. lies above the remaining developed countries, and the discrepancy is much more evident when the comparison is between the U.S. and the Northern European "welfare states" (Denmark, Finland, Iceland, Norway and Sweden), which have average tuition fees close to zero.

Figure 1.1: Average Public Tertiary Tuition Fee by Country

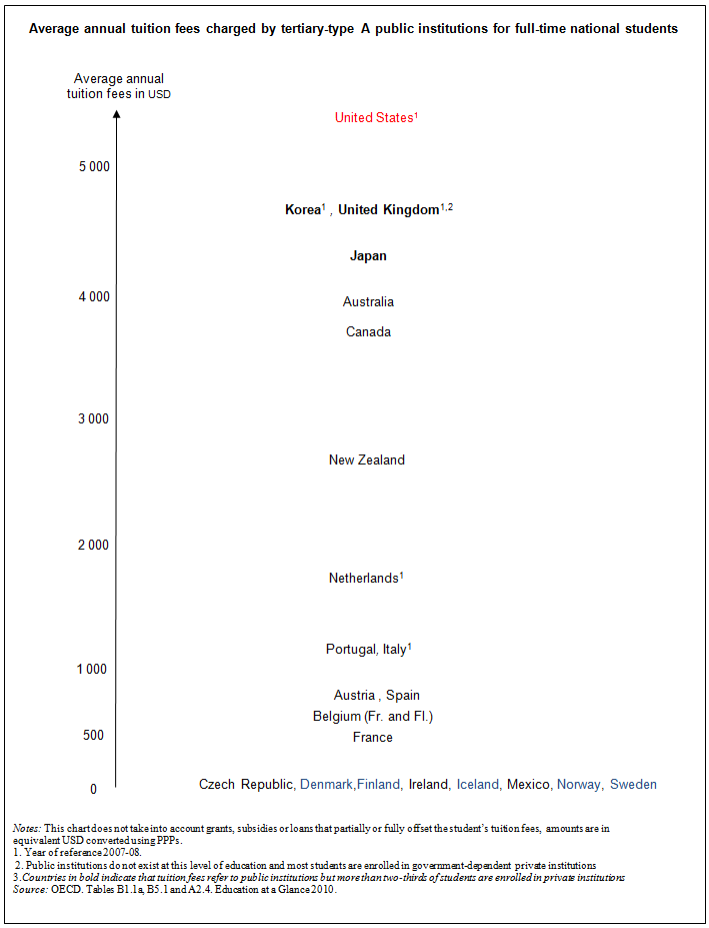


Figure 1.1 accounts only for the public institutions. In Table 1.1, I illustrate both public and private higher education expenditures, as well as some other educational indicators of the emphasized countries.

As shown in the first two columns, average tuition fee in the U.S. is not only

Table 1.1: Comparison of the U.S. & Scandinavian Tertiary Education Systems

	Average Public Institute Tuition[1]	Average Private Institute Tuition[1]	Average Tuition Net of Subsidies[1]	Average Tuition/ Per-capita Income	Ratio of Students in Public Education	Net Entry Rate in Higher Education	Ratio of Population with Higher Education[2]
Denmark	$0	N/A	-$217	-0.59%	98%	57%	34%
Finland	$0	$0	-$300	-0.87%	87%	71%	37%
Iceland	$0	$4,253	$851	2.26%	80%	73%	31%
Norway	$0	$5,427	$150	0.27%	88%	70%	36%
Sweden	$0	$0	-$239	-0.63%	93%	73%	32%
Nordic Average	$0	$2,420	$49	0.09%	89%	69%	34%
USA	$5,493	$21,979	$10,412	22.42%	67%	65%	41%

1. Fees are in equivalent USD converted using PPPs.
2. Among 25-64 year-old population.
Source: Education at a Glance 2010, OECD, and World Development Indicators database, 2010.

higher for public institutions but also for private institutions. Actually, it is possible to see that average private tuition for the Nordic countries is only one-tenth of that of the U.S. The fourth column in Table 1.1 shows that while no less than 89% of tertiary type-A students are enrolled in public institutions in Scandinavian countries, approximately two-thirds of students in the U.S. attend public type-A programmes.[4] Using these weights, as well as other data on scholarship opportunities, I derive average tuition fees net of subsidies and report the resultant numbers in the third and the fourth columns.[5] Macro data suggests that while average Scandinavian tuition fees are negligible relative to the per-capita income level, these fees amount to 22% of the U.S. per-capita income.[6] Also, as demonstrated in the 6th and 7th columns, net entry rates to higher education institutions and ratios of the population

[4]According to the OECD definition, tertiary-type A programmes (ISCED 5A) are largely theory-based and are designed to provide sufficient qualifications for entry to advanced research programmes and professions with high skill requirements, such as medicine, dentistry or architecture, and typically last four or more years.

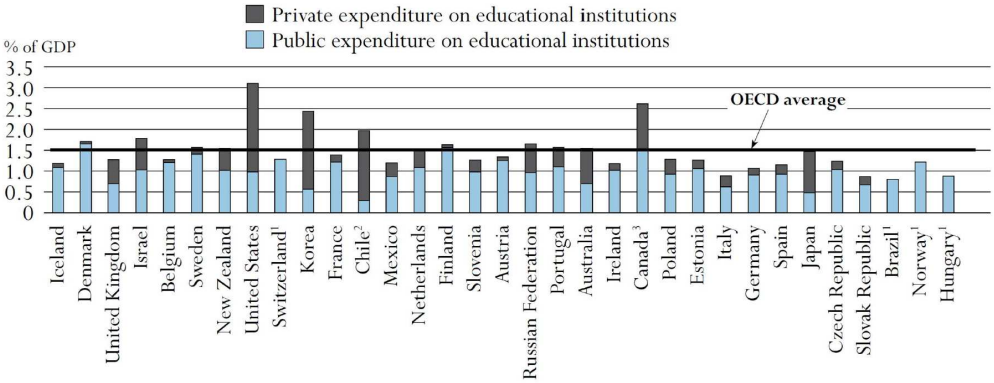
[5]Due to lack of some data including scholarship data for Norway, and average private tuition for Denmark, I estimate the average tuition fee in the most conservative way possible so as not to underestimate Nordic average tuition costs. Details of calculations are available upon request.

[6]One could suspect this discrepancy being as a result of implicit costs. Global Higher Education Rankings 2010 report Usher and Medow (2010) suggests that higher private education costs of the U.S. result holds even after controlling for all implicit costs, including cost of living, out-of-pocket expenses, tax-rate differentials, fellowship opportunities, etc.

holding higher education degrees are comparable among these countries.[7]

An alternative way to document the presence of structural disparities in higher education systems across countries is to analyze aggregate higher education expenditures and their composition. As illustrated in Figure 1.2, while the higher education expenditures as a share of GDP in the Scandinavian countries are only slightly above the OECD average, the U.S. has the noticeable largest higher education expenditure as a share of GDP.

Figure 1.2: Higher Education Expenditure by Country



1. Public expenditure only (for Switzerland, in tertiary education only).
2. Year of reference 2008.
3. Year of reference 2006.

Countries are ranked in descending order of expenditure from both public and private sources on educational institutions in primary, secondary and post-secondary non-tertiary education.

Source: OECD. Table B2.4. See Annex 3 for notes *(www.oecd.org/edu/eag2010)*.

I report the results of a deeper comparison of the higher education expenditures of the U.S. and the Nordic countries is in Table 1.2. The first column shows that the higher education expenditure per student in the U.S. is almost double that of the Nordic average, yet decomposing these expenditures reveals that public component

[7]Although population with higher education in the U.S. is slightly above that of the Nordic average, this result is mainly due to the inclusion of the older population: whereas the fraction of the older population (55-64) who hold a higher education degree in the U.S. is very close to that of the younger population (25-34), this is not the case for Scandinavia where the difference is higher in favor of the younger population. Accordingly, one could expect even closer participation rates in the medium-run.

of the higher education expenditure in the U.S. is still lower than that of Nordic countries, except for Iceland. Further, whereas the ratio of public higher education expenditure to total higher education expenditure is no less than 87.5% for the Scandinavian countries, this ratio is only about one-third for the U.S.

Table 1.2: Composition of the U.S. & Scandinavian Education Expenditures

	Higher Edu. Exp. per Student[1]	Public Exp. on Higher Edu./GDP	Private Exp. on Higher Edu./GDP	Public-to-Total Exp. on Higher Edu.	Public Exp. on Higher Edu. per Student[1]	Private Exp. on Higher Edu. per Student[1]
Denmark	$16,466	1.6%	0.1%	96.50%	$15,497	$969
Finland	$13,566	1.6%	0.1%	96.07%	$12,768	$798
Iceland	$6,721	1.1%	0.1%	91.01%	$6,161	$560
Norway	$17,754	1.2%	0.0%[2]	95.83%	$17,140	$614[2]
Sweden	$18,361	1.4%	0.2%	89.73%	$16,066	$2,295
Nordic Average	$14,451	1.4%	0.1%	93.90%	$13,526	$1,047
USA	$27,010	1.0%	2.1%	32.27%	$8,713	$18,297

1. Fees are in equivalent USD converted using PPPs.
2. Approximate value for Norway is calculated using OECD data and Docampo (2007).
Source: Education at a Glance 2010, OECD.

Finally, although there are no direct comparable measures of higher educational attainment by country, the literature on education uses international standardized tests conducted on population samples to infer educational dispersion. For instance, Blau and Kahn (2005) use OECD's International Adult Literacy Survey to show that there is a higher degree of variation in the test scores of the U.S. compared to those of the Scandinavian countries, as shown in Table 1.3. It is easy to notice that while the mean scores are not significantly different between the U.S. and the Nordic average, more disperse scores in both the right and the left end of the distributions are evident.

Additional anecdotal evidence supporting the presence of greater educational dispersion in the U.S. comes from Barry McGaw, (Director of Education for the OECD) who states in a speech that "...the very best schools in the U.S. are ex-

Table 1.3: Descriptive Statistics from the International Adult Literacy Survey

	Mean	Std. Dev.	Differential	
			50-10 Percentile	90-50 Percentile
Denmark	294.65	36.51	53.75	37.71
Finland	296.60	39.69	54.32	44.32
Norway	303.06	38.07	54.65	40.18
Sweden	310.07	44.73	54.53	51.48
Nordic Average	301.09	39.75	54.26	43.42
United States	289.27	60.61	76.84	59.16

Based on Blau and Kahn (2005).

traordinary ... but the big concern in the U.S. is the *diversity* of the quality of institutions..."(Fuller, 2005).

Another drastic Transatlantic difference is on taxation. The continental European countries, especially the Northern ones, are known to have considerably higher average income tax levels and more progressive tax systems than that of the United States. Although tax structures are highly sophisticated which makes cross-country comparison challenging, a simpler measure such as the taxes on income and profits as a percentage of GDP can be employed to show that Scandinavian governments levy significantly higher income taxes than the U.S. on average, as illustrated in Table 1.4. In addition, total tax revenues of the countries of interest also differ

Table 1.4: Tax Revenue from Incomes and Profits as a Share of GDP

	2005	2006	2007	2008	Average
Denmark[1]	31.16%	29.90%	29.36%	29.17%	29.90%
Finland	16.82%	16.69%	16.89%	16.82%	16.81%
Iceland	17.55%	18.28%	18.45%	17.83%	18.03%
Norway	21.43%	22.04%	21.09%	21.63%	21.55%
Sweden	19.12%	19.06%	18.35%	16.79%	18.33%
Nordic Average	21.22%	21.20%	20.83%	20.45%	20.92%
USA	12.65%	13.45%	13.61%	11.77%	12.87%

1. The total tax revenues have been reduced by the amount of any capital transfer that represents uncollected taxes. The capital transfer has been allocated.
Source: OECD Tax Database, 2010.

drastically, as shown in Table 1.5. While these governments use tax revenues for many purposes, at least some fraction of the tax pool is utilized in the financing of the provision of public education.[8]

Table 1.5: Total Tax Revenue as Share of GDP

	2005	2006	2007	2008	Average
Denmark[1]	50.83%	49.62%	48.98%	48.18%	49.40%
Finland	43.94%	43.84%	43.00%	43.13%	43.48%
Iceland	40.65%	41.49%	40.64%	36.79%	39.89%
Norway	43.52%	43.97%	43.82%	42.60%	43.48%
Sweden	48.87%	48.32%	47.36%	46.30%	47.71%
Nordic Average	45.65%	45.45%	44.76%	43.40%	44.79%
USA	27.10%	27.85%	27.86%	26.06%	27.22%

1. The total tax revenues have been reduced by the amount of any capital transfer that represents uncollected taxes. The capital transfer has been allocated.
Source: OECD Tax Database, 2010.

A final remark is that both the U.S. and the Nordic countries are well-established democracies with high performances in electoral processes and pluralism.[9] Therefore, it would be reasonable to expect that the different higher educational systems and tax policies receive considerable consent from the respective electorates.

The sources of and mechanisms for the coexistence of these two systems are not clear *a priori*. In particular, given that both the U.S. and Scandinavian countries are well-established democracies with comparable income levels, presence of the radical discrepancies in the composition of public versus private higher education choices deserves attention. This chapter intends to address the aforementioned differences with a two-fold agenda. First, using a general equilibrium model, I illustrate that tax differentials alone can explain the observed disparities, without having to

[8]For a detailed discussion on the taxation and redistribution of the countries of interest, see Alesina and Glaeser (2005).

[9]Among others, see The Economist Intelligence Unit's Index of Democracy 2007 and Freedom in the World: 2009 Edition.

rely on differences in preferences, variations in deep structural parameters or other unorthodox elements. While doing so, I use a heterogeneous-agent overlapping generations (OLG) model with both public and private education options available in the choice set of agents in the presence of positive externalities and distortionary taxes for public education financing. By calibrating the model to target countries' GDP (PPP) per capita and public-to-total-higher-education-expenditure ratios, I show that a reasonable tax rate difference of 7% can endogenously deliver a higher ratio of total higher education expenditure to GDP, higher hours worked, lower public school attendance ratios, and more unequal distributions of macro variables for the U.S. when compared to the Nordic countries. Next, by investigating welfare implications of different tax regimes, I show that either of the calibrated economies can gain political support from large measures of the population. This result is due to the U-shaped behavior of macro variables over the tax rate in the model, a phenomenon that I show is also present in the data. The intuition behind this result is that at low rates, an increase in taxes and public education spending dampens human capital accumulation due to decreases in private education attainment, while at high rates, public education provision gets sufficiently large so that the majority of the population prefers public education over private, and an increase in the tax rate boosts public education attainment more than it dampens private education.

The rest of this chapter is organized as follows: In Section 1.2, I discuss the related literature; in Section 1.3; I describe the model environment, in Section 1.4 I report and discuss results; and Section 1.5 concludes.

1.2 Related Literature

Previous studies in the macro branch of education literature and earlier research on Transatlantic differences have not reached a consensus on the sources of the aforementioned discrepancies, or their resultant macroeconomic implications. Very few studies attempt to explain the disparities in education using methods employed by the neoclassical economic theory. Benabou (2000) being the exception, investigates the role of progressivity in taxes and redistribution on educational outcomes in a heterogeneous-agent economy, and shows that two distinct equilibria can emerge depending on whether the efficiency-enhancing effect or the redistributive effect of education dominates. He emphasizes the role of imperfections in democracies to explain how different economies could stay inertial at different equilibria. However, he works with a stylized model, makes several restrictive assumptions on the parameter space to derive closed-form solutions, and does not study the co-existence of public and private education at the same system.

Soares (2006) also studies the relationship between education and macro variables in a general equilibrium model under democracy, but he does not focus on the aforementioned discrepancies between the countries of interest. Further, he introduces heterogeneity only in age cohorts by employing an overlapping generation model and studies the pivotal role of different age cohorts on educational and macro outcomes.[10] Finally, Zhang (2005) extends the model by Benabou (2000) and stud-

[10]The orthodox point of view in the literature is that the fundamental source of heterogeneity with regards to education should be in innate productivity (which in turn affects human capital, labor, income, wealth and education levels) (e.g. Benabou, 2000, 2002, 2005; Zhang, 2005), and accordingly it is crucial not to ignore heterogeneity in inborn abilities while studying the role of education, as studied in this chapter.

ies the role of education in the presence of both physical and human capital, and reaches similar qualitative conclusions as Benabou (2000). However, he does not address the Transatlantic differences or the implications of the co-existence of private and public education, either.

A related branch of literature examines why European countries have more pronounced redistributive policies than the United States. Lindbeck (1995) argues that habits and social norms influence economic incentives, which in turn shape habits and social norms. He claims that different multiple equilibria can emerge as a result of this feedback mechanism. Saint-Paul (2001) focuses on economic foundations of multiple equilibria and shows that, contrary to the general prediction that higher inequality induces more redistributive policies, if a large fraction of the population is concentrated in the lower-tail of the income distribution, redistribution may decrease and inequality may increase at the same time. Similar to the qualitative conclusions as in Saint-Paul (2001), Hassler *et al.* (2003) show that expectations of higher redistribution in the future can lead to lower investments today, which in turn increases future demand for redistribution, and this feedback mechanism allows for the emergence of multiple equilibria.

Alesina and Glaeser (2004) group potential sources of Transatlantic differences into economic, political and behavioral fundamentals. The first group, economic explanations, rely on the differences in variance and skewness of pre-tax income, social costs of taxation, and income mobility prospects of the median-voter. They claim that empirical evidence does not support economic explanations strongly, since pre-tax and transfer income in the United States has both higher variance and a

more skewed distribution than in Europe; deadweight losses from taxation are not noticeably lower in Europe; and European Union integration has not changed the degree of redistribution, hence the demand for insurance, significantly.[11]

The second category, political explanations, focus on the presence of institutions that prevent minorities of any sort from gaining political power and the enforceable laws protecting individuals' private property. Examples of such institutions can be U.S.'s lack of representative democracy, which could promote bargaining powers of for small groups with common interests, (e.g. the absence of a socialist party, which is represented strongly in many of the European countries), and the U.S. Supreme Courts' pro-private-property attitude (as in the rejection of federal income tax in 1894). Authors argue that political explanations have at least some degree of legitimacy in explaining the observed aforementioned differences. For instance, Alesina *et al.* (2005) claim that empirically racial discord hinders redistribution significantly. For the U.S. case, they claim that due to racial animosity, many white voters find it unappealing to vote for pronounced redistribution to the poor, who are proportionately black. Authors claim that electorates in the U.S. want to have control over their charitable donations, and direct them as they please.

Behavioral explanations focus on the perception of fairness of the market and the role of luck versus effort in the determination of economic outcomes. Alesina and Angeletos (2005) argue that if the common perception in an economy is that

[11] Alesina and Glaeser (2004) argue that prospects of moving up in the income distribution may be mildly higher for the U.S. middle-class households, which could incentivize them to vote for lower and less progressive redistributive policies, yet even in the presence of this controversial fact, authors believe the proposed economic explanations are not the likely roots of the divergent multiple equilibria.

luck is strongly decisive in economic outcomes, agents will unlikely be motivated to exert high effort. In equilibrium, due to limited effort exerted, luck indeed turns out to be influential, and initial beliefs that luck is decisive on final outcomes is verified. Meanwhile, in order to insure themselves against unlucky future scenarios, agents favor redistributive policies over *laissez-faire* ones, and economy stays inertial at the high tax and high-luck-decisiveness equilibrium. In contrast, if agents perceive the market to be fair and the role of luck to be minimal, they will be motivated to exert high effort, which in turn reduces the decisiveness of luck in equilibrium. Under this scenario, *laissez-faire* policies are favored over pronounced redistributive policies due to the foreseeable future and lower need for insurance. Authors show that 54% of Americans believe effort determines final outcome whereas only 29% of the population in Europe is in agreement with this belief. They document a significant correlation between perceptions on high decisiveness of luck and social spending per-capita across countries, and establish a model based on these preliminaries by extending Piketty (1995) that can generate multiple equilibria. However, the model they propose implies the suggested American equilibrium to Pareto-dominate the European one, and authors do not explain why Europeans would not want to switch to the better U.S. equilibrium. Also, they model household utility to decrease over the inequality in the economy they live in, which can be considered controversial. Benabou and Tirole (2006) also set up a model with beliefs that are verified in equilibrium, yet they do so by using the "need" to believe in a just world and "cognitive dissonance" as the necessary elements. However, the *de facto* degree of holding back bad news from offsprings is hard to measure, which makes the testing of the model

almost impossible. Although these studies shed light to Transatlantic differences to a great extent by formalizing behavioral explanations, they both rely on relatively unorthodox elements to the neoclassical economic theory, and the proposed models are not suitable for welfare comparisons or policy analyses.

So far, the determination and implications of an education system in which both public and private education options co-exist in the choice set of heterogeneous agents have not been investigated. Further, welfare analyses of individuals under different tax and education systems have often been neglected. This chapter intends to fill this gap in the literature by combining the features of a standard heterogeneous-agent general equilibrium model with the elements proposed in the education literature.[12]

1.3 Model

The model I propose in this section is a heterogeneous-agent overlapping generations (OLG) model with two cohorts: young and middle-aged, both with the same measure (normalized to unity), and without population growth. The young are born with an inborn exogenous cognitive competence, e.g. IQ shock. This stochastic

[12]The presence of co-existent education types is particularly interesting, because as I show in the following sections, it generates results that are considerably different than the scenario in which there is the provision of only a single education type, as in Benabou (2000). This result can be attributed to the fact that absence of co-existent education type fails to account for the crucial disincentivizing role of public education, which causes overestimation of the benefits of public education and generates misleading predictions on the behaviors of macroeconomic variables, specifically on average per-capita output, and inequality. Further, it is important to acknowledge that the form of public education in the Scandinavian countries are mostly predominant attendance to public schools, as opposed to subsidies for private education, which also supports the view that a more realistic representation of reality also requires the distinction between the two types of education systems while modeling. This chapter, at least partially, sheds some light on these grounds, as well.

capacity, together with educational bequests from parents (if any) or the present provision of public education, economy-wide human capital and parental non-labor time and human capital determine their human capital, which they use as a factor of production next period when middle-aged.[13] The middle-aged decide how much to work, consume, and bequeath for the offspring's education due to altruism motive.

There is a single distortionary income tax, which is the only instrument to finance public education. For simplicity, the model assumes the tax rate to be constant and exogenous to the economy, although its welfare implications are addressed and discussed in detail in the following sections.[14] Tax rate, together with the levels and distributions of human capital and labor supply determine the level of public education provision in the economy.

The primary focus of the chapter is to study long-run properties, therefore the model assumes there are no aggregate shocks, which in turn implies that the economy to stay inertial at its stationary equilibrium at all times and all aggregate variables and the consequent distributional properties are constant at their long-run values.

[13]The young do not optimize, and only abide by the law of motion for human capital. Further, the model assumes the young do not consume, or in other words their consumption is normalized to zero. This assumption is not critical for the results, yet facilitates the solution of the model.

[14]As it is discussed in detail in the following sections, the proposed model does not feature single-peaked preferences, and single-crossing property does not hold globally. In the absence of single-crossing property, dynamic politico-economic solution of the model, as in Corbae *et al.* (2009), is not as straightforward as keeping track of the median-voter's preferences, and accordingly is left to future research.

1.3.1 Model Environment

Middle-aged agent $i \in [0,1]$ begins the period with a human capital level $h \in \mathcal{H}$ and observes his child's inborn competence $\xi \in \Xi$. Next, for the given tax and public education levels, middle-aged agent decides whether to choose the state-funded public education or private education along with its level for his child, together with how much labor to supply and consume. Public education is provided in a rival and non-excludable way, yet offered in a take-it-or-leave-it fashion at some degree: Those who choose private education, regardless of the level of their choice, cannot fully enjoy public education benefits and incur an opportunity cost of forgoing some fraction of the benefits of the present public education.[15] Private education is not free, however it provides the middle-aged agents with the opportunity of picking any level of education they want at its respective cost.

Formally, the middle-aged agent i at time t solves:

$$V(h,\xi;\overline{H},\overline{E},\tau) = \max_{\{c,l,e\}} \left\{ u(c) + v(1-l) + \rho \sum_{\xi'} \pi(\xi',\xi) V(h',\xi';\overline{H},\overline{E},\tau) \right\} \tag{1.1}$$

subject to

$$c = (1-\tau)\Theta l^{(1-\lambda)} h^{\lambda} - e \tag{1.2}$$

$$e \geq 0 \tag{1.3}$$

[15] In reality, only about 40% of the students attend higher education for both the U.S. and the Scandinavian countries, which implies there is excludability present, although at similar degrees for the countries of interest. This assumption is aimed to keep model simple and tractable enough, and further research by relaxing these assumptions and studying the effects of participation constraints would be enlightening.

$$h' = \begin{cases} \xi(\overline{E})^{\varepsilon}((1-l)h))^{(1-\varepsilon)\gamma}\overline{H}^{(1-\varepsilon)(1-\gamma)} & e = 0 \\ \xi(e+\nu\overline{E})^{\varepsilon}((1-l)h)^{(1-\varepsilon)\gamma}\overline{H}^{(1-\varepsilon)(1-\gamma)} & e > 0 \end{cases} \tag{1.4}$$

$$\log(\xi) \sim N(\mu_{\xi}, \sigma_{\xi}^2) \tag{1.5}$$

for given parameters, tax rate τ, aggregate human capital $\overline{H}$, and public education level $\overline{E}$, where c denotes consumption, l denotes labor supplied, h denotes individual human capital at period t (h' denotes individual human capital at period $t+1$, as the other variables with prime notation), e denotes private education bequest, ρ denotes altruistic discount rate, Θ denotes the constant productivity technology, ξ denotes the inborn cognitive competence of the offspring, and $\pi(\cdot)$ denotes the Markov-chain transition probability matrix of the stochastic inborn competence process. Equation 1.2 is the standard budget constraint of the household. Output technology requires the use of labor and human capital as factors of production, and tax is paid to the government proportional to the income. Education and consumption decisions are made out of disposable income. As shown in Equation 1.3, private education bequests cannot take negative values.[16]

Human capital evolves according to Equation 1.4 so that there are economy-wide complementarities and limited transmission of skills across generations.[17,18]

[16] As it can be inferred from Equation 1.3, the relative price of education with respect to the consumption good is normalized to unity. This simplification is not central to the results, and does not change qualitative conclusions for a reasonable range of relative prices.

[17] In the literature, some authors (e.g. Benabou, 2005) introduce complementarities in the economy by incorporating aggregate human capital as a factor of production in the output production technology. I argue that incorporating complementarities in the law of motion of individual human capital, as in Zhang (2005), is a more reasonable approach, which can be interpreted as the knowledge-base of the economy facilitating the accumulation of human capital. Modeling complementarities as Benabou (2005) does not change results, qualitatively.

[18] Skill transmission of human capital across generations is a common approach employed in the

Finally, inborn competence is log-normally distributed as shown in Equation 1.5, and while households know its distribution, they cannot foresee or insure themselves against IQ shocks hitting future generations.

ν in Equation 1.4 denotes the fraction of public education benefit to the private school students, or the "public education spillover".[19] In other words, if ν takes a non-zero value, students who attend private education can still enjoy a fraction of the provided public education level.

Let $\tilde{e}(h, \xi; \overline{H}, \overline{E}, \tau)$ be the optimal education decision rule, and $\tilde{h}(h, \xi; \overline{H}, \overline{E}, \tau)$ be the individual human capital rule for the next period implied by the optimal education rule. Then, the stationary distribution of the economy satisfies:

$$\mu(h', \xi'; \overline{H}, \overline{E}, \tau) = \sum_{\xi'} \int_{\mathcal{H} \times \Xi} \chi_{\{\tilde{h}(h,\xi;\overline{H},\overline{E},\tau)=h'\}} \pi(\xi', \xi) d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.6}$$

where $\chi(\cdot)$ denotes the indicator function. The middle-aged household is rational in making his choices, so the aggregate human capital level household takes as given in the optimization problem must indeed be the economy's resultant aggregate human capital enforced by the stochastic processes, agents' decision rules and their

education literature. In fact, Schuetz *et al.* (2008) empirically verify the presence of intergenerational skill transmission across countries at different rates. For a detailed discussion on the family background effects on educational performance and list of a number of studies concentrating on the human capital transmission, see Hanushek and Woessmann (2010).

[19]Reasonably, one could model the spillover parameter ν in several ways, potentially as an increasing function of public school attendance ratio. However, there is no previous study or data that sheds light on the public education spillover effects, and taking it as a parameter, possibly as a result of the established institutions, can be regarded as the more conservative way of not to overstating the complementarity benefits of relying heavily on public education. More on this issue is discussed in the results section.

distribution:

$$\overline{H} = \int_{\mathcal{H}\times\Xi} h d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.7}$$

Finally, the government runs a balanced budget, so that the expenditure on the provision of public education does not exceed the tax revenue:

$$\overline{E} = \int_{\mathcal{H}\times\Xi} \tau(\Theta l^{(1-\lambda)} h^{\lambda}) d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.8}$$

1.3.2 Recursive Competitive Equilibrium

The recursive competitive equilibrium under constant exogenous taxes is a set of value functions, decision rules, allocations and stationary distribution, such that

1. Given $\overline{H}$, $\overline{E}$, and τ, $\tilde{c}(h, \xi; \overline{H}, \overline{E}, \tau)$, $\tilde{l}(h, \xi; \overline{H}, \overline{E}, \tau)$ and $\tilde{e}(h, \xi; \overline{H}, \overline{E}, \tau)$ are optimal decision rules to household agent i's problem, $\tilde{h}(h, \xi; \overline{H}, \overline{E}, \tau)$ is the implied human capital rule by the optimal education decision, $V(h, \xi; \overline{H}, \overline{E}, \tau)$ is the resultant value function, and inborn cognitive capability follows its exogenous law of motion:

$$V(h, \xi; \overline{H}, \overline{E}, \tau) = \max_{\{c,l,e\}} \left\{ u(c) + v(1-l) + \rho \sum_{\xi'} \pi(\xi', \xi) V(h', \xi'; \overline{H}, \overline{E}, \tau) \right\} \tag{1.9}$$

subject to

$$c = (1-\tau)\Theta l^{(1-\lambda)} h^{\lambda} - e \tag{1.10}$$

$$e \geq 0 \tag{1.11}$$

$$h' = \begin{cases} \xi(\overline{E})^{\varepsilon}((1-l)h))^{(1-\varepsilon)\gamma}\overline{H}^{(1-\varepsilon)(1-\gamma)} & e = 0 \\ \xi(e+\nu\overline{E})^{\varepsilon}((1-l)h)^{(1-\varepsilon)\gamma}\overline{H}^{(1-\varepsilon)(1-\gamma)} & e > 0 \end{cases} \tag{1.12}$$

$$\log(\xi) \sim N(\mu_{\xi}, \sigma_{\xi}^2) \tag{1.13}$$

2. The time-invariant stationary distribution satisfies:

$$\mu(h', \xi'; \overline{H}, \overline{E}, \tau) = \sum_{\xi'} \int_{\mathcal{H}\times\Xi} \chi_{\{\tilde{h}(h,\xi;\overline{H},\overline{E},\tau)=h'\}} \pi(\xi', \xi) d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.14}$$

3. All aggregate variables stay constant at all periods:

$$H_t = H_{t+1} = \ldots = \overline{H} \tag{1.15}$$

$$Y_t = Y_{t+1} = \ldots = \overline{Y} \tag{1.16}$$

$$C_t = C_{t+1} = \ldots = \overline{C} \tag{1.17}$$

$$L_t = L_{t+1} = \ldots = \overline{L} \tag{1.18}$$

$$\overline{E}_t = \overline{E}_{t+1} = \ldots = \overline{E} \tag{1.19}$$

4. Aggregate resource constraint holds:

$$\overline{Y} = \overline{C} + \overline{E} + \int_{\mathcal{H}\times\Xi} e d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.20}$$

5. Government runs a balanced budget:

$$\overline{E} = \int_{\mathcal{H}\times\Xi} \tau(\Theta l^{(1-\lambda)} h^{\lambda}) d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.21}$$

6. Markets clear, definitions and expectations hold:

$$\overline{H} = \int_{\mathcal{H}\times\Xi} h d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.22}$$

$$\overline{Y} = \int_{\mathcal{H}\times\Xi} y d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.23}$$

$$\overline{C} = \int_{\mathcal{H}\times\Xi} c d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.24}$$

$$\overline{L} = \int_{\mathcal{H}\times\Xi} l d\mu(h, \xi; \overline{H}, \overline{E}, \tau) \tag{1.25}$$

1.3.3 Calibration

Solving the stationary equilibria of the model economy analytically is not feasible due to the frequent corner solutions for most parts of the tax space, and a natural candidate for deriving optimal decisions is the use of value function iteration technique. Further, due to the absence of aggregate shocks, Huggett (1993) algorithm is convenient to solve the stationary competitive equilibrium by the use of Monte-Carlo simulations, the details of which I discuss in the appendix.

The benchmark parameter values I employ in the model are displayed in Table 1.6. Following Benabou (2002), I set the value for the share of human capital in output (λ) to 0.625, and mean and standard deviation of natural logarithm of the

Table 1.6: Benchmark Parameter Values

λ	0.625	Benabou (2002)
γ	0.200	Zhang (2005)
ρ	0.800	Zhang (2005)
ε	0.300	Benabou (2002) & Zhang (2005)
μ_ξ	0.000	Benabou (2002)
σ_ξ	1.000	Benabou (2002)
$\bar{l}$	0.330	RBC Literature
ν	0.500	Neutral Stance from Two Polar Cases
Θ	5.000	Calibrated to Match $\overline{Y}^{Nor}/\overline{Y}^{US} = 87\%$
τ^{US}	4.784%	Calibrated to Match $\overline{E}/\overline{\mathcal{E}} = 32.27\%$ for the U.S.
τ^{Nor}	11.774%	Calibrated to Match $\overline{E}/\overline{\mathcal{E}} = 93.90\%$ for the Nordic Average

inborn cognitive competence shock (μ_ξ and σ_ξ) to 0 and 1, respectively. Following Zhang (2005), I set the elasticity of human capital with respect to parental time-away from work (γ) to 0.2, and the altruistic discount rate (ρ) to 0.8. In the literature, the elasticity of human capital with respect to education (ϵ) varies between 0.15-0.4. I assign a value close to the mean, 0.3. I also set the total factor productivity technology (Θ) to 5 so as to match the share of public-to-total education expenditure for the U.S. and Nordic targets at their relative per-capita output values.

Due to the absence of earlier studies or available data on public education spillovers, I report results with three alternative parameter values, $\nu : 0, 0.5$ and 1. The model with $\nu = 0$, coined as the no public education spillover model can be considered an environment where there are only two major types of higher education institutions, and students can benefit from only one of the two types of institutes, and government does not subsidize private institutions at all. In other words, public education is offered in a perfectly take-it-or-leave-it fashion. The model with $\nu = 1$, tagged as the full public education spillover model, can be thought as an environment where there is only one type of an education type, which is public education, and students who want to get higher education have to attend public schools. In addition

to the public education, however, those who want to pursue further education can choose to attain additional private education, e.g. by private tutoring, certificate programs, etc. In other words, private education students have to incur nominal cost of private education, but they do not have to forgo public education benefits as in no spillover model.[20] Finally, the model in which spillover is set to $\nu = 0.5$, coined as the model with limited public education spillover, is intended to study the environment where students who participate in private education can still benefit from the provided public education, yet not as much as the public school students. In other words, they can still benefit from the public education level, yet only at the spillover fraction.[21] In reality, neither of the two polar cases are very likely, and a combination of the two is not only more reasonable, but also seems to fit better with the data, as shown in the results section.

Finally, for the U.S. and the Nordic average all parameter values are kept the same, except for the tax rate, which is calibrated so that higher public-to-total-education-ratios match the data. The primary purpose of this parametrization is to show that without introducing any unorthodox elements, or relying on variations in "deep" parameter values, the model can deliver many of the aforementioned

[20]Full spillover specification is intended to capture the dynamics of the Nordic economies better since public education attendance is very extensive for most of these countries, and the no spillover specification is not very suitable for such cases. To exemplify the degree of extensiveness of public education institutes in Scandinavia, an examination on the composition of Nordic European universities reveal that aside from very few exceptions, there are not any private universities in Finland or Sweden. In Denmark, the only private universities are business schools, and in Norway no less than 90% of the students attend public universities. Iceland, being a small outlier among the Nordic countries is private-reliant, yet her overall public higher school attendance ratio is no less than 80%. Also, note that an education system which provides only public education by the means of private school vouchers would be isomorphic to the full spillover model.

[21]Due to the lack of earlier studies on public education spillover, ν is set to 0.5 so as to model spillover as equally distant from the two polar cases.

Transatlantic differences by only relating to tax rate differentials.

For utility, I employ the natural logarithmic function. For the ease of delivering the intuition behind the model, at first, I make the following fairly restrictive assumption: although taxes are known to alter labor supply choice by economic theory, I fix the amount of labor supplied by all middle-aged individuals to a constant. I also normalize the utility from leisure $v(1-\bar{l})$ to zero. In a later section, I relax this assumption and endogenize labor in accordance with a balanced-growth-consistent functional form, and show that key findings under the fixed-labor assumption are not qualitatively different than the results with endogenous labor supply.

1.4 Results

In this section, I first display my findings on the behaviors of micro and macro variables under different tax regimes of the model with limited public education spillover. Next, I report comparative statics with alternative parameter values in order to illustrate how different channels affect the variables of interest. Then, I revisit real world evidence, and discuss how the model fits to the data not only for the U.S. and the Scandinavian countries, but also for the remaining developed OECD economies. Then, I drop the fixed labor assumption and compare how variables of interest differ with endogenous labor. Finally, I analyze the behavior of welfare of agents over taxes so as to provide insight into how calibrated economies can be gain political consent.

1.4.1 Benchmark Results with Limited Public Education Spillover

First, I derive the value functions and optimal decision rules of agents at different individual human capital and inborn competence state pairs ($\{h, \xi\} \in \mathcal{H} \times \Xi$). The value functions are verified to be smooth, concave and increasing in both dimensions.[22,23] The highest dynastic utility is attained under the *laissez-faire* economy for the rich (i.e. agents with high h and ξ pairs), and high enough tax environments (e.g. $\tau = 15\%$) for the poor, which is in accordance with the economic theory. In between the two tax rates, life-time utility values are lower compared to the two polar tax regimes, the reasons of which are discussed in detail in the following sections. Also, as tax rate goes up, value functions are observed to be more concave and less steep due to the moderating redistributive role of the taxes through the provision of public education.

In Figure 1.3 and 1.4, I illustrate the decision rules at the two extreme tax scenarios. Except for minor irregularities due to computational restrictions, education choices are observed to be concave and smooth for both tax regimes.

The flat surface in education choice under the high tax regime in Figure 1.4 reflects the public education choice of agents whereas the concave monotonically-increasing part is due to the private education choice. The extensive margin decision, which can be observed only high-enough tax regimes (since there is no provision of

[22]Given that inborn competence shocks are not persistent and mean-reverting, the life-time utility values in different cognitive-competence states are only moderately different. Conversely, individual human capital persists over generations as a result of limited intergenerational skill-transmission, which increases the responsiveness of the value function to the human capital state.

[23]The value function and decision rules reported in this section are calculated at the equilibria of the model economies at different tax rates. In order words, the aggregate human capital ($\overline{H}$) and public education ($\overline{E}$) arguments of optimal education rules ($\tilde{e}(h, \xi; \overline{H}, \overline{E}, \tau)$) and value functions ($V(h, \xi; \overline{H}, \overline{E}, \tau)$) are competitive equilibrium objects.

Figure 1.3: Education Decision Rules When $\tau = 0\%$

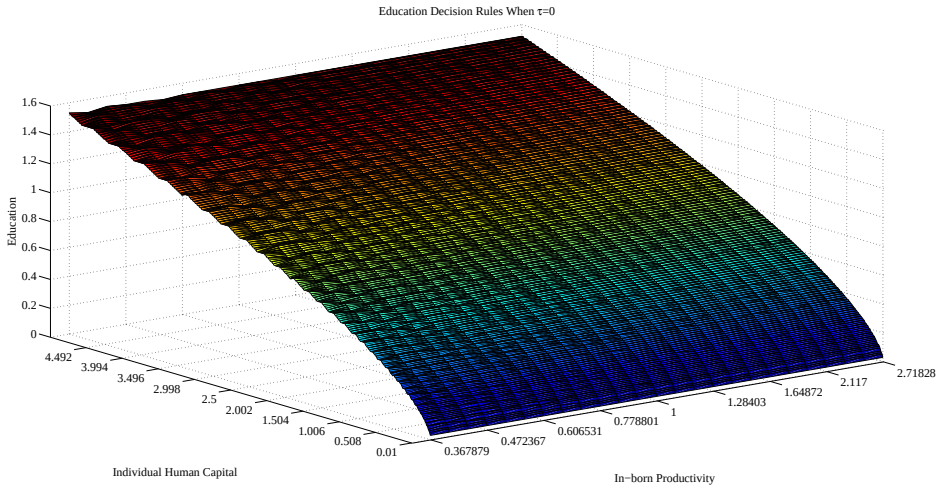
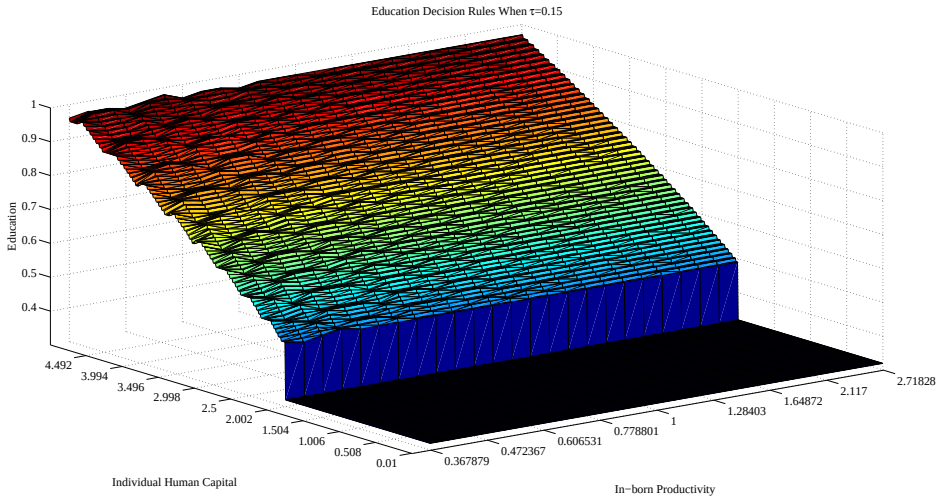


Figure 1.4: Education Decision Rules When $\tau = 15\%$



public education at the *laissez-faire* economy, thus no extensive margin decision) occurs at the kink point. Solving for all other tax rates reveal that extensive margins occur monotonically at higher human capital & inborn competence states as tax rate and the consequent public education levels increase. Finally, as tax rate goes up, private education choice decreases also in the intensive margin due to less disposable income, as well as because of lower return on education due to the burden of taxes.

Due to these features of the decision rules, it can be summarized that higher taxes monotonically disincentivize private education both on the extensive and on the intensive margin.

Table 1.7: Steady-State with Limited Public Education Spillover

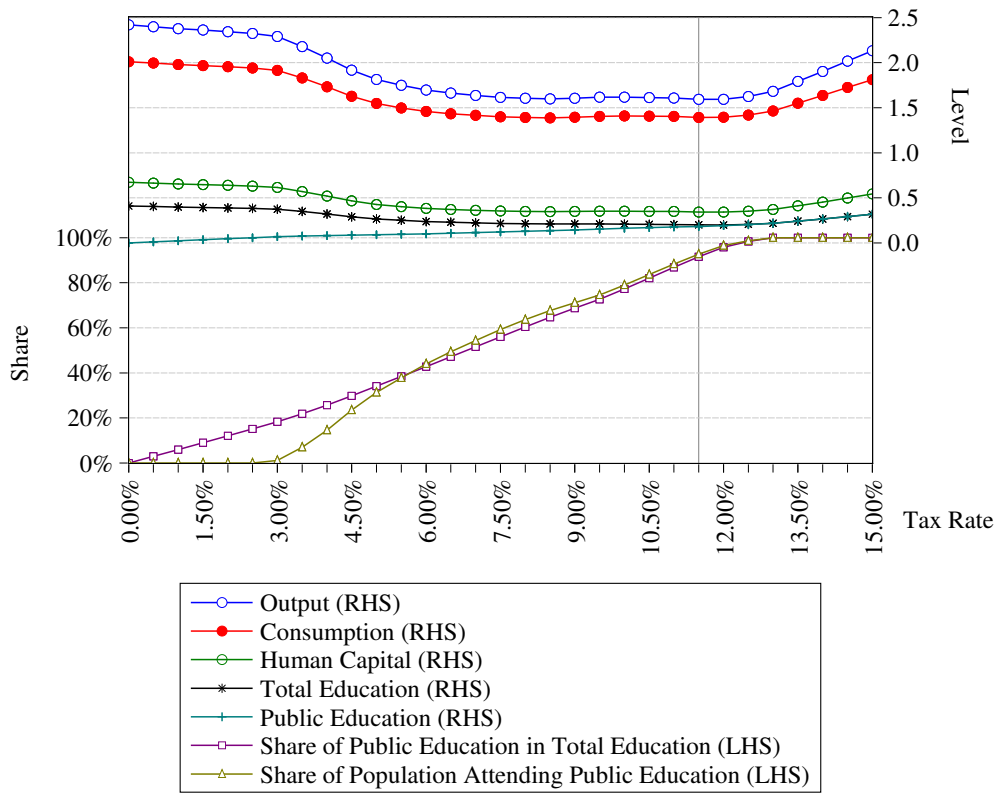
τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{C}/\overline{Y}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$
0.00%	0.672	2.419	2.010	0.831	0.410	0.000	0.00%	0.00%
2.50%	0.630	2.324	1.941	0.835	0.383	0.058	15.17%	0.00%
4.78%	0.441	1.851	1.577	0.852	0.275	0.089	32.27%	28.34%
5.00%	0.427	1.814	1.548	0.853	0.266	0.091	34.12%	31.34%
7.50%	0.354	1.615	1.398	0.866	0.216	0.121	55.99%	59.22%
10.00%	0.353	1.618	1.408	0.871	0.209	0.162	77.25%	78.99%
11.78%	0.343	1.593	1.393	0.875	0.200	0.188	93.90%	94.63%
12.50%	0.353	1.625	1.419	0.873	0.207	0.203	98.34%	98.64%
15.00%	0.544	2.131	1.812	0.850	0.320	0.320	100.00%	100.00%

Note: All variables are in per-capita terms. $\overline{H}$ denotes average human capital, $\overline{Y}$ denotes average output, $\overline{C}$ denotes average consumption,$\overline{E}$ denotes public education provision, $\overline{\mathcal{E}} = \overline{E} + \int_{\mathcal{H}\times\Xi} e(h,\xi;\overline{H},\overline{E},\tau)\ d\mu(h,\xi;\overline{H},\overline{E},\tau)$ denotes average per-capita expenditure on education, and $Pop._{\overline{E}}$ denotes the fraction of population who attends public schools.

Table 1.7 displays the behavior of aggregate variables under different tax regimes. Last three columns of Table 1.7 show that level of public education, share of public education in total education expenditure and share of population attending public schools are monotonically increasing in the tax rate, as expected. First three columns, however, reveal a different pattern: as economy's tax rate goes up, average human capital, output, consumption, and total education first decrease, and after a threshold they all start to increase. This U-shaped behavior can be observed more explicitly in Figure 1.5. The threshold tax rate where aggregate variables are minimized is roughly at $\tau = 11.5\%$, which is slightly below the tax rate at which whole population chooses to attend only public education, i.e. 12.5%.

A brief explanation on why the U-shaped pattern of the aggregate variables over taxes is present is as follows: starting from the *laissez-faire* economy, as the tax

Figure 1.5: Stationary-Equilibria with Limited Public Education Spillover



rate goes up, four factors are in effect, three of which are working against and one of which is working in favor of the aggregate variables: First, as a result of a higher tax rate, disposable incomes of the households decrease, which reduces the preferred private education choice of agents in the intensive margin. This effect applies to those middle-aged agents who still choose to bequeath private education to their kids, yet only at lower levels due to higher taxes.[24] Second, there is a disincentivizing extensive margin effect due to the level of public education. To exemplify this effect, suppose in the absence of a public education provision of 1 unit, middle-aged agent

[24]When there are no public education spillover benefits, i.e. $\nu = 0$, one can show that $\frac{\partial e}{\partial \tau} = -\frac{\lambda \rho \varepsilon \Theta h^{\lambda} \bar{l}^{1-\lambda}}{1-\rho(1-\varepsilon)\gamma} < 0$ as long as skill transmission and discount factor coefficients are lower than 1.

i chooses to bequeath 2 units of private education to his offspring. In the presence of 1 unit of public education provision, instead of paying the full private education cost of 2 units and benefitting from a total of $2+1\times\nu = 2.5$, the middle-aged agent optimally chooses to go for the public education level of 1 unit in order not bear the private financing cost and still enjoy a reasonable amount education. The presence of public education causes a decrease in the level of total education attained due to the extensive margin decisions of individuals whose optimal private education choices would have been in the close neighborhood *above* the public education level. Third, there is distortion to human capital investment caused by lower return on education: compared to a low tax environment, under a high tax regime the same level of education generates equal pre-tax output, but less post-tax disposable income, which accordingly discourages education attainment due to lower returns. These three effects, due to reducing private educational attainment, cause aggregate education in the economy to decrease, which in turn reduces the level of aggregate human capital; and given that production takes place with human capital and fixed labor only, lower aggregate human capital translates into lower output and consumption. The fourth effect, which works in favor of the aggregate variables is due to the extensive margin choice of the poor and the public education spillover to the private school students: those who would choose a private education bequest below the public education level in the absence of public education optimally choose public education when it is available. Accordingly, the presence of public education make the poor better off by enabling them attain better education through their extensive margin decision, which in turn increases aggregate education, human capital, output

and consumption. Also, private school students enjoy increase in total education attained in the presence of public education spillovers. All these four effects are amplified by the presence of complementarities in the economy.

When there are no public education benefits to private school students, i.e. when $\nu = 0$, and economy-wide complementarities are not strong enough, unless the whole population attends public schools, the former three negative effects dominate the positive one. The intuition behind this result can be described as follows: suppose the economy is initially at the minimum tax rate at which whole population attends public education. If the tax rate decreases by an infinitesimal amount, some small measure of the population chooses to exit the public education pool, and attend private education. At this slightly lower tax rate, the private education they prefer needs to be noticeably higher than the public education level so that they would be willing to bear full cost their private of education choice. Then, those who choose to bequeath private education would increase total education attainment in the economy, which in turn increases economy's aggregate human capital, and output. As tax rate goes down, there is also a negative effect in act: due to the lower tax revenue, public education provision goes down, which reduces the education attainment of a major fraction of the population attending public education. However, since tax decreases only marginally, and those who switch to private education still keep funding the public education system anyway, the drop in public education level is negligibly small, and is more than offset by the increase in the private education attainment of the rich. As a result of these channels, aggregate education increases as tax rate drops from the threshold tax rate at which public school attendance

reaches 100%. As total education goes up, so does aggregate human capital and output. On the opposite direction, if the tax rate increases beyond the threshold rate, public education level goes up, and since there is no change on the extensive margin decisions of individuals, aggregate education increases, which in turn boosts human capital and output.[25] When there is public education spillover, i.e. $\nu > 0$, the tax rate which minimizes aggregate output is no longer the tax regime where all students choose to attend public schools, but one at which there is still a large measure of households attending public schools. This result is mainly because of the fact that with public education spillovers the opportunity cost of forgoing public education for private school students gets smaller as public education spillover goes up. For the limited-spillover model where the spillover rate is 50%, beyond the tax rate where roughly 60% of agents attend public education, the two competing forces are roughly equivalent in magnitude so that aggregate macro variables stay almost constant for a noticeable tax range.

Because of the aforementioned effects, in the presence of distortionary taxes to finance public education and presence of economy-wide complementarities, in order to maximize aggregate output, a social planner needs to either set the tax rate to 0% or high enough (e.g. beyond 12.5%) so that the complementarity effects can dominate the distortion due to taxes and disincentivizing role of public education

[25] When the whole population attends public schools, with no intergenerational skill transmission, i.e. $\gamma = 0$, aggregate human capital in the economy can be derived implicitly by $\overline{H} = (\int_{\mathcal{H}\times\Xi} h^{(1-\lambda)\varepsilon} d\mu)^{1/\varepsilon}\tau\Upsilon$ where Υ is a positive constant. Since beyond the threshold tax rate at which all students choose public education, distribution of human capital across individuals do not change substantially in terms of higher moments, by looking at the implicit characterization equation, one can show that aggregate human capital increases in taxes.

provision.[26] Hence, a normative conclusion of the model is that instead of designing an education system where both public and private education are chosen by large measures of households, or taking the "middle road", it is aggregate-variable-enhancing to rely extensively on either of the two types of educations.

In Table 1.7's third row where the economy is under the constant 4.78% tax rate regime, the share of public education expenditure to total education expenditure is 32.27% and in the seventh row where there tax rate is 11.78%, the corresponding share of public education expenditure is 93.90%. These public education ratios are the ones seen in data for the U.S. and the Nordic average, and therefore they are the model economies calibrated to match the U.S. and Nordic average targets, respectively.

Next, I focus on distributional properties the model generates under different tax regimes, and display my findings in Table 1.8.

Table 1.8: Distributional Properties with Limited Public Education Spillover

τ	$GINI_h$	$GINI_y$	$GINI_c$	$GINI_e$
0.00%	0.400	0.265	0.266	0.264
2.50%	0.400	0.266	0.262	0.263
4.78%	0.414	0.276	0.251	0.330
5.00%	0.414	0.276	0.249	0.332
7.50%	0.410	0.272	0.239	0.298
10.00%	0.400	0.264	0.239	0.194
11.77%	0.389	0.258	0.249	0.063
12.50%	0.382	0.253	0.251	0.017
15.00%	0.379	0.252	0.252	0.000

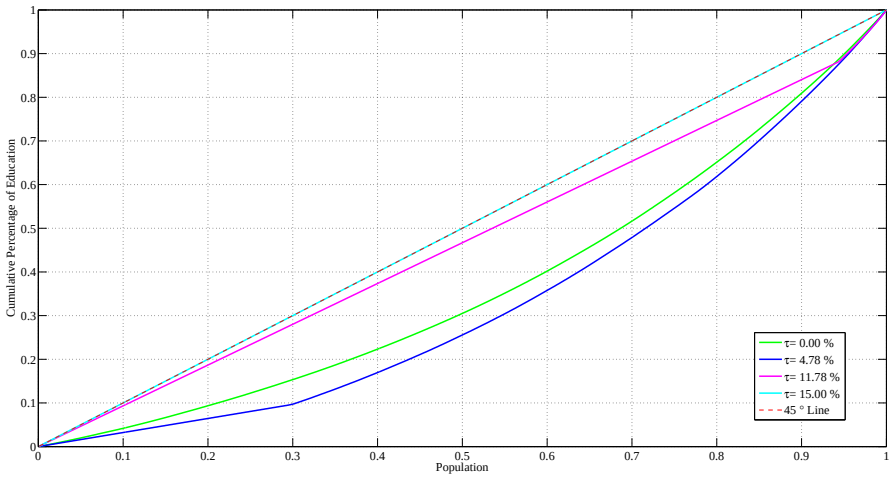
[26] As the tax rate goes up beyond 11.5%, aggregate output keeps increasing, which is due to the inelastic labor supply and absence of physical capital. In fact, as the tax rate goes up, economic theory suggests that due to the distortion on the labor wedge, labor supply should decrease and punitive taxes should discourage physical capital accumulation, as well as motivate the escape of physical capital to international markets for open economies. Endogenous labor, which is studied in the next section, is verified limit the production growth over taxes, yet in the absence of physical capital, the predictions for taxes beyond which there is already uniform public education attendance should be taken with a grain of salt.

Results from the calculated the gini coefficients of the variables of interest suggest that as tax rate goes up, so does inequality in human capital, output and education, up to a threshold tax rate of 5%, and vice versa beyond this rate so that there is an inverted U-shaped pattern. For human capital and output, gini coefficients stay constant only after the whole young population attends public schools, and for education since everyone attends only public schools so that there are no disparities across households, the education gini drops to zero. Regarding the inequality in consumption, results suggest there is not much variation over tax rates, and the U-shape pattern is not carried over to consumption much. This finding can be attributed to the following dynamics: as tax rate goes up, a significant fraction of people start to attend public education, whose education attainment is significantly lower than that of the private education average. Thus, those choosing public education have lower human capital endowments, which induce them produce less, thereby increases inequality output and consumption. At the same time, as the rich middle-aged choose high levels of private education for their kids, they incur higher costs of education financing, which they have to pay out of their disposable income, contrary to those who choose public schools. That the rich pay higher absolute amounts of taxes and private education costs therefore moderate consumption inequality. Further, as tax rate gets high enough so that everyone attends public education, consumption becomes only a fraction of output, and inequality in consumption remains similar to the inequality in output.

To show the impact of taxes on inequality, I display the Lorenz curves of edu-

cation under different tax regimes in Figure 1.6.[27] As mentioned earlier, Figure 1.6 verifies inequality in education first increases over taxes, and starts to diminish only after a threshold around 5%. These findings are in accordance with higher income and educational inequality predictions of the U.S. when compared to the Nordic European countries, and suggest that contrary to what has been put forward in the literature, public education does not monotonically translate into less inequality.

Figure 1.6: Lorenz Curves for Education Under Different Tax Regimes



Since the prime motivation of this chapter is to establish a model that can deliver the aforementioned differences between the U.S. and the Nordic countries, next I compare the predictions of the model with the data, and summarize my findings in Table 1.9.

At their respective public-to-total-education ratios, the model predicts the

[27]Other variables of interest also display similar Lorenz curve patterns as education, only with less pronounced variations in magnitude. The intuition behind lower inequality differences of these variables over tax rates can be summarized as follows: first, individual human capital depends also on factors other than education, such as aggregate human capital, parental human capital and competence shocks, therefore elasticity of human capital with respect to education defines how much variation in human capital be traced to educational differences. Second, the model currently assumes that the labor is fixed, which moderates variation in production for the given output technology, and accordingly less variant income translates into less variant consumption.

Table 1.9: Fit of Model's Predictions with the Data

	Country	$\overline{E}/\overline{\mathcal{E}}$	$\overline{Y}/\overline{Y}^{US}$	$\overline{\tau}$	$\overline{E}/\overline{E}^{US}$	$\overline{\mathcal{E}}/\overline{Y}$	$Pop._{\overline{E}}$	$GINI_{\overline{\mathcal{E}}}$
Model	U.S.	32.27%	4.78%	100%	100%	14.83%	28%	0.33
	Nordic Aver.	93.90%	11.78%	86%	211%	12.54%	95%	0.06
Data	U.S.	32.27%	12.87%	100%	100%	3.10%	67%	N/A (+)
	Nordic Aver.	93.90%	20.92%	87%	155%	1.60%	89%	N/A (−)

Note: $\overline{Y}$ denotes output per capita, $\overline{E}$ denotes public education expenditure, $\overline{\mathcal{E}}$ denotes total expenditure on education, $\overline{\tau}$ denotes taxes on income and profits as a percentage of GDP, and $Pop._{\overline{E}}$ denotes share of population who attend public education.

Scandinavian per-capita output to be 86% of the U.S. and the OECD database suggests approximately the same ratio. In this regard, the model can deliver the respective per-capita income level ratio with a high precision after calibration. While the tax rate on income and profits in Nordic average is roughly double that of the U.S. rate in the data, so is approximately the ratio predicted by the model. Further, whereas the data suggests that the public education expenditure per student in Nordic countries is significantly higher than the U.S. in absolute terms, 155% to be exact, the model makes a similar qualitative prediction, only with an overshooting ratio of 211%. Moreover, what we see in the data is that, the U.S. spends more on higher education, and lower fraction of students attend public schools in the U.S. Although not up to scale, the model delivers the same results qualitatively.[28] Finally, anecdotal evidence suggests that the inequality in educational attainment in the U.S. is noticeably greater than those of the Scandinavian countries, and the model provides the same distributional predictions. Therefore, it can be argued that the model can generate results that can deliver many of the observed discrepancies

[28]The order of magnitude difference in education spending ratio in the model compared to the data can be attributed to the fact that the model features only a single type of education, and therefore does not distinguish between the primary and secondary education or the participation rate.

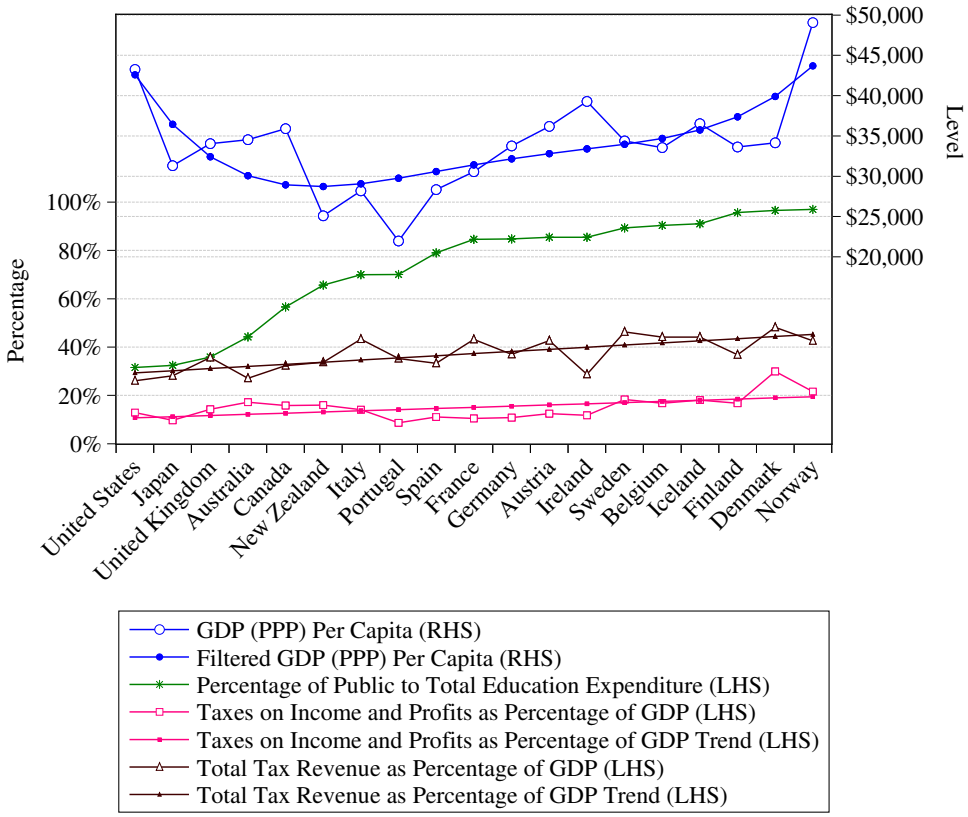
by relating only to differences in taxes.

Another merit of the model is on how well it fits not only for the calibration targets, but also for other developed economies. To show model's fit to the data, I do the following exercise: I sort the OECD countries whose data is available with respect to their public-to-total-higher-education ratios in ascending order, and plot them jointly with their GDP (PPP) per-capita levels. I also add these countries' taxes on income and profits and total tax revenues as percentages of the respective GDPs, and display the resultant graphs in Figure 1.7.[29]

First, there is a noticeable, yet slightly-distorted U-shaped pattern of per-capita output over public education shares, as in the benchmark results. I derive and plot also the filtered per-capita output series, which display the U-shape more clearly. I depict also tax rate trends, and show that aside from minor fluctuations, tax shares of countries tend to increase when public-to-total education shares go up, although total-tax-revenue-to-GDP ratio acting more in accordance than the taxes-on-income-and-profits-to GDP ratio. A simple ordinary least squares estimation of public education share on a constant and total tax ratio reveals that public education ratio is positively and significantly predicted by the tax rate for the linear equation of the form: $\frac{\overline{E_i}}{\mathcal{E}_i} = -0.149 + 2.354\tau_i$ with a probability value of $p = 0.0011$ for the coefficient before total tax rate. Therefore, it is possible to conclude that the U-shaped pattern generated by the model over taxes is also observable in data.

[29]Given that developed countries differ substantially in terms of to their tax systems by the use of very complicated tax elements and instruments, such as tax brackets, tax deductable incomes and expenditures, progressivity of different magnitudes, etc., instead of ranking countries with respect to their tax rates, I sort them with respect to their public-to-total education shares, which is a more objective and standardized measure across countries and is an endogenous outcome of the model.

Figure 1.7: Per-Capita Output, Tax Rate and Public Education Share by Country

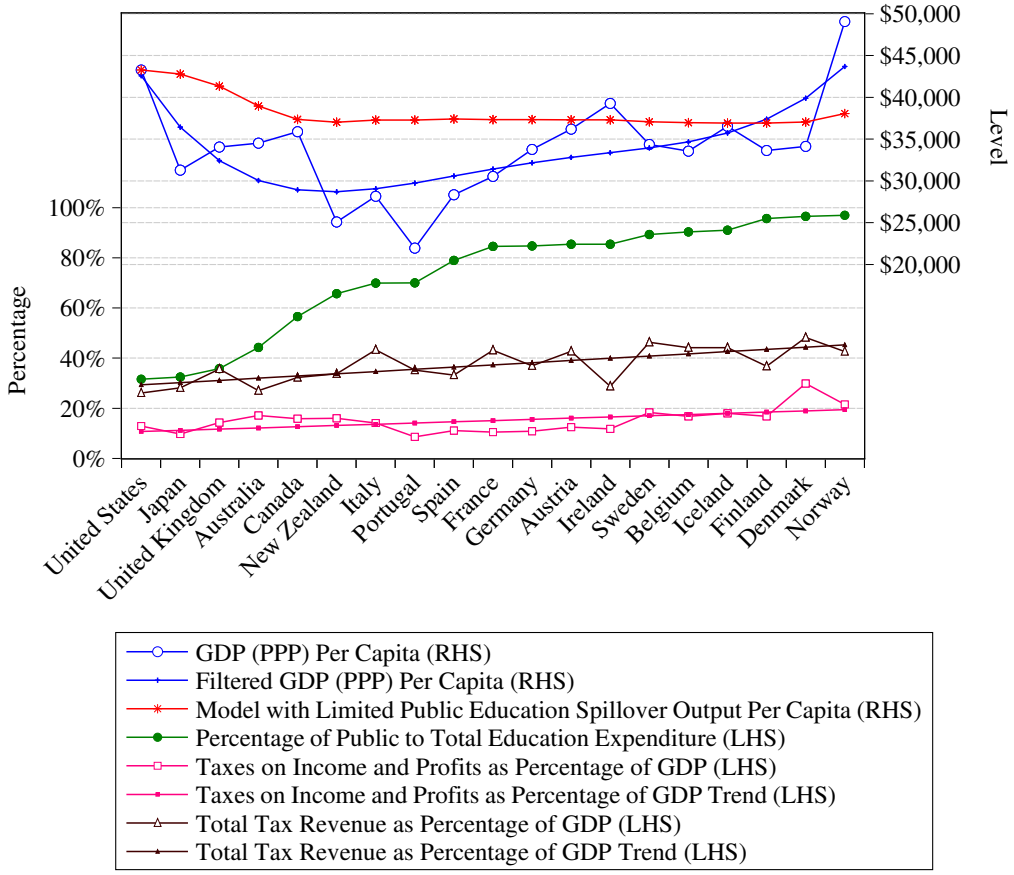


Source: OECD Tax Revenue Database, 2008.

Next I compare how well results generated by the model fit to the data. First, I interpolate the results for the limited number of tax rates and get finer measures, then I match interpolated economies to the OECD economies listed in Figure 1.7 with respect to their public-to-total higher education expenditure shares. I normalize the U.S. per-capita output to the correspondent equilibrium per-capita output in the model, and display in Figure 1.8 model's predictions on per-capita output at different tax rates jointly with the figures from the data.

It can be seen from the graph that both the model and data illustrate a de-

Figure 1.8: Limited Spillover Model's Fit with the Data



Source: OECD Tax Revenue Database, 2008.

creasing per-capita output pattern over public-to-total education expenditure ratio, and if the filtered GDP per-capita is compared to the predictions by the model, it is noticeable that both reach their respective minimum around 60% share, although the minimum generated by the model is much more prolonged and lies above than what the data suggests. Even though not to up scale, the model succeeds to generate the left arm pattern of the U-shape fairly well. Beyond 60% public education ratio, whereas the model suggests roughly a constant output per-capita prediction for a wide tax range, there is a clear upward pattern in the filtered series. The noticeable

portion of the right arm of the U-shape generated by the model starts only after Denmark, or roughly 96% public expenditure share, and keeps steadily increasing beyond this point as shown in Figure 1.5. Overall, it can be concluded that while the model succeeds to capture the initially-decreasing left arm in data fairly well, it does not have a good fit for the increasing right arm.[30]

In the next subsection, I present comparative statics with alternative parameter values to illustrate how different channels affect benchmark results.[31]

1.4.2 Comparative Statics with Limited Public Education Spillover

1.4.2.1 Absence of Idiosyncratic Shocks

In the absence of idiosyncratic shocks, i.e. $\sigma_\xi^2 = 0$, all households become identical, therefore the model transforms into a representative-agent model and the stationary values of all macro variables decrease substantially at all tax rates, as displayed in Table 1.10.

In essence, this result is comparable in spirit to the well-known "precautionary saving" phenomenon: when there is uncertainty on the inborn competence of future

[30]In regards to the loose fit of the economies on the right arm, it is probable that identical public education spillover imposition by the model for countries whose actual public education spillover rates are likely to differ might contribute to the poor goodness of fit. One could expect that a country where the only type of universities is free public schools to have a high spillover rate, as in Scandinavia, and a country where half of the higher education expenditure is on private education to have a comparably low spillover rate, as in Portugal. Results in the following subsections with different spillover rates show that high spillover values can generate higher per-capita output predictions at the same tax regimes, thus potentially improving models' fit on the right arm by the use of alternative parametrization. Lack of earlier studies on micro-level evidence admittedly limit the reliability of the predictions by the model.

[31]I analyze and document similar qualitatively comparative statics results for the models with different spillover values. I omit comparative statics results of the two polar specifications for brevity.

Table 1.10: Steady-State with No Idiosyncratic Shocks ($\sigma_\xi^2 = 0$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$\%Pop._{\overline{E}}$
0.00%	0.140	0.967	0.797	0.170	0.000	0.00%	0.00%
4.78%	0.112	0.838	0.703	0.135	0.040	29.62%	0.00%
11.78%	0.046	0.480	0.424	0.056	0.056	100.00%	100.00%
15.00%	0.094	0.752	0.639	0.113	0.113	100.00%	100.00%

Note: The results presented in this table, as well as Table 1.11-1.15 are of the model with limited public education spillover. Qualitatively similar results are obtained for the other two model specifications.

generations, middle-aged find it optimal to accumulate "precautionary human capital", some fraction of which they could pass to the next generations in the absence of physical capital. Accordingly, when there are no future shocks, middle-aged find it optimal to reduce education, which results in lower human capital accumulation, and accordingly output and consumption. Since the absence of uncertainty also removes heterogeneity, the fraction of population acquiring public education is either zero (at low tax rates) or unity (at high enough tax rates). The U-shape of the aggregate variables is preserved since the same competing effects are still in act.[32]

1.4.2.2 Higher Return on Education

When the elasticity of human capital with respect to education increases by 10%, i.e. $\varepsilon = 0.33$, levels of all aggregate variables at same tax rates increase, as shown in Table 1.11.[33]

From the middle-aged agent's point of view, education is a choice variable, as

[32]If agents have lasting "intelligence types", i.e. all agents in a dynasty have the same inborn competence draws at all times so that heterogeneity is preserved but future uncertainty is revoked, absence of precautionary human capital saving still causes a negative level shift in macro variables as in the representative-agent case.

[33]For this and next two experiments, note that the law of motion for human capital is homogenous of degree one in education, intergenerational skill transmission and economy-wide complementarity, which implies that an increase in one of the parameters would imply a drop in the parameter values for the remaining ones.

Table 1.11: Steady-State with Higher Return of Education ($\varepsilon = 0.33$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$\%Pop._{\overline{E}}$
0.00%	0.770	2.632	2.145	0.488	0.000	0.00%	0.00%
4.78%	0.544	2.107	1.759	0.349	0.101	28.90%	21.55%
11.78%	0.386	1.712	1.478	0.234	0.202	86.07%	87.65%
15.00%	0.495	2.011	1.709	0.302	0.302	100.00%	100.00%

opposed to intergenerational skill transmission or economy-wide complementarity, which they he takes as given in his optimization. Therefore, higher return of education on human capital accumulation encourages the middle-aged to bequeath more education to their offsprings, which causes a level shift in aggregate variables at all tax rates. Further, since education is more effective under this scenario, increases in the tax rate does not discourage middle-aged from attaining private education as much as in the benchmark case, therefore a lower measure of the population chooses public education over the private one in response to the same incremental tax increases. As a result, while the U-shape is preserved, the threshold tax rate at which everyone uniformly attends public schools is beyond 13%, compared to approximately 12.5% in the benchmark case.

1.4.2.3 Absence of Aggregate Complementarity

Absence of economy-wide complementarity of aggregate human capital, i.e. $\gamma = 1$, induces higher persistence in individual human capital levels. In the presence of aggregate human capital externalities, when average human capital is high, return on education gets higher, which in turn motivates middle-aged to bequeath more education, inducing even higher average human capital levels in the economy. In the absence of complementarities, there is greater intergenerational skill-transmission,

and given that idiosyncratic shocks do not change the level of average productivity in the economy, stronger parental transmission cannot deliver the same amplification effect as the aggregate human capital externalities. Further, more pronounced parental human capital transmission reduces future uncertainty, thus diminishing precautionary human capital savings. Therefore, lack of economy-wide complementarity causes the dismissal of the aforementioned amplification effect and reducing precautionary human capital accumulation, thereby pushing down macro variables at all tax rates, as illustrated in Table 1.12.

Table 1.12: Steady-State with No Aggregate Complementarity ($\gamma = 1$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$\%Pop._{\overline{E}}$
0.00%	0.431	1.646	1.111	0.535	0.000	0.00%	0.00%
4.78%	0.381	1.505	1.047	0.458	0.072	15.72%	16.47%
11.78%	0.258	1.156	0.844	0.312	0.136	43.61%	59.58%
15.00%	0.226	1.072	0.791	0.281	0.161	57.24%	72.35%

Also, the absence of complementarities causes weaker responses of aggregate variables to incremental increases in tax rates due to the lack of amplification mechanism, and this moves the output minimizing tax rate to show up at a point far beyond $\tau = 15$, around 30% to be exact. Accordingly, at the tax rate of $\tau = 15$, only 72.35% of the population chooses public education.

1.4.2.4 Absence of Intergenerational Skill Transmission

No transmission of skills across generations, i.e. $\gamma = 0$, implies stronger complementarity effect of aggregate human capital in the economy, which induces opposite results compared to the absence of complementarity exercise. Individual responses are amplified through the presence of high degree of externalities, which causes a

Table 1.13: Steady-State with No Intergenerational Skill Transmission ($\gamma = 0$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$\%Pop._{\overline{E}}$
0.00%	0.971	3.060	2.600	0.460	0.000	0.00%	0.00%
4.78%	0.584	2.219	1.934	0.285	0.106	37.21%	35.55%
11.78%	0.614	2.303	2.032	0.271	0.271	100.00%	100.00%
15.00%	1.172	3.449	2.931	0.517	0.517	100.00%	100.00%

positive level shift in macro variables, as shown in Table 1.13.

The same amplification mechanism causes arms of the U-shape to be steeper while preserving the U-shape. Due to the steeper left arm, the aggregate-output-minimizing tax rate is observed be around 9.4% compared to 11.5% in the benchmark case, and the tax rate at which the entire population attends public schools occurs at a tax rate below 12.5%.

1.4.2.5 Lower Labor Supply

As briefly mentioned earlier, economic theory suggests that an increase in the distortionary tax rate is expected to reduce labor supplied by middle-aged agents. Further, there is a growing literature on why Americans supply more labor than Europeans.[34]. In light of these insights and evidences, I conduct the experiment of deriving the stationary-equilibria with a 10% lower inelastic labor supply, $\bar{l} = 0.297$. Although a lower fixed labor supply might initially be thought as a negative shift in the technology parameter which clearly diminishes the levels of aggregate variables, the non-trivial aspect of this exercise is that lower fixed supply would also imply greater time devoted on parental education of the young through $1 - \bar{l}$, thereby increasing the effectiveness of education on human capital.

[34]Among others, see Alesina *et al.* (2005), and Prescott (2004).

Table 1.14: Steady-State with Lower Labor Supply ($\overline{l} = 0.297$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$\%Pop._{\overline{E}}$
0.00%	0.645	2.266	1.882	0.384	0.000	0.00%	0.00%
4.78%	0.426	1.741	1.483	0.258	0.083	32.22%	27.80%
11.78%	0.330	1.495	1.308	0.187	0.176	93.99%	94.95%
15.00%	0.523	2.001	1.700	0.300	0.300	100.00%	100.00%

As it can be seen in Table 1.14, with the benchmark parameters, the negative effect dominates the positive one in equilibrium, and there is a negative level shift at all tax rates while the U-shape of macro variables is preserved.

1.4.2.6 Persistent Inborn Productivity Shocks

While economists model inborn competence shocks in a non-persistent log-normal way, mostly due to general equilibrium concerns (e.g. Benabou, 2000, 2005; Zhang, 2005), geneticists show that heritability of IQ in the U.S. is measured to differ between 0.40 to 0.80 (e.g. Plomin *et al.*, 1994). In light of such evidence, I model innate competence shock as a first-order autoregressive stochastic process as follows:

$$\log \xi^i_{t+1} = \kappa \log \xi^i_t + u_{t+1} \tag{1.26}$$

where $u_{t+1} \sim N(0, \sigma_u^2)$ and $\sigma_u^2 = \frac{\sigma_\xi^2}{1-\kappa^2}$ so that both specifications have the same mean and variance. I set the value of the autoregressive coefficient to a positive constant $\kappa = 0.40$, and report the results in Table 1.15.

My findings reveal that while the U-shape is preserved, there is a significant drop in the levels of aggregate variables at all tax rates, as displayed in Table 1.15. When inborn competence shocks are persistent, a middle-aged agent with

Table 1.15: Steady-State with Persistent Inborn Shocks ($\kappa = 0.40, \sigma_\xi^2 = 1.19$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$\%Pop._{\overline{E}}$
0.00%	0.078	0.605	0.500	0.106	0.000	0.00%	0.00%
4.78%	0.063	0.531	0.450	0.080	0.025	31.68%	31.08%
11.78%	0.051	0.463	0.395	0.068	0.054	80.34%	83.88%
15.00%	0.068	0.558	0.469	0.089	0.084	94.04%	94.60%

a low competence draw is likely to have a child with a low competence draw, as well. Especially, if his disposable income is also low due to limited human capital endowment, he would not be motivated to bequeath a high level of education to his offspring since next generations' competence draws are likely to be low, thus education bequests will contribute only marginally. For those with high inborn competence draws, since future generations are likely to have good draws as well, too much education bequests are not vital, which induces lower degrees of precautionary human capital accumulation. As a result of these forces, lower educational bequests dampen the level of aggregate human capital, and together with its complementarity effect, return on education gets even lower, further amplifying the negative level shifts of aggregate variables at all tax rates.[35]

For the remaining parameters, I verify that increasing the share of human capital in the production function, i.e. λ, and the altruistic discount rate, i.e. ρ, boost the level of aggregate variables at all tax rates while preserving the U-shaped pattern.

Next, I show how results vary with different public education spillovers by focusing on the two polar cases.

[35]Note that persistent inborn competence shocks imply stronger intergenerational transmission channels, since parental transmission of human capital is still present.

1.4.3 Results with No Public Education Spillover

In this subsection, I report and discuss about the results from the model with no public education spillover, i.e. the environment in which students who attend private schools cannot benefit from the provision of public education, at all. Again, value functions and optimal decision rules are confirmed to be smooth and concave in both dimensions. Further, extensive margin decisions for the non-zero tax rates are observed to display sharper jumps compared to the limited-public-education-spillover model. This result is due to the presence of even greater opportunity costs of private education in the absence of public education spillovers: when students attend private schools, their parents not only have to bear the full costs of private education, but also they consider the additional costs of giving up all the benefits from the provision of public education. For those middle-aged agents who choose to bequeath private education for their offsprings, benefits from choosing private education must exceed the sum of the two costs, which is greater than benchmark specification, thereby causing even more distinct jumps in the optimal education decision rules on the extensive margin.

Table 1.16 summarizes the results from the model under different tax regimes. The first three and the fifth columns display comparable findings as the benchmark model. Aggregate variables display a U-shaped pattern, although the arms being steeper and the depth of the U-shape being greater than the former model. Figure 1.9 facilitates the display of this pattern.

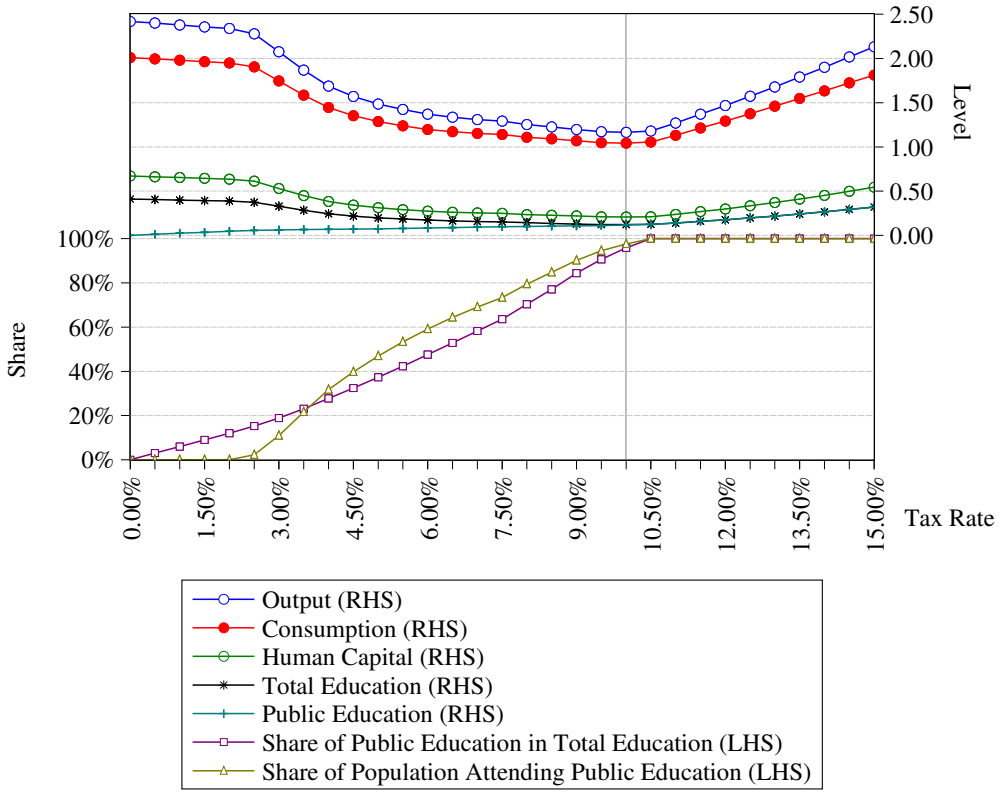
This result can also be attributed to the greater forgone benefits of public

Table 1.16: Steady-State with No Public Education Spillover ($\nu = 0$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{C}/\overline{Y}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$
0.00%	0.672	2.419	2.010	0.831	0.410	0.000	0.000%	0.000%
2.50%	0.612	2.279	1.905	0.836	0.374	0.057	15.224%	2.151%
5.00%	0.312	1.486	1.287	0.866	0.199	0.074	37.253%	46.853%
7.50%	0.248	1.292	1.140	0.882	0.152	0.097	63.591%	73.419%
10.00%	0.207	1.165	1.043	0.896	0.122	0.117	95.768%	97.557%
12.50%	0.334	1.573	1.376	0.875	0.197	0.197	100.000%	100.000%
15.00%	0.544	2.132	1.813	0.850	0.320	0.320	100.000%	100.000%

education when private education is chosen, hence less *de facto* education attainment at all tax rates, except for the tax regimes at which all students attend either only public or only private schools. The tax rate that minimizes aggregate output emerges approximately at 10.2% beyond which the whole population starts uniformly attending public schools. Output minimizing public education share in the

Figure 1.9: Stationary Equilibria with No Public Education Spillover



data was shown to be roughly 60%, hence the absence of public education spillover suggests somewhat unrealistic and counterintuitive predictions as model's goodness of fit with the real the world evidence worsen compared to the limited-spillover model.

Table 1.17: Distributional Properties with No Public Education Spillover

τ	$GINI_h$	$GINI_y$	$GINI_c$	$GINI_e$
0.00%	0.400	0.266	0.265	0.264
2.50%	0.402	0.267	0.258	0.273
5.00%	0.421	0.281	0.251	0.372
7.50%	0.409	0.270	0.246	0.286
10.00%	0.387	0.257	0.253	0.041
12.50%	0.379	0.252	0.252	0.000
15.00%	0.379	0.252	0.252	0.000

Next, I analyze the distributional properties of the variables of interest and summarize the results in Table 1.17. First, second and fourth columns reveal that similar to the limited-spillover model, human capital, output and education inequalities first increase as economy's tax rate goes up, and after a threshold tax rate of 5%, they all start to decrease, as in the limited-spillover model. However, inequality measures are documented to vary more in magnitude over taxes compared to the former model, which is due to the greater variation of fundamental variables under the no-spillover specification. Third column shows that consumption inequality across individuals behave similarly as in the benchmark model, both in terms of its pattern and its magnitude. Inequality in consumption initially decreases over tax rates, and after the tax rate at which the entire population attends public schools, it stabilizes. Overall, it can be concluded that distributional properties of the macro variables in the no-spillover model closely mimic those of the limited-spillover model, while magnitude-wise the latter model generates more pronounced variations.

1.4.4 Results with Full Public Education Spillover

In this subsection, I report the results from the model with full public education spillover, i.e. the environment in which all students, regardless of their education choice, can benefit fully from the public education provision. First, I verify that the value functions and optimal decision rules are smooth and concave, as in the earlier specifications. Contrary to the two former models, however, for the non-zero tax rates at which some measure of individuals finds it optimal to attend public schools under zero and limited spillover specifications, there are not any distinct jumps in the extensive margin (e.g. as in Figure 1.4), but smooth transitions. This result is due to the fact that, under the full-spillover model, the choice of private education, even at an infinitesimal level, does not require giving up the benefit from the provision of public education, and the only cost of private education is the actual expenditure itself.

Table 1.18: Steady-State with Full Public Education Spillover ($\nu = 1$)

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{C}/\overline{Y}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$
0.00%	0.672	2.419	2.010	0.831	0.410	0.000	0.00%	0.00%
2.50%	0.633	2.330	1.947	0.836	0.383	0.058	15.20%	0.00%
5.00%	0.597	2.245	1.887	0.840	0.358	0.112	31.32%	0.00%
7.50%	0.567	2.175	1.837	0.845	0.338	0.163	48.26%	9.28%
10.00%	0.593	2.238	1.889	0.844	0.349	0.224	64.06%	30.43%
12.50%	0.677	2.436	2.040	0.837	0.396	0.304	76.89%	45.31%
15.00%	0.810	2.729	2.256	0.827	0.473	0.409	86.56%	59.09%

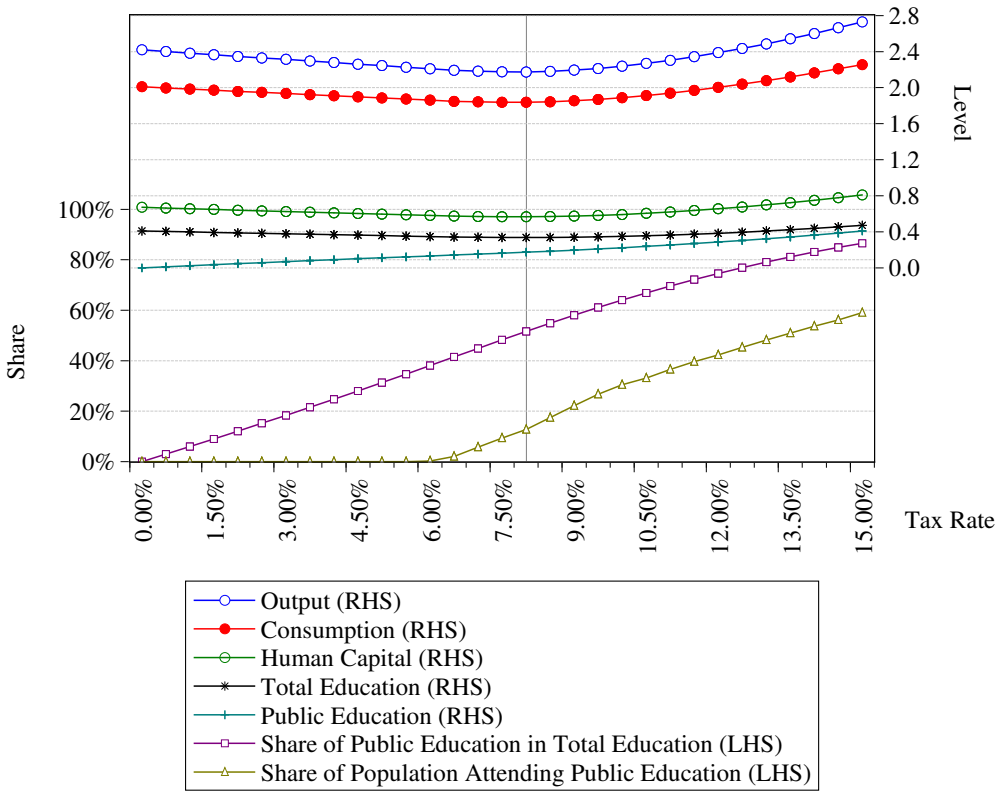
Table 1.18 displays the behavior of aggregate variables over taxes. The first three and the fifth columns reveal that similar to the limited-spillover model, there is a U-shaped pattern, although considerably flatter in magnitude. The minimum levels of aggregate variable levels are noticeably higher than those of the two former

models. Whereas the *laissez-faire* economy is identical to the former model case, as it should be, in response to higher taxes only minor incremental drops in aggregate variables are observed. Further, beyond the tax rate at which aggregate output is minimized, $\tau \approx 8\%$, the full-spillover model predicts higher aggregate variable levels compared to the former two models. These results can be expected since the *de facto* education attainment of the young is increasing over public education spillovers.

The last three columns of Table 1.18 show that while the level of public education is greater in magnitude compared to the former two models in all tax regimes (except for the *laissez-faire* case), the share of public sources in overall education expenditure and the fraction of population attending only public schools are much lower. Specifically, under this specification, no one chooses *only* public education unless the tax rate exceeds 6%. Also, while the entire population attends public schools in the no-spillover model when the tax rate is 10.2%, only one-third of the population prefer only public education in this model environment. This prediction by the model can again be attributed to the lower opportunity cost of forgoing private education. Quantitative details of the behavior of aggregate variables can be examined in detail in Figure 1.10.

Table 1.19 displays the distributional properties of interest over tax rates. The gini coefficients of aggregate human capital and output stay roughly the same up to $\tau = 7.5\%$, and they start to decrease beyond this tax rate. Further, the gini coefficients of consumption and education are observed to decrease monotonically over tax rates contrary to the earlier two models. Therefore, it could be concluded that the model with full public education spillover predicts monotonically less unequal

Figure 1.10: Stationary Equilibria with Full Public Education Spillover



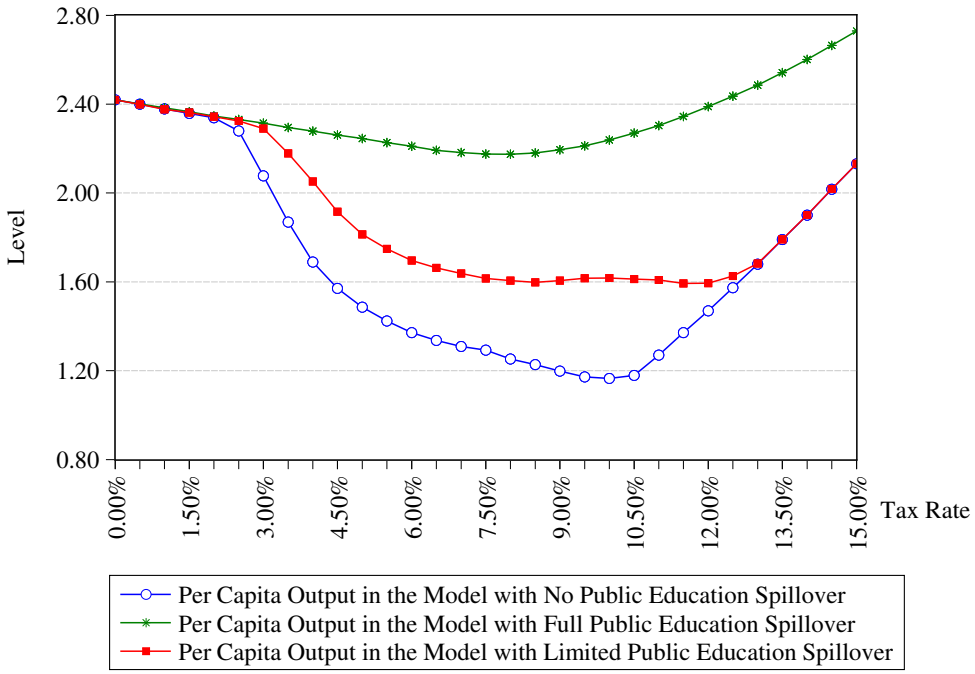
distributions of fundamental variables over tax rates, as in the earlier studies in the literature that do not study the co-existence of education types.[36]

Table 1.19: Distributional Properties with Full Public Education Spillover

τ	$GINI_h$	$GINI_y$	$GINI_c$	$GINI_e$
0.00%	0.400	0.265	0.266	0.264
2.50%	0.401	0.266	0.259	0.261
5.00%	0.401	0.267	0.253	0.257
7.50%	0.401	0.267	0.246	0.249
10.00%	0.398	0.264	0.243	0.210
12.50%	0.392	0.260	0.242	0.155
15.00%	0.387	0.257	0.243	0.100

[36] Although the model with full public education spillover generates admittedly unrealistic predictions, a promising merit it provides is that it suggests alternative country-specific parametrization could enhance model's goodness of fit on the right arm of the U-shape, particularly for the countries which rely extensively on public education.

Figure 1.11: Per-Capita Output Predictions by Spillover Rates



A comparison of the output per-capita by the three specifications is displayed in Figure 1.11. The *laissez-faire* economies of the three models are identical since different ways of modeling public education spillover does not alter the results in an environment at which the provision of public education is zero. As tax rate goes up, the no-spillover model generates the lowest and the full-spillover model generates the highest per-capita output. The limited spillover model lies in between the two polar specifications up to the tax rate $\tau \approx 12.5\%$ at which the entire population attends only public schools. Beyond this tax rate, since all students choose only public schools in both the no-spillover and the limited-spillover specifications, the two models converge. The intuition behind this result is similar in spirit to the *laissez-faire* case: given that at the convergent model environments there is only

public *de facto* educational attainment, modeling how public education provision affects private school students has no effect in equilibrium. At this tax rate only half of the students attend public education under the full-spillover environment. The three models converge when the entire population in the full-spillover model attends only public schools, which emerges at an unrealistically high tax rate.

1.4.5 Results with Endogenous Labor

Having established results under the fixed-labor-supply specification, next I turn to relaxing the restrictive assumption on labor choice and analyze the consequent changes. In order to endogenize labor, first I modify the utility function of the middle-aged by employing the following functional form:

$$u(c) + v(1 - l) = \log(c) - \phi \frac{l^{1+\omega}}{1 + \omega} \tag{1.27}$$

Next, I set $\omega = 0.5$ so that Frisch elasticity of labor supply equals 2 as in the mainstream macro literature. I calibrate the multiplier before disutility of labor to $\phi = 2.138$ so that the average labor supply in the endogenous labor model at the *laissez-faire* economy equals $l = 0.33$, as in the fixed-labor model. Also, I keep $\nu = 0.5$ so that the results are comparable to the limited public education spillover model, which fits the data better among the three specifications.

I verify the value functions and optimal decision rules for education to be smooth and concave as before. I also document distinct jumps in the private education extensive margin for the non-zero tax rates, as in the fixed-labor specification.

Further, for the non-zero tax rates, labor supply decision is documented to illustrate minor jumps: the middle-aged agents who choose public education for their offsprings supply lower labor than those who choose private education, however variation across individuals with different extensive margin decisions for a given tax rate is observed to not to be substantial. Also, labor supply variation within the intensive margin is documented to be minimal, as well. This result that less productive individuals with convex distaste in labor work less than their productive counterparts is in accordance with economic theory.

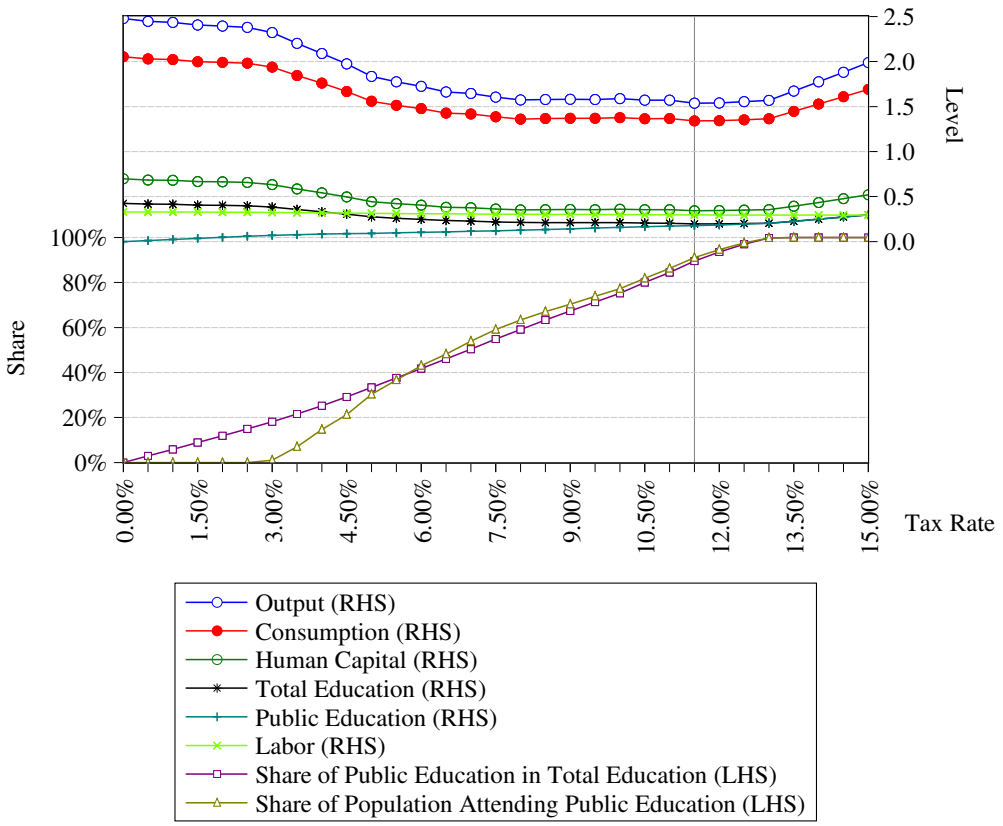
Table 1.20: Steady-State of the Model with Endogenous Labor

τ	$\overline{H}$	$\overline{Y}$	$\overline{C}$	$\overline{C}/\overline{Y}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$
0.00%	0.698	2.477	2.052	0.828	0.330	0.425	0.000	0.00%	0.00%
2.50%	0.657	2.378	1.980	0.833	0.326	0.398	0.059	14.94%	0.00%
4.89%	0.458	1.871	1.590	0.850	0.315	0.281	0.091	32.26%	29.08%
5.00%	0.443	1.834	1.559	0.850	0.315	0.275	0.092	33.36%	30.33%
7.50%	0.363	1.604	1.385	0.863	0.306	0.219	0.120	54.87%	59.05%
10.00%	0.359	1.587	1.376	0.867	0.300	0.211	0.159	75.25%	77.21%
12.02%	0.346	1.544	1.345	0.871	0.296	0.199	0.187	93.83%	94.90%
12.50%	0.350	1.553	1.353	0.871	0.295	0.200	0.194	96.95%	97.53%
15.00%	0.520	1.988	1.690	0.850	0.295	0.298	0.298	100.00%	100.00%

Table 1.20 displays the behavior of aggregate variables over taxes. The pattern illustrated by the variables of interest is identical to the fixed-labor model, except for the aggregate labor supply which decreases monotonically over the tax rate. This result is due to the fact that income tax creates an intratemporal wedge, thereby distorting labor supply decisions. Another observation from the first row of the table is that under the *laissez-faire* economy of the endogenous-labor-model, although average labor is matched to the fixed-labor model, average human capital and average output are higher than those predicted by the fixed-labor model. This result is due to the fact that with endogenous labor, middle-aged agents with

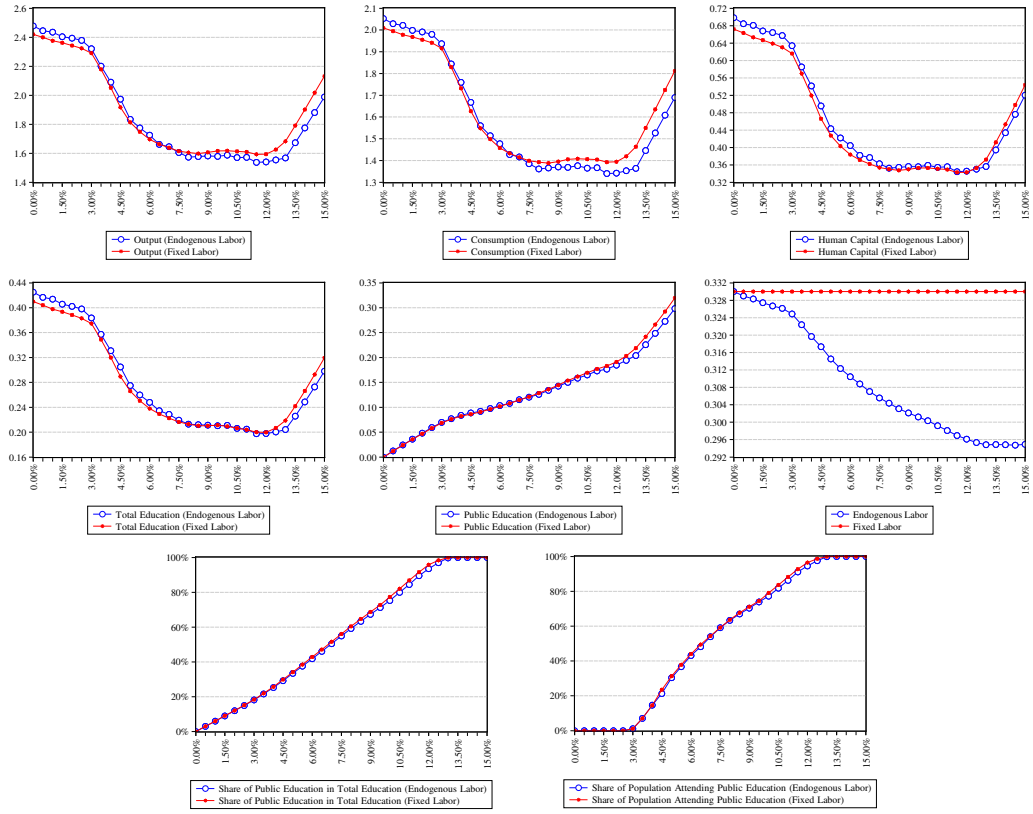
high human capital endowments and inborn competence draws work more hours, and the more productive labor force boosts overall human capital accumulation and production even at the same average labor level as in the fixed-labor model. Another observation from Table 1.20 is that the calibrated tax rates to match the U.S. and Nordic countries are slightly higher than the predictions by the fixed-labor model, although the differences being considerably slight and no more than 0.25% for both of the calibration targets. Further details on the behavior of aggregate variables can be examined in Figure 1.12.

Figure 1.12: Stationary Equilibria with Endogenous Labor



Next, I compare the behaviors of macro variables by the endogenous-labor model to those from the fixed-labor model, and display my findings in Figure 1.13. The first six graphs in Figure 1.13 reveal that predictions on all aggregate variables but the total labor supply by the endogenous-labor model are higher at low tax rates, and lower at the high tax regimes. This result is due to fact that higher productivity of the endogenous-labor environment as a result of better allocation of labor and education is more than offset by the fall in labor supply at high tax rates. However, the differences in the aggregate variables are notably minor, and variables in percentages (i.e. the share of public education and the fraction of public school students) are almost identical for both of the models.

Figure 1.13: Fixed vs. Endogenous Labor Supply



The model predicts average labor supply in the U.S. to be 1.064 times higher than that of the Nordic average. According to Alesina *et al.* (2005) in terms of "usual" hours worked, which is defined as the most common weekly working schedule over a selected period of a person in *employment*, U.S. employees work 1.047 times more than their Scandinavian counterparts. If the total hours worked, which accounts also for unemployment, is considered, this ratio goes up to as high as 1.242. Since the proposed model does not feature contractual employment or unemployment, the relative labor supply ratio generated by the model can be considered to fit fairly well with the data by being located in the associated interval.

Table 1.21: Distributional Properties of the Model with Endogenous Labor

τ	$GINI_h$	$GINI_y$	$GINI_c$	$GINI_e$	$GINI_l$
0.00%	0.400	0.265	0.267	0.260	0.002
2.50%	0.400	0.266	0.268	0.256	0.003
4.89%	0.415	0.283	0.257	0.330	0.023
5.00%	0.414	0.282	0.256	0.330	0.023
7.50%	0.410	0.280	0.240	0.303	0.024
10.00%	0.400	0.271	0.237	0.204	0.017
12.02%	0.390	0.261	0.249	0.068	0.006
12.50%	0.385	0.256	0.251	0.027	0.003
15.00%	0.379	0.252	0.252	0.000	0.001

Table 1.21 shows the distributional properties of the model with endogenous labor by focusing on the gini coefficients. Noticeably, the gini coefficients of human capital, output, consumption and education under the endogenous labor specification are almost identical to the predictions by the fixed-labor model at all tax rates. Inequality in labor displays a similar U-shaped pattern as in human capital and output: as tax rate goes up, labor supply inequality initially increases and starts to decrease beyond a threshold of 7.5%. This result is essentially due to the aforementioned labor supply disparities among those who differ in terms of their

public versus private education choices, together with the phenomenon that more productive workers supply more labor than their unproductive counterparts.

Overall, it is reasonable to conclude that the fixed-labor assumption does not offer unrealistic predictions since key results of the model hold even with the fairly restrictive constant labor assumption.

1.4.6 Welfare Analysis

Having derived the results on the behavior of aggregate variables and their distributional properties, next I focus on how agents' welfare varies over taxes. For this purpose, first I show the stationary distributions of households over individual human capital and inborn competence states by the limited-spillover model for the calibrated U.S. and the Nordic economies so as to examine how agents are populated. Next, I illustrate individuals' preferences over taxes by deriving their consumption equivalent gains in different tax regimes.

In Figure 1.14 and 1.15, I illustrate how middle-aged agents are distributed over human capital and inborn productivity states at the calibrated economies. I also graph the respective average human capital levels of these model economies as transparent light purple surfaces. It can be seen from the figures that in both economies of interest, a predominant majority of the population is endowed with human capital endowment levels below the economy average, and a noticeable fraction of agents is populated at the very low end of human capital states. Further, due to the notable variance of the inborn competence shocks, a non-trivial fraction of the

population is located around the upper and lower bounds of the inborn productivity states. The log-normal distribution of the inborn competence shocks, together with the optimal decision rules yield these results such that a majority of the population has below-average human capital, and accordingly pre-tax income levels.

Figure 1.14: Stationary Distribution of the Calibrated U.S. Economy

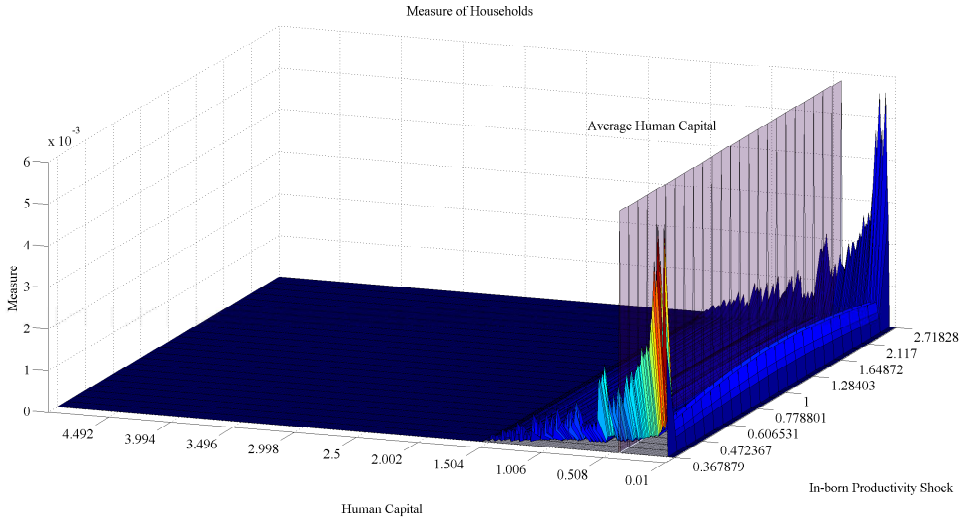
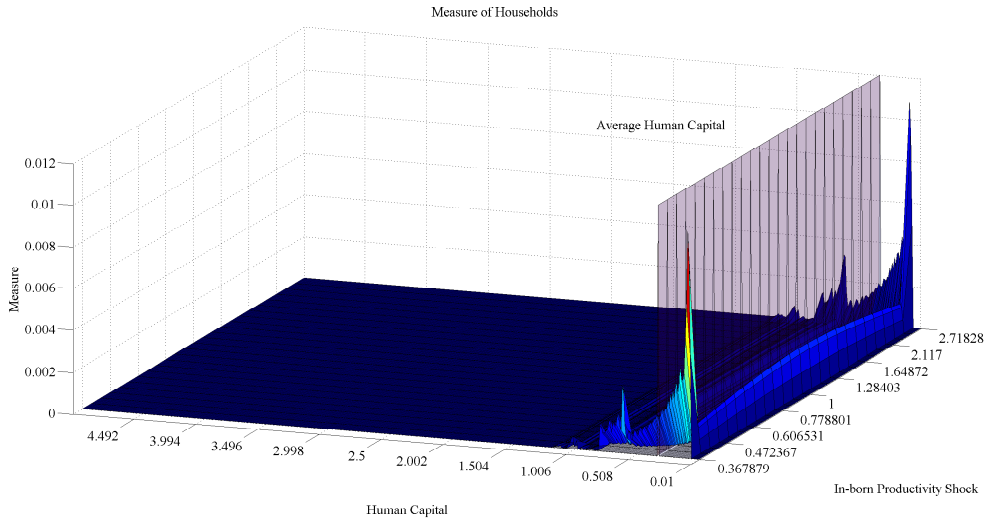


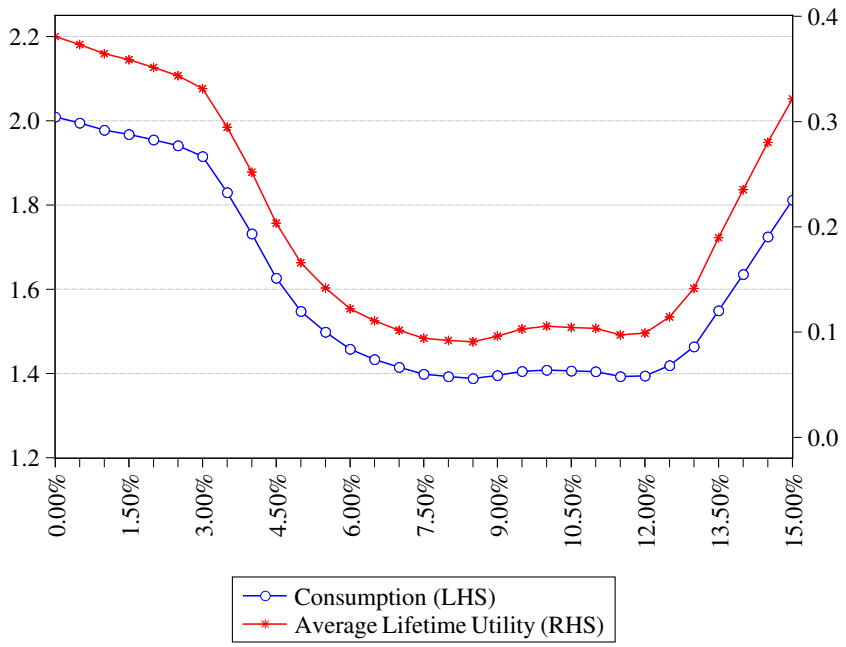
Figure 1.15: Stationary Distribution of the Calibrated Scandinavian Economy



Next, I derive how aggregate consumption and a utilitarian welfare measure calculated as the sum of dynastic utility levels of middle-aged agents weighted by

their respective population densities vary over taxes, and display my findings in Figure 1.16. Noticeably, the utilitarian welfare measure mimics aggregate consumption and displays a U-shaped pattern over taxes as the other macro variables. Yet, it would be erroneous to immediately conclude just by Figure 1.16 that the *laissez-fair* or high tax rates Pareto-dominate policies in between the two polar cases. In fact, next I show this is indeed not the case.

Figure 1.16: Average Utilitarian Welfare and Average Consumption



I analyze how life-time utility levels of individuals vary over taxes at different state pairs, and display the resultant graphs, together with a zero surface, in Figure 1.17 to 1.22. The former three figures display middle-aged agents' consumption equivalent gains over taxes for given levels of inborn competence, and the latter three graphs display consumption equivalent gains for given levels of human capital.[37]

[37]The consumption equivalent gains in these graphs are calculated by the use of "equivalent

Figure 1.17: Consumption Equivalent Welfare Gains over Taxes with the Lowest Inborn Productivity State ($\xi = 0.37$)

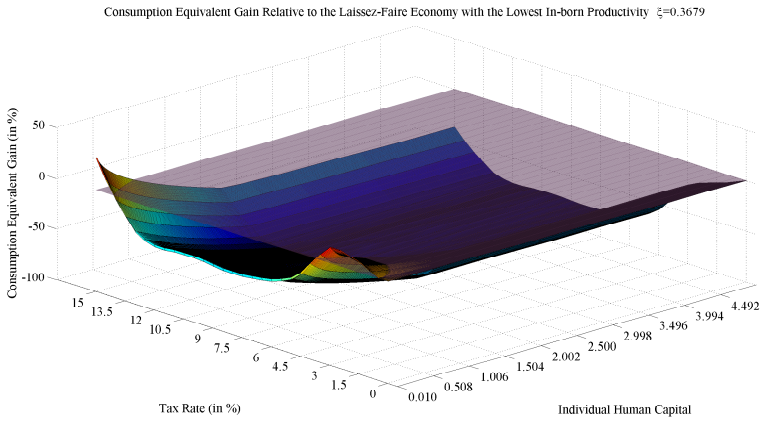


Figure 1.18: Consumption-Equivalent Welfare Gains over Taxes with the Median Inborn Productivity State ($\xi = 1.00$)

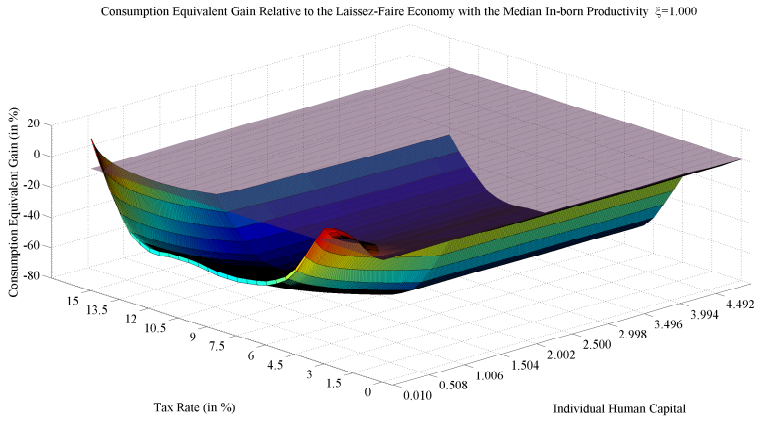
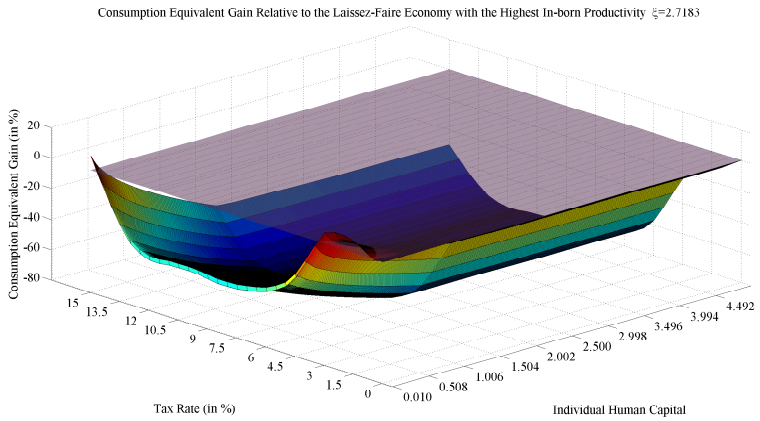


Figure 1.19: Consumption-Equivalent Welfare Gains over Taxes with the Highest Inborn Productivity State ($\xi = 2.72$)



A careful examination of Figure 1.17 to 1.19 reveals that similar to the behavior of aggregate variables, welfare gains of agents for given inborn competence levels display a U-shaped pattern over taxes, although with a minor yet critical novel feature: the middle-aged agents whose human capital endowments are low and inborn competence draws are not very high are better off in a tax regime around 3.5% compared to the *laissez-faire* economy, and the consumption equivalent gains of those at the very low end of distribution are more pronounced than their productive counterparts. Beyond this tax rate, welfare levels first decrease up of a tax rate of roughly 11.5% and start to increase beyond this threshold. While minor differences across states are noticeable, the spike on the left arm of the U-shaped pattern in welfare gains is present for a non-trivial measure of states. For those at high human capital and inborn competence states, intergenerational welfare initially decreases over taxes and starts to increase after the same threshold tax rate, thereby displaying a standard U-shaped pattern over taxes, comparable to that of the aggregate variables.

Figure 1.20 to 1.22 magnify this pattern from a different angle: keeping individual human capital states constant, the figures illustrate consumption equivalence gains of agents over taxes for given inborn competence levels. Figures reveal that agents with the lowest human capital states enjoy the most pronounced welfare gains from incremental increases in taxes from the *laissez-faire* economy, as well as from switching to a high tax regime. As agents' human capital endowments increase, their

variation": in order to leave an individual at a particular state indifferent between switching from the *laissez-fair* economy to another tax regime, how much more (or less) compensation as a percentage of his *laissez-faire* consumption is to be made.

Figure 1.20: Consumption-Equivalent Welfare Gains over Taxes When $h = 0.05$

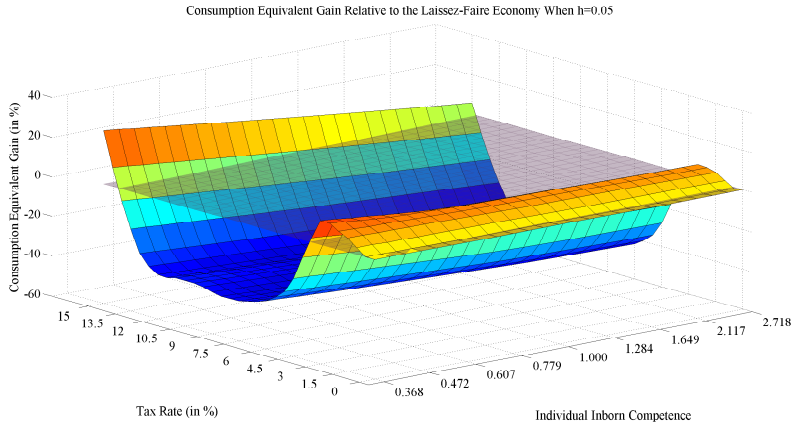


Figure 1.21: Consumption-Equivalent Welfare Gains over Taxes When $h = 0.15$

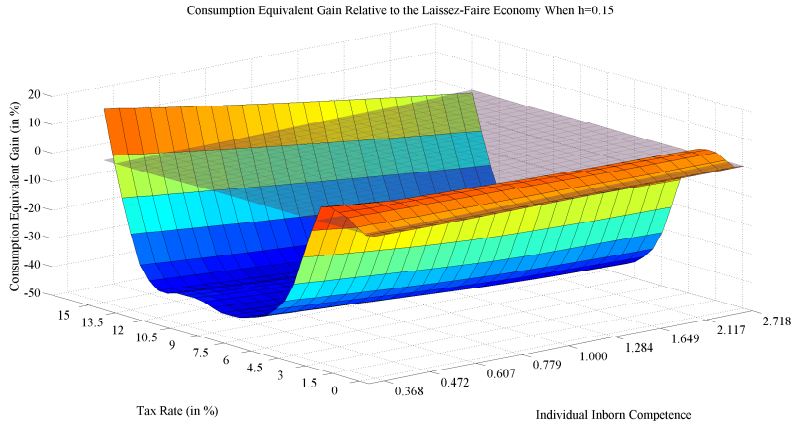
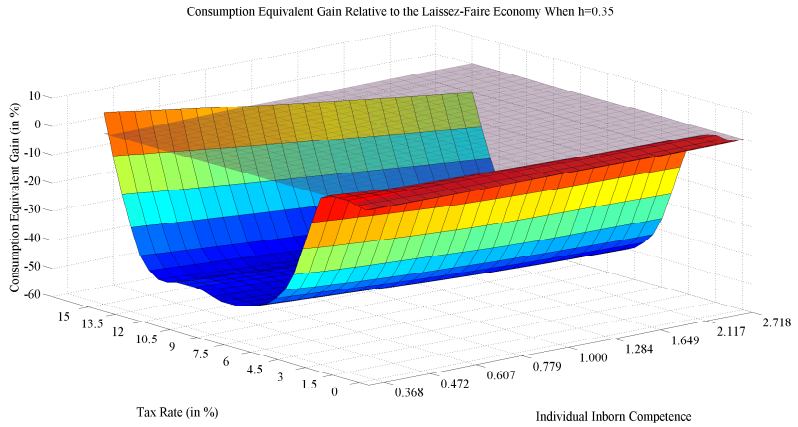


Figure 1.22: Consumption-Equivalent Welfare Gains over Taxes When $h = 0.35$



welfare gains from switching to the 3.5% tax regime from the *laissez-faire* economy first diminish and eventually disappear, while high enough tax regimes still provide comparable welfare levels as the 3.5% tax regime to most middle-aged households with not too high human capital and/or inborn competence states.

The presence of double-peaked preferences in education types is not a novel idea, but a highlighted phenomenon in the earlier microeconomics literature.[38] The intuition behind the double-peaked preferences of households over taxes can be summarized briefly as follows: agents at the low end of the income distribution prefer a non-zero tax regime to the *laissez-faire* economy due to the provision of free public education provision, which is financed mostly by the well-endowed agents in the economy. This redistributive benefit enjoyed by the less-endowed could be considered as a variant of the well-known Meltzer and Richards (1981) effect.

However, these agents with limited human capital endowments care also about the aggregate state of the economy since they use economy's aggregate human capital as a means to accumulate their offsprings' human capital for their. Thus, on the left arm of the U-shape, they want a non-zero tax regime in which the tax rate is not too high that gains from the redistributive benefits of free public education are not offset by the drop in aggregate human capital. Beyond this tax rate which makes the less-endowed agents better off, further increases in the tax rate have more marked negative effects on aggregate human capital, therefore benefits from

[38]For the introduction of single-dipped/double-peaked preferences in the presence of public and private education, see Stiglitz (1974), and Barzel and Deacon (1975), and Flowers(1975). Note that all the earlier papers that study the micro-foundations of double-peaked preferences are limited to the investigation of endowment economies, and none of these studies concentrate on the interaction of double-peaked preferences with endogenous aggregate outcomes.

incremental increases in the public education provision are outweighed by the drops in aggregate human capital.

Once the economy reaches a sufficiently high tax regime in which a majority of the population chooses to attend public schools, drops in private education attainment as a result of higher taxes is more than offset by the increase in total public education attainment and its spillovers. Further, with the pronounced positive economy-wide complementarity effects, agents start to enjoy welfare gains to increase over taxes again.

Clearly, the single-crossing property does not to hold globally in this model environment. However, a weaker *local* variant of it is verified to hold around the two peaks: the model numerically predicts that if an agent with the individual human capital state (h^1, ξ^j) prefers the tax rate $\tau = 3.5\%$ over $\tau = 0$, then so does the agent with (h^2, ξ^j) state pair where $h^1 > h^2$. Similarly, if a middle-aged household with the human capital state (h^1, ξ^j) prefers a tax rate above $\tau = 11.5\%+$ to one below $\tau = 11.5 - \%$, then so does the individual with the (h^2, ξ^j) state pair. Also, while tax regimes below 3.5% offer higher dynastic utility than 11.5% for most of the individuals, such comparison is not immediately applicable for tax rates close to 15% from below, and a considerable heterogeneity in welfare gains is present.

If the tax rate in the economy is sufficiently close to $\tau = 3.5\%$, as in the case for the calibrated U.S. economy, agents with limited human capital endowments who constitute a majority of the population would object to lowering of the taxes since they would be worse off in the absence of free public education provision. Further, if the economy could not switch swiftly from its current tax rate to a high

tax regime above $\tau = 11.5\%+$, all households would incur non-trivial welfare losses throughout the transition process. If such costs exceed benefits from reaching a high tax environment, households would almost uniformly object to a higher tax rate, as well. Therefore, majority of the electorates of the calibrated U.S. economy could be content in the neighborhood of their tax regime, thus the economy could stay inertial at this tax rate.

Regarding the calibrated Nordic economy, agents would almost uniformly vote against a lower tax rate in the close neighborhood of the targeted tax rate $\tau = 11.78\%$, since they would have to incur output and consumption losses as a result of drops in the tax rate. Further, if the labor supply gets distorted significantly in response to upward movements in the tax rate, a much higher tax rate would not be welcome by the electorates, either.[39] Finally, if the economy cannot switch rapidly from a high tax regime to a significantly lower one $\tau = 3.5\%$, possibly due to the presence of preexisting institutions, voters would not want to suffer the non-negligible transition costs. Thus, they could be content staying inertial in a tax regime around the calibrated Nordic economy.

In light of these findings, the proposed model can rationalize why large measures of households could prefer their calibrated tax regimes, and how such economies

[39] As mentioned in the earlier sections, in the absence of labor supply choice and especially physical capital, it is probable for the model to overestimate the benefits from high taxes. Future research on the introduction of physical capital would be enlightening on the limits of high tax regimes.

can stay inertial at the two distinct equilibria.[40,41]

1.5 Conclusions

This chapter concentrates on the differences between the U.S. and the Nordic European countries in their higher education systems and their finances. To study the Transatlantic differences, I develop a parsimonious heterogeneous agent OLG model with both public and private education options available in the choice set of agents, presence of economy-wide complementarities, spillover benefits from public education provision to private school students, and distortionary taxes for public education financing. I first show that the proposed model can deliver the U-shaped pattern of per-capita output over public education expenditure shares, a phenomenon I show is also present in the data. Next, I show that tax differences alone can deliver many of the observed Transatlantic discrepancies without having to rely on differences in agents' preferences, variations in deep structural parameters or introduction of other unorthodox elements. In particular, by calibrating the model to target countries' GDP (PPP) per capita and public-to-total higher education expenditure ratios, I show that a reasonable tax rate difference of 7 percent can endogenously generate

[40] While analyzing the welfare gains of households over tax rates, off-the-equilibrium-path beliefs are not implemented and dynamic distributional effects of electorate choices are not taken into account. Instead, welfare gains at different equilibria are studied to provide insight into potential ways of endogenizing taxes. Therefore, while it would be erroneous to make inferences on the "politico-economic" equilibrium, the model can still provide reasonable insight into the electoral preferences of voters on stationary equilibria choices.

[41] Introduction of adjustment costs in taxes, e.g. physical allocative costs due to restructuring education, psychological costs due to cognitive dissonance, internalizing social norms, presence of history-dependent preferences, etc. can be incorporated into the model to formalize for a more accurate and rigorous targeting for economies to stay inertial at the exact targeted tax rates. This chapter aims to deliver the intuition behind the model with the most parsimonious structure possible, and introduction of these elements is left to future research.

higher U.S. total education-expenditure-to-GDP ratio, lower U.S. public school attendance ratio and higher U.S. labor supply, as well as more unequal distributions of income and output for the U.S. when compared to the Nordic countries. Finally, by investigating welfare implications of alternative tax regimes, I show that either of the calibrated economies can gain political support from their respective populations, thereby providing insight into how the two economies can stay inertial at their distinct equilibria. This result is also essentially arising from the U-shaped behavior of macro variables over taxes, and the intuition behind this finding is that while at low rates, an increase in taxes and the provision of public education dampens human capital accumulation due to drops in private education attainment, at high tax rates, public education provision gets sufficiently large that a majority of the population prefer public education over the private one, and an increase in tax rate boosts public education provision and attainment more than it dampens private education.

The proposed model clearly has its limitations, too. First, most parameter values employed in the model are set in accordance with the previous literature, which offers limited wisdom on the real-world estimates of the model parameters. Further research, preferably on the micro-level estimation of the parameter values would certainly improve the reliability of model's predictions.

Second, in the absence of single-peakedness of preferences over taxes, this chapter does not endogenize model economy's taxes, and instead it concentrates on comparing the welfare consequences of alternative long-run tax regimes. Endogenizing taxes would clearly contribute to our understanding of the cross-country

differences in higher education, yet being beyond the scope of this paper, studying the formal politico-economic equilibrium is left for future research.

Third, while the model can provide insight into how two distinct equilibria can gain political consent from their respective electorates and stay inertial at their long-run equilibria, it does not extend the discussion on the transitional dynamics or the Transatlantic divergence.[42] Especially, the study of transitional dynamics can contribute to the understanding of off-equilibrium preferences and beliefs of electorates, thereby enabling the politico-economic equilibrium solution of the presented heterogeneous-agent economy with uninsurable risk and double-peaked preferences.[43] Future work on the transitional dynamics and study of divergence would be enlightening.

Finally, while the model can contribute to the discussion on how the U.S. and Scandinavian systems can stay inertial at their stationary equilibria, it cannot be employed to explain how developed countries featuring predominant public and private education attainment could be politically sustainable for the same parameter value space. Further research on the estimation of the model parameters would contribute to our understanding of these incidences, as well.

[42] Alesina and Glaeser (2004) discuss the lack of considerable differences in taxation and redistribution between the U.S. and the continental European countries before the late nineteenth century, and only a limited number of studies focus on the endogenous evolution of institutions after this period. Further, those exceptional studies do not particularly concentrate on the divergence of Transatlantic redistributive or public versus private education policies. For the discussion on the evolution of institutions, see Aghion *et al.* (2004), Acemoglu and Robinson (2000) and Acemoglu *et al.* (2012), among others.

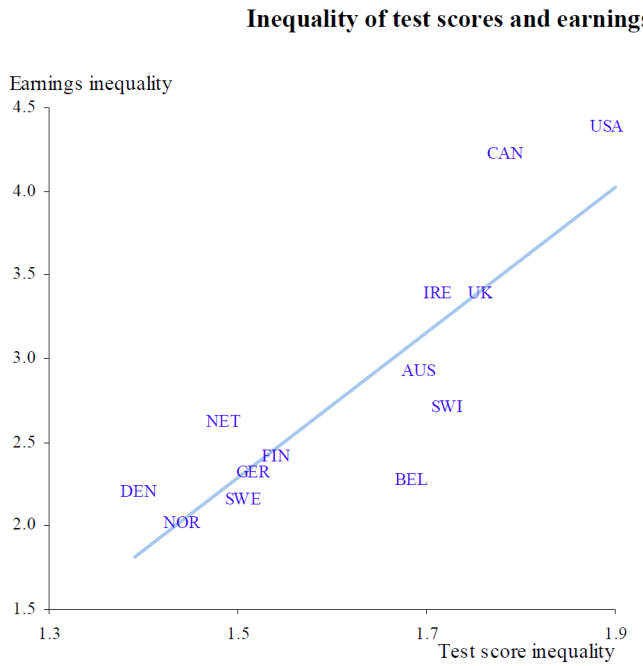
[43] Concerning the formal politico-economic equilibrium of the presented model economy, it is may be essential use to make some necessary refinements on the choice set of agents. Specifically, in the case of a unique tax rate that maximizes the welfare of a winning coalition of electorates regardless of the initial conditions, restrictions on the choice of upper and lower bounds for taxes could be utilized for the survival of two distinct equilibria.

In spite of these limitations, this chapter can shed at least some light on the determination and implications of the co-existence of public and private education types, the presence and sustainability of the Transatlantic differences in education, as well as extending the discussion on how different complementarity and spillover channels can interact in a general equilibrium set-up.

1.6 Appendix

Appendix - Figures

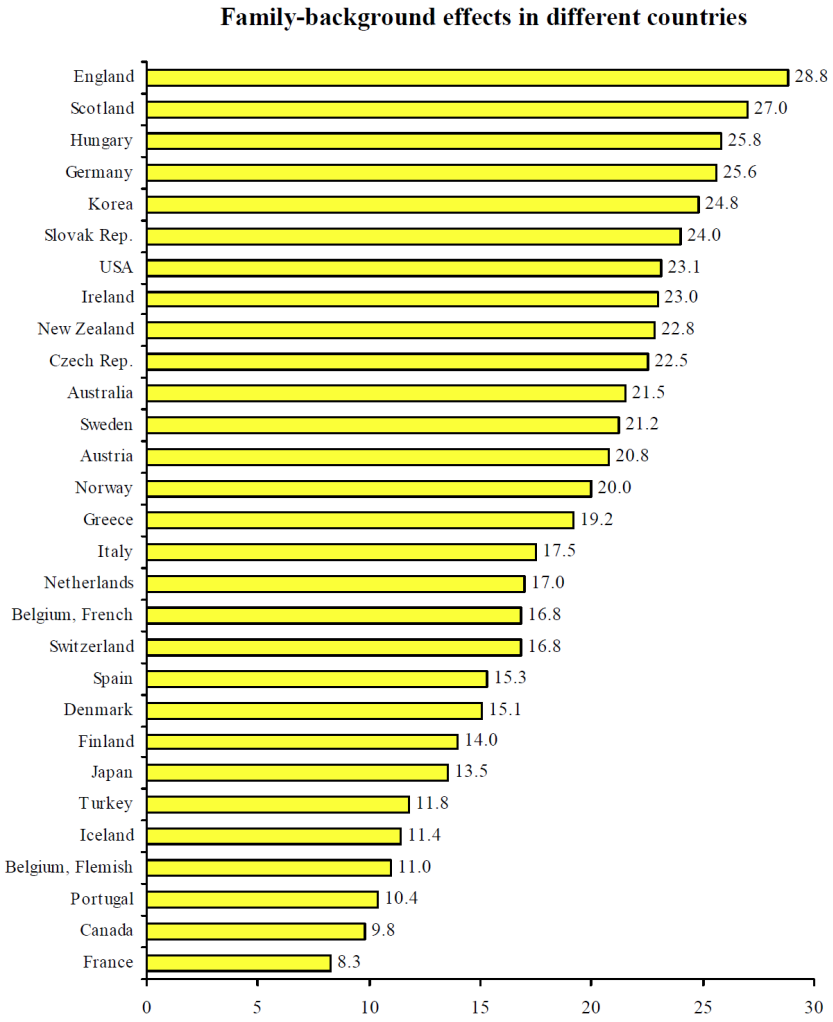
Figure 1.23: Return on Education and Literacy Score Inequality by Country



Notes: Measure of inequality is the ratio of ninth decile to first decile in both cases; test performance refers to prose literacy in the International Adult Literacy Survey.

Source: Based on Nickell (2004).

Figure 1.24: Intergenerational Skill Transmission by Country



Notes: Coefficient estimates from a student-level regression within each country of the mean of math and science performance in the TIMSS-95 and TIMSS-Repeat international tests on books at home, which is a categorical variable with five categories. Regressions control for age, gender, family status, student born in country, mother born in country, father born in country, interactions between the three immigration variables and books, and a dummy for the second test cycle. All estimates are statistically significantly different from zero at the 1 percent level.

Source: Based on Schuetz, Ursprung, and Woessmann (2008), Table 3.

Appendix - Computational Strategy

The computational strategy I employ to solve for the recursive competitive equilibrium is a modified heterogeneous-agent economy with incomplete markets algorithm *à la* Huggett (1993). The way the algorithm is utilized is as follows: for a given tax rate, first I make initial guesses for aggregate human capital $\overline{H}$ and public education $\overline{E}$ jointly. Second, taking these values given, I solve for the optimal decision rules of agents in all possible individual-specific human capital h and inborn cognitive competence ξ state pairs by the use of value function iteration. Third, I perform Monte Carlo simulations for sufficiently large number of periods and households (11000 periods and 1000 households), discard some initial number of periods (1000 periods). Then, making use of the generated data, I calculate the mean of the aggregate human capital and public education levels from simulations, i.e. $\sum_{t=1}^{T} \frac{H_t^{sim}}{T} = \overline{\widehat{H}}$ and $\sum_{t=1}^{T} \frac{E_t^{sim}}{T} = \overline{\widehat{E}}$. If the mean of simulated value for aggregate human capital or public education is different than initial guess for the variables at a reasonable tolerance level, i.e. if $|\overline{\widehat{H}} - \overline{H}| > \epsilon^{tol}$ or $|\overline{\widehat{E}} - \overline{E}| > \epsilon^{tol}$, I update the initial guesses and go over the same steps until convergence is achieved. For robustness check, I also derive the theoretical stationary distribution of population using the decision rules and the exogenous law of motion for the inborn competence shocks, and using the stationary distribution, I calculate the implied theoretical aggregate human capital and public education, and compare them against the simulated values. I verify that the implied human capital and public education values are the same convergent values derived through Monte Carlo simulations. Through these steps, I also ensure that grids are

fine enough so that computational errors are kept at a minimal level. For each tax rate I go over the same steps and derive the respective stationary equilibrium.

Chapter 2

Transatlantic Differences in Taxation, Redistribution and Provision of Public Goods: How Fair is Inequality?

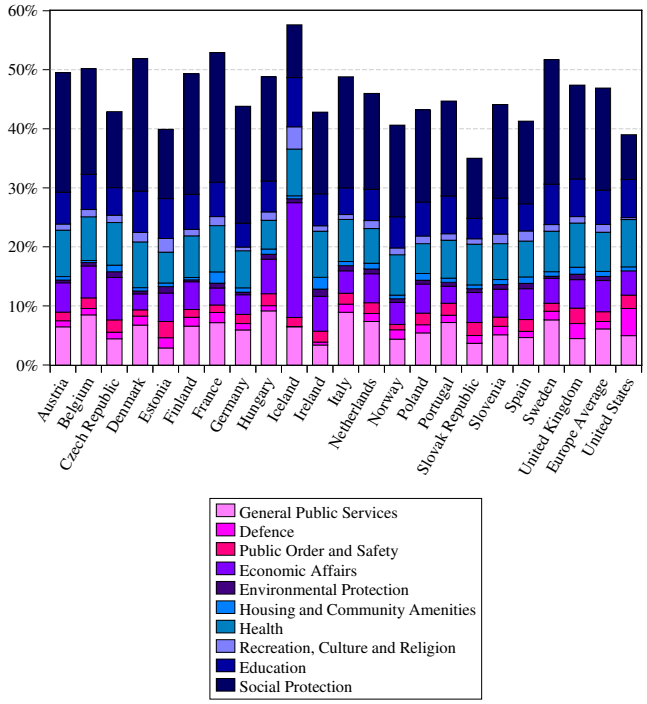
2.1 Introduction

Transatlantic differences in taxation, redistribution, and provision of public and private goods have been investigated extensively. In particular, the fact that the U.S. has lower average tax revenue as a share of production, lower share of public expenditure in overall education and health care provision, lower social protection expenditure as a share of government budget, higher average number of hours worked and higher income, education and health care inequality than its continental European counterparts has been a source of inspiration for a number of studies.[1] Further, a growing body of literature documents that while a majority of Americans believe in a more pivotal role of effort and skill in the determination of final outcomes, Europeans put more emphasis on the decisiveness of luck. This chapter proposes a model to explain for the coexistence of these Transatlantic differences, and intends to provide insight into their political sustainability.

To illustrate the differences in the size of government, Figure 2.1 shows the level and composition of government spending by country. Noticeably, the U.S.

[1] For a detailed discussion on the economic and political differences between the U.S. and Europe, see Alesina and Glaeser (2004).

Figure 2.1: Government Spending by Country (% of GDP)

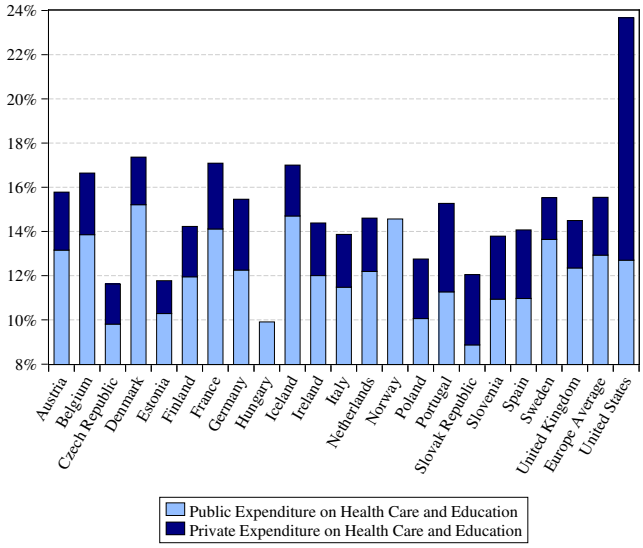


Source: OECD Database (2004-2008)

government spends less as a share of GDP compared to the developed European economies, and the difference is particularly more pronounced when the comparison is between the U.S. and Northern European countries. Figure 2.1 also displays the composition of government expenditures, which differs considerably across countries on most, but not all accounts. Of particular importance, while at first glance education and health care expenditures do not seem to differ radically across the Atlantic, further investigation on the private provision of these goods reveal otherwise. In order to highlight these Transatlantic differences, Figure 2.2 shows the level and composition of overall health care and education expenditure as a share of GDP. It can be seen that while the share of public resources allocated to health

care and education in the U.S. is only mildly lower than that of the European average, private funds allocated in the U.S. on the two accounts far exceed that of the European average, which in turn implies both the fraction of private expenditure and the level of aggregate expenditure on education and health care to be markedly higher in the U.S.[2]

Figure 2.2: Health Care & Education Expenditure by Country (% of GDP)



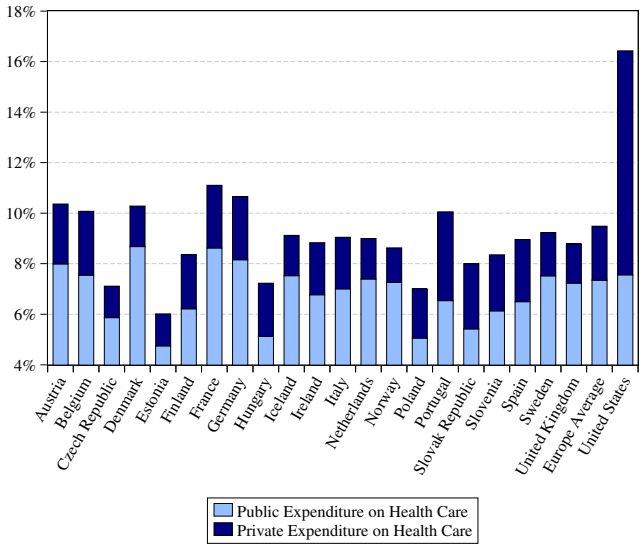
Source: OECD Database (2004-2008)

Next, I turn to analyzing Transatlantic differences in health care and education expenditures separately, and show in Figure 2.3 that as the U.S. spends significantly more on health care compared to the European countries, it relies more heavily on private financing.

In Figure 2.4, I display total education expenditure by source and show that the U.S. spends the most on education of any country save Iceland, and private

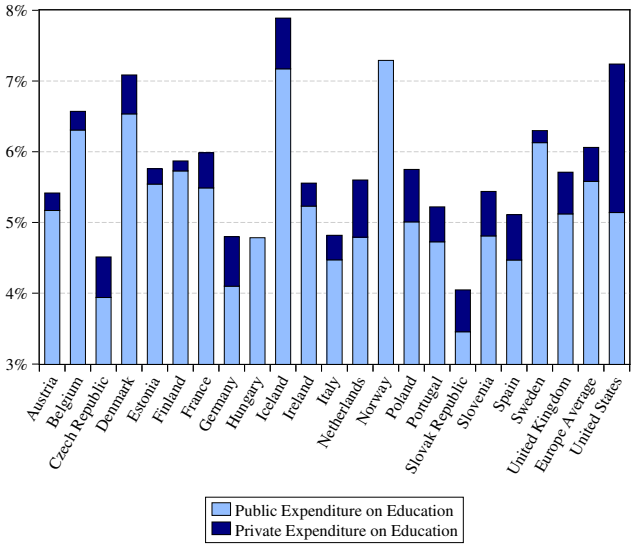
[2]For the European average, I use the same subset of developed countries as in Alesina and Angeletos (2005): Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

Figure 2.3: Health Care Expenditure by Country (% of GDP)



Source: OECD Database (2004-2008)

Figure 2.4: Education Expenditure by Country (% of GDP)



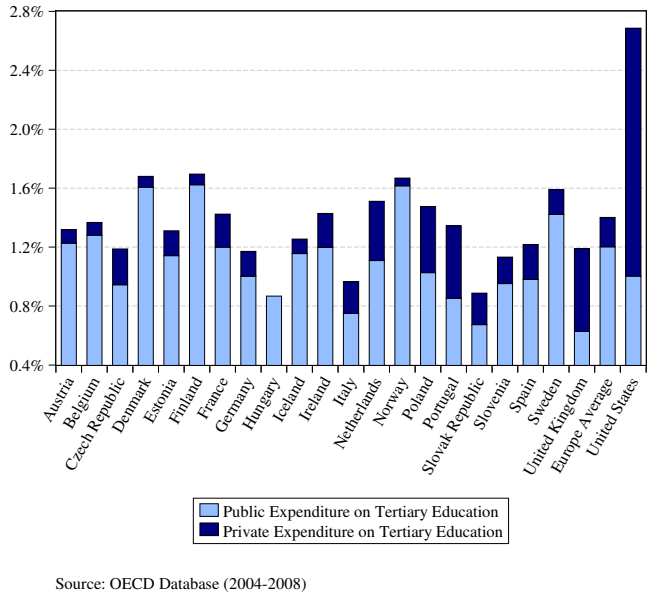
Source: OECD Database (2004-2008)

spending on education in the U.S. exceeds that of all remaining countries.

As higher education plays a seminal role in the determination of earnings, in Figure 2.5, I concentrate solely on tertiary education and show that U.S.'s reliance

on private resources for tertiary education financing far exceeds that of the European countries, even more so than the figures in overall education, implying similar expenditure compositions in primary and secondary education provisions among countries under investigation.[3]

Figure 2.5: Tertiary Education Expenditure by Country (% of GDP)



Source: OECD Database (2004-2008)

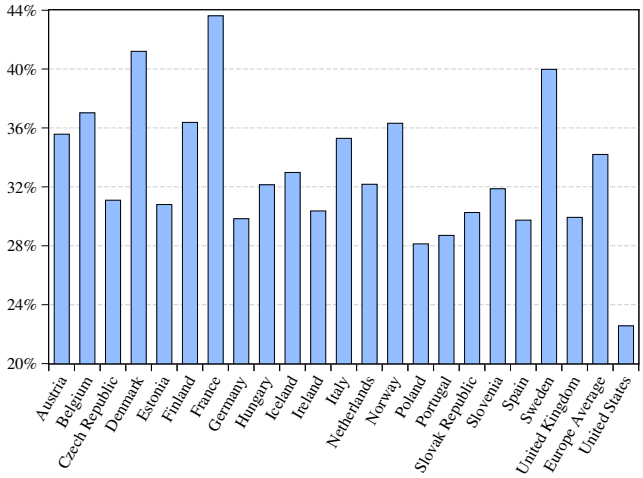
On the income side, I display total tax revenue by country in Figure 2.6 and show that in accordance with the patterns in government spending, the U.S. has the lowest average tax revenue as a share of its GDP among countries of interest.

When income inequalities of the U.S. and Europe are investigated, gini coefficients suggest that both pre-tax and post-tax income inequality in the U.S. exceeds those of all developed European countries, as shown in Figure 2.7.[4] While the gini

[3]Figures on primary and secondary education expenditure by country are available in the Appendix section.

[4]The same pattern is observed when other inequality measures, such as the mean log deviation of income from country means are employed. For a detailed discussion on the Transatlantic differences in income inequality and their evolution, see Guvenen *et al.* (2009).

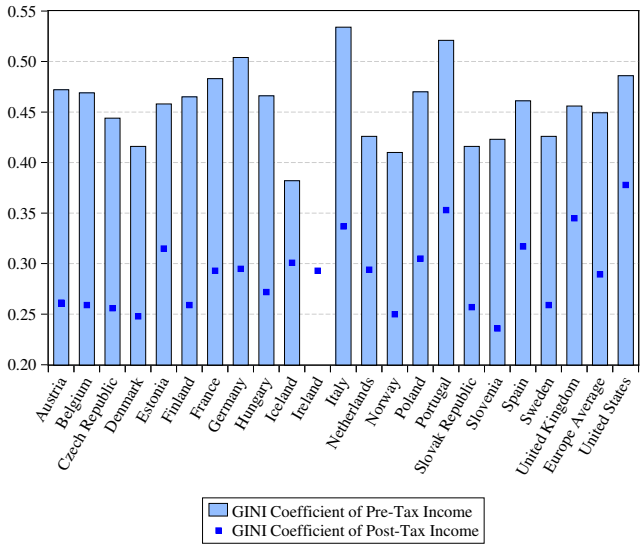
Figure 2.6: Tax Revenue by Country (% of GDP)



Source: OECD Database (2004-2008)

coefficient on pre-tax income in the U.S. is only slightly higher the European average, post-tax income inequality is noticeably greater in the U.S., consistent with the moderating role of higher taxes, redistribution and public goods in Europe.

Figure 2.7: Pre-Tax & Post-Tax Income Inequality by Country



Source: OECD Database (2004-2008)

Although there are no directly comparable measures of educational attainment by country, the literature on education employs international standardized surveys conducted on population samples to infer the nature of educational dispersion. For instance, Blau and Kahn (2005) use OECD's International Adult Literacy Survey and show that there is a higher degree of variation in the U.S. educational attainment compared to the European countries, as shown in Table 2.1. They document that while the mean scores are not significantly different between the U.S. and the European countries, U.S. displays more disperse scores in both the right and the left end of the distribution. Further anecdotal evidence supporting greater inequality in the U.S. educational attainment is by Barry McGaw, (Director of Education for the OECD) who states in a speech that "...the very best schools in the U.S. are extraordinary ... but the big concern in the U.S. is the *diversity* of the quality of institutions..." (Fuller, 2005).[5]

In accordance with economic theory, higher taxes in Europe coincide with lower average hours worked, as documented by a large number of studies.[6] Figure 2.8 displays this pattern by showing average annual hours actually worked per worker by country. While the Transatlantic differences in hours worked are not as pronounced as the spending and revenue indicators, it can be seen that American employees work 9.9% more on average than their European counterparts. Further, except for Iceland and Italy, American workers on average work longer hours than average

[5]Regarding health care attainment inequality, although there are not any studies quantifying inequality across countries, many medical researchers, e.g. Starfield (2000), emphasize that greater income inequality in the U.S. translates into a relatively higher degree of health care attainment inequality as well, particularly through the extensive variation in the extent of private medical insurance coverage.

[6]Among others, see Prescott (2004), and Alesina *et al.* (2005).

Table 2.1: Descriptive Statistics from the International Adult Literacy Survey

Male

	Mean	Standard Deviation	Differential	
			50-10 Percentile	90-50 Percentile
Denmark	296.44	38.00	51.44	38.92
Finland	296.75	40.19	54.14	45.82
Italy	251.86	56.58	88.74	52.48
Netherlands	294.07	40.43	55.88	41.12
Norway	300.09	38.62	57.96	40.00
Sweden	311.60	46.37	57.63	52.03
Switzerland	283.36	51.19	64.12	44.18
Europe Average	290.60	44.48	61.42	44.94
United States	288.97	61.43	80.67	59.98

Female

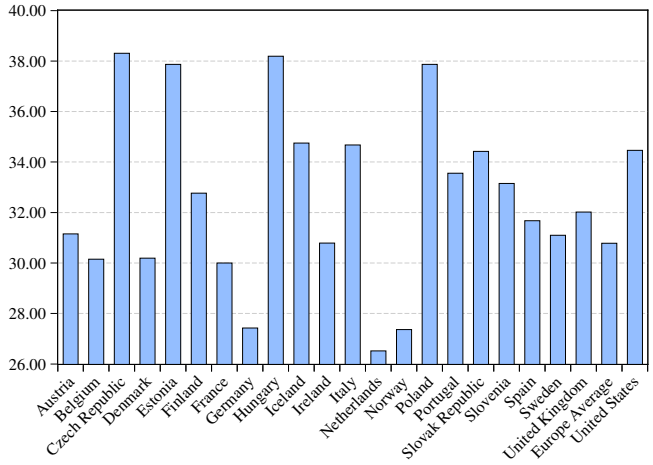
	Mean	Standard Deviation	Differential	
			50-10 Percentile	90-50 Percentile
Denmark	292.86	35.01	56.05	36.49
Finland	296.45	39.18	54.49	42.82
Italy	259.75	50.31	75.07	49.32
Netherlands	300.53	34.17	52.80	36.54
Norway	306.02	37.51	51.33	40.36
Sweden	308.54	43.08	51.01	50.93
Switzerland	278.51	47.53	53.17	43.16
Europe Average	291.81	40.97	56.28	42.81
United States	289.56	58.79	73.01	58.34

Based on Blau and Kahn (2005).

workers in all developed European economies.

Alesina and Angeletos (2005) and Benabou and Tirole (2006) emphasize another striking Transatlantic difference in regards to the perception of fairness and relative importance of effort vs. luck in the determination of final outcomes. They show that according to the World Values Survey (WVS) 54% of Americans believe skill and effort is decisive in final outcomes whereas only 29% of Europeans are in agreement with this belief, with the majority of Europeans believing that luck is

Figure 2.8: Average Weekly Hours Worked by Country

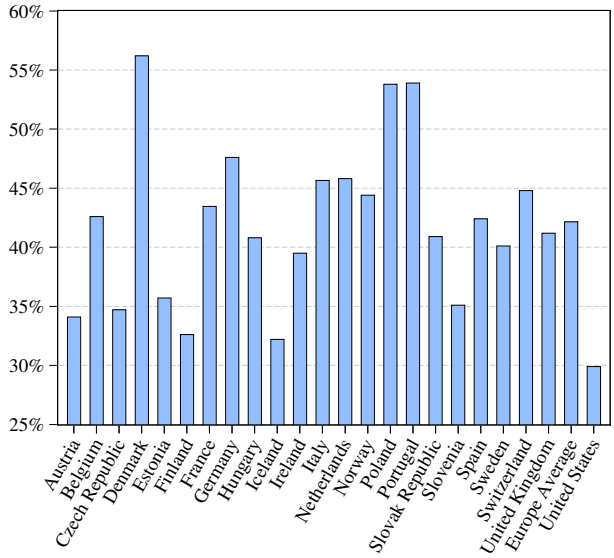


Source: OECD Database (2004-2008)

more pivotal. They also argue for significant uni-directional causality from the perception of high decisiveness of luck to higher per-capita social protection spending, and they conclude that cross-country differences in perception of fairness endogenously lead to different levels of governmental intervention in the form of taxation and redistribution, which in turn induces a more unequal income distribution in the U.S. compared to Europe. Using the same source WVS and extending the sample size to 2009, I display the fraction of populations with the belief that luck determines outcomes in Figure 2.9, which suggests comparable statistics as in Alesina and Angeletos (2005).[7]

[7]WVS Association and International Social Survey Programme conduct some further surveys on the role of effort and roots of poverty. Due to the relatively limited sample size of these survey results, as well as for comparability and brevity purposes, I display only the results from the question with the WVS code E040, as in Alesina and Angeletos (2005) and Benabou and Tirole (2006). In the appendix I also show the results from the survey question with the code E131, which asks the respondents why they believe people are in need. Results reveal that while a predominant majority of Europeans believe people are in need due an unfair society, even a greater fraction of Americans believe people are poor due to laziness. Such findings, implying even more pronounced differences across the Atlantic, support evidence on the divergence in beliefs on the role of effort vs. luck.

Figure 2.9: Fraction of the Population with the Belief Luck Determines Income



Source: World Values Survey (1981-2008)

A final remark on the countries of interest is that both the U.S. and the Western European countries are known to be well-established democracies with good performances in measures of electoral process quality and pluralism.[8] Therefore, it can be safe to conclude that tax and redistribution systems, as well as public good provision policies of the U.S. and European governments should receive considerable consent from the electorates of their respective countries.

It is a puzzle how such differences in taxation, public good provision, inequalities and beliefs can persist. Earlier attempts addressing Transatlantic differences succeed to explain only a limited subset of the aforementioned discrepancies, and only a very limited number of studies incorporate beliefs in their analyses.[9] Alesina

[8]See The Economist Intelligence Unit's Index of Democracy, 2007 and Freedom in the World, 2009 Edition, among others.

[9]Benabou and Tirole (2006) propose a stylized model with beliefs about the "need" to believe in a just world through cognitive dissonance mechanism. In their model multiple equilibria emerge due to different levels of effort and concealing bad news from offsprings. The elements of their

and Angeletos (2005), being an exception, argue by extending Piketty (1995) that if common perception in an economy is that luck is strongly decisive in economic outcomes, agents will unlikely be motivated to exert high effort, which in equilibrium causes luck to be strongly influential and initial beliefs to be verified. In this environment, in order to insure themselves against unlucky future scenarios, electorates favor redistributive policies over *laissez-faire* ones and economy stays inertial at the high tax high-luck-decisiveness equilibrium. In contrast, if agents perceive market to be fair and the role of luck to be minimal, they will be motivated to exert high effort, which in turn reduces the decisiveness of luck and motivates electorates to favor *laissez-faire* policies over pronounced redistributive ones due to foreseeable future, and thus less need for insurance. However, tailored to explain variations in beliefs, conclusions of the model by Alesina and Angeletos (2005) rely on unorthodox restrictions on preferences such as a distaste in inequality, and provide unreasonable predictions on the political sustainability of the multiple equilibria since their suggested U.S. and European economies are Pareto-ranked.[10] Further, authors do not study on the role of public vs. private goods in their analysis.[11]

model, such as the degree of holding back bad news from offsprings are hard, if not impossible, to measure, which makes the testing of their model challenging and casts doubts on the reliability of predictions of their model.

[10]In particular, the low-tax equilibrium for the U.S. by Alesina and Angeletos (2005) features roughly 5 times greater per-capita labor supply and output than the high-tax equilibrium for the E.U., and the authors leave it unanswered why Europeans would be content to stay at the Pareto-dominated equilibrium.

[11]This chapter also relates to the education and human capital literature. One of the few studies addressing Transatlantic differences, Benabou (2000) investigates the role of progressivity of taxes and redistribution on education and shows that two distinct equilibria can emerge depending on whether the efficiency-enhancing effect of education or the redistributive one dominates. However, he does not study the implications of the coexistence of public and private education, and does not take the predictions of his stylized model to data. For other studies, see Zhang (2005), Soares (2006), Benabou (2002), and Benabou (2005).

This chapter intends to fill this gap in the literature by proposing an overlapping generations (OLG) general equilibrium model to address the aforementioned economic differences and differences in perceptions. In order to do so, I propose a heterogeneous-agent model in which agents can either choose public or private good (e.g. education), where public education confers positive externalities but requires distortionary taxation. To study Transatlantic differences in perceptions, I introduce the idea of decomposing income inequality with respect to its "fairness" by defining whether inequality arises from foreseeable actions and abilities of individuals, or pure luck. For this purpose, the model features two different types of shocks: an inborn competence shock which affects optimal consumption, labor and public vs. private education decision rules together with parental and economy-wide human capital, and an additively-separable income shock which is orthogonal to decision rules and individual competence levels. I show that low taxes coupled with low public education provision in the U.S. induce a large impact of inborn competence on schooling and labor supply, which in turn implies that a large share of U.S. income differences are due to skill, education and effort, in line with the perceptions of Americans on income inequality. In Europe, by contrast, a combination of high taxes and high public education provision minimizes differences due to inborn competence, and magnifies the impact of luck on income differences, in accordance with European beliefs.

The intuition behind these findings is briefly as follows: first, macro variables in the model display a U-shaped pattern over taxes, a phenomenon that I show is also seen the data. This U-shape of variables is because of the fact that starting from

the *laissez-faire* economy as economy's tax rate increases, so do public education provision and redistribution. This, however, reduces private education attainment of agents due to the distortionary role of taxes, as well as the disincentivizing extensive margin effect of free public education. In low tax regimes, decreases in private education attainment due to higher taxes outweigh the benefits acquired from greater public education provision, which in turn lowers aggregate education attainment. Lower education attainment induces lower aggregate human capital accumulation, which accordingly reduces total production in the economy, hence generating the left arm of the U-shape. As the tax rate keeps increasing, public good provision gets large enough that the majority of the population optimally chooses public education over the private one, and an incremental increase in taxes boosts public education attainment more so than it dampens private education, thereby fostering total education attainment, and thus elevating aggregate human capital and output over taxes.

In regards to the structure of income inequality, attendance at the same public school equalizes human capital formation across agents, which reduces both total income inequality and the share of income inequality due to differences in skills and decision rules. In a low tax regime in which public school attendance is limited, income inequality is mostly attributed to varying levels of human capital across households as a result of diverse private education choices. In a regime which displays a high degree of total income inequality, the share of income variation due to investment in human capital, competence, and labor supply, i.e. the "fair" variation, is high relative to the "luck" variation, thereby justifying American perceptions in

the decisive role of effort and skills. In contrast, in a high tax environment where predominant public education attendance limits variation in human capital due to differences in idiosyncratic competence levels, luck shocks account for a higher share in total income variation, which is in line with European perceptions in a pivotal role of luck.

This chapter contributes to the literature also by being the earliest calibration attempt to deliver several economic and behavioral Transatlantic differences jointly. Further, the calibrated U.S. and European economies, which differ only in regards to their tax policies, are located on the left and right arms of the U-shape respectively, which gives rise to the phenomenon that large measures of the electorates of the targeted economies have comparable welfare levels, thereby providing insight into how the two regimes can be politically sustainable at the same time.

The rest of this chapter is organized as follows: In Section 2.2, I describe the model environment, in Section 2.3, I report and discuss about my findings, and Section 2.4 concludes.

2.2 Model

2.2.1 Model Environment

The model I propose is a heterogeneous-agent OLG model with two cohorts, young and middle-aged, both with the same measure normalized to unity, and there is no population growth. The young are born with an exogenous stochastic level

of cognitive competence, which can be thought of as an IQ draw.[12] The young accumulate human capital as a function of competence, as well as private education bequests from parents (if any), the level of public education consumed, economy-wide human capital and the parental human capital. Human capital is used to earn income when middle-aged. The young do not optimize, and only abide by the law of motion for human capital. The middle-aged decide how much to work, consume and bequeath for the offspring's private education given his altruistic preference towards the young.

There is a single distortionary income tax, which is the only instrument to finance public education and government transfers. For simplicity, the model assumes the constant long-run tax rate to be exogenous to the economy, although welfare implications of different tax rates are analyzed as part of the analysis of political stability. Therefore, the tax rate and fiscal policy rule (i.e. what fraction of the government spending to be allocated on the provision of public education vs. government transfers), together with the level and distribution of human capital and labor supply, determine the level of public education provision and government transfers.

The primary focus of this chapter is to study the long-run properties of the variables of interest. Therefore the model assumes there are no aggregate shocks, which in turn induces the economy to remain at its stationary equilibrium at all

[12]For the ease of discussion, I use education as model's "good". Alternatively, one could model genetic health draws in lieu of cognitive competence shocks and health care expenditure as a form of productive investment that can improve health, accordingly human capital. Therefore, it is possible to extend the framework to address other forms of goods provisions that contribute to human capital.

periods where all aggregate variables, as well as their distributional properties, are constant at their steady-state values.[13]

In terms of the model's timing, the middle-aged agent i enters period with a human capital endowment $h \in \mathcal{H}$ and observes his child's inborn competence $\xi \in \Xi$. Next, for the given tax rate τ, public education provision $\overline{E}$ and government transfer $\overline{Tr}$, the middle-aged agent i decides whether to choose the public or a different level of private education e for his offspring, along with what fraction of the period to devote to work. Public education is provided in a rival and non-excludable way, yet is offered in a somewhat take-it-or-leave-it fashion: the private school students, regardless of education bequest levels from their parents, cannot fully enjoy public education benefits as they have to incur an opportunity cost of forgoing at least some fraction of the public education benefits. Middle-aged agents who choose private education for their children incur out-of-pocket costs, but these parents have the flexibility to pick their desired level of education bequests for their children as long as they incur their respective pecuniary costs.

When solving for optimal decisions, middle-aged agents can optimize only over contemporaneous *expected* consumption due to an additively-separable idiosyncratic "luck" shock that affects income and *actual* consumption. In other words, the middle-aged agent i chooses optimal labor and education *after* observing his offspring's inborn competence draw, but before the realization of his idiosyncratic

[13]Note that in the absence of aggregate shocks, a stationary-equilibrium model in which agents vote every period features constant endogenous taxes. Therefore, the constant tax assumption of this model can be considered as a reduced-form extension of a voting model, as welfare implications of the suggested U.S. and European equilibria are shown to be in accordance with household preferences in the following welfare subsections.

luck shock, which in turn requires him to maximize life-time utility over *expected*, and not *actual* consumption. The intuition behind this way modeling is to clarify the distinction between fair versus luck variation in income: while the middle-aged agent can alter his labor and education choices in order to respond optimally to the state of the nature, thereby giving rise to the formation of cross-sectional "fair" variation in income due to abilities and actions, he cannot respond to or insure himself against orthogonal income shock draws which induce the "luck" variation in income.[14,15]

Output is produced using a labor and human capital augmented technology, along with an additively-separable the luck component.

Formally, middle-aged i at time t solves:

$$V(h,\xi;\overline{H},\overline{E},\overline{Tr},\tau) = \max_{\{l,e\}}\Bigg\{ \sum_{\eta} \pi_{\eta}(\eta)u(c(\eta)) + v(1-l) + \rho \sum_{\xi'} \pi_{\xi}(\xi',\xi)V(h',\xi';\overline{H},\overline{E},\overline{Tr},\tau)\Bigg\} \tag{2.1}$$

[14]Note that alternatively if middle-aged agents were to decide on optimal education and labor decisions *after* observing the realization of the income shock, the resultant human capital and labor choices of the young would have been affected both by their inborn competence draws *and* income shocks of their parents, which would clearly obscure the distinction between the fair and luck components of income.

[15]The sequentiality of the model suggests by the time a middle-aged agent decides on the optimal education choice of his offspring, he forms rational expectations on future earnings of the offspring, which only "on average" have to hold, i.e. the "actual" earning of the offspring might differ from the ex-ante predictions due to the role of pure lock. To exemplify this timing structure, one can think of the case that by the time a college student commits to a university and a major, while she can form rational expectations on her future earnings, her actual job market outcome could diverge from her predictions due to unforeseeable factors such as nepotism, which is captured by the introduction of the luck shock in the model. However, it must also be the case that the forward-looking college students are not structurally fooled, or in other words when unobservable factors are neither good nor bad, the expected earnings are equal to the actual earnings.

subject to

$$y = \Theta l^{(1-\lambda)} h^{\lambda} + \eta \tag{2.2}$$

$$c = (1-\tau)y + \overline{Tr} - e \tag{2.3}$$

$$e \geq 0 \tag{2.4}$$

$$h' = \begin{cases} \xi(\overline{E})^{\varepsilon} h^{(1-\varepsilon)\gamma} \overline{H}^{(1-\varepsilon)(1-\gamma)} & e = 0 \\ \xi(e + \nu\overline{E})^{\varepsilon} h^{(1-\varepsilon)\gamma} \overline{H}^{(1-\varepsilon)(1-\gamma)} & e > 0 \end{cases} \tag{2.5}$$

$$\log(\xi) \sim N(\mu_{\xi}, \sigma_{\xi}^2) \tag{2.6}$$

$$\eta \sim TN(0, \sigma_{\eta}^2) \tag{2.7}$$

for given income tax rate τ, aggregate human capital $\overline{H}$, public education provision $\overline{E}$, government transfer $\overline{Tr}$, and other model parameters, where c denotes consumption, l denotes labor, h denotes individual-specific human capital at period t (h' denotes individual-specific human capital at period $t+1$, as do other variables with prime notation), e denotes private education bequest, ρ denotes the altruistic discount rate, Θ denotes the level of constant productivity, ξ denotes the inborn cognitive competence of the offspring, $\pi_{\xi}(\cdot)$ denotes the Markov chain transition probability matrix of the inborn competence process, and $\pi_{\eta}(\cdot)$ denotes probability distribution of the luck shock, which is independent and identically distributed across agents and time, hence does not depend on the realization of last period's luck draw for a given dynasty.

Equation 2.2 and 2.3 constitute the standard budget constraint of the house-

hold. Output requires the use of labor and human capital as factors of production, and tax is paid to the government proportional to income. Education and consumption decisions are made out of disposable income, i.e. net of taxes and transfers. As shown in Equation 2.4, private education bequests cannot take negative values, and the private education choice of zero units implies the attendance to public schools.[16] Human capital evolves according to Equation 2.5, so that there are economy-wide complementarities and limited transmission of skills across generations.[17] Given the role of parental human capital in the determination of individual-specific human capital, middle-aged agents solve a dynamic optimization problem with human capital being the endogenous and inborn competence the exogenous state. Aggregate-human capital in the economy facilitates the accumulation of individual-specific human capital, thereby serving as economy-wide externalities in middle-aged agents' constrained maximization.

The inborn competence shock is log-normally distributed as shown in Equation 2.6. While households know the distribution of the competence shock, they cannot foresee or insure against unfavorable competence draws of future generations. Finally, the luck shock η is distributed with a left-truncated normal distribution with

[16]As it can be inferred from Equation 2.4, the price of education is normalized to unity, which is also the price of the consumption good. This simplification is not central to the results, and does not change qualitative conclusions of the model for a reasonable range of relative prices. In the case of very adverse realizations of luck shocks which would otherwise force the middle-aged to consume in negative quantities, I restrict actual consumption to be infinitesimal above zero. This assumption has negligible general equilibrium consequences, and is intended for computational purposes.

[17]Persistent dynastic human capital is a common modeling approach in the literature. Schuetz *et al.*(2008) empirically verify the presence of intergenerational skill-passing across countries at different rates. For a detailed discussion on family background effects of educational performance and list of studies concentrating on the dynastic human capital transmission, see Hanushek and Woessmann (2010).

zero mean and a constant variance as shown in Equation 2.7, and it is orthogonal to decision rules and inborn competence shocks, i.e. $\text{cov}(\xi, \eta) = 0$.[18]

ν in Equation 2.5 denotes the fraction of public education benefits to private school students, or the "public education spillover". In other words, if ν takes a non-zero value, students who attend private education can still enjoy a fraction of the public education provision, and ν is less than 1 private school students cannot enjoy public education benefits as much as those who attend public schools.[19]

Let $\tilde{e}(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ be the optimal education decision rule to middle-aged agents' problem, and $\tilde{h}(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ be the individual-specific human capital for next period implied by the optimal education rule. Then, the stationary distribution of the economy $\mu(\cdot)$ satisfies:

$$\mu(h', \xi'; \overline{H}, \overline{E}, \overline{Tr}, \tau) = \sum_{\xi'} \int_{\mathcal{H} \times \Xi} \chi_{\{\tilde{h}(h,\xi;\overline{H},\overline{E},\overline{Tr},\tau)=h'\}} \pi(\xi', \xi) d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.8}$$

where $\chi(\cdot)$ denotes the indicator function. The middle-aged agents have rational expectations, so the aggregate human capital level they take as given in their optimization problems must indeed be economy's resultant aggregate human capital

[18]The left-truncated distribution assumption is not central for the results and is utilized so that agents who are are forced to consume at negative levels due to being hit by unfavorable luck shocks consume at a positive infinitesimal quantity instead. This assumption is essentially because household preferences are not defined over consumption at non-positive quantities. Note that when agents have a utility function the slope of which goes to infinity when consumption approaches zero, as in the presented model, the "punitive" infinitesimal unit of consumption motivates households to choose "precautionary" labor and education levels that keep them from consuming at the lower bound for almost all realizations of the luck shock.

[19]The intuition behind the introduction of public education spillovers is to provide the model flexibility to investigate alternative school systems. Implications of different spillover rates are discussed in detail in the following sections.

induced by the decision rules and distribution of the agents:

$$\overline{H}(\tau) = \int_{\mathcal{H}\times\Xi} h d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.9}$$

Further, government runs a balanced budget so that sum of funds allocated on public education and government transfers does not exceed total tax revenue:

$$\overline{E}(\tau) + \overline{Tr}(\tau) = \overline{\mathcal{T}}(\tau) = \int_{\mathcal{H}\times\Xi} \tau y d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.10}$$

For simplicity, the model assumes government spends a fixed fraction of its funds in the form of public education and the rest as transfers while satisfying its budget constraint.[20]

$$\overline{Tr}(\tau) = \psi\overline{\mathcal{T}}(\tau) \tag{2.11}$$

$$\overline{E}(\tau) = (1-\psi)\overline{\mathcal{T}}(\tau) \tag{2.12}$$

For the purpose of decomposing variations in income, let total income inequality be defined as follows:

$$\sigma_y^2(\tau) = \int_{\mathcal{H}\times\Xi} (y - \overline{Y}(\tau))^2 d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.13}$$

Then, given the additively-separable nature of the luck shock and its orthogonality to decision rules, variance of income due to luck is determined only by the

[20] I investigate the implications of different fiscal policy rules in the comparative statics subsection.

stochastic luck process:

$$\sigma_l^2 = \sigma_\eta^2 \tag{2.14}$$

Therefore, fair variation is the residual variance in income defined as follows:

$$\sigma_f^2(\tau) = \sigma_y^2(\tau) - \sigma_l^2 \tag{2.15}$$

Accordingly, the share of fair and luck variation can be defined as follows respectively:[21]

$$\iota_f(\tau) = \frac{\sigma_f^2(\tau)}{\sigma_y^2(\tau)} \tag{2.16}$$

$$\iota_l(\tau) = 1 - \iota_f(\tau) = \frac{\sigma_l^2(\tau)}{\sigma_y^2(\tau)} \tag{2.17}$$

For the definition of fair and luck variations in income, following from the macro literature, income variance decomposition relies on whether inequality arises from foreseeable actions and abilities of households or from pure luck, as displayed in equations 2.16 and 2.17. According to this definition, if for instance, two middle-aged agents with identical inborn skills, education and labor supply choices and parental human capital happen to have different earnings, the associated discrepancy is attributed to the role luck. If, however income differences arise from objec-

[21]For the purpose of studying post-tax income inequality, let $\tilde{y} = (1-\tau)y + \overline{Tr}$ denote disposable income of y after taxes and transfers. Then, post-tax income inequality equals $\tilde{\sigma}_y^2(\tau) = \int_{\mathcal{H}\times\Xi}(\tilde{y} - \tilde{\overline{Y}}(\tau))^2 d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$, where $\tilde{\overline{Y}} = (1-\tau)\overline{Y} + \overline{Tr}$ denotes the average disposable income after taxes and transfers. The post-tax income inequality due to luck then follows $\tilde{\sigma}_l^2(\tau) = (1-\tau)^2\sigma_\eta^2$, which implies the fair variation in income to be the residual variance as before: $\tilde{\sigma}_f^2(\tau) = \tilde{\sigma}_y^2(\tau) - \tilde{\sigma}_l^2(\tau)$. Accordingly, the share of fair variation in post-tax income can be defined as $\tilde{\iota}_f(\tau) = \frac{\tilde{\sigma}_f^2(\tau)}{\tilde{\sigma}_y^2(\tau)}$ and share of variation due to luck can be defined as $\tilde{\iota}_l(\tau) = 1 - \tilde{\iota}_f(\tau) = \frac{\tilde{\sigma}_l^2(\tau)}{\tilde{\sigma}_y^2(\tau)}$.

tive sources such as different inborn competence capacities of households, unequal investment decisions on human capital accumulation in the form of education, or different choices on the number of hours worked, the consequent income differences are considered a part of the fair variation, as the associated differences are justifiable by economic foundations.[22]

2.2.2 Recursive Competitive Equilibrium

The recursive competitive equilibrium under constant taxes and fiscal policy rule is a set of value functions, decision rules, allocations and stationary distribution, such that

1. Given $\overline{H}$, $\overline{E}$, $\overline{Tr}$ and τ, $\tilde{l}(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ and $\tilde{e}(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ are optimal decision rules to household agent i's problem, $\tilde{h}(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ is the implied human capital rule by optimal education decision, $V(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ is the resultant value function, and inborn competence and luck shocks follow their

[22] Clearly, there is no single definition for the fairness of income inequality and different choice of benchmarks give rise to different outcomes. The definition followed in this chapter is accordingly not a universal definition, but the closest one to relate to the mainstream macro literature and reconcile with the connotations by the World Values Survey. The definition I follow suggests inequality that cannot be attributed to any economic foundations is to be associated with the role of luck, while income differences due to economic fundamentals, regardless of the concerns on the distribution of aggregate income, is considered a part of the fair variation. Hence, it is important to note that the use of the word "fair" in this chapter may not overlap with other subbranches of economics or disciplines, and is primarily aimed to reconcile with the World Values Survey figures to address the Transatlantic differences in perceptions.

exogenous law of motions:

$$V(h,\xi;\overline{H},\overline{E},\overline{Tr},\tau) = \max_{\{l,e\}}\Bigg\{ \sum_{\eta} \pi_{\eta}(\eta)u(c(\eta)) + v(1-l) + \rho \sum_{\xi'} \pi_{\xi}(\xi',\xi)V(h',\xi';\overline{H},\overline{E},\overline{Tr},\tau)\Bigg\} \tag{2.18}$$

subject to

$$y = \Theta l^{(1-\lambda)}h^{\lambda} + \eta \tag{2.19}$$

$$c = (1-\tau)y + \overline{Tr} - e \tag{2.20}$$

$$e \geq 0 \tag{2.21}$$

$$h' = \begin{cases} \xi(\overline{E})^{\varepsilon}h^{(1-\varepsilon)\gamma}\overline{H}^{(1-\varepsilon)(1-\gamma)} & e = 0 \\ \xi(e+\nu\overline{E})^{\varepsilon}h^{(1-\varepsilon)\gamma}\overline{H}^{(1-\varepsilon)(1-\gamma)} & e > 0 \end{cases} \tag{2.22}$$

$$\log(\xi) \sim N(\mu_{\xi},\sigma_{\xi}^2) \tag{2.23}$$

$$\eta \sim TN(0,\sigma_{\eta}^2) \tag{2.24}$$

2. Aggregate variables stay constant at all periods, and the time-invariant stationary distribution satisfies:

$$\mu(h',\xi';\overline{H},\overline{E},\overline{Tr},\tau) = \sum_{\xi'} \int_{\mathcal{H}\times\Xi} \chi_{\{\tilde{h}(h,\xi;\overline{H},\overline{E},\overline{Tr},\tau)=h'\}}\pi(\xi',\xi)d\mu(h,\xi;\overline{H},\overline{E},\overline{Tr},\tau) \tag{2.25}$$

3. Variable definitions and expectations hold:

$$\overline{H}(\tau) = \int_{\mathcal{H}\times\Xi} h d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.26}$$

$$\overline{Y}(\tau) = \int_{\mathcal{H}\times\Xi} y d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.27}$$

4. Government runs a balanced budget and follows its predetermined fiscal rule:

$$\overline{E}(\tau) + \overline{Tr}(\tau) = \overline{\mathcal{T}}(\tau) = \int_{\mathcal{H}\times\Xi} \tau y d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.28}$$

$$\overline{Tr}(\tau) = \psi\overline{\mathcal{T}}(\tau) \tag{2.29}$$

$$\overline{E}(\tau) = (1-\psi)\overline{\mathcal{T}}(\tau) \tag{2.30}$$

5. Aggregate resource constraint holds:

$$\overline{Y}(\tau) = \overline{C}(\tau) + \overline{E}(\tau) + \int_{\mathcal{H}\times\Xi} e d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.31}$$

6. Total variation, fair variation and luck variations satisfy rational expectations:

$$\sigma_y^2(\tau) = \int_{\mathcal{H}\times\Xi} (y - \overline{Y}(\tau))^2 d\mu(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau) \tag{2.32}$$

$$\sigma_l^2 = \sigma_\eta^2 \tag{2.33}$$

$$\sigma_f^2(\tau) = \sigma_y^2(\tau) - \sigma_l^2 \tag{2.34}$$

7. Share of fair and luck variation satisfy:

$$\iota_f(\tau) = \frac{\sigma_f^2(\tau)}{\sigma_y^2(\tau)} \tag{2.35}$$

$$\iota_l(\tau) = 1 - \iota_f(\tau) = \frac{\sigma_l^2}{\sigma_y^2(\tau)} \tag{2.36}$$

2.2.3 Calibration

Deriving analytical solutions to middle-aged agent's optimization problem is not feasible due to non-trivial corner solutions in the extensive-margin decision in education. The nature of the model necessitates the use of global approximation methods. Accordingly, I employ value function iteration technique as a part of my computational solution strategy. Further, due to the absence of aggregate shocks Huggett (1993) algorithm is suitable in solving for the stationary competitive equilibrium computationally, details of which I discuss in the Appendix.

The parameter values I employ in my benchmark computation are displayed in Table 2.2. Following Benabou (2002), I set the value of the share of human capital (λ) to 0.625 and labor to 0.375. Following Zhang (2005), I set the elasticity of human capital with respect to parental human capital (γ) to 0.2, and the altruism rate (ρ) to 0.8. In the literature, as the elasticity of human capital with respect to education (ϵ) varies between 0.15-0.4, I assign a value in between 0.3. Heathcote *et al.* (2010) decompose the U.S. wage inequality, and distinguish whether inequality arises from observables or residuals. They show that post-2000 variance is fairly stable in the U.S., especially regarding the residual income inequality. I take their estimate for

Table 2.2: Benchmark Parameter Values

λ	0.625	Benabou (2002)
γ	0.200	Zhang (2005)
ρ	0.800	Zhang (2005)
ε	0.300	Benabou (2002) & Zhang (2005)
σ_η^2	0.259	Heathcote *et al.* (2010)
ν	0.500	Neutral Stance from Two Polar Cases
ψ	0.370	US Redistribution Share (OECD Database, 2008)
ω	0.500	Frisch Elasticity=2
ϕ	0.513	Calibrated to Match US Labor=0.287
σ_ξ^2	0.769	Calibrated to Match US $\iota_l = 29.88\%$
Θ	3.345	Calibrated to Match Europe $\iota_l = 42.75\%$
τ^{US}	7.13%	Calibrated to Match US $\overline{E}/\overline{\mathcal{E}} = 44.83\%$
τ^{EU}	11.96%	Calibrated to Match Europe $\overline{E}/\overline{\mathcal{E}} = 78.54\%$

the variance of residuals for the luck shock σ_η^2 after distributional adjustments.[23]

Regarding the value of the benchmark fiscal rule parameter, I use OECD's estimate for the U.S. $\psi = 0.370$ on the share of sum of education and health care spending in total government spending comprised of education, health care and social protection expenditure only.[24]

For utility, I use the following balanced-growth consistent contemporaneous utility function of the form:

$$u(c) + v(1-l) = \log(c) - \phi\frac{l^{1+\omega}}{1+\omega} \tag{2.37}$$

I set $\omega = 0.5$ so that Frisch elasticity of labor supply equals 2 as in the mainstream

[23]In particular, as their estimates are of log-normal wage earnings and the luck shock in my model is normally distributed, I calculate the variance of the luck shock as $\sigma_w^2 = (e^{\sigma_\eta^2} - 1)(e^{\mu+\sigma_\eta^2})$, where σ_w^2 refers to the residual wage variance with zero mean.

[24]As mentioned in the introduction section, primary and secondary education expenditure levels and compositions of the U.S. and European economies are very similar, which rules out the possibility that the Transatlantic differences are due to the differences in the early stages of education. Therefore in the benchmark parametrization, I include only the tertiary education expenditure and health care spending to proxy for the public good. Inclusion of primary and secondary education does not alter results of this chapter, qualitatively.

macro literature. I calibrate the multiplier before disutility of labor to $\phi = 0.513$ so that average hours worked by the model for the calibrated the U.S. economy coincides with the data.

Due to the absence of earlier studies and data on the public good spillover rate, I take a neutral stance from the two polar scenarios and set the spillover rate to $\nu = 0.5$, while I also report the results with alternative parameter values $\nu = 0$ and $\nu = 1$ so as to clarify its implications.

The model with no public education spillover $\nu = 0$ can be considered an environment where agents can benefit only from one of the two types of education, or in other words the public education is offered in a perfectly take-it-or-leave-it fashion. The model with full public good spillover model $\nu = 1$ can be thought of as an environment where all agents, regardless of their public vs. private good choices, attend public schools and enjoy full benefits of public education, and those who want to attain further education beyond the publicly provided level can choose to do so, only at its respective cost. In other words while agents who choose to attain private education have to incur its nominal costs, they do not have to forgo public educations benefits at all. The benchmark model where the spillover is set to $\nu = 0.5$ is tagged as the "limited public good spillover model", and it is intended to proxy for the environment where agents choosing private education can still benefit from the public education, yet not as much as the those who choose public education. In reality, neither of the two extreme scenarios is very likely and the limited public good spillover specification is employed for the sake of neutrality, as discussed in detail in the results section.

The inborn competence variance $\sigma_\xi^2 = 0.769$ and production technology $\Theta = 3.345$ parameter values are chosen so as to target for belief statistics on the share of luck in total income inequality both for the U.S. and European economies.

Finally, in the computational exercises to target for the U.S. and the European economies, all parameter values are kept the same except for the tax rate, which is used for calibration purposes. This parametrization intends to show that without introducing any unorthodox elements, or relying on variations in "deep" parameter values, the model can deliver the aforementioned Transatlantic differences just by relating to tax rate differentials and their endogenous implications.

2.3 Results

In this section, I first report my findings on the behaviors of micro and macro variables under different tax regimes. Next, I discuss comparative statics with alternative parameter values in order to illustrate how different channels affect variables of interest. Then, I compare model's predictions with the data and discuss how well the model fits not only for the calibration targets, but also for remaining developed economies. Finally, I analyze the behavior of agents' welfare over taxes so as to provide insight into how calibrated economies can gain politically consent.

2.3.1 Benchmark Results

2.3.1.1 Value Functions and Decision Rules

First, I derive value functions and optimal decision rules of households at different individual-specific human capital and inborn competence state pairs $\{h, \xi\} \in \mathcal{H} \times \Xi$, the former being the endogenous and the latter being the exogenous state from the household's point of view. Value functions are verified to be smooth, concave and increasing in both dimensions.[25,26]

Households who are endowed with high levels of human capital and have offsprings with high inborn competence draws are better off under the *laissez-faire* economy compared to a high tax environment, and agents with low human capital and inborn competence levels are better off under a high enough tax environment (e.g. $\tau = 20\%$) compared to the zero-tax regime. In economies with a tax rate in-between the two extremes, life-time utilities of agents are typically lower compared to the two polar tax regimes the reasons of which are discussed in detail in the following subsections.

In the *laissez-faire* economy, there is clearly neither any public education provision nor government transfers, which induces all households to choose private education, yet at different levels due to their of their human capital endowments

[25]Given that inborn competence shocks are mean-reverting and not persistent, life-time utility values vary only moderately across inborn competence states. Individual-specific human capital, however, persists in a dynasty as a result of limited intergenerational skill-transmission, which increases the elasticity of the value function to human capital state.

[26]The value function and decision rules reported in this section are calculated at the equilibria of the model economies at different tax rates, i.e. the aggregate human capital $\overline{H}$, public education provision $\overline{E}$ and government transfer $\overline{Tr}$ arguments of optimal education rules $\tilde{e}(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ and value functions $V(h, \xi; \overline{H}, \overline{E}, \overline{Tr}, \tau)$ are the resultant recursive competitive equilibrium objects.

and inborn competence draws. As economy's tax rate goes up, agents with low human capital and inborn competence states start to leave the private education pool so as to attend public schools that do not require any out-of-pocket costs. Figure 2.10 and 2.11 display this pattern in education decision rules under two tax regimes.

Figure 2.10: Education Decision Rule When $\tau = 7.13\%$

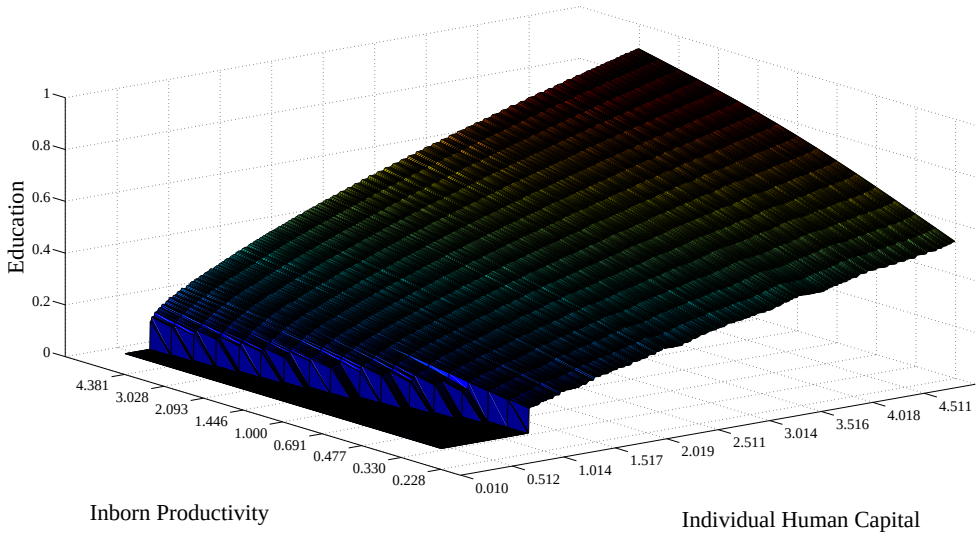
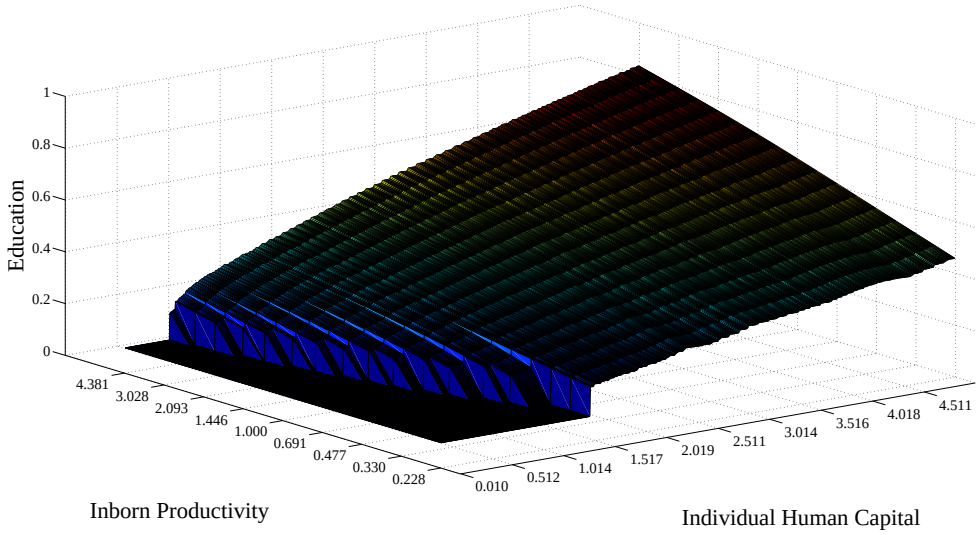


Figure 2.11: Education Decision Rule When $\tau = 11.96\%$



First, except for minor irregularities due to computational limitations, education choices are observed to be concave and smooth for both tax regimes. Second, the flat surfaces in these figures refer to the optimal public education choices of agents, whereas the monotonically-increasing concave parts refer to the private education decisions. It is easy to notice that the flat surface in the higher tax regime in Figure 2.11 is larger than that of the lower tax regime in Figure 2.10, which exemplifies that higher taxes and accordingly higher levels of public education provision incentivize a larger measure of households to optimally choose public education over the private one. Also, as the tax rate goes up, in addition to a lower measure of households choosing private education, optimal private education expenditures diminish in magnitude, as well, i.e. parents choose lower private education levels in the intensive margin because of their lower disposable income and less return on education. Hence, it can be summarized that higher taxes monotonically disincentivize private education both in the extensive and intensive margin.

Regarding optimal labor supply decisions, Figure 2.12 and 2.13 reveal that while the number of hours worked do not differ considerably among middle-aged workers whose human capital exceeds a certain threshold, agents with low human capital states do not supply as much labor as their productive counterparts. This result holds as long as economy's tax rate is high enough so that the middle-aged agents with very low productivity levels can attain sufficient government transfers that enable them to enjoy benefits from extra units of leisure that can outweigh benefits from labor. Further, number of hours worked at different state pairs typically decrease over taxes as it can be seen by comparing Figure 2.12 and 2.13, yet

differences in labor supplied as a result of tax rate differentials are much milder compared to cross-sectional dispersion for a given tax regime.

Figure 2.12: Labor Decision Rule When $\tau = 7.13\%$

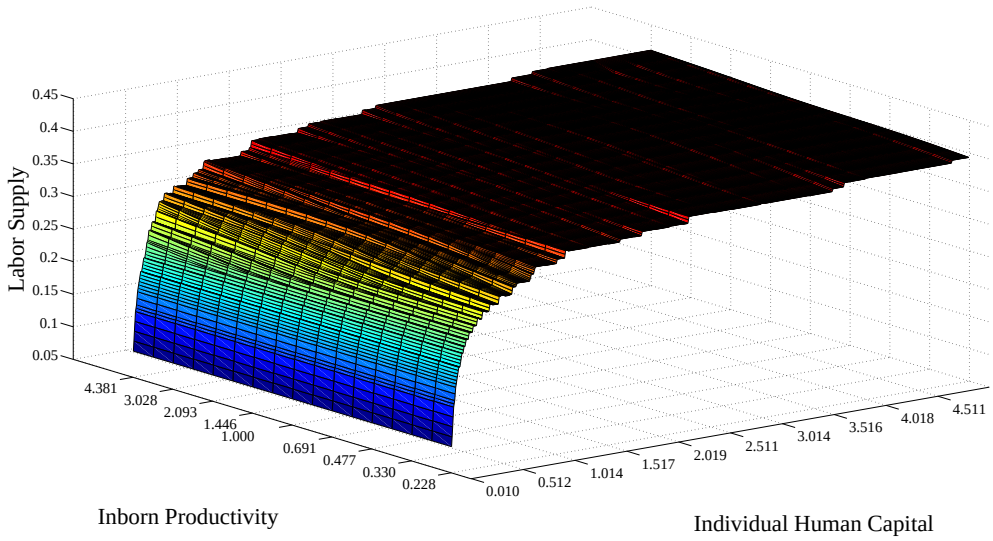
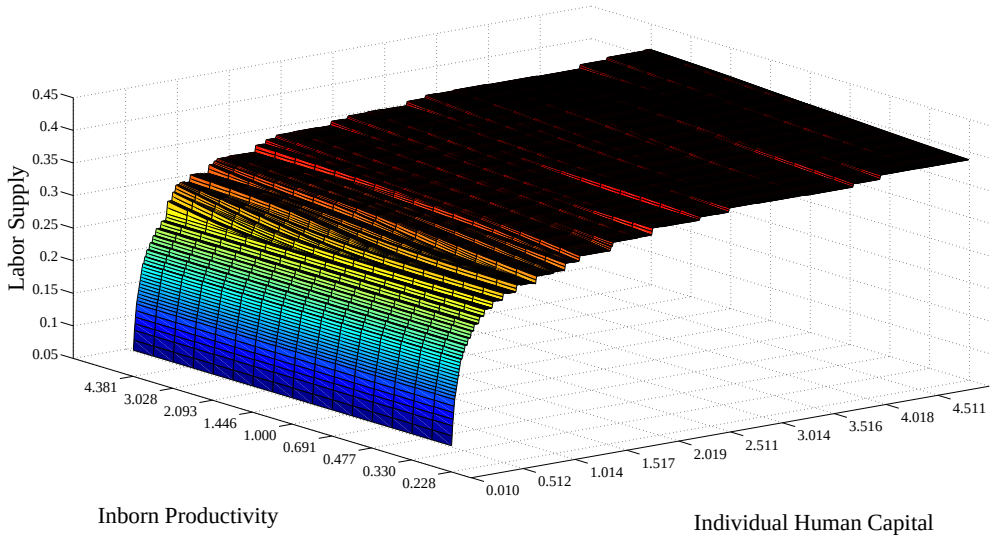


Figure 2.13: Labor Decision Rule When $\tau = 11.96\%$



2.3.1.2 Behavior of Aggregate Variables

I compute the recursive competitive equilibria under different tax rates, and show how aggregate variables change over taxes in Table 2.3. Last five columns of Table 2.3 except for the very last one reveal that levels of public education and government transfers, as well as the share of public education in total education and fraction of students attending public schools are all monotonically increasing over tax rates, as expected. Yet, the first five columns of Table 2.3 display a different pattern in macro variables: as economy's tax rate increases, average human capital, output, consumption, and education first all decrease, and after a threshold they start to increase.[27] The U-shaped pattern of the aggregate variables can be observed more explicitly in Figure 2.14.

Table 2.3: Stationary Distribution Results over Taxes

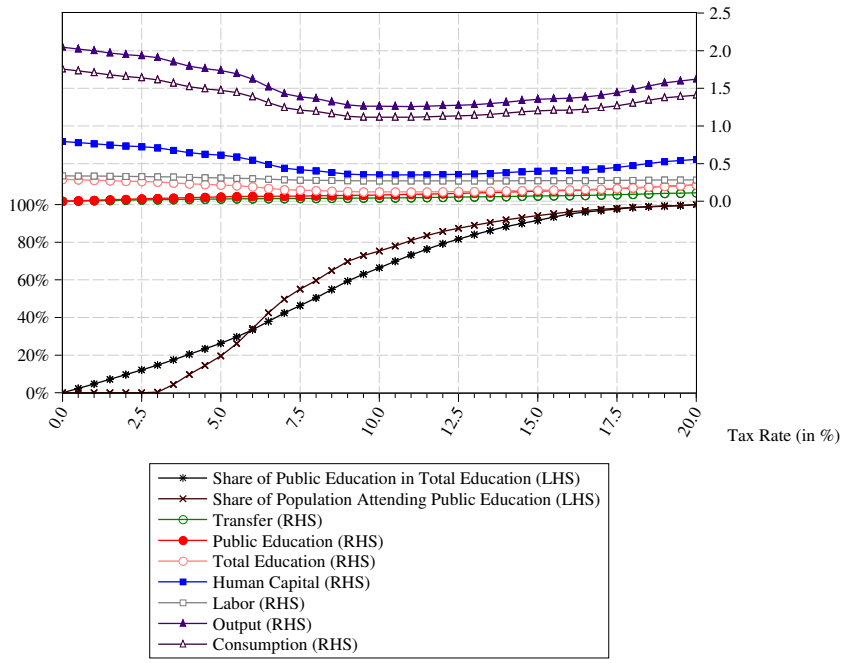
τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$Pop._{\overline{E}}$	$\overline{E}/\overline{\mathcal{E}}$	ι_l
0.00%	2.046	1.756	0.793	0.338	0.290	0.000	0.000	0.00%	0.00%	16.87%
2.50%	1.933	1.640	0.725	0.328	0.262	0.032	0.019	0.00%	12.09%	18.50%
5.00%	1.737	1.475	0.612	0.310	0.217	0.057	0.034	19.56%	26.35%	21.49%
7.13%	1.401	1.220	0.424	0.283	0.150	0.067	0.040	53.03%	44.83%	29.88%
7.50%	1.387	1.210	0.417	0.281	0.147	0.068	0.040	55.04%	46.38%	31.37%
10.00%	1.263	1.117	0.351	0.271	0.125	0.083	0.049	75.32%	66.42%	40.76%
11.96%	1.268	1.128	0.355	0.270	0.126	0.099	0.058	85.25%	78.54%	42.75%
12.50%	1.275	1.134	0.357	0.270	0.128	0.105	0.062	87.47%	81.67%	43.22%
15.00%	1.355	1.202	0.400	0.264	0.146	0.134	0.079	94.20%	91.63%	40.08%
17.50%	1.442	1.268	0.448	0.257	0.169	0.166	0.097	98.04%	97.70%	36.89%
20.00%	1.624	1.409	0.557	0.251	0.213	0.213	0.126	100.00%	100.00%	29.99%

Note: $\overline{Y}$ denotes average output, $\overline{C}$ denotes average consumption, $\overline{H}$ denotes average human capital, $\overline{C}$ denotes average labor, $\overline{E}$ denotes public education expenditure, $\overline{\mathcal{E}}$ denotes total expenditure on education, $\overline{Tr}$ denotes government transfers, $Pop._{\overline{E}}$ denotes the fraction of population who attend public education, and ι_l denotes the share of income inequality due to luck.

A brief explanation for the U-shaped pattern of aggregate variables over taxes is as follows: starting from the *laissez-faire* economy, as economy's tax rate goes up,

[27] Average number of hours worked, being the only exception, monotonically decreases over taxes, in accordance with economic theory due to the distortionary role of proportional income taxes.

Figure 2.14: Results of the Benchmark Model



four factors are in effect, three of which work in favor of and one of which works against macro variables. First, as taxes lower their disposable incomes, middle-aged agents reduce their optimal private education decision in the intensive margin. This effect is valid only for those middle-aged agents who still choose to bequest private education to their kids, and do not leave private education to join for the public school pool.[28]

Second, public education provision has a disincentivizing effect in the extensive margin. To exemplify this effect, suppose that in the absence of a public education level of 1 unit, a middle-aged agent chooses to bequest 2 units of private education to his offspring, which allows the offspring to enjoy a total benefit level of 2 units.

[28]When there are no public education spillovers, and government transfers, one can show that $\frac{\partial e}{\partial \tau} = -\frac{\lambda \rho \varepsilon \Theta h^{\lambda} \bar{l}^{1-\lambda}}{1-\rho(1-\varepsilon)\gamma} < 0$ as long as skill transmission and discount factor coefficients are lower than 1.

In the presence of public education, instead of paying the full private education cost of 2 units and benefit from a total of $2 + 1 \times \nu(= 0.5) = 2.5$, the middle-aged agent optimally chooses to go with the lower public education level of 1 unit so as not to bear any private financing costs, and still enjoy a reasonable amount of education benefits. Hence, public education provision causes a decrease in the level of total education attained for the individuals whose optimal private education choices would have been in the close neighborhood from *above*.

Third effect is the distortions in human capital investment as a result of lower returns on education: in a high tax rate regime, while the level of education as in a low tax environment generates the same pre-tax output, respective post-tax disposable income in the high tax regime is clearly lower than that of the low tax regime, which discourages private education attainment of the middle-aged. These three effects, by lowering private education bequests, cause aggregate education to decrease, which in turn reduces the level of aggregate human capital, and output since production technology uses human capital and labor, and finally consumption due to lower disposable income.

The fourth effect, which is the only one working in favor of aggregate variables is due to the extensive margin decision of the less endowed and limited or full public education benefits to a certain fraction or all of the population: those who would choose a private education level below the public education provision in the absence of public education optimally choose to attend free public schools when they are available, which induces agents with low human capital and inborn competence states to be better off by allowing them to attain higher levels of education, thereby

increasing economy's aggregate education, human capital, output and consumption. Also, note that while those in the public education pool fully benefit from an increase in taxes due to higher public education provision, those who choose to attend private schools can enjoy partial spillover benefits conditional on the presence of public education spillovers, as well. All these four effects are amplified by the presence of economy-wide aggregate human capital complementarities.

2.3.1.3 Fairness of Income Inequality

After investigating the behavior of aggregate variables over taxes, I decompose income inequality and analyze whether it arises from foreseeable actions and abilities of agents, or from pure luck. The last column of Table 2.3 displays the share of luck variation it total pre-tax income inequality.[29] While the share of inequality due to luck accounts only for 16.87% under the *laissez-faire* economy, it monotonically increases over taxes up to 43.22% at $\tau = 12.5\%$, and starts to decrease beyond this tax rate. The intuition behind the inverted U-shape of the share of luck in total income variation can be summarized as follows: starting from the zero-tax environment where all students attend only public schools, as taxes increase two factors affect the level and composition of income inequality. First, since macro variables such as human capital and output decrease over taxes, the additively-separable luck shock accounts automatically for a larger share in total variation in income, which can be thought of as a level effect. Second and more importantly, as taxes increase,

[29]Note that since the variance of luck is constant and independent of the variance of output, a high number for the share of luck variation implies lower cross-sectional income inequality.

both the provision of public education and government transfers increase, and so does the measure of agents choosing to attend public schools. The fact that agents receive the same public education equalizes human capital across agents after a threshold tax rate, thus reducing total income inequality. Less income inequality in the presence of a constant luck variance translates into a higher share of luck in total inequality, or a less "fair" inequality. Between the tax rates 0% and 10%, both the left arm of the U-shape of macro variables and the moderating effect of taxes together amplify the share of luck, and beyond this tax rate, increasing macro variables and moderating role of taxes act in opposite directions. Between the rates 10% to 12.5%, the latter effect dominates the former, thereby lowering fair inequality and total inequality, and beyond the rate 12.5%, the former effect dominates in the presence of an already large body of students attending public schools.

2.3.1.4 Distributional Properties of Variables

Next, I study the distributional properties of the variables by focusing on gini coefficients under different tax regimes. Table 2.4 shows that starting from the zero-tax environment, as tax rate increases, inequalities in human capital, pre-tax and post-tax output, education and labor all increase up to a threshold tax rate of slightly more than 7%, and then decrease beyond this rate, thereby displaying an inverted U-shape pattern over taxes.

Highest variation over taxes in inequality measures is observed in educational attainment, the gini coefficient of which starts from 0.30, peaks up to 0.366 and then

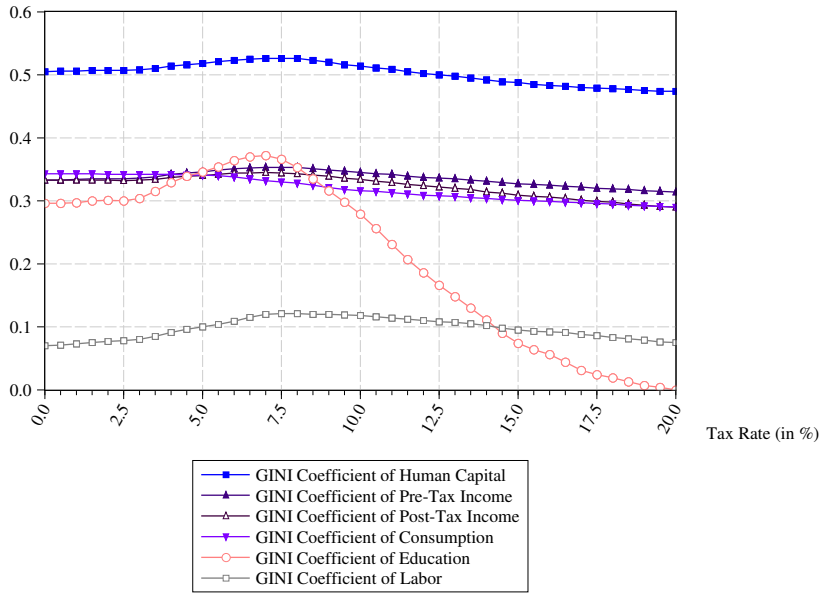
Table 2.4: Distributional Properties of the Benchmark Model

τ	$GINI_y$	$GINI_{\widehat{y}}$	$GINI_c$	$GINI_h$	$GINI_l$	$GINI_e$
0.00%	0.333	0.333	0.343	0.505	0.070	0.296
2.50%	0.335	0.332	0.342	0.507	0.078	0.300
5.00%	0.346	0.340	0.341	0.518	0.100	0.346
7.13%	0.353	0.345	0.330	0.527	0.121	0.369
7.50%	0.353	0.344	0.330	0.526	0.121	0.366
10.00%	0.345	0.334	0.316	0.514	0.118	0.279
11.96%	0.338	0.324	0.309	0.503	0.111	0.190
12.50%	0.336	0.322	0.308	0.500	0.108	0.166
15.00%	0.327	0.309	0.301	0.488	0.095	0.074
17.50%	0.320	0.299	0.296	0.479	0.086	0.024
20.00%	0.314	0.290	0.290	0.474	0.075	0.000

decreases down to 0 when all students choose to attend public schools. This result is not documented in the earlier literature, and is mainly due to the distortionary role of public education provision in the extensive margin, which could not have been observed unless the coexistence of both of the education types is studied. As discussed earlier, as long as the tax rate is not sufficiently large, the fraction of students who choose to attend public schools is limited; and these students, because they do not want to bear private education costs, attain less schooling than they would otherwise in the absence of public school provision. Accordingly, that these students are content with lower levels of education magnifies cross-sectional disparity in education, thereby translating into higher gini coefficients in education in low tax regimes. When tax rate and public education provision get high enough so that a large measure of agents leave private education pool, taxes moderate inequality in education, human capital and output, similar to the findings in the literature.

Human capital is distributed more unequally than hours worked, which creates a less unequal distribution of income than that of human capital. Due to co-movement of output and education, gini coefficient of consumption does not display a marked U-shaped pattern but decreases monotonically over taxes, although

Figure 2.15: Distributional Properties of the Benchmark Model



the variation is relatively milder. The patterns in the distributional properties of variables can be observed more explicitly in Figure 2.15.

2.3.1.5 Model Fit with the Data

As mentioned earlier, I use tax rates to calibrate the model to match the targets, U.S. and the European average. The predictions of the model, along with the respective figures in the data are displayed in Table 2.5. At the tax rate of 7.13%, the model endogenously generates a public-to-total-good expenditure ratio of 44.83% as in the U.S., and at the tax rate of 11.96%, the expenditure ratio is 78.54% as in the Europe average. Also, at the tax rate of 7.13% the share of luck in income variation is endogenously 29.88%, whereas at the tax rate of 11.96% the correspondent number is 42.75%, which are the respective perception figures according to the WVS

Table 2.5: Comparison of Model's Predictions with the Data

	Country	$\overline{\tau}$	$\overline{E}/\overline{\mathcal{E}}$	ι_L	$\overline{Y}/\overline{Y}^{US}$	$\overline{L}$	GINI(y)	GINI($\widehat{y}$)	GINI(e)
Data	U.S.	12.02%	44.83%	29.88%	1.000	0.287	0.486	0.378	N/A (+)
	Europe	21.19%	78.54%	42.75%	0.815	0.257	0.449	0.290	N/A (−)
Model	U.S.	7.13%	44.83%	29.88%	1.000	0.283	0.353	0.345	0.369
	Europe	11.96%	78.54%	42.75%	0.910	0.270	0.338	0.324	0.190

data. The model predicts the high tax regime to have an average output of 0.910 times that of the low-tax regime, while the data suggests a slightly lower ratio of 0.815.[30] The normalized actual hours worked in the U.S. is 0.287 of a unit period, whereas this number is only 0.257 in Europe. Model predicts similar numbers, 0.283 and 0.270 for the respective economies. The gini coefficients of both the pre-tax and the post-tax income in the U.S. is higher than those of Europe in the data, and due to the moderating role of taxes and transfer, the gini coefficient of the pre-tax income is higher than that of the post-tax income. Although not up to scale, the model also suggests similar qualitative prediction on pre-tax and post-tax income inequality measures. Finally, anecdotal evidence suggests that education and health care inequality in the U.S. is higher than that of the European countries, and the distributional predictions of the model are in accordance with such evidence. Overall, it is reasonable to conclude that the model can deliver the Transatlantic differences on several accounts fairly well.

Another merit of the model is in its ability to mimic the U-shape of per-capita output over public-to-total-good expenditure ratio, as seen in the data, not only for the calibration targets, but also for the other developed economies. In

[30]Note that the model locates the calibrated U.S. economy on the left arm of the U-shape, whereas the calibrated European economy is on the right arm. The importance of the locations of the targets with regards to U-shape of the aggregate variables is discussed in detail in the following welfare subsections.

order to illustrate this feature, first I sort OECD economies with respect to their public-to-total-good ratios in an ascending order, and then graph public good ratios jointly with real GDP (PPP) per-capita data. I also include total tax revenues of these countries as a percentage of their GDPs, and display the resultant graphs in Figure 2.16.[31] It is easy to detect the slightly-distorted U-shape of per-capita output of countries over their public-to-total-good expenditure ratios, especially when the filtered per-capita output values are considered.[32] Further, the tax trend reveals that aside from some minor fluctuations, total tax revenue to GDP ratio goes hand-in-hand with public-to-total-good expenditure ratio.[33] Hence, it would be fair to conclude that the U-shaped pattern generated by the model over taxes and public good shares is observable in the data as well.

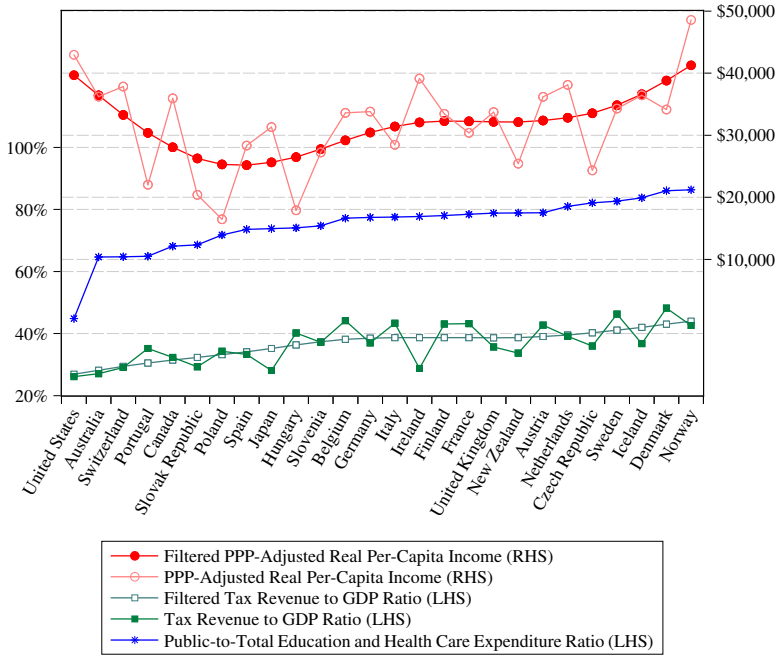
Next, I analyze how well results generated by the model fit to country-specific data. In order to do so, first I interpolate model's predictions over the tax rate to get finer estimates, then I match the interpolated results to the developed Western European economies with respect to their public-to-total good expenditure shares. I also do the same exercise for the country-specific WVS belief statistics, as well as for

[31]Given that developed countries differ substantially in regards to their tax systems which consist of several complicated non-linear instruments including tax brackets, tax deductable definitions, progressivity of different magnitudes, etc., instead of ranking countries with respect to their tax rates, I sort them with respect to their public-to-total good expenditure shares, which is a simpler yet more objective and standardized measure across countries, and is an endogenous outcome of alternative fiscal policies.

[32]One can see in Figure 2.19 that when only the more homogenized subset of Western European economies are studied (so that the transition economies and non-European countries are excluded) the U-shape pattern of per-capita income is clearer.

[33]A simple ordinary least squares regression of public good share on total tax revenue to GDP ratio unveils that public good ratio is positively and significantly predicted by taxes for the linear equation of the form: $\frac{\overline{E_i}}{\overline{\mathcal{E}_i}} = 0.398 + 0.957\tau_i$ with a probability value of $p = 0.0001$ for the coefficient before total taxes, and this result is robust to the exclusion of transition and non-European economies.

Figure 2.16: Tax, Output and Public Education Share by Country



Source: OECD Database (2004-2008)

the average tax shares allocated to the financing of social protection, education and health care expenditures, as calculated in the fiscal policy parameter calculation. In Figure 2.17, I show that the tax rate predictions by the model moves in the same direction as the data, and their co-movement is more evident when the non-linear trend of the tax rate in the data is considered. Despite the co-movement, however, the two series are not up to scale due to the parsimonious design of the model.

In Figure 2.18, I show that the non-linear trend of the WVS belief statistics match the predictions by the model almost one-to-one.

In Figure 2.19, I normalize the per-capita output by the model to the U.S. per-capita output at its correspondent public-good-expenditure rate, and graph it jointly with the filtered per-capita output in the data. Figure 2.19 reveals that both per-

Figure 2.17: Model's Fit in Taxes by Country

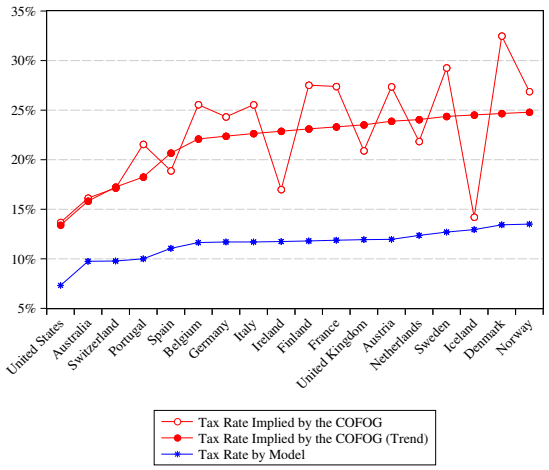


Figure 2.18: Model's Fit in Perceptions on the Decisiveness of Luck by Country

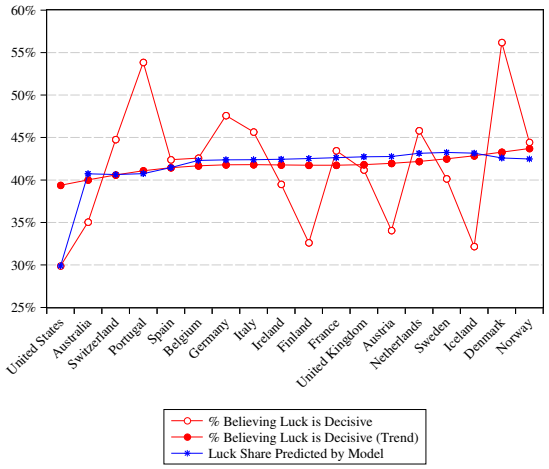
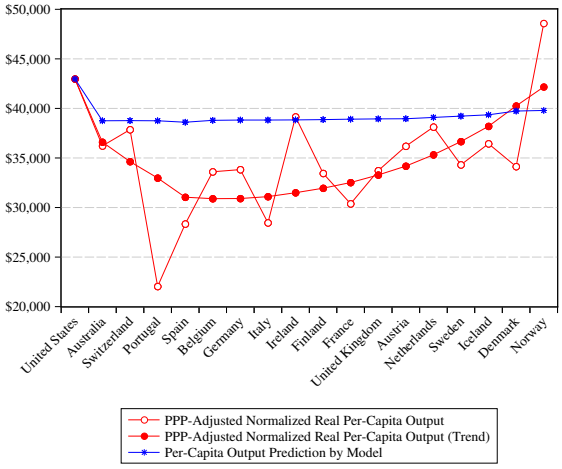


Figure 2.19: Model's Fit in Output by Country



capita output predictions by the model and the filtered per-capita output in the data initially decrease over public-to-total-good expenditure ratio, and start to increase after a threshold. Both of the series are minimized at a public-to-total good share of roughly 77%, although the minimum generated by the model is considerably higher in magnitude, and model's predicted output displays significantly less variation over taxes relative to the data. The noticeable parts of the right arm of the U-shape by the model are more evident at higher public share rates, and it can be concluded that while the model succeeds to mimic the patterns in the data well qualitatively, quantitative performance of the model for country-specific cases could be improved with a different calibration and parametrization strategy.[34]

2.3.2 Comparative Statics

In the following subsections, I report and discuss results with alternative parameter values so as to illustrate the role of different channels in model's predictions.

2.3.2.1 Public Good Spillover

No Public Good Spillover: I start my comparative statics analysis by studying the role of the public good spillover parameter, ν, which is taken equally distant from the two polar cases in the benchmark specification. Keeping the discussion still on education, first I display the results of the model when there is no public education

[34]Note that the calibration strategy and parameter values of the model are independent of the individual European observations, and despite the choice of only dual targets for calibration, the model succeeds to mimic the U-shape of per-capita output, qualitatively. As discussed in the comparative statics section, alternative choices for parameter values, especially on the public good spillover rate, can improve the goodness of fit of the model in terms of country-specific observations.

spillover, i.e. the environment where private school students cannot benefit from the provision of public education at all.

Value functions and optimal decision rules are confirmed to be smooth and concave as in the benchmark case, yet the jumps in the extensive margin decisions for education are observed to be higher in magnitude relative to the benchmark model. This finding is due to even higher opportunity costs of private education in the absence of public education spillovers: in this environment, when students attend private schools, their parents not only have to bear full private education costs, but also incur the cost of giving up all benefits from the public education provision. Accordingly, for middle-aged agents who choose private education for their offsprings, benefits from the choice of private education must exceed the greater sum of two costs, thereby causing even more marked jumps in the extensive margin of education choices.

Table 2.6 summarizes the behaviors of aggregate variables over taxes. Aggregate variables display a U-shaped pattern as before, however, without the public education spillover especially the left arm is steeper and the depth of the U-shape is greater in magnitude compared to the benchmark model. This result is again due to the fact that as the cost of education is higher due to greater forgone benefits of public education when private education is chosen, education is now less attractive and hence students attain relatively lower *de facto* education at all tax rates unless either all students attend only public or only private schools.[35]

[35]Note that the deeper U-shape of the variables in the model with no public education spillover implies that for a better country-specific match, a lower public good spillover rate for at least for some subset of countries could improve the goodness of fit of the model.

Table 2.6: Stationary Distribution Results over Taxes with Zero Spillover ($\nu = 0$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$Pop._{\overline{E}}$	$\overline{E}/\overline{\mathcal{E}}$	ι_l
0.00%	2.046	1.756	0.793	0.338	0.290	0.000	0.000	0.00%	0.00%	16.87%
2.50%	1.916	1.630	0.714	0.327	0.258	0.030	0.018	2.20%	11.89%	18.83%
5.00%	1.649	1.412	0.550	0.312	0.190	0.053	0.031	25.54%	29.52%	24.69%
7.50%	1.305	1.158	0.360	0.294	0.125	0.065	0.038	59.00%	52.63%	39.30%
10.00%	1.172	1.063	0.299	0.285	0.107	0.077	0.045	82.18%	72.24%	46.18%
12.50%	1.191	1.084	0.308	0.278	0.110	0.097	0.057	93.94%	87.81%	45.65%
15.00%	1.238	1.127	0.330	0.272	0.125	0.122	0.072	98.56%	97.91%	43.97%
17.50%	1.363	1.226	0.397	0.263	0.158	0.158	0.093	100.00%	100.00%	38.83%
20.00%	1.624	1.409	0.557	0.251	0.213	0.213	0.125	100.00%	100.00%	29.99%

Another observation from Table 2.6 is that while at all tax rates aggregate education, human capital, output and consumption are less than or equal to the values from the limited-spillover model, public-to-total education ratio and the fraction of students attending public schools are higher at all tax rates except for the ones at which students uniformly attend public or private schools so that the equilibria under the two specifications are identical. As a result of greater reliance on public schools and its moderating role on human capital inequality, together with the level effect in output, the share of luck in income inequality is higher than the benchmark model for the tax regimes, except for the ones at which the two economies are identical.

Table 2.7: Distributional Properties of the Model with Zero Spillover

τ	$GINI_y$	$GINI_{\widetilde{y}}$	$GINI_c$	$GINI_h$	$GINI_l$	$GINI_e$
0.00%	0.333	0.333	0.343	0.505	0.070	0.296
2.50%	0.337	0.334	0.339	0.510	0.082	0.317
5.00%	0.349	0.344	0.324	0.526	0.114	0.407
7.50%	0.355	0.348	0.313	0.533	0.143	0.435
10.00%	0.348	0.339	0.304	0.521	0.145	0.337
12.50%	0.328	0.315	0.295	0.489	0.137	0.112
15.00%	0.324	0.309	0.293	0.484	0.132	0.047
17.50%	0.319	0.299	0.291	0.475	0.110	0.001
20.00%	0.314	0.290	0.290	0.474	0.075	0.000

Next, I focus on the distributional properties of the model with no public education spillover and summarize my findings in Table 2.7. Similar to results

from the benchmark model, starting from the zero-tax economy education, human capital, labor, pre-tax and post-tax output inequalities all increase initially over taxes, and after a threshold of approximately 7.5% the gini coefficients start to decrease, as in the benchmark model. Also, consumption inequality decreases over the tax rate as in the former specification. Contrary to the former results, however, gini coefficients vary more in magnitude relative to the benchmark model, and the reason is essentially due to higher variation in education, and accordingly human capital and output as discussed. Overall, it can be concluded that distributional properties from the no-spillover model mimic findings from the limited-spillover model closely, although the latter model generates more pronounced variations in magnitude.

Full Public Good Spillover: In this subsection, I report and discuss the results when there is full spillover from public education to private school students, i.e. the environment where all students, regardless of their education choices, can fully benefit from the available public education provision. As discussed earlier, an alternative way to interpret this specification is that in this environment all students uniformly attend public schools, and those who are interested in further schooling choose to attend private education of their choice.

First, I verify the value functions and optimal decision rules to be smooth and concave as in the two former models. However, under this specification I document that there are no distinct jumps but smooth transitions in the extensive margin for education, contrary to the former models featuring opportunity costs of forgoing

public education when private education is chosen. This finding is due to the fact that the choice of an infinitesimal higher level of private education compared to the public school provision does not require giving up public education benefits at all, and the only opportunity cost of private education in this set-up is the *actual* expenditure spent on schooling.

Table 2.8 summarizes the results for aggregate variables. Similar to the limited and no spillover models, macro variables display a U-shaped pattern over the tax rate, however the trough points of aggregate variables are far greater in magnitude compared to those from the two former specifications.

Table 2.8: Stationary Distribution Results over Taxes with Full Spillover ($\nu = 1$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$Pop._{\overline{E}}$	$\overline{E}/\overline{\mathcal{E}}$	ι_l
0.00%	2.046	1.756	0.793	0.338	0.290	0.000	0.000	0.00%	0.00%	16.87%
2.50%	1.935	1.672	0.729	0.325	0.263	0.030	0.018	1.64%	11.65%	18.49%
5.00%	1.862	1.617	0.696	0.297	0.240	0.061	0.036	16.13%	25.59%	19.53%
7.50%	1.832	1.596	0.672	0.269	0.234	0.091	0.054	31.58%	39.03%	19.96%
10.00%	1.807	1.574	0.655	0.249	0.233	0.119	0.070	43.12%	50.89%	20.74%
12.50%	1.816	1.580	0.658	0.251	0.236	0.148	0.087	53.97%	62.65%	20.52%
15.00%	1.867	1.605	0.696	0.249	0.263	0.184	0.108	62.21%	70.06%	19.18%
17.50%	1.980	1.675	0.768	0.244	0.305	0.229	0.135	67.63%	75.05%	17.43%
20.00%	2.089	1.761	0.849	0.244	0.328	0.274	0.161	72.47%	83.70%	15.41%

Starting from the *laissez-faire* economy, incremental drops in aggregate variables as a result of higher taxes are much smaller in magnitude. As a result, at any tax rate macro variables are higher in levels relative to those from the former two models featuring less-than-full public education spillovers. These findings are in accordance with economic theory since under this specification the young attain higher *de facto* education at any tax regime compared to the limited or the no-spillover models. Moreover, as a result of the fact that a lower fraction of the population attends solely public schools compared to the former two models and

that higher private education amplifies fair income inequality, model's predicted share of inequality due to luck is relatively lower at all rates.

Further, while the level of public education at any tax rate beyond zero is greater in magnitude compared to the former models, the share of public sources in overall education expenditure and the fraction of population attending *only* public schools are significantly lower than those from the former two models. Also, while the tax rate at which the whole population attends only public schools is 20% in the benchmark model, only 83.70% of the population finds it optimal to choose only public education when there is full public education spillover, which again can be attributed to the lower opportunity cost of private education.

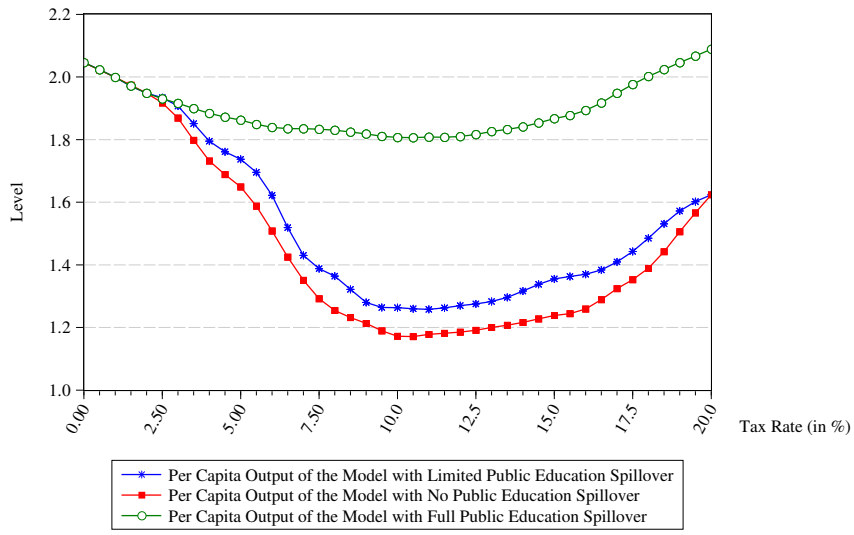
Table 2.9: Distributional Properties of the Model with Full Spillover

τ	$GINI_y$	$GINI_{\widehat{y}}$	$GINI_c$	$GINI_h$	$GINI_l$	$GINI_e$
0.00%	0.333	0.333	0.343	0.505	0.070	0.296
2.50%	0.336	0.333	0.342	0.508	0.079	0.298
5.00%	0.341	0.335	0.343	0.510	0.093	0.284
7.50%	0.344	0.336	0.343	0.510	0.107	0.268
10.00%	0.342	0.330	0.337	0.509	0.100	0.254
12.50%	0.335	0.318	0.321	0.500	0.068	0.200
15.00%	0.332	0.312	0.313	0.492	0.060	0.188
17.50%	0.327	0.303	0.300	0.479	0.048	0.173
20.00%	0.323	0.296	0.285	0.471	0.041	0.154

Table 2.9 displays the distributional properties of variables. Although the gini coefficients display the inverted U-shape as before, the variation in these coefficients are considerably smaller in magnitude. The most marked difference compared to the former two models is in the inequality of education, the gini coefficient of which is only halved in magnitude at the tax rate 20% relative to the *laissez-faire* economy, whereas there is no cross-sectional dispersion in education at this tax rate in the former two specifications.

In Figure 2.20, I highlight the behavior of per-capita output by the three models over the tax rate. As discussed briefly, the *laissez-faire* economies of the three spillover specifications are identical, since alternative ways of modeling public education spillover has no effect under the tax regimes at which no one attends public schools. As tax rate goes up, the no-spillover model generates the minimum and the full-spillover model generates the maximum per-capita output since *de facto* education attainment increases over the spillover rate.

Figure 2.20: Model's Per-Capita Output Predictions with Different Spillover Rates



The benchmark model with partial spillover generates output levels that are in-between the predictions by the two polar scenarios, yet this result holds only up to the tax rate $\tau \approx 20\%$ at which equilibrium the whole population attends only public schools. At this tax rate and beyond, since all students choose only public schools both in the no-spillover and the limited-spillover environments, the two models converge. The intuition behind this result is comparable to that of

the *laissez-faire* case: given that there are no private school students in either of the two equilibria, modeling how public education provision affects private school students has no real effect. At this tax rate, less than three-fourths of the young attend solely public education under the full-spillover set-up, and the three models converge when the whole population in the full-spillover model chooses to attend only public schools, which happens at an unrealistically high tax rate.

2.3.2.2 Other Comparative Statics

Absence of Inborn Productivity Shocks: In the absence of idiosyncratic inborn competence shocks, i.e. $\sigma_\xi^2 = 0$, middle-aged agents become *ex-ante* identical, and the only variation across households is due to the realizations of luck shock, which does not influence optimal decision rules, as discussed earlier. Therefore, the absence of inborn productivity shocks transforms the model into an *ex-ante* representative-agent model. Table 2.10 summarizes results in the absence of inborn competence shocks, and shows that macro variables decrease substantially at all tax rates when there is no uncertainty in regarding ability draws.

Table 2.10: Absence of Idiosyncratic Productivity Shocks ($\sigma_\xi^2 = 0$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	0.818	0.622	0.200	0.342	0.197	0.000	0.000	0.00%	0.00%	100.00%
7.13%	0.586	0.472	0.124	0.311	0.113	0.026	0.015	23.24%	0.00%	100.00%
11.96%	0.253	0.234	0.034	0.287	0.019	0.019	0.011	100.00%	100.00%	100.00%
20.00%	0.421	0.368	0.080	0.268	0.053	0.053	0.031	100.00%	100.00%	100.00%

In essence, this result is comparable to the "precautionary saving" phenomenon seen in models with physical capital: when there is uncertainty in inborn competence draws of future generations, middle-aged agents find it optimal to accumulate

"precautionary human capital" some fraction of which they pass to the next generations in the absence of physical capital. Accordingly, when there is no possibility of unfavorable future competence draws, middle-aged agents find it optimal to devote less resources to education, which results in lower human capital accumulation, and hence output and consumption. Since the absence of competence shocks eliminates *ex-ante* heterogeneity, the fraction of the population attending public schools is either zero or unity, depending on level of the tax rate. The U-shape of the aggregate variables is preserved since the same competing effects are still in act. Finally, as the only source of variation across agents is due to luck shocks, the share of luck in total income inequality is 100%.[36]

Persistent Inborn Productivity Shocks: While economists generally model inborn competence shocks having log-normal distributions for general equilibrium purposes, geneticists show that heritability of intelligence in the U.S. is measured to differ between 0.40 to 0.80.[37] In order to show the effects of intergenerational persistence of inborn competence shocks, I model the idiosyncratic competence stochastic shock as a first-order autoregressive process as follows:

$$\log \xi_{t+1}^{i} = \kappa \log \xi_{t}^{i} + u_{t+1} \tag{2.38}$$

[36]If agents have lasting productivity types, i.e. if all agents in a dynasty have the same inborn competence draws at all times so that heterogeneity is preserved but future uncertainty is eliminated, the absence of precautionary human capital saving still causes a negative level shift in macro variables while agents are non-degenerately distributed. The absence of luck shocks does not alter the qualitative conclusions on the U-shape.

[37]For discussions on general equilibrium concerns of productivity shocks, see Benabou (2000), Benabou (2005), Zhang (2005), and for discussion on heritability of intelligence, see Plomin *et al.* (1994)

where $u_{t+1} \sim N(0, \sigma_u^2)$ and $\sigma_u^2 = \frac{\sigma_\xi^2}{1-\kappa^2}$ so that both this specification and the benchmark model have the same mean and variance for the inborn competence shock. I set the value of the autoregressive coefficient to a positive constant, $\kappa = 0.40$, and I report the consequent results in Table 2.11.

Table 2.11: Persistent Inborn Productivity Shocks ($\kappa = 0.40, \sigma_\xi^2 = 0.915$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	2.012	1.736	0.759	0.351	0.276	0.000	0.000	0.00%	0.00%	16.99%
7.13%	1.318	1.177	0.378	0.290	0.141	0.059	0.035	41.98%	49.12%	33.12%
11.96%	1.135	1.018	0.311	0.256	0.117	0.083	0.049	71.16%	77.84%	46.36%
20.00%	1.537	1.339	0.508	0.224	0.197	0.196	0.135	100.00%	100.00%	32.14%

My findings reveal that while the U-shape of the macro variables is preserved, there is a mild drop in the levels of aggregate variables at all tax rates despite a higher variance of the shock, σ_u^2. When the inborn competence shocks are persistent, a middle-aged agent with a low competence draw knows that his offspring is likely to have a low competence draw as well. If his disposable income is also low due to limited human capital endowment, he would not be motivated to bequest high levels of private education since next generations' low competence draws will likely hinder their human capital accumulation anyway. For the middle-aged agents with high human capital endowments and better inborn competence draws, since future generations are also likely to have decent inborn competence levels, too much education is not extremely essential, which reduces the incentive for precautionary human capital accumulation. Therefore, information on future shocks by the autoregressive specification reduces the incentive for educational attainment, which in turn dampens aggregate human capital; and together with economy-wide complementarities, return on education gets even lower, further amplifying the negative level shift in

aggregate variables at all tax rates.[38]

Higher Complementarity Effect of Aggregate Human Capital: In the presence of higher economy-wide externalities by aggregate human capital, i.e. $\gamma = 0$, return on education gets higher, which in turn encourages middle-aged agents to bequest more education, thereby inducing even higher aggregate human capital accumulation in the economy, and pushing up returns on education even further. Moreover, higher economy-wide aggregate human capital complementarities imply less pronounced intergenerational skill-transmission, which amplifies future uncertainty that boosts precautionary human capital savings. As a result, macro variables at all tax rates get higher in magnitude in the presence of higher aggregate human capital complementarities, as shown in Table 2.12.

Table 2.12: Higher Complementarity of Aggregate Human Capital ($\gamma = 0.00$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	2.361	2.039	0.996	0.345	0.321	0.000	0.000	0.00%	0.00%	11.71%
7.13%	1.442	1.281	0.444	0.285	0.133	0.068	0.040	50.74%	58.56%	31.30%
11.96%	1.388	1.251	0.416	0.277	0.127	0.110	0.064	86.31%	90.41%	37.47%
20.00%	1.936	1.682	0.759	0.293	0.254	0.254	0.149	100.00%	100.00%	21.44%

While the U-shape of macro variables is preserved, the aforementioned forces induce the U-shape to have steeper arms, which causes the aggregate-variable-minimizing tax rate to be lower than the benchmark case, and the share of public education expenditure and the fraction of population attending public schools to be higher than the benchmark results.[39]

[38]Note that persistent inborn competence shocks imply a stronger intergenerational transmission channel, since parental transmission of human capital is still present.

[39]For this and the next exercise, note that the law of motion for human capital is homogenous of degree one in education, intergenerational skill transmission and economy-wide complementarity,

Higher Return on Education: When the elasticity of human capital with respect to education increases by 10%, i.e. $\varepsilon = 0.330$, there is an upward level shift in the values of macro variables at all tax rates, as shown in Table 2.13.

Table 2.13: Higher Return on Education ($\varepsilon = 0.33$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	2.111	1.783	0.835	0.343	0.328	0.000	0.000	0.00%	0.00%	15.64%
7.13%	1.555	1.322	0.511	0.295	0.192	0.073	0.043	38.06%	42.14%	24.94%
11.96%	1.321	1.186	0.367	0.274	0.135	0.100	0.059	74.39%	82.01%	36.68%
20.00%	1.697	1.492	0.591	0.288	0.206	0.206	0.121	99.50%	99.50%	25.15%

Education is a choice variable from a middle-aged agent's point of view, as opposed to intergenerational skill transmission or economy-wide complementarities which he takes as given in his optimization problem. Thus, higher return of education encourages middle-aged agents to bequest more education to offsprings, which boosts aggregate human capital and accordingly the remaining macro variables. Further, as education contributes more to human capital accumulation in the presence of higher returns on education, an increase in the tax rate does not discourage the middle-aged agents to reduce their private education decisions as much as in the benchmark case, which in turn causes a lower measure of students to choose public education over the same incremental tax increase. Thus, while the U-shape of the variables is still preserved, the threshold tax rate at which everyone attends public schools is observed to be slightly above 20%.

Higher Share of Redistribution in Fiscal Spending: As discussed in detail in the model environment section, tax revenue raised by the government is used both for

which implies that an increase in one of the parameters would induce a decrease in the values of the remaining ones. In the absence of the complementarity effect of aggregate human capital, i.e. $\gamma = 1$, opposite results relative to the higher complementarity exercise are documented.

the provision of public education and for government transfers. While the former form of government spending, by contributing to the accumulation of human capital, can boost aggregate variables, the latter expenditure is not internalized by the atomistic middle-aged agents and is used only for consumption purposes. Accordingly, as displayed in Table 2.14, raising the share of transfers in government's budget reduces the level of aggregate variables for the tax regimes other than the *laissez-faire* economy at which equilibrium there is no tax revenue raised and fiscal rule is thereby irrelevant.[40]

Table 2.14: Higher Share of Redistribution in Government Budget ($\psi = 0.407$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	2.046	1.756	0.793	0.338	0.290	0.000	0.000	0.00%	0.00%	16.87%
7.13%	1.159	1.043	0.403	0.270	0.116	0.054	0.080	46.55%	53.45%	31.48%
11.96%	1.018	0.912	0.337	0.256	0.106	0.090	0.073	85.09%	89.62%	44.02%
20.00%	1.537	1.370	0.525	0.273	0.197	0.196	0.135	100.00%	100.00%	31.50%

For the remaining parameters, I verify that increasing the share of human capital in the production function λ, and the altruism (discount) rate ρ boost the level of aggregate variables at all tax rates while preserving the U-shaped pattern, which can be seen in the appendix.

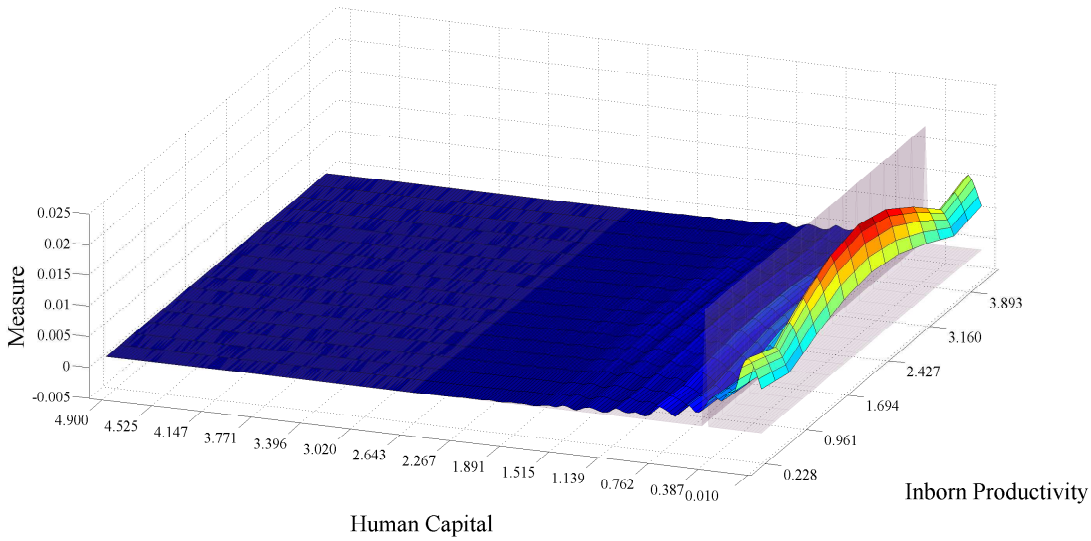
2.3.3 Welfare Analysis

After studying the behavior of aggregate variables and comparative statics, next I analyze how agents' *ex-ante* welfare vary under different tax regimes. For this purpose, first I display the distribution of households over individual human capital

[40]Note that, despite its adverse affects on the level of aggregate variables, a higher share of redistribution can still be desirable among a subset of the agents with low very low human capital endowments and inborn competence draws, who are in the immediate risk of hitting zero bound for consumption.

and inborn productivity states for the calibrated U.S. and European economies. Then, I report and discuss the preferences of agents over taxes so as to provide insight into political sustainability of the targeted economies.

Figure 2.21: Stationary Distribution of the Calibrated the U.S. Economy



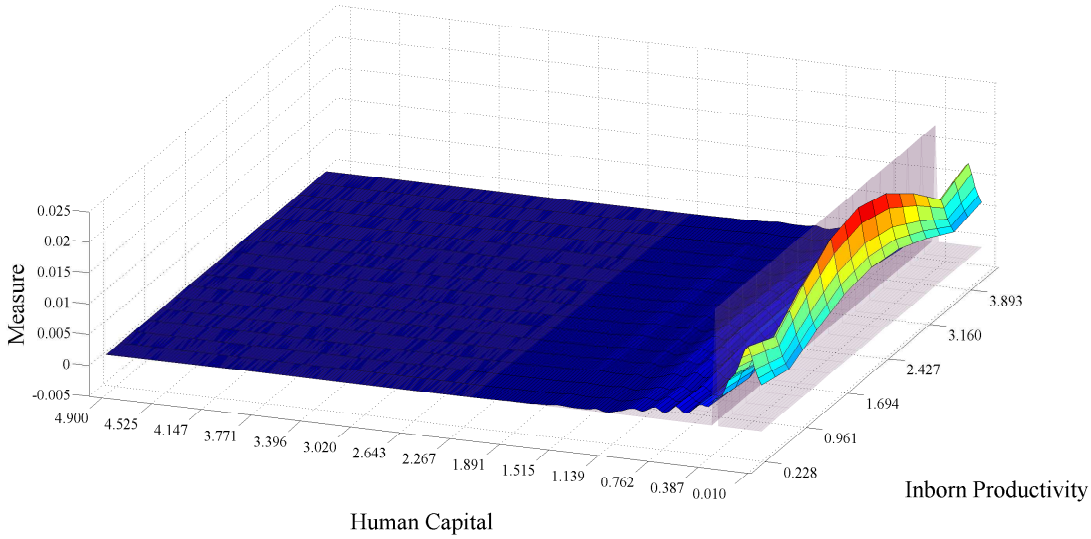
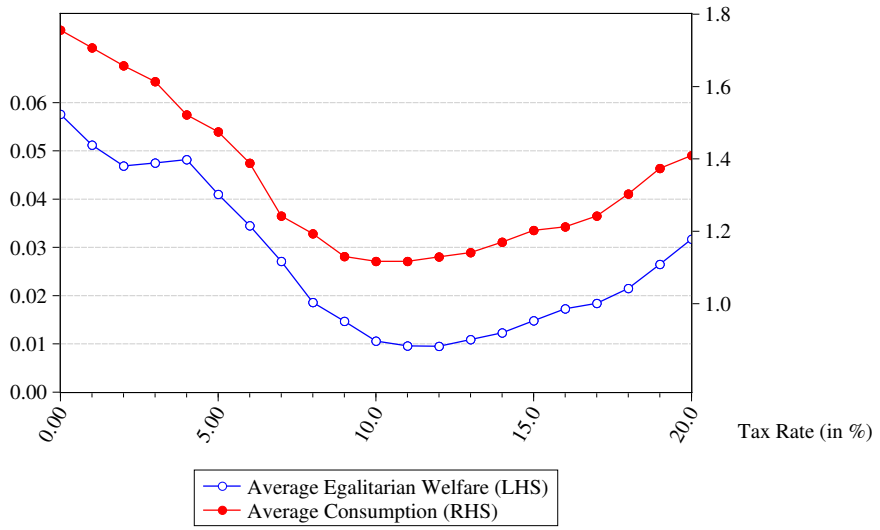


Figure 2.22: Stationary Distribution of the Calibrated European Economy

In Figure 2.21 and 2.22, I display the distribution of middle-aged agents over human capital and inborn productivity state pairs for the calibrated U.S. and Euro-

pean economies. I also add respective average human capital levels of the calibrated economies as the transparent light purple surfaces. It is evident from the figures that predominant majorities in both simulated economies are endowed with human capital endowments less than the economy averages. Also, due to the symmetric stochastic specification of inborn competence shocks, agents are distributed symmetrically with respect to inborn productivity states. Therefore, log-normal distribution of the inborn productivity shock, together with optimal education decisions yield such results that majorities of households in both economies are endowed with human capital levels less than the country averages, and when optimal labor decisions are also taken into consideration, it is easy to show that the same majorities earn less pre-tax incomes compared to economy averages.

Figure 2.23: Average Egalitarian Welfare and Consumption



In Figure 2.23, I display how the aggregate consumption and an egalitarian welfare measure, which I calculate as the sum of life-time *ex-ante* welfare of agents

weighted by their respective population densities, vary over taxes. It can be seen that the welfare metric mimics average consumption closely, and also displays the U-shaped pattern over the tax rate with the exception of a noticeable local peak on the left arm. However, it would be erroneous to immediately conclude from this graph that the *laissez-fair* tax policies or very high tax regimes Pareto-dominate policies in between the two polar cases. In fact, I show in Figure 2.24 and 2.25 that this is indeed not the case by studying the behavior of value functions of agents over taxes at agent-specific state pairs.[41]

Figure 2.24 shows how *ex-ante* utility of middle-aged households with the same median inborn productivity but different individual human capital states vary over taxes. It is easy to see that *ex-ante* welfare of agents increases over the human capital state, since middle-aged agents who are endowed with higher levels of human capital are inherently more productive, thereby they can earn higher pre-tax incomes than those with lower human capital endowments levels with the same amount of labor.

Another noticeable pattern in Figure 2.24 is the slightly-distorted U-shape of life-time utility of most of the households except for the ones endowed with very limited human capital levels. Especially, *ex-ante* welfare levels of households who are endowed with high human capital levels and inborn productivity draws initially decrease over taxes and start to increase after a threshold tax rate, with a U-shape comparable to that of aggregate variables.

[41]Because there are four dimensions associated with welfare analyses, i.e. individual human capital and inborn productivity states, economy's tax rate and the correspondent value of *ex-ante* life-time utility, first I keep the inborn productivity state constant in Figure 2.24, then the individual human capital state constant in Figure 2.25 to be able to report results using three-dimensional graphs.

Figure 2.24: Lifetime Welfare with the Median Inborn Competence ($\xi = 1.00$)

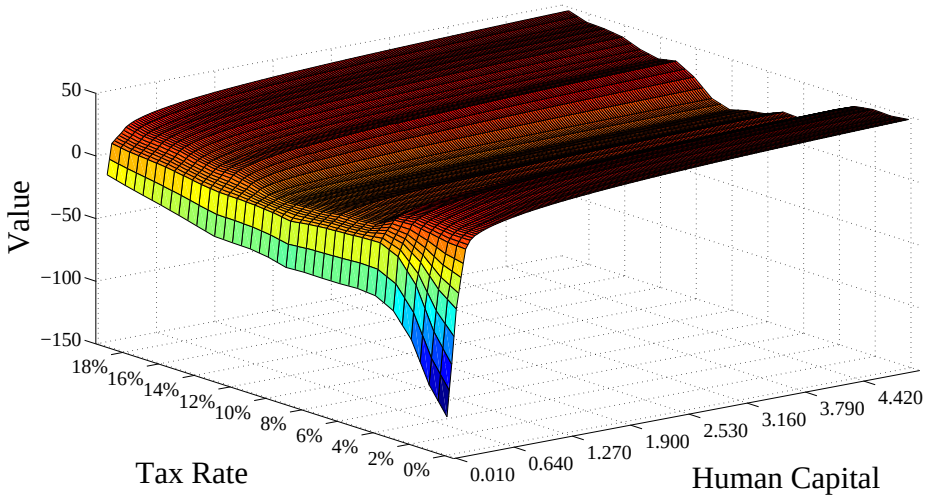
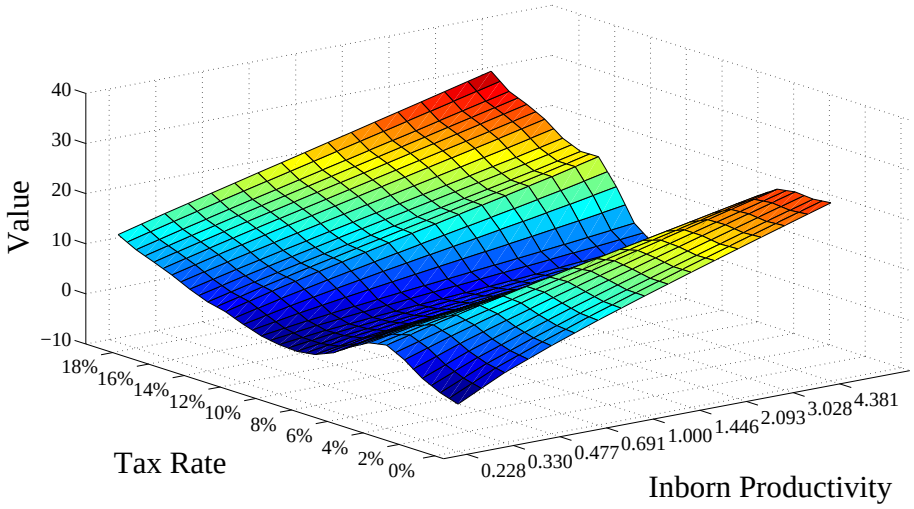


Figure 2.25: Lifetime Welfare with a Below-Average Human Capital ($h = 0.20$)



Regarding the distortions in the U-shape, first it is evident from Figure 2.24 that agents with the lowest human capital endowments prefer higher tax regimes to the lower ones monotonically, and that they are ones with most pronounced welfare gains over taxes. It is not surprising that these households who contribute lowest to the tax revenue base and benefit no less than others prefer high levels of public education provision and government transfers, thereby higher tax rates.[42] Perhaps, more interesting is another deviation from the U-shape that is also present in Figure 2.23: middle-aged agents whose human capital states are low but not on the very lowest end of human capital distribution are better off at a tax rate close to 5% relative to the *laissez-faire* economy. Beyond this tax rate, *ex-ante* welfare of all middle-aged agents but those with the lowest human capital endowments first decrease up of a tax rate of approximately 10.5% and then start to increase beyond this threshold. While minor differences across states are observable, the spike on the left arm of the U-shape is evident for a non-trivial measure of states. Figure 2.25 magnifies this pattern from an another angle: keeping individual human capital state constant at $h = 0.200$, i.e. the level around which the largest measure of households are populated in both of the calibrated economies, I display how *ex-ante* welfare of agents vary over taxes for different inborn productivity draws. First, it is easy to notice that *ex-ante* welfare of middle-aged agents increase over inborn productivity draws as expected, since higher draws facilitate the accumulation of human capital

[42]The careful reader may notice the striking differences in *ex-ante* welfare between the agents with lowest human capital endowments and those who own moderately higher human capital. In essence, this is due to the fact that the middle-aged agents at the very low end of the human capital distribution are the ones who are more likely to be pushed to the zero bound for consumption in the event of adverse luck shock realizations, which therefore reduces their expected *ex-ante* welfare levels considerably.

of the offsprings, which they uses next period when middle-aged. Second, Figure 2.25 makes it clear that agents with moderate levels of human capital, especially the ones with low inborn productivity draws, are better off in a tax regime around 5% relative to the *laissez-faire* economy. As mentioned earlier, while middle-aged agents with low human capital endowments prefer high tax regimes to the lower ones monotonically, households with high levels of human capital have smooth U-shaped preferences over taxes, as the spike on the left arm of the U-shape in *ex-ante* welfare first diminishes and then disappears over human capital states.

Although contrary to the canonical Meltzer and Richards (1981) preferences over taxes, the idea of double-peaked preferences in education types is not novel.[43] The intuition behind the double-peaked preferences over taxes can be summarized as follows: Middle-aged agents endowed with limited but not extremely low human capital levels prefer non-zero taxes up to a rate on the left arm such that gains from redistribution and public education provision, a variant of the Meltzer-Richards effect, are not offset by the distortionary effects of taxes on aggregate human capital, a factor pivotal in determining the effectiveness of education on the accumulation of human capital.

Beyond the threshold tax rate of $\tau = 5\%$, further increases in the tax rate have adverse effects on the level of aggregate human capital, and benefits from higher public education provision and government transfers are more than offset by

[43]For the micro-foundations of single-dipped/double-peaked preferences in the presence of public and private education, see Stiglitz (1974), Barzel and Deacon (1975), Flowers (1975), and for a recent discussion on single-dipped/double-peaked preferences over the provision of public goods, see Barbera *et al.* (2009). Note that all these studies concentrate on the micro-foundations of preferences in endowment economies, and do not study the interaction of preferences with endogenous general equilibrium outcomes.

the drops in aggregate human capital. Once the economy reaches a sufficiently high tax regime at which majority of students optimally chooses to attend public schools, positive complementarity effects of aggregate human capital are pronounced again and the *ex-ante* welfare of middle-aged agents starts to increase over taxes.[44]

When economy's tax rate is close enough to 5%, as in the case for the calibrated U.S. economy featuring $\tau = 7.13\%$, agents with low human capital endowments who constitute the majority of the electorates as shown in Figure 2.21, would object to a significant reduction in the tax rate since they would be worse off in a very low tax regime. Further, if the economy could not switch immediately from a tax rate of 5% to a sufficiently high tax regime beyond $\tau = 10.5\%+$ for reasons such as institutional restrictions, physical or social adjustment costs, history-dependent preferences, etc., electorates might have to incur non-trivial welfare losses throughout the transition process, and if such costs exceed benefits from switching to the new equilibrium, high-tax regime supporters may not be able to form a winning coalition. Therefore, in the neighborhood of the calibrated economy, majority of the electorates could be content with the present tax rate, and the economy could stay inertial at this equilibrium.[45]

Electorates in the calibrated European economy almost uniformly object to

[44]Clearly, single-crossing property does not hold globally, yet a weaker *local* version is observed to hold around the two peaks: numerically, if a middle-aged agent with the individual human capital state (h^1, ξ^j) prefers $\tau = 5\%$ over $\tau = 0$, so does the agent with (h^2, ξ^j) pair where $h^1 > h^2$. Similarly, if the middle-aged agent with (h^1, ξ^j) prefers $\tau = 10.5\%+$ to $\tau = 10.5 - \%$, so does the middle-aged with (h^2, ξ^j). Also, while tax rates below 5% give more life-time utility than 10.5% for most of the individuals, such comparison is not immediately applicable for the higher tax regimes.

[45]The deviation of the calibrated economy from the politically-favored tax regime of 5% could be attributed to the calibration strategy, as well as to other democratic imperfections, such as "status-quo bias". For instance, Gilens (2012) shows that the probability of adopting of a new policy in the U.S. is only 50% even when up to 90% of Americans favor policy changes, especially regarding redistributive policies.

a lower tax rate in the close neighborhood of the targeted rate of $\tau = 11.96\%$, since their welfare would decrease as a result of a drop in the tax rate due to consequent decreases in the provision of public education, government transfers, and aggregate human capital. If the economy cannot move swiftly from a high tax regime to a significantly lower one around 5%, possibly due to the aforementioned reasons, electorates would not vote in favor of the regime-switch in order not bear the non-negligible transition costs, and would be content staying at the targeted tax regime.[46]

In light of these results, the proposed model can provide insight into why large measures of households could prefer the targeted tax regimes, thus how the calibrated economies can stay inertial at the two distinct equilibria.

2.4 Conclusions

In this chapter, I concentrate on the differences between the U.S. and Europe in the levels of taxation, redistribution, provision of public goods, and perception of fairness in income inequality. I propose a heterogeneous-agent OLG model in which agents can choose either public or private education, and public education confers positive externalities but requires distortionary taxation. To study the Transatlantic differences in perceptions, I decompose income inequality with respect to its "fair-

[46]If the model was enriched in a way that the punitive role of taxes were incorporated (for instance by relaxing the closed-economy, or absence of physical capital assumptions), predictions that a higher tax rate than the calibrated European equilibrium is favored by electorates could be revised. Further, note that the higher *de facto* redistributive share of government spending in Europe, which was not taken into consideration in model's predictions, also puts a limit on the benefits from very high tax regimes.

ness" by defining whether inequality arises from foreseeable actions and abilities of individuals, or from pure luck. The model I propose features two different types of shocks: an inborn competence shock which affects optimal consumption, labor and education decision rules together with parental and economy-wide human capital, and an additively-separable income shock which is orthogonal to decision rules and competence draws of agents. I show that low taxes and low public education provision in the U.S. induce a large impact of inborn competence on schooling and labor supply, which in turn implies that a large share of U.S. income differences are due to ability, education and effort. In Europe, by contrast, high taxes and high public education minimize differences due to inborn competence, and magnify the impact of luck on income differences, as in accordance with existing beliefs. I also show that, due to the U-shaped behavior of macro variables over tax rates as seen in the data, both the U.S. and European economies can be preferred by large measures of electorates, providing insight into how the two different regimes can be politically sustainable at the same time. The intuition behind the U-shape of macro variables is that at low tax rates an increase in taxes and public education provision dampens human capital accumulation due to drops in private education attainment, while at high tax rates, public education provision gets large enough that the majority of the population prefers public education over the private one, and further increases in the tax rate boost public education attainment more than they dampen private education.

Aside from its merits, admittedly the model has some limitations. First, most parameter values employed in the model are set in accordance with the previous

literature, which is yet very limited. The values of some of these parameters, such as the public good spillover rate, are challenging to link to the data. Further research, especially on the micro-level estimation of these parameter values could improve the reliability of model's predictions.

Second, while the model can provide insight into how the U.S. and European systems gain support from their respective electorates, it does not address how developed countries with predominant mixture of public and private goods systems are sustainable for the same parameter sets. Therefore, further research on micro-foundations of the model parameters would contribute to our comprehension of country-specific cases better, as well.

Finally, although the model can provide insight into how the two different equilibria can gain political support and persist, it does not put forward the sources of the divergence in the last one and a half centuries, which is beyond the scope of this chapter.[47] Future work on transitional dynamics of the Transatlantic divergence, as well as transitional properties of the presented model would contribute to the literature considerably.

Despite these limitations, this chapter succeeds to shed light on the role of taxes and fiscal policies in the determination of Transatlantic differences in economic and behavioral variables, implications of the coexistence of public and private goods, as well as different complementarity and spillover channels in a general equilibrium

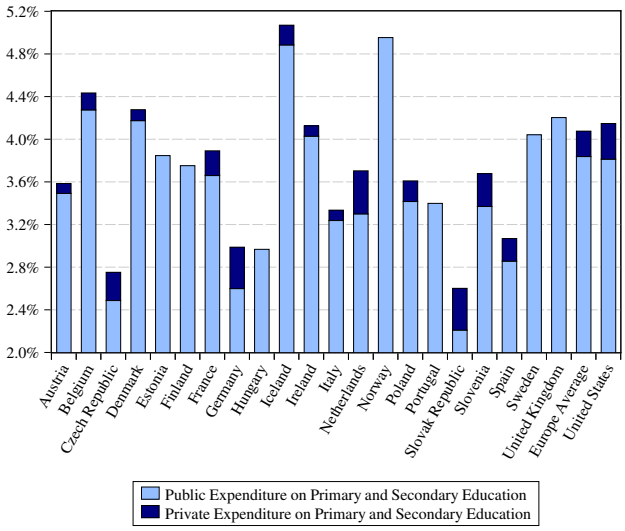
[47] Alesina and Glaeser (2004) document that there were not substantial differences between the U.S. and the continental European countries in terms of taxation and redistributive policies back in 1870s. Only a limited number of studies concentrate on endogenizing the evolution of institutions, and the exceptions do not particularly concentrate on the public vs. private good compositions or differences in beliefs. For the literature on the endogenous evolution of institutions, see Aghion *et al.* (2004), Acemoglu and Robinson (2000), and Acemoglu *et al.* (2012).

design. Further, by proposing a simple yet powerful heterogeneous OLG model, this chapter opens a gate to the study of Transatlantic differences within the neoclassical economic framework, thereby providing guidance to future studies with general equilibrium focus.

2.5 Appendix

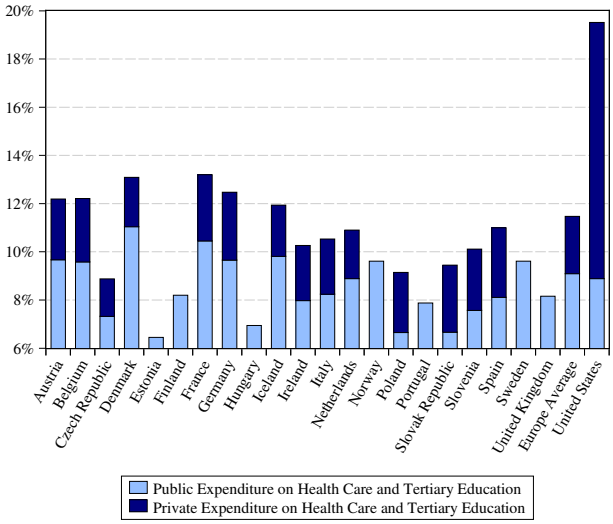
Appendix - Figures

Figure 2.26: Primary & Secondary Education Expenditure (% of GDP)



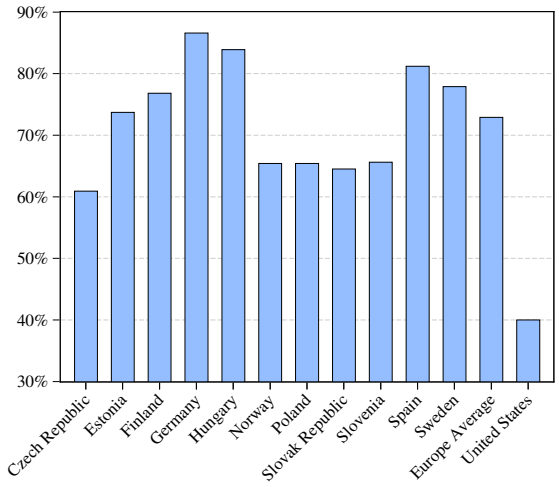
Source: OECD Database (2004-2008)

Figure 2.27: Health Care & Tertiary Education Expenditure (% of GDP)



Source: OECD Database (2004-2008)

Figure 2.28: Fraction of the Population with the Belief that People are in Need due to an Unfair Society



Source: World Values Survey (1981-2008)

Figure 2.29: Lorenz Curves for Education with Limited Spillover

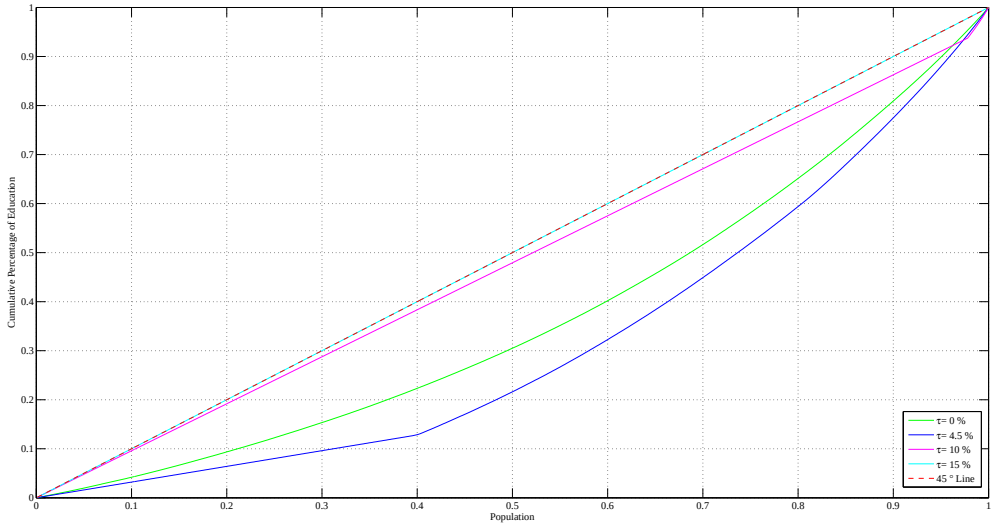
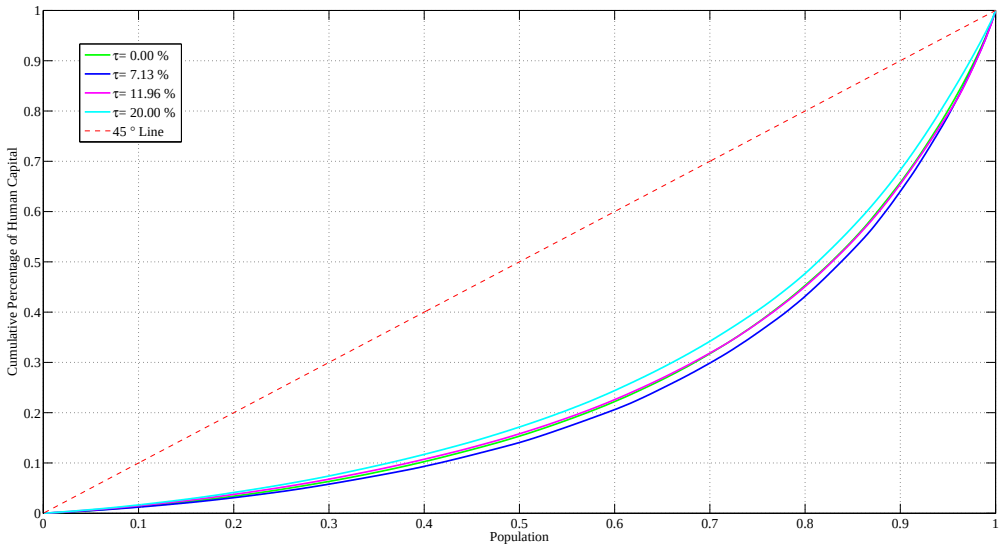


Figure 2.30: Lorenz Curves for Human Capital with Limited Spillover



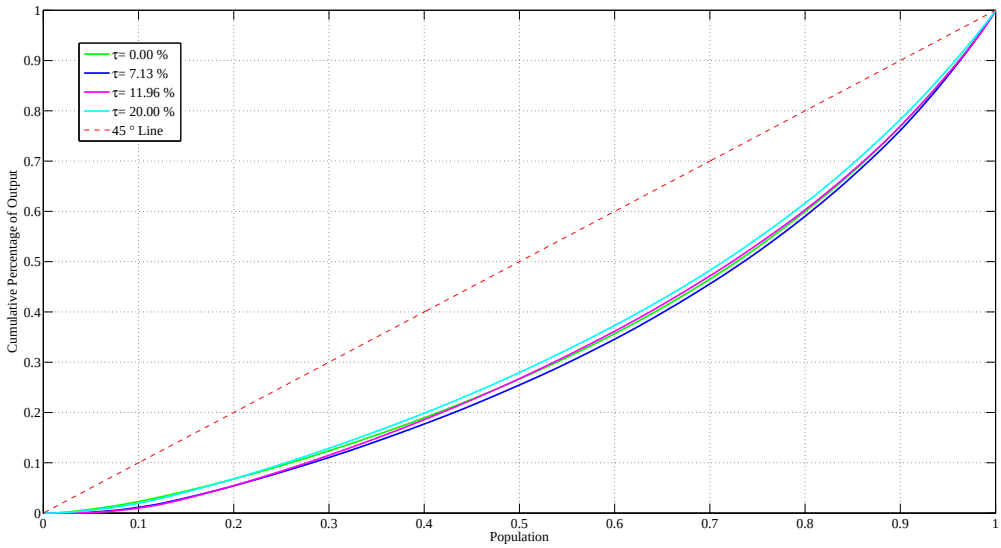


Figure 2.31: Lorenz Curves for Output with Limited Spillover

Figure 2.32: Lorenz Curves for Consumption with Limited Spillover

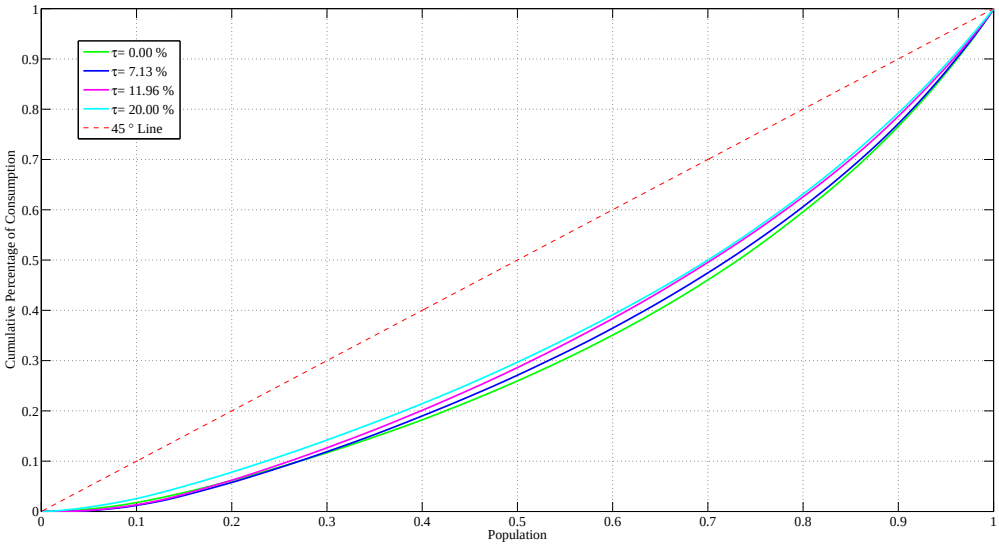
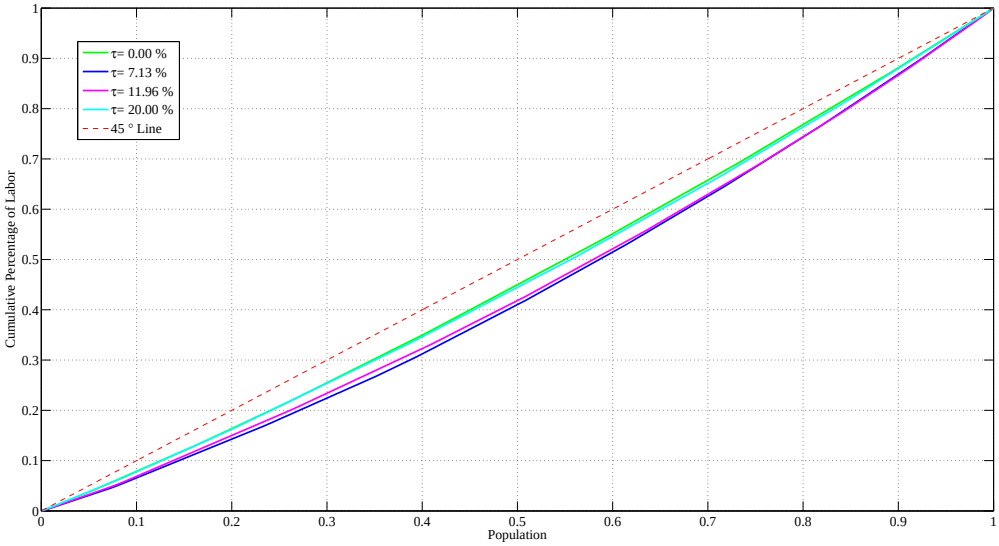


Figure 2.33: Lorenz Curves for Labor with Limited Spillover



Appendix - Tables

Table 2.15: Higher Share of Human Capital in Production ($\lambda = 0.686$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	2.111	1.783	0.835	0.343	0.328	0.000	0.000	0.00%	0.00%	15.64%
7.13%	1.555	1.322	0.511	0.295	0.192	0.073	0.043	38.06%	42.14%	24.94%
11.96%	1.321	1.186	0.367	0.274	0.135	0.100	0.059	74.39%	82.01%	36.68%
20.00%	1.697	1.492	0.591	0.288	0.206	0.206	0.121	99.50%	99.50%	25.15%

Table 2.16: Higher Altruism Rate ($\rho = 0.880$)

τ	$\overline{Y}$	$\overline{C}$	$\overline{H}$	$\overline{L}$	$\overline{\mathcal{E}}$	$\overline{E}$	$\overline{Tr}$	$\overline{E}/\overline{\mathcal{E}}$	$Pop._{\overline{E}}$	ι_l
0.00%	2.355	1.978	1.000	0.353	0.377	0.000	0.000	0.00%	0.00%	12.99%
7.13%	1.743	1.465	0.620	0.307	0.225	0.080	0.047	35.53%	39.28%	20.54%
11.96%	1.415	1.233	0.433	0.280	0.157	0.111	0.065	70.62%	79.25%	32.03%
20.00%	1.663	1.439	0.581	0.286	0.220	0.215	0.126	97.93%	98.42%	27.62%

Appendix - Computational Strategy

The computational strategy I employ to solve for recursive competitive equilibrium is a modified heterogeneous-agent economy with incomplete markets algorithm *à la* Huggett (1993). The proposed algorithm works as follows: for a given tax rate, first I make initial joint guesses for aggregate human capital $\overline{H}$, public education $\overline{E}$ and government transfers $\overline{Tr}$. Second, taking these values given, I solve for optimal decision rules of agents in all possible idiosyncratic human capital h and inborn productivity ξ state pairs by the use of value function iteration technique. Third, I perform Monte Carlo simulations for sufficiently large number of periods and households (11000 periods and 1000 households), discard some initial number of periods (1000 periods), and using the generated data, I calculate averages of the simulated aggregate human capital, public education and government transfer levels, i.e. $\sum_{t=1}^{T} \frac{H_t^{sim}}{T} = \overline{\widehat{H}}$, $\sum_{t=1}^{T} \frac{E_t^{sim}}{T} = \overline{\widehat{E}}$, and $\sum_{t=1}^{T} \frac{Tr_t^{sim}}{T} = \overline{\widehat{Tr}}$. If any of the simulated

values is different than the initial guess for the variables at a reasonable tolerance level, i.e. if $\max\{|\overline{\widehat{H}}-\overline{H}|, |\overline{\widehat{E}}-\overline{E}|, |\overline{\widehat{Tr}}-\overline{Tr}|\} > \epsilon^{tol}$, I update my initial guesses and go over the same steps until convergence is achieved. For robustness check, I also derive the theoretical stationary distribution employing decision rules and exogenous law of motion for the inborn productivity shocks, and using the stationary distribution I calculate the implied theoretical aggregate human capital, public education and government transfers, and compare them against the simulated values. I verify that the implied human capital, public education and government transfer values are the same convergent ones from the Monte Carlo simulations. Throughout these steps, I also ensure that the grids and interpolations are fine enough so that computational errors are kept at a minimal level. For each tax rate I go over the same steps and derive the respective stationary equilibrium.

Appendix - World Values Survey

The World Values Survey (WVS) is a wave of surveys conducted by the non-profit The World Values Survey Association seated in Stockholm, Sweden. The WVS aims to investigate beliefs, perceptions, values and motivations of people throughout the world for the purpose of better serving social scientists and policy-makers. In order to keep track of the trends, the WVS (jointly with European Values Survey, EVS) has executed six waves of surveys, from 1981 to 2012, and the findings from the earlier five waves, covering up to 2007 are available online. In my analyses, I make use of all the publicly-available data. The wording and structure of the questions I

and earlier studies employed are as below:

- Hard work brings success (WVS Code E040)

How would you place your views on this scale? 1 means you agree completely with the statement on the left; (10) means you agree completely with the statement on the right; and if your views fall somewhere in between, you can chose any number in between.

Agreement: Hard work brings success.

Possible Answers

(1) In the long run, hard work usually brings a better life

(10) Hard work doesn't generally bring success - it's more a matter of luck and connections

I rescale the responses coded on a scale of 1 to 10 to range between 0 and 1, and calculate the relevant statistics.

- Why are people in need (WVS Code E131):

Why, in your opinion, are there people in this country who live in need? Here are two opinions: Which comes closest to your view?

Possible Answers

(1) Poor because of laziness and lack of will power

(2) Poor because of an unfair society

(3) Other answer

I exclude the observations with the “other answer”, and rescale the responses coded on a scale of 1 to 2 to range between 0 and 1.

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