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Abstract

This thesis consists of three essays that study the effects of different government policies by developing new quantitative models which account for varying degrees of heterogeneity and consider the distributional aspects of several macroeconomic channels.

In the first essay, *"Quantifying the Effects of Basic Income Programs in the Presence of Automation"*, I evaluate the introduction of basic income programs when firms can endogenously invest in labor displacing technology. To this end, I develop a quantitative theory that allows for an analysis of the interaction between unconditional transfers and automation. My framework reveals a negative relationship between the generosity of the basic income and the investment in robots, which also leads to mostly adverse effects on economic aggregates. Concerning worker welfare, the analysis highlights a generational conflict: When comparing stationary equilibria, workers would always prefer being born into an economy without a basic income. However, older cohorts who are already alive during the introduction of the basic income can expect welfare gains during the transition to the new equilibrium.

The second essay, *"Naïve Consumers and Financial Mistakes"*, is joint work with Florian Exler. We formulate a new model for unsecured credit contracts that incorporates fees for financial mishandling. We then incorporate this formulation together with the concept of naïve consumers into a standard heterogeneous agent economy. This enables us to examine financial mistakes within a quantitative macroeconomic setting and to create an explicit role for credit market regulations such as information requirements and fee limits. The model exhibits cross-subsidization for sophisticated borrowers, since lenders offer lower interest rates to profit from higher fee payments from naïves. We use this framework to analyze two unexplored features of the CARD act: transparency requirements and penalty fee limits. Both policies reduce financial mistakes and increase the welfare of naïves. The effects on sophisticates, in contrast, are negative: If naïves make

fewer mistakes, sophisticates lose cross-subsidization and experience welfare losses. The same holds true in the case of fee limits. When high-fee contracts are banned, expected revenue from naïve fee payments falls and interest rates rise. As a result, sophisticates experience a welfare loss.

The third essay, *"The Distributional Effects of Tax Evasion"*, investigates the aggregate and distributional effects of tax evasion using a general equilibrium model with heterogeneous households. I set up a quantitative macroeconomic model which is able to replicate highly skewed wealth distributions and introduce the possibility for households to understate their true tax base, which runs the risk of being detected and having to pay a penalty fee. The findings suggest that if individuals can try to evade some of their tax payments, wealth inequality is higher under a tax regime with positive capital gains taxes. Moreover, a counterfactual analysis shows that replacing capital gains taxes with a general tax on wealth could potentially enhance welfare.

Zusammenfassung

Die vorliegende Dissertation besteht aus drei Kapiteln, in denen die Auswirkungen verschiedener Regierungsmaßnahmen analysiert werden. Dies geschieht unter Verwendung quantitativer Modelle, die verschiedene Grade der Heterogenität berücksichtigen und auch die verteilungspolitischen Aspekte mehrerer makroökonomischer Kanäle abbilden können

Im ersten Kapitel *"Quantifying the Effects of Basic Income Programs in the Presence of Automation"* bewerte ich die Einführung von verschiedenen Programmen eines Grundeinkommens, wenn Unternehmen endogen in Technologien investieren können, die Arbeitsplätze verdrängen. Zu diesem Zweck entwickle ich eine quantitative Theorie, die eine Analyse der Wechselwirkung zwischen einem bedingungslosen Grundeinkommen und Automatisierung ermöglicht. Mein Modell zeigt eine negative Beziehung zwischen der Großzügigkeit des Grundeinkommens und der Investition in Roboter, womit auch größtenteils negative Auswirkungen auf wichtige gesamtwirtschaftliche Statistiken einhergehen. Hinsichtlich des Wohlstands der Arbeitnehmer offenbart die Analyse einen Generationenkonflikt: Beim Vergleich stationärer Gleichgewichte würden Arbeiter immer lieber in eine Wirtschaft geboren werden, in der kein Grundeinkommen existiert. Ältere Kohorten hingegen, die bei Einführung des Grundeinkommens bereits am Leben sind, können während des Übergangs zum neuen Gleichgewicht Wohlfahrtsgewinne erwarten.

Das zweite Kapitel, *"Naïve Consumers and Financial Mistakes"* ist eine gemeinsame Arbeit mit Florian Exler. Wir entwickeln ein neues Modell für ungesicherte Kredite, das Gebühren für finanzielles Fehlverhalten berücksichtigt, und kombinieren es mit der Theorie von naiven Konsumenten. Dies ermöglicht es uns, finanzielle Fehler innerhalb eines quantitativen makroökonomischen Rahmens zu untersuchen und eine explizite Rolle für Kreditmarktregulierungen wie Informationsanforderungen und Gebührengrenzen zu schaffen. Das Modell zeigt eine Quersubventionierung für erfahrene Konsumenten, da Kreditgeber niedrigere Zinssätze anbieten, um von höheren Gebührenzahlungen der naiven

Verbraucher zu profitieren. Wir nutzen dieses Rahmenwerk, um zwei unerforschte Merkmale des CARD-Acts zu analysieren: Transparenzanforderungen und Strafgebührenlimits. Beide Maßnahmen reduzieren finanzielle Fehler und erhöhen den Wohlstand der naiven Verbraucher. Die Auswirkungen auf erfahrene Kreditnehmer sind dagegen negativ: Wenn naive Verbraucher weniger Fehler machen, verlieren erfahrene Konsumenten die Quersubventionierung und erleben Wohlstandsverluste. Das Gleiche gilt für den Fall von Gebührengrenzen. Wenn Verträge mit hohen Gebühren verboten werden, sinken die erwarteten Einnahmen aus Gebührenzahlungen der naiven Verbraucher und die Zinssätze steigen. Folglich erleben erfahrene Kreditnehmer einen Wohlstandsverlust.

Das dritte Kapitel, *"The Distributional Effects of Tax Evasion"*, untersucht die aggregierten und verteilungspolitischen Auswirkungen von Steuerhinterziehung anhand eines allgemeinen Gleichgewichtsmodells mit heterogenen Haushalten. Dazu entwickle ich ein quantitatives makroökonomisches Modell, das in der Lage ist, hohe Vermögensungleichheit zu replizieren und zugleich die Möglichkeit beinhaltet, dass Haushalte ihre Steuern hinterziehen, was das Risiko birgt, entdeckt zu werden und eine Strafgebühr zahlen zu müssen. Die Ergebnisse deuten darauf hin, dass wenn Einzelpersonen versuchen, einen Teil ihrer Steuerzahlungen zu hinterziehen, die Vermögensungleichheit höher bei positiven Kapitalgewinnsteuern. Darüber hinaus zeigt eine kontrafaktische Analyse, dass eine Ersetzung der Kapitalgewinnsteuern durch eine allgemeine Vermögensteuer potenzielle Wohlstandsgewinne liefern könnte.

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General Introduction

This thesis consists of three essays that study the effects of different government policies by developing new quantitative models which account for varying degrees of heterogeneity and consider the distributional aspects of several macroeconomic channels. In the past three decades, there has been a notable upswing in the utilization of heterogeneous agent models in academic literature. These models have demonstrated the ability to replicate a multitude of characteristics which are evident in empirical distributions derived from micro-data pertaining to household attributes, such as wealth, income, and consumption. Accounting for the rich heterogeneity observed in the data can yield drastically different results in the evaluation of government policies. Hence, a widely accepted notion in economic theory today is that "inequality matters for macro, and macro matters for inequality", meaning that the form of inequality and heterogeneity between households affects the macroeconomy, but macroeconomic outcomes also affect said inequality and household heterogeneity.

Since the early quantitative explorations by Bewley (1986), Hugget (1993) and Aiyagari (1994), heterogeneous agent models have been widely employed to investigate various topics, including the assessment of government policies and the provision of quantitative estimates for counterfactual analyses. Conesa et al. (2009), for example, use an overlapping generations model with idiosyncratic, uninsurable income shocks to contest the old view that capital should not be taxed and provide a welfare analysis for an optimal tax on capital and labor income. Similarly, Guvenen et al. (2023) study the difference between wealth taxation and capital income taxation. They find that introducing a wealth tax could yield large welfare gains by raising efficiency and lowering inequality. In the context of evaluating credit market policies, the seminal work by Chatterjee et al. (2007) and Livshits et al. (2007) introduced unsecured borrowing and equilibrium default while matching earnings and wealth distributions. This allows for a study of the implications of different bankruptcy rules and a quantitative exploration of the consequences of smoothing consumption with unsecured debt. Also, in recent years, there has been growing interest in the analysis of basic income programs. Lopez-Daneri (2016) reports that a revenue-neutral reform of the U.S. income tax and welfare system, incorporating a Negative Income Tax, may yield potential welfare gains. However, Daruich and Fernández (2021) and Conesa et al. (2021) have emphasized potential welfare losses from the provision of a universal basic income.

Numerous additional examples could be provided as the field of quantitative evaluations of government policies is constantly expanding, with new research ideas and more sophisticated modeling approaches being developed by economists. This thesis adds to the literature by providing novel insights on timely topics through the incorporation of new channels into widely used quantitative frameworks. Chapter 1 develops a model that can analyze the complicated interactions between automation decisions by firms and basic income programs provided by the government. In Chapter 2, we incorporate naïve consumers and a new bundle of credit contracts to create an explicit role for credit market regulations, such as information requirements and fee limits, in the standard heterogeneous agent setting. Lastly, Chapter 3 contributes to the discussion about the taxation of capital by accounting for tax evasion and analyzing the resulting implications for the macroeconomy and government policies.

1. Quantifying the effects of Basic Income Programs

Chapter 1 aims to quantify the impact of basic income programs on the labor market and the economy as a whole when firms have the option to invest in labor-displacing technology, while workers can choose markets with different exposures to automation risk. The idea of providing workers with a guaranteed subsistence level has been part of philosophical and economic considerations for centuries. Possible programs include replacing social security, public housing, and other safety-net programs with a Negative Income Tax (e.g., Friedman, 1962), or with Universal Basic Income which provides the same transfers to everyone irrespective of their age, income or other personal characteristics (e.g., Atkinson, 1995).

More recently, Universal Basic Income (UBI) has also become an attractive topic for public and political discussions due to its simplicity and easy to understand concept. By providing an unconditional income to the entire population, UBI ensures 100 percent coverage without any stigma or eligibility issues. It is also thought to avoid distortions caused by welfare benefits, which can discourage job searching. Additionally, UBI has gained popularity due to economic challenges such as recessions, stagnation of wages, automation, and rising inequality. The surge in inflation due to the COVID-19 pandemic and Russia's invasion of Ukraine have further increased the need for programs that might be able to mitigate economic crises. Especially the rise of automation remains a long-term challenge for the labor market, with evidence suggesting that it displaces employment in the industries in which it originates. In this case, a basic income may offer security and educational opportunities, but opponents argue it could also incentivize workers to demand higher wages, potentially fueling automation, making the total effect unclear and highlighting the need to consider the relationship between automation and basic income programs.

The framework developed in this chapter allows for the first quantitative evaluation of these interactions and reveals a negative relationship between the generosity of the basic income and the investment in robots. The effects of UBI on economic aggregates seems to be mostly negative. Moreover, workers would always prefer being born into an economy without a basic income in terms of welfare. Only some of the older cohorts can expect welfare gains during the transition to the new equilibrium, thereby highlighting a possible generational conflict.

2. Naïve Consumers and Financial Mistakes

Chapter 2, co-authored with Florian Exler, provides a new quantitative framework to evaluate credit market reforms such as the CARD-Act in the US. Financial contracts can be complex, and many credit card holders struggle to grasp important terms such as when their actions trigger penalty fees (GAO, 2006). Besides paying interest, credit card borrowers incur penalty fees for repaying financial obligations too late or for exceeding lines of credit. Agarwal et al. (2015) report that the average credit card holder paid \$58 in fees per year, with late fees and over limit fees constituting the largest items.

Consequently, financial mistakes are the focus of much regulation due to their high cost and potential consequences. Policy makers often address the issue through transparency requirements and caps on penalty fees such as those in the US 2009 CARD Act; however, state-of-the-art quantitative research cannot inform regulators about their costs and consequences, since standard models simply abstract from penalty fees and have no roll for financial mistakes. Without these important ingredients, transparency requirements or fee limits as mandated by the CARD act seem futile. We address this gap in the literature by quantitatively analyzing the consequences of financial mistakes for credit market outcomes and assessing the effectiveness of regulations similar to the CARD act.

By incorporating naïve consumers and a new set of credit contracts into a standard heterogeneous agent economy, our framework can give rise to financial decisions that we call mistakes. Thus, to the best of our knowledge we are the first to quantitatively examine the consequences of naïve behavior on the credit market and the implications of regulations such as information requirements and fee limits. The model exhibits cross-subsidization for sophisticated borrowers, since lenders offer lower interest rates to profit from higher fee payments from naïves. Calibrating the model outcome to important moments of the US economy we find that both, transparency requirements and penalty fee limits, reduce financial mistakes and increase the welfare of naïves. However, sophisticates experience a welfare loss, since expected revenue from naïve fee payments falls. As a result, interest rates rise which hurts the sophisticates.

3. The Distributional Effects of Tax Evasion

Finally, Chapter 3 contributes to the existing literature on capital taxation by incorporating tax evasion. The traditional view that capital income should be exempt from taxation has been challenged in the academic literature with the use of incomplete markets models and the incorporation of rich heterogeneity (e.g.: Aiyagari, 1995, or Conesa et al., 2009). However, although the literature on optimal taxation is already vast and continuously growing, discussions about the effectiveness of capital taxation often neglect to consider the issue of tax avoidance and evasion through legal or illegal means, which can undermine the intended redistribution effects of such policies. As empirical evidence indicates the significance of tax evasion especially among the very rich, as shown in Alstadsaeter et al. (2019), it is critical for debates on optimal tax systems to incorporate the behavioral responses of taxpayers towards such policies.

The aim of this chapter is therefore to shed light on two important questions which have been neglected in the macroeconomic literature so far: What are the consequences of tax evasion on the aggregate economic outcomes? And should capital be taxed if the rich have access to the means of evading their tax payments while the poor do not?

To study these questions, I set up a quantitative macroeconomic model which is able to replicate highly skewed wealth distributions and introduce the possibility for households to understate their true tax base, which runs the risk of being detected and having to pay a penalty fee. The findings suggest that if individuals can try to evade some of their tax payments, wealth inequality is higher under a tax regime with positive capital gains taxes. Moreover, a counterfactual analysis shows that replacing capital gains taxes with a general tax on wealth could potentially enhance welfare.

Chapter 1

Quantifying the Effects of Basic Income Programs in the Presence of Automation

The trend towards increasing automation and robotization is a challenge for the labor market, especially for the demand for low skilled labor. Concepts of a Universal Basic Income (UBI) are often brought up as potential reforms to current welfare systems which could provide additional insurance against this trend. I develop a quantitative theory of the labor market where firms endogenously decide on their investment in robots, while workers can insure themselves against the risk of automation induced job-loss by obtaining a college degree. This framework allows for an analysis of the interaction between unconditional transfers and automation and reveals a negative relationship between the generosity of the basic income and the investment in robots. UBI lowers the effective marginal tax rates for unemployed and reduces the incentives for obtaining a college degree. Both effects lead to an increase in participation and search effort in the automation sector and investment in robots is discouraged while employment increases. Concerning worker welfare, my framework highlights a generational conflict: When comparing stationary equilibria, workers would always prefer being born into an economy without a basic income. However, older cohorts who are already alive during the introduction of the basic income can expect welfare gains during the transition to the new equilibrium.

JEL Codes: E24, H24, H31, I38, J24

Keywords: Universal Basic Income, Negative Income Tax, Automation, Labor Market Frictions, Overlapping Generations

1.1 Introduction

The idea of a society in which every individual is guaranteed a basic income without any obligations has been part of philosophical considerations for centuries. In his famous book about the perfect state (Utopia, 1516), Thomas Moore already claimed that the state should provide unconditional subsistence for everyone in order to prevent thievery. In economics, too, the idea is not new, and several different concepts have been considered. In his discussion of the role of economic capitalism in a liberal society, Friedman (1962), for example, proposes replacing social security, public housing, and other safety-net programs with a Negative Income Tax (NIT). Later, Atkinson (1995) discussed the replacement of the social security system by a guaranteed basic income which provides transfers to everyone irrespective of their age, income, or other personal characteristics.

The concept of such a Universal Basic Income (UBI) or of similar programs is also often brought up in political discussions, especially among critics of current social welfare systems. In 1969, US President Richard Nixon proposed to replace a welfare program aimed at families with children with a guaranteed minimum income for all these families. As a reason he cited the apparent failure of the current welfare system to prevent poverty.[1] Thereafter, four well-known field experiments were conducted in the US analyzing the effects of unconditional transfers in the form of a negative income tax.[2] In an overview of the results, Munnell (1986) states that reductions in work effort were only moderate, while school attendance increased. Others, however, have questioned the results from such experiments as they are not able to capture general equilibrium effects or to provide insights on the effects on the broader population (see, e.g., Zellner and Rossi 1986).

More recently, 2020 former Democratic presidential candidate Andrew Yang proposed a "Freedom Dividend", a guaranteed payment of $1,000 per month to every U.S. citizen aged 18 or older (Yang, 2018). In Switzerland, a national referendum about a basic income was held in 2016 (and rejected by the population[3]) and in Germany, an ongoing experiment

[1] In his Address to the Nation on Domestic Programs in 1969 he stated: “Whether measured by the anguish of the poor themselves, or by the drastically mounting burden on the taxpayer, the present welfare system has to be judged a colossal failure.”

[2] Namely: The New Jersey Graduated Work Incentive Experiment, The Rural Income-Maintenance Experiment in Iowa and Carolina, The Seattle/Denver Income-Maintenance Experiments and The Gary, Indiana Experiment

[3] Although the text of the initiative did not mention a specific amount of the provided basic income, the initiators advocated a monthly payment of CHF 2,500 for every adult citizen (roughly $1,600 at the

provides unconditional cash transfers of $1,200$ EUR to a randomized treatment group to study the effects of a UBI. More examples and a deeper discussion of UBI in advanced countries are provided in the review by Hoynes and Rothstein (2019).

Several key features of UBI make it especially appealing for public and political discussions. First, as a concept it is easy to understand, and an adoption appears to be straightforward. Second, since it is an unconditional program aimed at the whole population it would yield a 100 percent coverage and avoid frictions from stigma or eligibility. Lastly, providing an unconditional income is thought to yield a minimum of distortions as it is a lump-sum transfer which avoids problems from bunching below certain costly thresholds. This is particularly relevant with regard to the effective marginal tax rates faced by unemployed. If welfare benefits are being retracted when people start working, they might be discouraged from actively searching for jobs. An unconditional income is thought to reduce this friction and could even lead to higher labor force participation.

Besides these appealing features, the concept of UBI programs has also found increasing interest due to several developments in most western countries, which have experienced a recent recession, a stagnation of median wages, a surge in automation and robotization, and a rise in inequality of wealth and income. Also, due to the coronavirus pandemic, several countries in Europe and the US have faced a considerable increase in unemployment rates, while Russia's invasion of Ukraine has caused a surge in inflation rates. The insurance provided by basic income programs is often brought up as a possible means to mitigate the impacts of such crises on the economy and poorer households in particular.

Some of these crises should be only temporary in nature, whereas the rise in robotization is generally thought to remain a major challenge for the labor market going forward. While automation can be both, a complement and a substitute for labor, recent evidence suggests that the substitution effect might be dominant in the short-run. Autor and Salomons (2018), for example, report that the observed decrease in aggregate labor shares in most western countries stem from within-industry movements and that automation displaces employment in the industries in which it originates. Similarly, Kindberg-Hanlon (2021) estimates that a 10 percent technology-driven improvement in labor productivity reduces employment by 2 percent in advanced economies.

These observations lead to an increased fear of job-loss due to the displacement of

time of the referendum).

low skilled workers by the adoption of robots and many believe that programs such as UBI might be necessary to counteract the resulting rise in inequality.[4] A basic income could provide much needed insurance and give people the freedom to learn new skills according to their talents. At the same time, however, opponents of a UBI often mention the possibility that improving the workers' outside option could incentivize them to demand higher wages, thereby even encouraging further investment in automation and exacerbating the situation. Hence, the total effect is not clear beforehand and since the trend towards increasing robotization is likely to only accelerate in the years to come, understanding the interactions between automation and basic income programs becomes ever more important.

While the literature on the effects of unconditional transfers is already extensive and still growing, studies mostly rely on empirical data or contained field experiments (see, among others, Cesarini et al., 2017 on the effects of lottery wins, or Jones and Marinescu, 2022 on the effects of the Alaska Permanent Fund). However, one should be careful before extrapolating the results of such experiments, since their ability to provide insights on general or even partial equilibrium effects for the broader population and other sub-populations is very limited (Zellner and Rossi, 1986). Moreover, such experiments only study the responses from workers, while understanding the reactions of firms and their investment decisions might be just as important. These shortcomings can only be addressed within a model framework which allows for an evaluation of different basic income programs and a qualitative counterfactual analysis.

In the macroeconomic literature, however, UBI and similar concepts have only recently received more attention. Lopez-Daneri (2016) provided the first quantitative assessment of a Negative Income Tax within a general equilibrium setting. Concerning UBI, quantitative studies are still scarce but notable working papers include Conesa et al. (2021), Luduvice (2021) and Chang et al. (2021). While all these papers are highly complementary, they mostly focus on different aspects of how UBI would affect macroeconomic outcomes and none of them consider the interaction with endogenous automation decision.

The aim of this paper is therefore to add to the discussion about the impacts of basic income programs by developing a new model framework which is able to provide novel

[4] Andrew Yang's "Freedom Dividend", for example, was also meant to prevent poverty from automation induced job-loss.

insights on equilibrium effects in several dimensions. First, in contrast to the existing literature on UBI, I consider two segregated sectors for workers with and without a college degree. The two sectors differ in their exposure to robotization, which provides workers with the opportunity to insure themselves against automation induced job-loss by obtaining a college degree. Hence, the effects of automation are not homogeneous across workers and also depend on the workers' decisions. Next, I include labor market frictions and job-search. The introduction of a basic income not only affects wages and labor supply, but also the decision of how much effort to put into finding a job during unemployment. This has implications for the overall employment in the economy, as well as for the expected profits by firms. Both dimensions are important when talking about the effects of basic income programs. If the aggregate search effort by workers falls considerably, firms might be inclined to invest more into automation to avoid keeping costly vacancies. Consequently, in this paper, I allow firms in one of the two sectors to adopt a robot instead of hiring a worker. Thus, the risk of automation induced job-loss is not an exogenous shock but arises endogenously from the mechanisms within the model setup. This enables me to study the general equilibrium effects which result from the impact the introduction of a basic income has on firm decisions.

The model is calibrated to the US economy and the results show that a reform towards a basic income program has strong effects on firms' automation decisions: higher transfers actually increase the demand for labor while decreasing the investment in automation. There are several forces at play which drive this result. First, a more generous basic income leads to less labor force participation in the college sector, effectively decreasing human capital and output in the economy. At the same time, unemployed workers face lower effective marginal tax rates since they do not lose all their unemployment benefits when taking up a job. Both effects lead to a sharp increase in participation and search effort in the automation sector. Consequently, firms can expect higher profits in the labor market and investment in automation is discouraged while employment increases. Concerning welfare, the effects are not so easily summarized. Since the basic income is mostly financed through income taxes, the introduction of UBI leads to a redistribution from high income earners to low income earners. During the transitional periods towards the new equilibrium, current cohorts in the automation sector can expect welfare gains. In particular, low productive workers benefit from the UBI, as they receive additional transfers without being hurt by the higher tax rates needed to fund the basic income. Overall, a majority of the current generation would vote in favor of the reform. Comparing the stationary equilibria under the veil of ignorance, in contrast, reveals that most workers would prefer being born into the benchmark economy without a basic income. Also, in the new equilibrium, college rates, output and average consumption are lower.

This paper is organized as follows. The subsequent section describes relevant literature and highlights the contributions to the ongoing discussion. Section 1.2 then presents the model setup, while the parameterization and calibration strategy of the benchmark economy are described in Section 1.3. In Section 1.4, I discuss the effects of a basic income of varying generosity and compare the two most common proposal, a Negative Income Tax and Universal Basic Income. Section 1.5 then provides a deeper analysis of one specific basic income program. Section 1.6 briefly analyses an optimal tax and transfer system, and Section 1.7 concludes.

1.1.1 Related Literature

This paper contributes to several strands of the literature. First, this paper is most closely related to the growing quantitative macroeconomic literature on the evaluation of welfare reforms. The first quantitative assessment of a basic income program was conducted by Lopez-Daneri (2016), who studied the impacts of a Negative Income Tax (NIT) as a revenue-neutral reform of the U.S. income tax and welfare system. Lopez-Daneri (2016) uses a life-cycle economy with individual heterogeneity and uninsurable idiosyncratic labor risk to show that an NIT can lead to considerably welfare gains for households born after the introduction of the reform. Also, regarding labor market outcomes, the author finds an increase in labor supply measured in efficiency units, as well as an increase in the number of hours worked. Section 1.6 of this paper brings forth similar results and therefore partially confirms previous findings.

Recently, similar model environments have been used to assess the consequences of UBI. Luduvice (2021), for example, introduces on-the-job learning and child-bearing costs and finds that the introduction of a UBI leads to a growth in output and capital due to higher precautionary savings, while labor market responses by households are only moderate. Daruich and Fernández (2021) incorporate human capital accumulation and endogenous intergenerational links and find mostly negative effects for younger households and future generations. The authors also address the concern of higher job separations due to a rise in automation by simply increasing the proportion of workers in their model setup who receive an out-of-work shock. While their analysis suggests possible gains from UBI in an environment with rising risk of job-loss, their model is not designed to understand automation decisions and consequently, misses some important general equilibrium effects. In this paper, however, automation decisions are endogenous and their interaction with the generosity of the unconditional transfers is shown to have important quantitative impacts on the welfare results.

Another related paper is Conesa et al. (2021) which focuses on the distinction between basic and non-basic consumption goods. With their model setup the authors can show that a generous UBI together with a progressive tax on consumption could lead to ex-ante welfare gains. However, current households would face high welfare losses during the transitional phase. Finally, Chang et al. (2021) use the standard Aiyagari (1994) economy with endogenous labor supply to compare a UBI to an NIT, finding that both programs can provide identical economic incentives, while differing vastly in other aspects such as required funding. In this paper, the focus lies more on the interaction between endogenous automation decisions and occupational choice by workers. Consequently, the results of this paper are complementary to the existing literature and provide insights into new channels through which basic income programs affect the economy.

Next, the model setup in this paper allows for a labor-substituting technology and therefore draws from existing literature on the substitution of labor by investment in automation. Models in which robots and workers compete in the production of different tasks include Acemoglu and Autor (2011) and Acemoglu and Restrepo (2018), among others. Empirical evidence of such labor-substituting innovations is provided by Autor and Salomons (2018), who look at four decades of harmonized cross-country and industry data and find that automation displaces employment in the industries in which it originates. Also, using evidence from structural vector autoregressions on a large global sample, Kindberg-Hanlon (2021) finds that the substitution effect of new technologies dominates the complementary aspect in most economies. Leduc and Liu (2021) incorporate these insights into a quantitative general equilibrium model, where the threat of automation weakens workers bargaining power. This paper extends this framework by introducing two sectors which differ in their possibility of automation and by introducing additional frictions on the labor market to analyze the interactions that may arise from the introduction of a UBI policy. Lastly, this paper is in spirit very similar to the analysis by Jaimovich et al. (2021) but differs in some important aspects. For example, in this paper there is no ex-ante distinction between low-skill workers and high-skill workers. Hence, the selection between markets occurs endogenously. Also, workers face income risks over their life-cycle and matching frictions occur in all sectors, not only in the automation sector.

Furthermore, this paper relates to recent studies on the role of UBI in the discussions about welfare reforms. Banerjee et al. (2019), for example, study the role of UBI in developing countries by gathering information from different pilot studies. Hoynes and Rothstein (2019), in contrast, discuss the potential role of different universal transfer systems in advanced countries and find that UBI policies would generally direct larger transfers to childless and middle-income rather than poor households. They assert that a UBI large enough to increase transfers to low-income families would be enormously expensive, about twice the cost of all existing transfers in the US. Hence, the distributional effects of UBI crucially hinge on the source of new funding and its interaction with other macroeconomic factors. This paper contributes to these existing studies by providing a new quantitative theory which can shed light on some of the advantages as well as the challenges of UBI policies, while also assessing the distributional effects within a general equilibrium framework.

Lastly, assessing UBI policies also relates to the empirical literature concerning the effects of unconditional transfers. Beginning in the end of 1960s, four pilot studies using a negative income tax were conducted in the US and showed only moderate reductions in work effort in response to the treatment (see, e.g., Munnell, 1986). The long-term effects of one of these experiments[5] were studied by Price and Song (2018). The authors caught up with participants four decades after the program and found that reductions in earnings in response to the cash assistance were mainly related to retirement. Similar modest results were found more recently in studies exploiting lottery wins. Cesarini et al. (2017), for example, used evidence from Swedish lotteries to show that a monetary win only leads to a moderate reduction in earnings, while the uncompensated labor supply

[5]Namely, the Seattle-Denver Income Maintenance Experiment

elasticity is close to zero. Similarly, Jones and Marinescu (2022) exploit data from the Alaska Permanent Fund, which pays a yearly dividend to all residents, and find no effect on employment. While all these empirical studies provide partial insights on the effects of a guaranteed income, their results cannot simply be extrapolated on a broader population, as mentioned by Zellner and Rossi (1986), among others. Such low-scale experiments cannot provide insights on general equilibrium effects as they only focus on the responses of a small sub-population, while ignoring reactions by firms. Moreover, they often even fail to explain partial equilibrium effects, since they do not capture decisions over the whole life-cycle. Hence, this paper provides a quantitative framework to test these results within a model setup which allows for the analysis of general equilibrium effects and the evaluation of counterfactual policies.

1.2 Model Setup

Time is discrete and there are two types of agents: Capitalists who own firms and hire labor, and workers who provide this labor. There exist two segregated markets which differ in labor demand while sharing the same capital stock. Intermediate goods are produced in one-worker firms and are used in the competitive final goods production.

1.2.1 Workers

There is a measure 1 of workers who do not save but use all their labor income for consumption. They live for J periods, are ex-post heterogeneous with respect to their labor productivity and seek to maximize expected life-time utility

$$\mathbb{E}\left(\sum_{j=1}^{J}\beta^{j-1}u(c_j,h_j)\right),$$

where preferences are based on consumption, c, and labor supply, h. Per-period utility is described by

$$u(c,h)=\frac{c^{1-\sigma}}{1-\sigma}-\phi\frac{h^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}}, \tag{1.1}$$

where σ denotes the risk aversion parameter, γ the Frisch elasticity and ϕ a multiplicative constant which is used to match average hours worked in the economy. Also, note that workers can be unemployed, in which case h measures the effort put into finding a new job.

The labor market is segregated as there exist two types of jobs. An agent's decision which market to enter is made in the first model period depending on whether a college degree is obtained. Both markets share the same capital stock and produce intermediate goods for final production. In the first market, which does not require a college degree, workers can be replaced by robots, while production in sector 2 always requires labor input.

Skills. A worker enters the model with an idiosyncratic productivity level z and taste for college z_c. Taste for college is only relevant in the first model period by influencing the decision to join sector 2 which requires a college degree. Going to college yields a disutility in the first model period of $\delta_c z_c$. The productivity level z follows a first-order Markov process.

Labor Market. The matching process in the labor market closely follows the specification in Landais et al. (2018), with the exception that in this paper there exist two segregated markets. There is a measure one of heterogeneous workers who can enter one of two markets, $m \in \{1, 2\}$. Initially, all workers are unemployed and search for a job with individual search effort h, while firms can post vacancies to recruit workers. Based on the aggregate search effort in each market, $\mathcal{H}_m$, and open vacancies in that market, v_m, the matching function $\mathcal{M}(\mathcal{H}_m, v_m)$ determines the number of worker-firm matches formed at the beginning of the model period. The function $\mathcal{M}$ has constant returns to scale, is differentiable and increasing in both arguments, and satisfies $\mathcal{M}(\mathcal{H}_m, v_m) \leq 1$. The labor market tightness, θ_m, of each market is given by the relation between open vacancies and aggregate search effort, i.e. $\theta_m = v_m/\mathcal{H}_m$. Due to the properties of the matching function, the labor market tightness determines the probability with which a worker who exerts search effort h finds a job and probability that an open vacancy is filled. The job-finding probability per unit of search effort is given by $f(\theta_m) = \mathcal{M}(\mathcal{H}_m, v_m)/\mathcal{H}_m = \mathcal{M}(1, \theta_m)$, so that an individual who exerts effort h finds a job with probability $h \cdot f(\theta_m)$. An open vacancy is filled with probability $g(\theta_m) = \mathcal{M}(\mathcal{H}_m, v_m)/v_m = \mathcal{M}(1/\theta_m, 1)$. Also, existing matches are separated with exogenous probability ψ, which is the same in each market.

Employed Workers. Workers who find a job are paid a wage rate, w, per unit of effective labor supply. Thus, gross income of employed workers is given by $\tilde{y} = whze_j$, where the wage rate is multiplied by productivity z, nominal labor supply h and an age-specific experience premium e_j. Wage rate and labor supply are determined by Nash-Bargaining when an open vacancy is matched with an unemployed worker. Gross income is then subject to a progressive income tax given by

$$T(\tilde{y}) = \tilde{y} - \lambda_0 \tilde{y}^{1-\lambda_1}, \tag{1.2}$$

where the parameter λ_1 determines the degree of progressivity, while λ_0 shifts the tax function and determines the average level of taxation in the economy. This specification has been introduced into dynamic macroeconomic models with heterogeneous agents by Bénabou (2002) and allows for closely mimicking existing tax systems with only two variables. Net income, y, is then given as $y = \tilde{y} - T(\tilde{y}) = \lambda_0 \tilde{y}^{1-\lambda_1}$. Also, note that this specification does not provide transfers for unemployed, since $T(0) = 0$. Unemployment benefits are described below and subsection 1.2.5 discusses the possible forms of UBI.

The decision which market to enter has already been made upon entering the model and cannot be changed thereafter. Hence, from period 1 onward the state of a worker can be summarized as $s = (z, z_{-1}, m, j, u)$, with z_{-1} being last period's productivity (which influences unemployment benefits), $m \in \{1, 2\}$ the market, j age and $u \in \{0, 1, 2\}$ the unemployment status (0 meaning employed, 1 indicating short-term unemployment and 2 denoting long-term unemployment). Also, note that wages and labor supply will be decided by Nash-Bargaining and are therefore functions of s, $w = w(s)$ and $h = h(s)$.

Then, a worker's decision problem is given by

$$\begin{aligned} W(s) = &\max_{c \geq 0} \; u(c,h) + \beta \mathbb{E}\Big[(1-\psi)W(s') + \psi U(s')\Big] \\ &s.t \quad y(s) \geq (1+\tau_c)c \end{aligned} \tag{1.3}$$

with $W(\cdot)$ being the value function of employed workers, $U(\cdot)$ the value function of a worker who becomes unemployed, ψ the exogenous separation rate and τ_c the tax on consumption.

Unemployed Workers. Unemployed workers do not earn income but receive benefits from the government. Workers who are unemployed for the first period ($u = 1$) receive benefits, b_j, based on their past productivity and the average wage rate in their respective sector. Hence, $b_j = \varrho \bar{w}_m z_{j-1} e_{j-1}$, where $\bar{w}_m$ is the average wage rate in sector m and ϱ the replacement rate. Long-term unemployed workers ($u = 2$), i.e. workers who are unemployed for two or more consecutive periods, receive only a subsistence level of benefits, $\bar{b}$, which is independent of previous productivity and $\bar{b} \leq \min\{b_j\}$. Also, workers who are unemployed in the very first model period do not have a past productivity and thus only receive the subsistence level $\bar{b}$.

Unemployed workers have to exert effort, h, to find a job. The probability of being matched with a firm in market m with market tightness θ_m is given by $h \cdot f(\theta_m)$. Let s again denote the worker's state, then the decision problem for an unemployed worker is

$$\begin{aligned} U(s) = \max_{c \geq 0, h \in [0,1]} \quad & u(c,h) + \beta \mathbb{E}\Big[h f(\theta_m) W(s') + (1 - h f(\theta_m)) \bar{U}(s') \Big] \\ s.t \quad & b(s) \geq (1 + \tau_c) c \end{aligned} \tag{1.4}$$

where $\bar{U}(\cdot)$ denotes the value function of long-term unemployed. Note that $b(s) = \bar{b}$ if $u = 2$.

Market Decision. It is assumed that workers who enter the model for the first period have been exerting the maximum amount of effort for finding a job. Thus, the probability of being employed in the very first model period is simply given by $f(\theta_m)$. With $W_1(z, m)$ denoting the value function of an employed worker in the first period and $U_1(z, m)$ denoting the value function of being unemployed in the first period, the expected lifetime utility of a worker entering market m with taste for college z_c and productivity z is given as

$$V(z, z_c, m) = f(\theta_m) \cdot W_1(z, m) + (1 - f(\theta_m)) \cdot U_1(z, m) - \delta_c z_c \cdot \mathbb{1}_{m=2},$$

with $\delta_c z_c$ being the disutility from college education if the worker chooses to enter the college sector.

Hence, a worker decides to enter sector 2, iff

$$V(z, z_c, 2) > V(z, z_c, 1). \tag{1.5}$$

In equilibrium, the fraction of workers in both sectors stays constant and is determined by cut-off values for z and z_c.

1.2.2 Capitalists and Production

The final good Y is produced using the output from the two sectors as intermediate goods. Let y_1 and y_2 denote the output of one firm from sector 1 and sector 2, respectively. Intermediate goods are produced according to a Cobb-Douglas technology within a firm:

$$y_m = k^{\alpha} n^{1-\alpha},$$

where $n = hze_j$ is effective labor supply and $\alpha \in [0, 1]$.

Alternatively, firms in sector 1 can invest in robots with productivity ζ and produce according to

$$y_1 = k^{\alpha} \zeta^{1-\alpha},$$

where the productivity of the robot, ζ, follows an idiosyncratic first-order Markov process.

Let Y_1 and Y_2 denote the aggregate output from all firms in sector 1 and 2, respectively. The final good Y is then produced using these aggregated intermediate goods as input:

$$Y = Y_1^{\mu} Y_2^{1-\mu}$$

with $\mu \in [0, 1]$.

The final goods producing sector is competitive and prices of the intermediate goods are determined by their marginal product.

One-Worker Firms. All firms in sector 2 as well as those firms in sector 1 who do not adopt a robot are randomly matched with unemployed workers in their respective market.

The value of a job filled with a worker in state s in sector m is given by

$$\begin{aligned} J(s,m) = \max_k \; & p_m \cdot k^{\alpha}(hze_j)^{1-\alpha} - (r+\delta)k - whze_j \\ & + \frac{1}{1+r}\Big[\psi J_m^v + (1-\psi)\mathbb{E}\Big(J(s',m)\Big)\Big], \end{aligned} \tag{1.6}$$

where p_m denotes the prices for intermediate goods in sector m and J_m^v denotes the value of an open vacancy in sector m. Again, the capital input does not influence next-periods profits and consequently, the firms' first-order conditions imply

$$k^* = zh\left(\frac{r+\delta}{\alpha p_m}\right)^{\frac{1}{\alpha-1}}.$$

Value of vacancies. To post a vacancy the firm has to pay a flow cost κ_m^v, which potentially varies between markets, and since the matching process is random, the firm can be matched with every unemployed worker. With $g(\theta_m)$ being the probability of being matched with a worker in sector m and with $J(s,m)$ being the value of a job filled with a worker in state s and sector m, the value of posting a vacancy is given by

$$J_m^v = -\kappa_m^v + \frac{1}{1+r}\Big(g(\theta_m)\mathbb{E}\Big(J(s,m)\Big) + \Big(1-g(\theta_m)\Big)J_m^v\Big), \tag{1.7}$$

where the expectation is formed with respect to the worker state s. Since there is free entry in both markets, in equilibrium firms will continue creating new vacancies until the value of a new vacancy is zero, i.e. until $J_m^v = 0$

Automation. Firms in the automation sector ($m = 1$) can decide to invest in robots instead of searching for a worker. Adopting a robot requires an investment x^a which is drawn from the iid distribution $G(x^a)$ and firms will create automated jobs if $x^a < x_t$ for some cut-off value x_t which could change between periods. Hence, in every period t the fraction of newly automated jobs is given by $q_t = G(x^a < x_t)$. At the same time, existing robots can become obsolete or break down with probability δ^a. Therefore, the stock of automated jobs evolves according to

$$A_t = (1-\delta^a)A_{t-1} + q_t$$

In the stationary equilibrium, with $A_{t-1} = A_t = A^*$ and $q_{t-1} = q_t = q^*$, we get

$$A^* = \frac{q^*}{\delta^a}$$

A robot which is used for production necessitates flow costs κ^a. Thus, the value of automation with a robot of productivity ζ is given by

$$J^a(\zeta) = \max_k \ p_1 \cdot k^\alpha \zeta^{1-\alpha} - \kappa^a - (r+\delta)k + \frac{(1-\delta^a)}{1+r}\mathbb{E}\Big(J^a(\zeta')\Big), \tag{1.8}$$

where p_1 denotes the price for the intermediate good in sector 1. Note that the capital input does not influence next-periods profits. Therefore, the firms' first-order conditions imply that

$$k^* = \zeta \left(\frac{r+\delta}{\alpha p_1}\right)^{\frac{1}{\alpha-1}}$$

The threshold cost x_t up until which automation occurs is simply pinned down by the value of adopting a robot: Firms will automate jobs as long as they can expect the value from automating being higher than the adoption costs. Hence, automation occurs if and only if,

$$\mathbb{E}(J^a) - x_t > 0,$$

where the expectation is formed with respect to the productivity of the robot.

Wage determination. When a firm is matched with a worker, a contract specifying the wage rate w and labor supply h is determined through Nash-bargaining. There is no long-run commitment, contracts are set every period. With $U(s)$ denoting the value function for an unemployed agent in state s and $W(w,h,s)$ the value function for an employed worker in state s with wage rate w and labor supply h, the bargaining solution is given by

$$(w,h) = \operatorname*{arg\,max}_{w \geq 0, h \in [0,1]} \Big(W(w,h,s) - U(s)\Big)^\xi \cdot \Big(J(w,h,s) - J^v\Big)^{1-\xi}, \tag{1.9}$$

with ξ representing the worker's bargaining power which is the same in both sectors.

The Timing of Events. At the beginning of a model period idiosyncratic productivity of workers and robots are realized as well as investment costs for automation. Based on the investment costs a fraction of firms invests in the adoption of robots in sector 1. At the same time, open vacancies are randomly matched with unemployed workers, while ongoing work relationships are terminated with exogenous probability ψ. Matched firms and workers then decide on wages and labor supply through Nash Bargaining. Lastly, firms who enter a relationship with a worker or adopted a robot make an investment decision and final goods are produced with intermediate inputs from both sectors. Households consume all their income. The timing of events is illustrated in Figure 1.1.

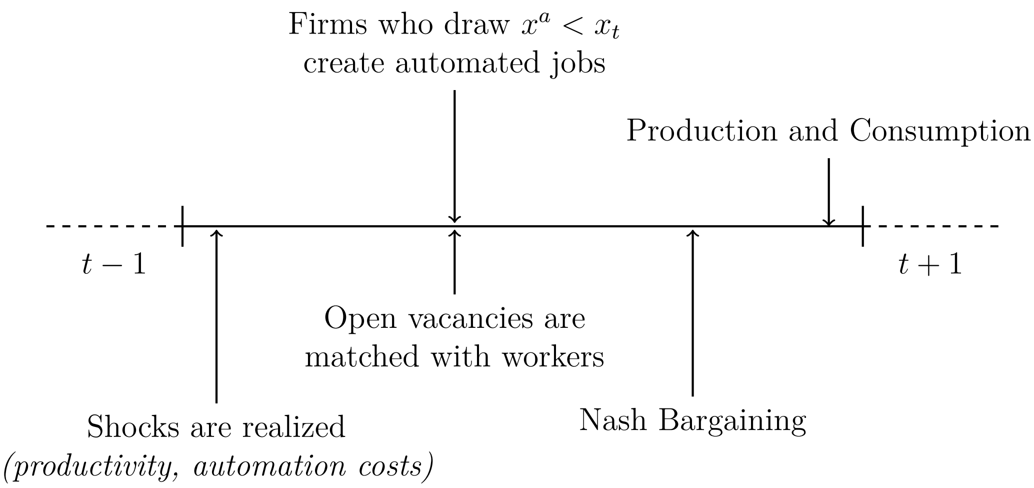


Figure 1.1: The timing of events in period t

The representative capitalist. Let Π_t denote the total profits from all one-worker firms and all automated jobs in period t. The supply of capital evolves according to

$$(1 + r - \delta)K_t^s + (1 - \tau_a)\Pi_t - \kappa^v v_t - \bar{x}q_t - (1 + \tau_c)c_t^{\text{cap}} = K_{t+1}^s \tag{1.10}$$

with $\kappa^v v_t$ being the total costs of vacancies, $\bar{x}q_t$ the costs of newly automated jobs, τ_a a tax on profits and c_t^{cap} the consumption of capitalists.

The decision problem of the capitalists can be thought of as the decisions of a representative capitalist who perfectly diversifies. With Φ and A denoting the distributions over employed workers and automated jobs, the value function of this representative capitalist is given by

$$V^C(K_t,\Phi_t,A_t) = \max_{c_t,v_t,A_{t+1},K_{t+1}} \quad u(c_t) + \frac{1}{1+r}\mathbb{E}\Big[V^C(K_{t+1},\Phi_{t+1},A_{t+1})\Big]$$
$$s.t \quad (1+r-\delta)K_t + (1-\tau_a)\Pi_t - \kappa^v v_t - \bar{x}q_t - (1+\tau_c)c_t^{\text{cap}} = K_{t+1}.$$

In a stationary equilibrium, where capital stock, K, and distributions over states, Φ and A, are constants, $V^C = u(c^*)\left(\frac{1+r}{r}\right)$.

1.2.3 Government

The government taxes labor income, consumption, and profits and uses the revenue to finance welfare transfers and public consumption G. Public consumption is given as an exogenous fraction of GDP, $G = gY$, and does not enter the utility of households.

Tax revenues from labor income, R_ℓ, consumption, R_c and profits, R_π, are given by

$$\begin{aligned}
R_\ell &= \int_S \tilde{y}(s) - \lambda_0\Big(\tilde{y}(s)\Big)^{1-\lambda_1} \mathrm{d}\Phi(s),\\
R_c &= \tau_c \cdot \int_S \tilde{c}(s)\,\mathrm{d}\Phi(s) + \tau_c \cdot c_{cap},\\
R_\pi &= \tau_a \cdot \Pi,
\end{aligned}$$

while payments to unemployed are given by

$$B = \int_S b(s)\,\mathrm{d}\Phi(s),$$

where $b(s) = 0$ for employed workers ($u = 0$) and $b(s) = \bar{b}$ for long-term unemployed workers ($u = 2$).

The government runs a balanced budget every period, that is

$$R_\ell + R_c + R_\pi = B + G \tag{1.11}$$

1.2.4 Stationary Equilibrium

At each point in time an agents state is given by $s = (z, z_{-1}, m, j, u)$, with z being persistent productivity, z_{-1} last period's persistent productivity, $m \in \{1, 2\}$ the market, j

age and $u \in \{0, 1, 2\}$ the unemployment status (0 meaning employed, 1 indicating short-term unemployment and 2 denoting long-term unemployment). Let the space of possible states be denoted by $S = Z \times Z \times m \times J \times u$.

A stationary equilibrium is an allocation of value functions for employed and unemployed workers, $W(s)$ and $U(s)$, a decision rule for consumption $c(s)$, prices of intermediate goods p_1 and p_2, work contracts over wages $w(s)$ and labor supply $h(s)$, a distribution over states $\Phi(s)$, social transfers and taxes such that:

1. The value functions and the optimal decision rule for consumption $c(s)$ solve the optimization problems of the households (1.3) and (1.4) given the factor prizes, bargaining outcomes, and initial conditions.

2. The measure of households over states $\Phi(s)$ is constant.

3. Wages $w(s)$ and labor supply $h(s)$ solve the bargaining problem (1.9)

4. The optimization of capitalists together with the optimal decision rules of workers yields an expectation of 0 for opening new vacancies and the measure over vacancies and automated jobs is constant.

5. Prices of intermediate goods solve the optimization of the competitive final goods production and are determined by their marginal product, i.e.:

$$p_1 = \mu \left(\frac{Y_1}{Y_2} \right)^{\mu - 1}$$
$$p_2 = (1 - \mu) \left(\frac{Y_1}{Y_2} \right)^{\mu}$$

6. The government runs a balanced budget

$$R_\ell + R_c + R_\pi = B + G$$

1.2.5 Basic Income

Section 1.4 will discuss the effects of introducing a basic income which is provided by the government and financed through labor income taxes. There are several concepts of how to provide unconditional transfers to everyone which are often used interchangeably in the public discussion. However, most of them can be described as a combination of two ideas which theoretically yield the same outcome, but diverge conceptually in their approach. The first refers to a policy as proposed by Atkinson (1995) and provides a fixed amount of lump-sum transfers to every individual irrespective of their age, income or other personal characteristics. The other is a tax system as discussed by Friedman (1962), where everyone again receives a fixed amount of transfers, but these transfers slowly phase out when people start earning income. Although the two concepts can often be designed to achieve the same result and are thus not always distinguishable, for the purposes of this paper, the former will be referred to as Universal Basic Income (UBI), and the latter will be called Negative Income Tax (NIT).

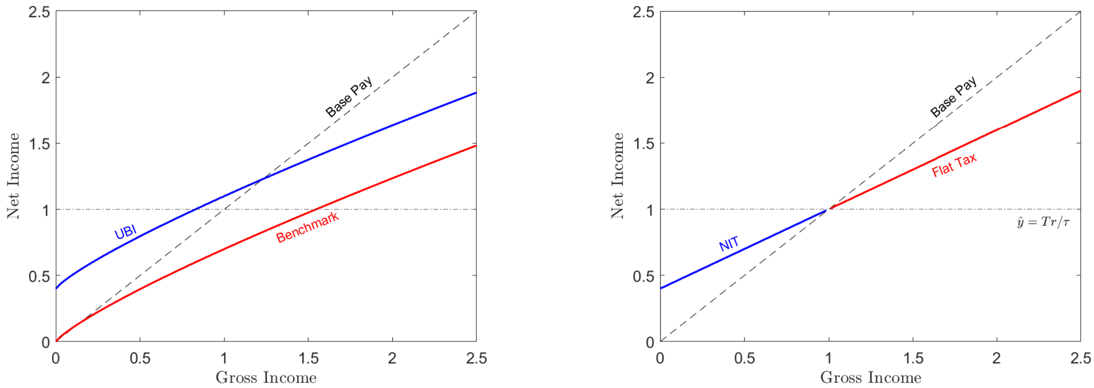
A reform towards UBI simplifies the problem of unemployed workers as they only receive the lump-sum transfer b^{UBI} irrespective of their individual state. However, employed workers also receive this transfer. Hence, with gross income of employed workers being denoted by $\tilde{y}$, net disposable income in the case of UBI is given by

$$y^{disp} = \begin{cases} \tilde{y} + b^{UBI} - T(\tilde{y}) & u = 0 \\ b^{UBI} & u \in \{1, 2\} \end{cases} \tag{1.12}$$

with $T(\cdot)$ being the progressive tax on labor income as specified in Equation 1.2.[6] Within this paper, I focus on the case where the UBI is introduced without changing the progressivity of the tax schedule. Figure 1.2a shows how the introduction of a UBI which provides transfers in the amount of median income to everyone would shift disposable income compared to a given benchmark economy when the degree of progressivity remains unchanged.

The concept of an NIT is similar to that of a UBI, as both aim to provide a basic income to individuals, regardless of their employment status, wealth, or education. However, there is a slight difference between the two: while a UBI provides everyone with the same amount of transfers, an NIT gradually phases out transfers as household income rises above a certain threshold, denoted by $\hat{y}$. As a result, an NIT leads to less transfers and consequently also requires less taxes, even if both programs yield the same disposable

[6]Note that this specification means that the UBI transfers are not subject to taxation. This can potentially lower the marginal tax rates when entering employment but does not have significant effects on the analysis otherwise.



(a) UBI (b) Linear NIT

Figure 1.2: Universal Basic Income and Negative Income Tax

income. Mathematically, a general NIT with a linear phase-out rate of transfers is given by

$$y^{disp} = \begin{cases} \tilde{y} + Tr - \tau\tilde{y} & \tilde{y} \leq \hat{y} \\ \tilde{y} - T(\tilde{y} - \hat{y}) & \tilde{y} > \hat{y}, \end{cases} \tag{1.13}$$

where $\tilde{y}$ denotes gross income, Tr the transfers to households with no income, and τ the phase-out rate of the transfers. Hence, once the household's income surpasses the threshold $\hat{y}$, they start paying taxes on the additional income above $\hat{y}$ according to a tax schedule $T(\cdot)$.[7] Here, the threshold level is determined by the transfer level and the phase-out rate, i.e. $\hat{y} = Tr/\tau$. For this paper, I focus on the simplest case where income is taxed linearly at the same rate τ as the transfers phase out. Thus, the tax schedule in Equation 1.13 can be simplified to

$$y^{disp} = (1 - \tau)\tilde{y} + Tr. \tag{1.14}$$

Figure 1.2b shows an example of how such a tax can look like when households are guaranteed transfers in the amount of median income and transfers phase out at a rate of 40% (which is also equal to the tax rate above the threshold level).[8] In this special case with a linear tax that is equal to the phase-out rate, introducing a UBI alongside a flat tax

[7]Note that this specification already includes unemployment benefits, since $b(s) = y(0) = Tr$.

[8]I also conducted an experiment with a progressive tax schedule, but the effects did not vary drastically. The rest of this section only presents the results from the flat tax, since its implementation is more straightforward and easier to understand and should therefore be preferred in view of similar outcomes.

Table 1.1: Difference between linear NIT and linear UBI

	UBI	**NIT**
Gross Income	$\tilde{y}$	$\tilde{y}$
Transfers	Tr	$(Tr - \tau\tilde{y})1_{\tilde{y}\leq\hat{y}}$
Taxes	$\tau\tilde{y}$	$\tau(\tilde{y} - Tr/\tau)1_{\tilde{y}>\hat{y}}$
Disposable Income	$(1-\tau)\tilde{y} + Tr$	$(1-\tau)\tilde{y} + Tr$

would be equivalent to implementing an NIT. However, this equivalence only holds with regard to the disposable income of the household. From the government side there are still differences in the amount of taxes and transfers that are being paid. These difference are summarized in Table 1.1. In the case of UBI, everyone receives the same amount of transfers and also faces the same average tax rate, τ. In the case of NIT, in contrast, transfers phase out, while taxes are only paid on income exceeding the threshold level. Thus, the average tax rate is $\tau - Tr/\tilde{y}$, which is increasing in $\tilde{y}$. Hence, despite having the same gross income and resulting net income, households under the NIT system are subjected to lower average tax rates and receive fewer transfers compared to households in the UBI system.

Within the scope of this paper, I analyze two opposing regimes: A UBI as in Equation 1.12, and an NIT as in Equation 1.14. Thus, the former refers to a tax system where a basic income is introduced without changing the progressivity of the tax system, while the latter refers to the introduction of basic income together with a reform towards a linear tax system in the form of an NIT. Unless otherwise specified, all subsequent analyses in this paper refer to these two cases when mentioning UBI and NIT.

Because of the difference in tax schedules, the two reforms differ in their resulting incentives in two important ways: firstly, they affect the marginal tax rates of the unemployed, and secondly, they impact the tax burden of high-income earners. With an NIT, the flat tax rate results in the same marginal tax rate for everyone. If transfers are phasing out quickly, workers can potentially face high marginal tax rates starting with the very first dollar they earn. Since the government runs a balanced budget, these higher tax rates at the lower end of the income distributions lead to lower tax rates for high income earners. Introducing a UBI, in contrast, keeps the current progressivity of the tax system unchanged. Consequently, unemployed workers and low income earners face low marginal tax rates and additional revenue is collected from high income earners. Thus, both reforms can yield both positive and negative incentives for labor supply and it is not clear beforehand, which effect should dominate.

Other reforms towards a basic income can often be realized as a convex combination of the two programs shown in Figure 1.2. For example, one could imagine a Negative Income Tax with varying tax rates for different income groups. This would lead to a situation which closely resembles UBI as discussed above. At the same time, one could also imagine a reform towards UBI in which the transfers are included in the tax base. This would lead to a situation in which tax rates for employed and unemployed workers become more equal. Hence, such a reform would closely resemble an NIT with a progressive tax schedule. Consequently, in this paper I only discuss the two boundary cases and highlight their possible benefits as well as their expected disadvantages. The effects of other programs can then often be inferred from the results presented in this paper.

1.3 Parameterization

This section presents the parameter values used to numerically solve the benchmark economy.[9] I calibrate the model to certain moments of the U.S. economy in order to provide an insightful analysis of the possible effects of different basic income programs. Some parameters are set externally (cf. Table 1.2), while others are estimated using a Simulated Method of Moments approach to match important labor market outcomes (cf. Table 1.3). Lastly, Table 1.4 provides a brief overview of the benchmark economy, before the effects of introducing a basic income are discussed in section 1.4.

1.3.1 Households

Households enter the model at age 21 and die with certainty at age 80. One model period corresponds to six months. There is no formal retirement, but the households' age-dependent experience premium drops after the age of 65. The experience premium

[9] For details on the computational solution method see appendix C.

is set exogenously and normalized to yield a life-time mean of 1. The evolution of the experience premium is plotted in Figure A1 in appendix A.

Households discount the future with the discount factor $\beta = 0.992$ and per-period utility is described by

$$u(c, h) = \frac{c^{1-\sigma}}{1-\sigma} - \phi \frac{h^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}},$$

where the risk-aversion parameter, σ, is set to 2, which is standard in the literature. The Frisch elasticity γ is chosen to be 0.7 as estimated by Hall (2009). The multiplicative disutility of supplying labor, ϕ, is calibrated endogenously to yield an average labor supply of 40% of total labor endowment, which is in the range of standard values in the literature.

Persistent labor productivity follows a simple AR(1) process where the annual auto-correlation parameter is set to $\bar{\rho} = 0.95$ and the variance of the iid shock chosen to be $\bar{\sigma}^2 = 0.025$. All these values are within the range of standard literature. To map these values into biannual numbers, I set $\rho = \bar{\rho}^{1/2}$ and $\sigma^2 = \bar{\sigma}^2/(1+\rho^2)$.

Finally, disutility from college is given by $\delta_c z_c$, where z_c is drawn from a normal distribution with mean 1 and standard deviation 0.1 at the beginning of the first model period. The utility costs, δ_c, are calibrated endogenously to match an average college attendance of 31%.

1.3.2 Production

The capital share in production of intermediate goods, α, is chosen to match the average of capital income over total income in the U.S. between 1960—2007, which is 0.35 as reported by Lopez-Daneri (2016). Final production uses an equal share of intermediate goods from both markets, i.e. $\mu = 0.5$. The biannual depreciation rate, δ, is set to 5% and the biannual nominal interest rate is given by $r = 1/\beta - 1 = 0.8\%$.

Automation. The productivity of a robot, ζ, evolves according to an AR(1) process. For the quarterly autocorrelation, $\hat{\rho}$, and the quarterly standard deviation of the normal innovation, $\hat{\sigma}$, Leduc and Liu (2021) estimate values of 0.86 and 0.029, respectively. I map these quarterly values into biannual values and set $\rho_a = \hat{\rho}^2$ and $\sigma_a = (1+\hat{\rho}^2) \cdot \hat{\sigma}$.

The costs of automating an open vacancy, x^a, are drawn from a uniform distribution with support $[0, \bar{x}]$. The upper bound $\bar{x}$ determines the probability of automating an open

Table 1.2: Directly specified parameters

	Parameter	Value	Target/Source
Preferences			
Risk aversion	σ	2	standard
Frisch elasticity	γ	0.7	Hall (2009)
Discount factor	β	0.992	standard
Labor income			
Autocorr. labor efficiency	ρ	0.95	standard
Variance labor efficiency	σ^2	0.025	standard
Production			
Capital share	α	0.35	Lopez-Daneri (2016)
Intermediate Input	μ	0.5	standard
Depreciation	δ	5%	standard
Automation			
Autocorr. efficiency	ρ_a	0.86	Leduc and Liu (2021)
Std. dev. efficiency	σ_a	0.028	Leduc and Liu (2021)
Maintenance costs	κ^a	0.34	see text
Probability of obsolescence	δ^a	0.08	Leduc and Liu (2021)
Labor Market			
Job finding probability	χ	0.97	Krusell et al. (2010)
Elasticity of matching function	η	0.72	Shimer (2005)
Bargaining power workers	ξ	0.72	Shimer (2005)
Government			
Consumption tax	τ_c	7.5%	McDaniel (2007)
Capital income tax	τ_a	25%	McDaniel (2007)
Curvature of income taxes	λ_1	0.137	Holter et al. (2019)

vacancy and is chosen endogenously to match an automation rate in the economy of 30% as reported in Leduc and Liu (2021). The probability with which a robot becomes obsolete or breaks down, δ^a, is set exogenously to 8%. This leads to a situation in which the average annual lifespan of a robot is in line with the data reported by the International Federation of Robotics (IFR) as used in Leduc and Liu (2021). Lastly, following the estimation in Leduc and Liu (2021), maintenance costs of robots are given by $\kappa^a = 0.34$, which yields annual profits of 2% of annual revenue by adopting a robot.

Table 1.3: Jointly calibrated parameters

	Parameter	Value	Target
Disutility of college	δ_c	720	31% college attendance
Investment costs	$\bar{x}$	9.8	33% automation rate
Labor disutility	ϕ	56	Avg. labor hours 0.4
Average taxation	λ_0	0.63	Avg. taxation 22%

1.3.3 Labor market.

Workers and open vacancies are matched according to the function $m(u, v) = \chi u^{\eta} v^{1-\eta}$, as in Shimer (2005). Following Shimer (2005), I calibrate χ by targeting a market tightness of $\theta = 1$ for both sectors and setting χ to match the average probability of finding a job. As reported in Krusell et al. (2010), a worker finds a job with probability 0.45 per month. Hence, on average the biannual flow arrival rate of job offers equals $1 - (1 - 0.45)^6 = 0.97$ and with an equilibrium market tightness of $\theta = 1$, this pins down the value $\chi = 0.97$.[10]

Next, as estimated in Shimer (2005) the elasticity of the matching function is assumed to be equal to the bargaining power of the workers and hence, $\eta = \xi = 0.72$. Also, the exogenous probability of a job separation, ψ, is set to 4%, which is twice as high as the probability with which a robot becomes obsolete. Finally, the costs of posting a vacancy, κ_m^v, are chosen so that the market tightness of $\theta = 1$ satisfies the equilibrium free-entry condition for posting a vacancy in both markets, meaning that expected profit of creating a new vacancy is 0 in both markets.[11]

1.3.4 Government

The replacement rate for short-term unemployed is set to be 0.5, while long-term unemployed receive transfers of 40% of median income to assure a subsistence level of consumption. Also, there are three different tax parameters to be chosen. Tax rates on

[10]Note that this market tightness in the automation sector occurs after the decision of automating open vacancies. Hence, the flow arrival rate of job offers is the same in both markets. However, the additional possibility of automating a job increases the expected profits of keeping a vacancy open, thus leading to less matches for the same number of job offers.

[11]In subsequent policy experiments, these benchmark costs of creating a vacancy will be held constant. In order to still get the equilibrium free-entry condition for posting a vacancy, the market tightness becomes a free parameter and will adjust to again yield zero expected profits of creating a new vacancy.

Table 1.4: Benchmark Outcomes

College Share		31%
Automation Rate		35%
Unemployment Rate		7%
	autom. sector	7.9%
	college sector	5.1%
Mean Net Income[1]		1.5
	autom. sector	0.94
	college sector	2.78
Average Taxation		23%

[1] Note: Average income is given in relation to median income and only includes employed workers.

consumption and capital gains for the U.S. are taken from McDaniel (2007), who reports $\tau_c = 7.5\%$ and $\tau_a = 25\%$. The parameter λ_1, which measures the rate of progressivity, is based on Holter et al. (2019) who find an estimated value for the US of 0.137. The parameter λ_0, which shifts the tax function and determines average level of taxation, is chosen endogenously to match an average taxation in the economy of 22% as estimated in McDaniel (2007). The resulting tax revenue will exceed payments for unemployment insurance and this surplus amount will be assumed to be exogenous government consumption G, which will be held fixed in subsequent policy experiments.

1.3.5 The Benchmark Economy

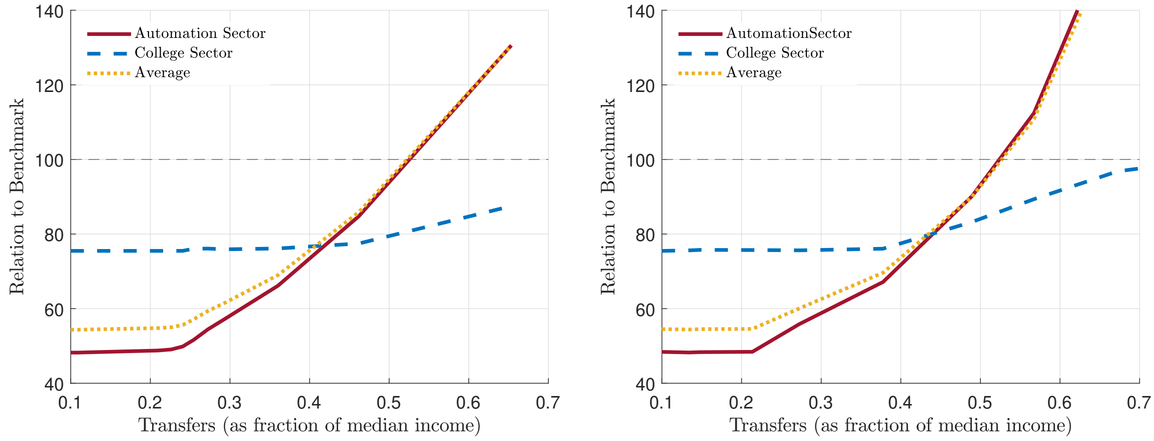
Before introducing a universal basic income, Table 1.4 summarizes the outcome of the benchmark equilibrium with the parameterization as described above. The equilibrium college share is 31% and the automation sector sees a share of 35% of automated jobs. Also, we can see sizable differences between the markets. While the overall unemployment rate is given by 7%, it is higher in the automation sector than in the college sector with 7.9% against 5.1%, respectively. The probability to invest in robots instead of workers also has implications for wages. Average income is nearly three times higher in sector 2 than in sector 1. Workers who obtained a college degree earn 278% of median income on average, while the average worker in the automation sector only earns 94% of median income. Lastly, employed workers face an average tax rate of roughly 23%,

1.4 The Effects of a Basic Income

As discussed in subsection 1.2.5, most popular concepts for an unconditional income can be thought of as a combination of UBI and NIT. This section therefore describes the effects of replacing unemployment benefits with a UBI program or an NIT scheme as described in Equations 1.12 and 1.14 and shown in Figure 1.2. I introduce unconditional transfers of different amounts and measure their generosity in terms of their fraction of the median income in the new stationary equilibrium. Exogenous parameters, including government consumption, are kept constant at their benchmark level. To still ensure a balanced budget, the average taxation of income in the economy is adjusted upwards or downwards. All other tax rates remain unchanged.[12]

Hence, introducing a UBI only changes the parameter λ_0 which determines the average tax on income. The progressivity of the tax system remains unchanged. The NIT program, in contrast, replaces the benchmark tax system with a flat tax schedule as given in Equation 1.14. The flat income tax, τ, which is also the phase-out rate of the transfers, is then chosen to keep the government budget balanced with regards to the exogenous parameters. Note that the break-even income at which households receive no transfers and pay no taxes is immediately determined by the transfer level and the tax rate, $\hat{y} = Tr/\tau$, so that it cannot be used as additional policy variable. All else equal this scheme should result in a smaller tax burden for the households than the introduction of UBI, since transfers are not distributed in a lump-sum manner but phase out for higher income earners. However, as discussed in subsection 1.2.5, the different incentives of the two programs might have different consequences for the economy and thus, it is not clear in advance whether one of these programs should be strictly preferred.

[12]This leads to a slight change in the computational solution method: The average labor income tax is now an equilibrium outcome and pinned down by the balanced budget condition. Also, the costs of creating a vacancy, κ_m^v, are now held constant and instead the market tightness will shift to adjust to the new equilibrium.



(a) NIT (b) UBI

Figure 1.3: Effects of a basic income on unemployment rates

Labor Market. First, Figure 1.3 shows how the introduction of a basic income would affect unemployment rates in the economy, when the basic income is provided either by the NIT or the UBI proposal. We can see that the relationship between unemployment and the generosity of the transfers is increasing in both cases. If transfers are low, staying in unemployment becomes so costly that unemployed workers increase their search effort and also accept lower wages. These channels have a positive effect on employment and with both, NIT and UBI, the unemployment rate in the automation sector falls below 50% of the benchmark level for exceedingly low transfer levels. As the welfare benefits become more generous, in contrast, the workers' outside option improves and they lower their search effort while demanding higher wages. Consequently, unemployment rates rise until they exceed the benchmark level.

Concerning the different sectors, Figure 1.3 reveals sizable differences between workers in the automation sector and the college sector. Workers who obtained a college degree earn higher wages on average and thus, unemployment has already been very costly for them in the benchmark economy. They react less strongly to a reduction in the transfer level, as they have already made exerted high effort for finding a job in the benchmark economy. As transfer levels get higher, workers in the college sector bear most of the additional tax burden, which slightly reduces their incentive to work. However, comparing Figure 1.3a and Figure 1.3b reveals differences between NIT and UBI. As transfers become more generous, the additional revenue required for financing the reform leads to higher tax rates on labor income. The NIT reform introduces a flat tax which distributes the

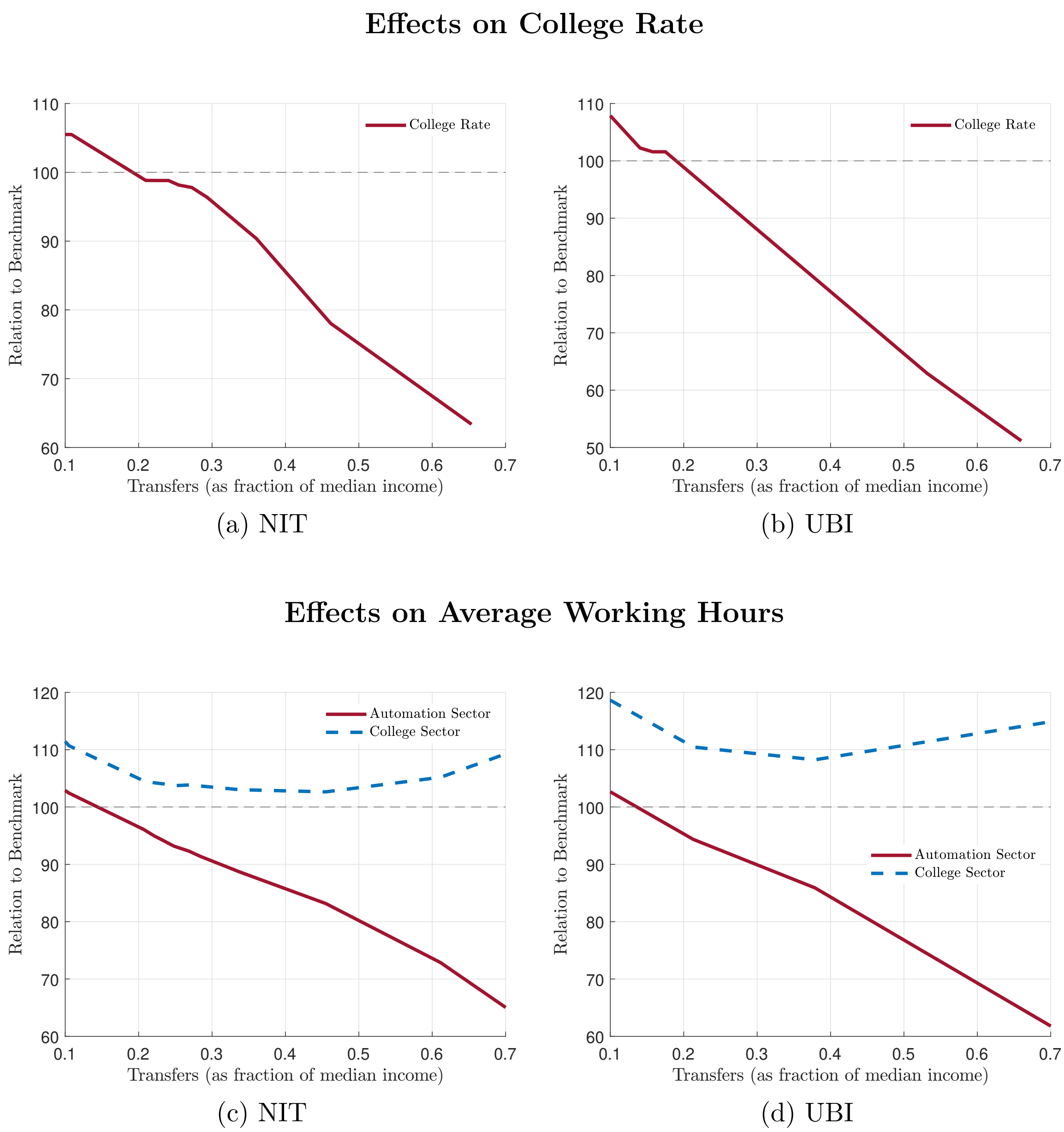


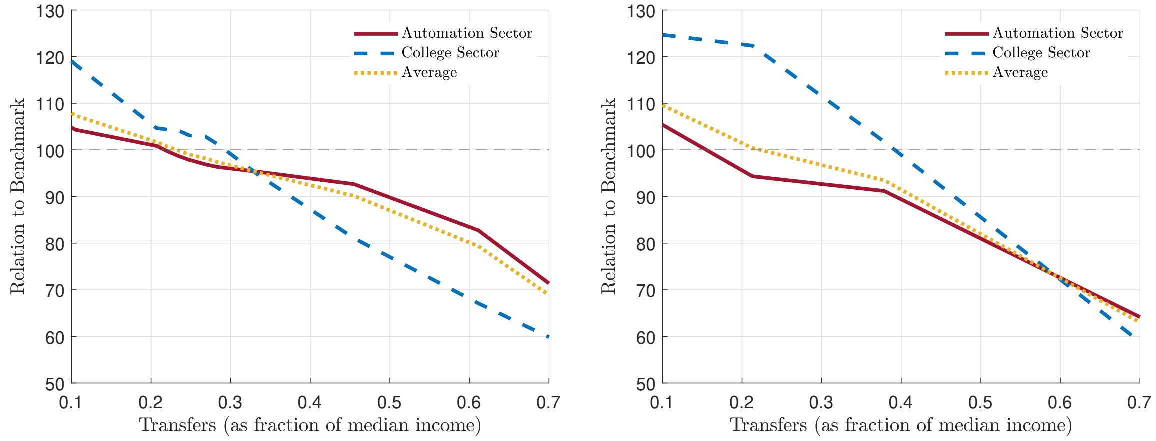
Figure 1.4: Effects of a basic income on the college rate and average Working hours.

tax burden evenly among the income groups, since everyone faces the same average tax rate. The UBI reform, in contrast, keeps the progressivity of the benchmark tax system unchanged and increases the tax burden of high income earners. Consequently, the UBI reform has stronger effects on workers in the college sector, as they face higher marginal tax rates than in the benchmark economy. The NIT reform, in comparison, has a greater impact on workers in the automation sector since the flat tax leads to higher marginal tax rates for low-income earners.

Next, Figure 1.4 shows the effects of an NIT and a UBI on the overall college rate in the economy and average working hours in both sectors. Both reforms lead to a sharp decrease in the fraction of people who are obtaining a college degree. Higher transfers are financed by higher income taxes. At the same time, the insurance against automation induced job loss provided by a college degree is partially offset by the unconditional transfers provided by the higher basic income. Together, these channels reduce the incentive to join the college sector and discourage workers from obtaining a degree early in life. Hence, human capital is adversely affected by the introduction of a basic income. Overall, college attendance drops to nearly 60% of the benchmark level under the NIT regime and to nearly 50% with a UBI.

With regards to average working hours, we can see that the college sector is positively affected by both reforms. There are two channels which drive this result: When transfers are low, more people are obtaining a college degree and firms pay lower wages. Lower wages together with lower tax rates which are needed for funding the transfer system incentivize workers in the college sector to increase their hourly labor supply. When transfers are high, in contrast, the fraction of people in the college sector drops and firms pay higher wages. Again, this leads to an increase in the average labor supply by college educated workers. Concerning workers in the automation sector, Figure 1.4 reveals a clear negative trend in the amount of average hours worked. In both reforms, the NIT and the UBI, higher transfers reduce the work incentives for low income earners. With a UBI, all the workers receive additional transfers which are mostly financed through higher tax rates at higher income levels. Hence, low income earners can enjoy more leisure with comparable levels of disposable income. With the NIT reform, transfers phase out as workers earn more income and consequently, low income earners are again discouraged from supplying more hours of labor. Overall, low income earners seem to gain from both reforms. Also, both reforms seem to provide the same incentives for labor supply, since the differences between Figure 1.4c and Figure 1.4d seem to be negligible.

Lastly, combining the insights from above, Figure 1.5 shows the effects of a basic income on total labor supply in the economy and in both sectors. Again, we can see a clear negative trend with more generous transfer systems. However, the reason for the reduction in overall labor supply is very different. In the college sector the decline is only driven by the fall in the college rate, while average working hours actually increase



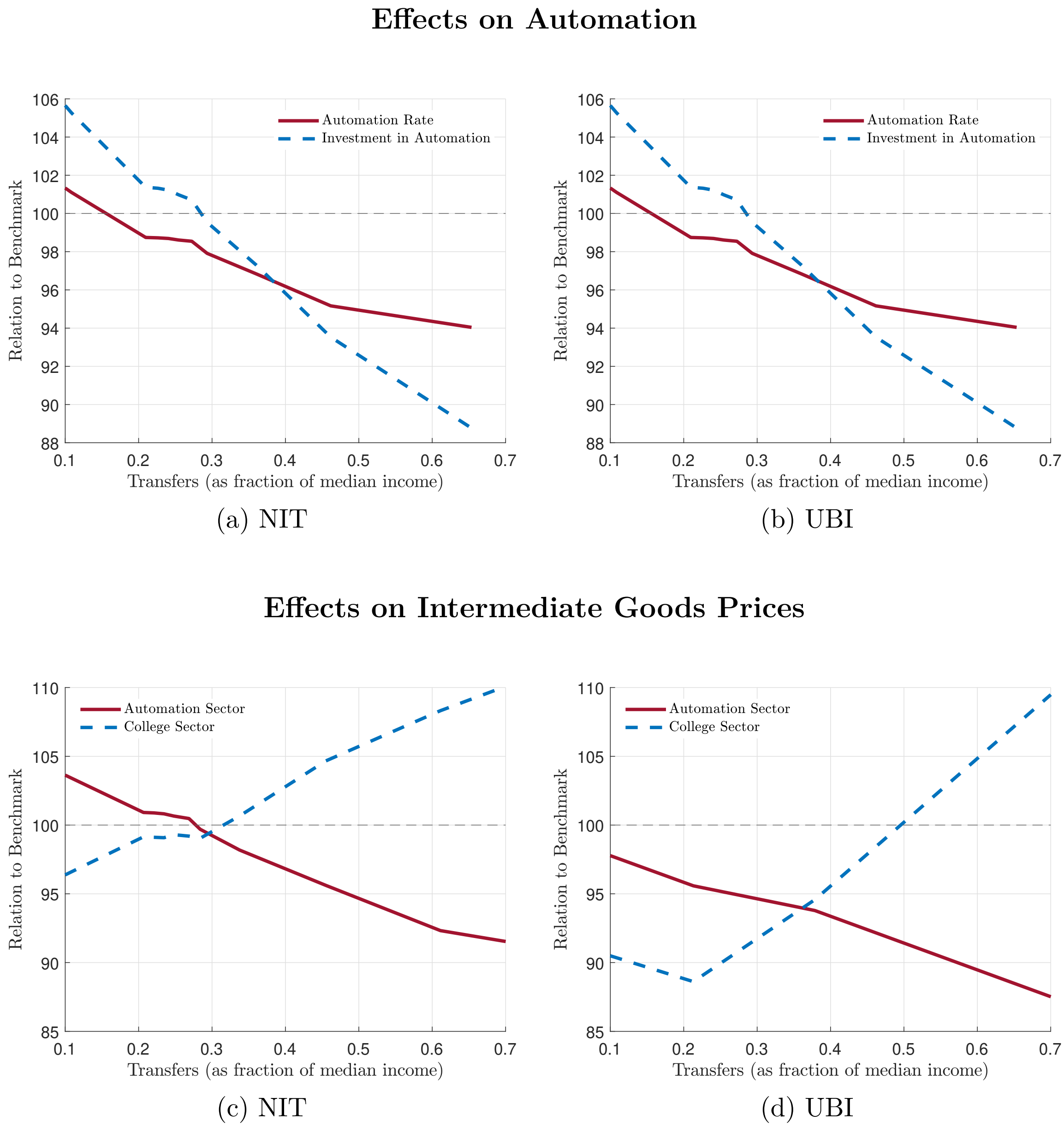
(a) NIT

(b) UBI

Figure 1.5: Effects of a basic income on total labor supply.

(cf. Figure 1.4). In the automation sector, the opposite happens: more workers are entering the automation sector, but they reduce their average working hours. Overall, the reduction in working hours is much stronger than the increase in the participation rate and total labor supply drops by roughly 30% with the highest transfer schemes. Also, comparing Figure 1.5a and Figure 1.5b shows that the effects on the college sector are stronger with a reform towards UBI. Funding a UBI usually requires more revenue than funding an NIT reform and seemingly, this difference in tax rates for the high income earners is large enough to yield considerably stronger effects with a UBI.

Effects on Automation. Seeing how labor supply decreases with higher transfers poses the natural question whether firms will react by increasing their investment in automation. Figure 1.6, however, reveals that automation is also negatively affected by more generous transfer systems. When transfers are below 30% of median income, firms start to invest more in automation, while the investment is discouraged when transfers become higher. This effect is driven by the responses in the labor market which also deeply impact the prices for the intermediate goods (cf. Figure 1.6c and Figure 1.6d). With the fall in the college rate, production in the college sector decreases and consequently, the price for the intermediate good from the college sector increases. Meanwhile, the price for the intermediate good from the automation sector falls, which depresses expected profits from investing in robots. Also, with a more generous basic income unemployed workers face lower effective marginal tax rates since they do not lose all their unemployment benefits



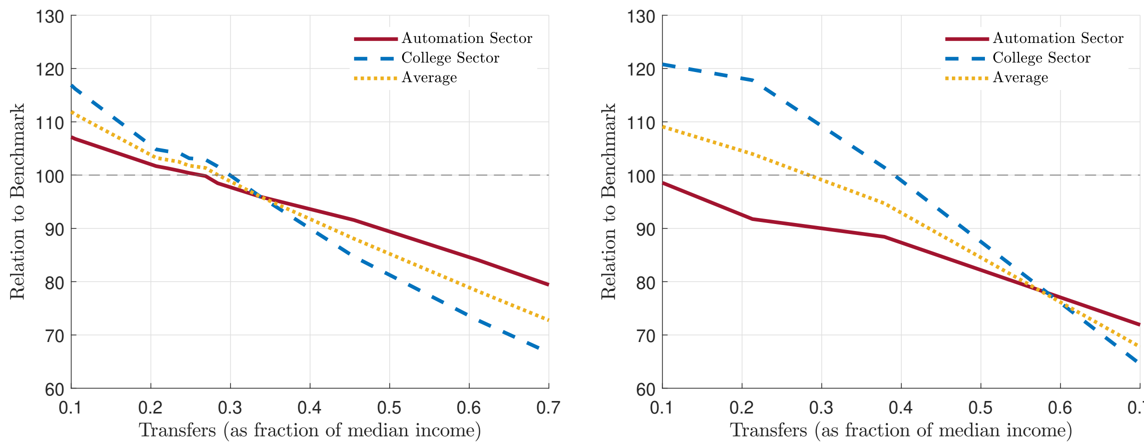
(a) NIT (b) UBI

(c) NIT (d) UBI

Figure 1.6: Effects of a basic income on automation and intermediate goods prices.

when taking up a job. Together with the decline in the college rate, this leads to a sharp increase in participation and search effort in the automation sector. Consequently, firms can expect to fill their vacancies on the labor market more easily, and investment in automation is discouraged while employment increases.

This result reveals two things: First, introducing a basic income does not lead to a surge in unemployment rates due to the displacement of costly labor by cheap robots. The insurance effect of a basic income against automation induced job-loss is far greater



(a) NIT

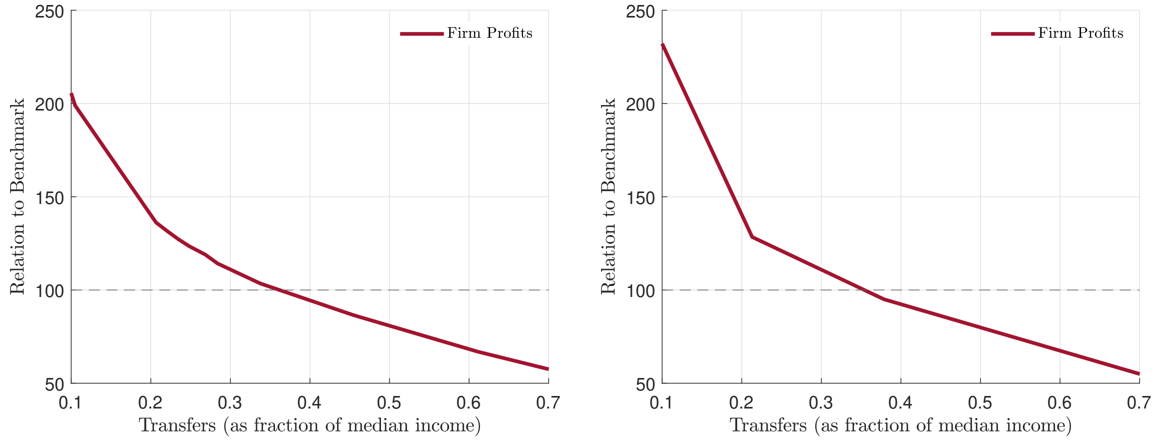
(b) UBI

Figure 1.7: Effects of a basic income on output.

than even proponents of such reforms might have thought. Not only are workers not being displaced by robots, but firms actually decrease their investment in automation and the labor share in the economy rises. Second, the fall in total labor supply is not offset by investment in automation. If low-skill jobs are being automated, overall output might remain unchanged, while low productive workers could enjoy welfare gains from their improved outside option. However, investment in automation follow the same pattern as total labor supply, and overall output in the consumption falls.

This can be seen in Figure 1.7, which plots output in both sectors and the economy as a whole for both the NIT and the UBI reform. We can see that under the NIT regime the college sector reacts more strongly to the generosity of the transfer system, while under the UBI regime both sectors seem to react in the same way. The overall pattern, however, is again only negative. An NIT policy which provides more than 60% of median income as unconditional transfers leads to a fall in overall output by more than 20% relative to the benchmark level. With the UBI reform, the output even falls by more than 30%. With lower transfers, however, the supply of labor increases in both sectors together with investment in automation which leads to higher output. And again, the effect is stronger under the UBI regime.

Capitalists. Lastly, it is also worthwhile to look at the effects the basic income has on capitalists. How does the change in the labor share affect firm profits? Figure 1.8 shows the relationship between average profits before and after the introduction of the basic



(a) NIT (b) UBI

Figure 1.8: Effects of a basic income on firm profits.

income. Once again, we can see a downward pattern with falling profits when the transfer system becomes more generous. However, for transfer schemes which provide less than 40% of median income as unconditional subsistence to everyone, profits are considerably higher than in the benchmark economy. With lower benefits for unemployed, workers accept lower wages and supply more labor (cf. Figure 1.5). Together this leads to higher profits in both sectors and also a higher output. As the basic income gets more generous, in contrast, labor falls while workers demand higher wages. At the same time, the price for the intermediate good in the automation sector falls, which further depresses expected profits. Hence, capitalists stand to lose from more generous reforms an NIT policy which provides unconditional transfers of about 60% of median income leads to a fall in profits by more than 20%. Note that the fall in profits also means less tax revenue for the government from capital gains taxes and consequently, income taxes will rise even more.

1.4.1 Welfare Implications

To understand the welfare effects of a basic income policy, I compute the consumption equivalence value (CEV), which is the factor by which the consumption of a households has to be increased in order to make the household indifferent between the benchmark economy and the new economy after the reform towards a basic income. Specifically, for an individual in state s, the CEV is calculated by

$$V^B((1+CEV)c(s), h(s)) = \tilde{V}(c(s), h(s)) \tag{1.15}$$

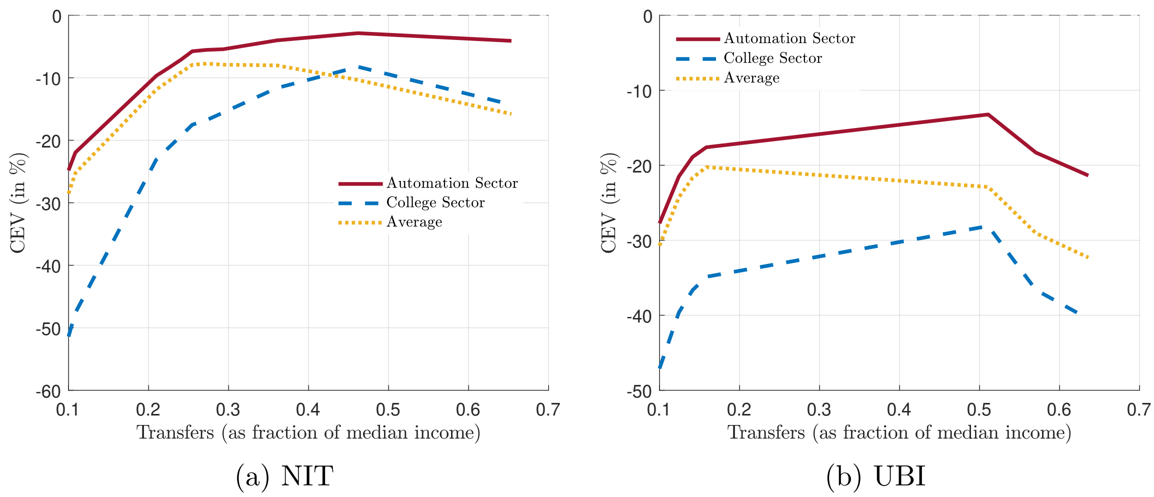


Figure 1.9: Effects of a basic income on worker welfare.

where V^B and $\tilde{V}$ indicate the value functions in the benchmark economy and the counterfactual economy, respectively. Hence, if $CEV > 0$ households prefer the economy with a basic income over the benchmark economy given their state s.

Figure 1.9 shows the expected welfare gains or losses of a newborn, where the comparison is between the benchmark economy and the new stationary equilibrium after the reform. No transition dynamics are considered[13]. Expected welfare is shown for both, an NIT and a UBI reform, and between sectors. The average welfare effect depicted in Figure 1.9 is the expected change in life-time utility of a newborn under the veil of ignorance. The welfare gains or losses within one specific sector refer to the average expected change in life-time utility for newborn workers who will enter one of the two sectors.

Looking first at average welfare, the graph reveals a slight u-shape, showing that very high transfers are nearly as bad for the workers as exceedingly restrictive ones. However, even with the transfer levels which lead to the lowest welfare loss, workers still experience a loss in consumption equivalence of about 9%. The reason for the strong negative effects of a basic income scheme with low transfers seems clear: Relative to the benchmark economy unemployed workers receive far less benefits (especially high productive workers who in the benchmark economy can enjoy a fraction of their past income). This leads to a reduction in expected life-time consumption, even if working hours remain the same. With a more generous basic income scheme, the reason for the negative effects is different.

[13]A discussion of the effects of a reform towards basic income on the periods preceding the new stationary equilibrium follows in section 1.5.

Unemployed workers can now enjoy a fixed amount of high transfers. This particularly favors low productive workers who also reduce their average working hours when finding a job. High productive workers, in contrast, stem most of the tax burden, as their higher income finances the transfers to the rest. Overall, this again leads to lower disposable income, lower consumption, and consequently, lower welfare in the economy.

Looking at the effects on the different sectors reveals similar patterns for all workers. However, workers in the college sector experience higher losses than workers in the automation sector. This is mostly due to the income premium in the college sector. Workers with a college degree earn higher wages than workers in the automation sector on average and therefore finance the unconditional transfers through higher tax payments. At the same time, high income earners often prefer the benchmark economy even when being unemployed, since their benefits are independent of their productivity under the basic income policy, while in the benchmark economy they can enjoy a fraction of their past income. Overall, we can conclude that high productive workers experience large welfare losses which are not counteracted by welfare gains in the automation sector. Under the veil of ignorance, workers would always prefer being born into the benchmark economy, irrespective of the generosity of the unconditional transfers.

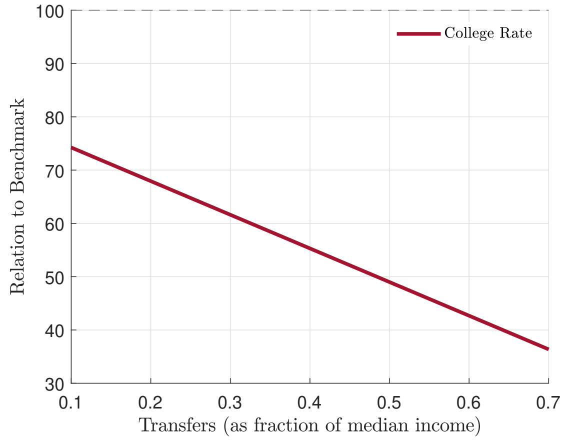
Lastly, comparing the two concepts for a basic income, the NIT policy seems to be strictly better than the UBI policy in terms of worker welfare. While both show the same qualitative pattern, quantitatively they seem to give hugely different results. Workers experience considerably higher welfare losses after the introduction of a UBI than after the introduction of an NIT. With a UBI reform, average expected welfare never drops by less than 20% in terms of CEV, irrespective of the generosity of the transfers. In comparison, the expected welfare loss after the introduction of an NIT is always less than 20% for transfers above 15% of median income. Also, with the NIT the average welfare losses in the automation sector are close to zero for very high transfers, showing that there are likely some workers who even experience welfare gains. With the UBI, in contrast, welfare in the automation sector drops by more than 10% in terms of CEV throughout all transfer levels. At the same time, the introduction of a UBI requires much more additional revenue than an NIT, since transfers are paid to everyone and do not phase out. For example, the introduction of a UBI which provides 60% of median income and keeps the government budget balanced requires an increase in the average income taxation by more than 100%, while average taxation actually falls under the NIT scheme.

1.4.2 Robustness Checks

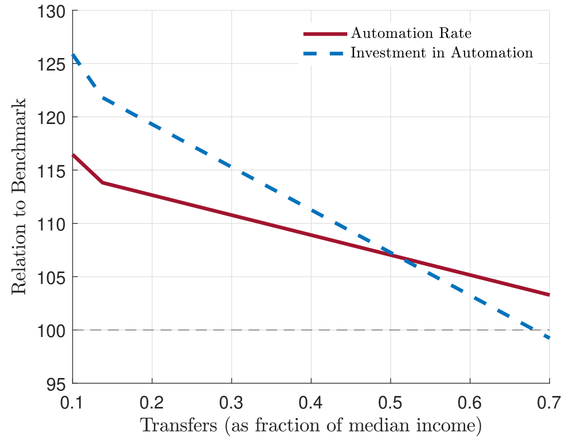
Most of the effects described above crucially hinge on the workers' responses to the various reforms. Hence, this section describes several robustness checks by reporting results for different parameterizations of the workers' per-period utility function:

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} - \phi \frac{h^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}}$$

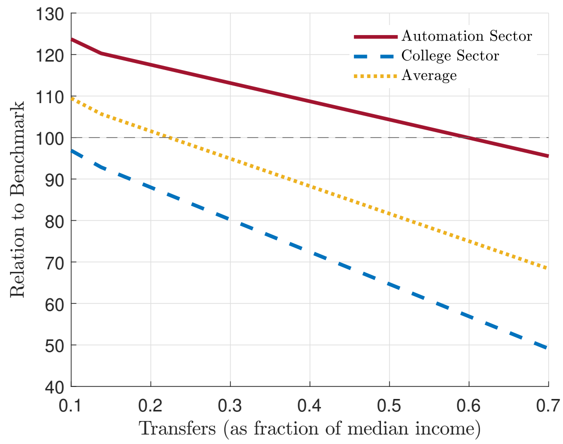
First, in the benchmark economy, the risk aversion parameter for consumption in the CRRA utility function, σ, was chosen to be 2. When changing the functional form of the utility derived from consumption to a log-utility specification, all the results from section 1.4 still hold and remain mostly unchanged. Second, the Frisch elasticity in the benchmark economy was chosen to be 0.7. The results above have shown that this parameterization can lead to strong reactions in the labor market. To see how much of these effects was driven by the parameter γ, Figure 1.10 shows some of the same statistics as discussed in section 1.4, but this time an even lower Frisch elasticity of $\gamma = 0.2$ was used. We can see that the overall patterns remain mostly the same. More generous transfer systems lead to a fall in labor market related variables. However, quantitatively a big difference can be seen in the automation sector. While with a Frisch elasticity of 0.7 investment in automation falls by roughly 10% in relation to the benchmark for higher transfer schemes (cf. Figure 1.6a), with a Frisch elasticity of 0.2 the automation rate lies above its benchmark level throughout most transfer levels. This also leads to a slightly different picture of the drop in output. Output in the automation sector does not decline as much as with the benchmark parameterization, while output in the college sector reacts even stronger. However, effects on welfare are still exclusively negative. Overall, changing the parameterization does not change the qualitative pattern of the results, but only the quantitative interpretation.



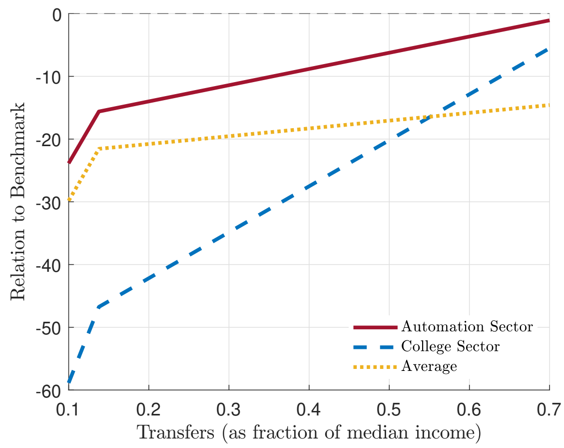
(a) Effects on the college rate



(b) Effects on automation



(c) Effects on Output



(d) Effects on welfare

Figure 1.10: Effects of an NIT reform with lower Frisch elasticity 0.2

1.5 The case for a specific NIT policy

So far, the analysis has focused only on a comparison of stationary equilibria. However, introducing a reform towards a basic income would first lead to a transitional period, in which current cohorts might be affected differently than future generations. This might be especially important when talking about the welfare implications of the new policy. Hence, while the discussion in section 1.4 indicates that the introduction of a basic income policy which is solely financed by adjusting average income taxation does not seem desirable, it is still worthwhile to disentangle the equilibrium effects by analyzing the transition dynamics and to compare the new equilibrium to the benchmark economy in more detail.

This section therefore analyzes the introduction of a specific policy. Seeing how the

NIT scheme seems to be strictly preferable over the UBI proposal in terms of worker welfare (cf. Figure 1.9), a natural starting point is an NIT scheme which at least provides an income of the level of the at-risk-of-poverty threshold which is commonly set around 60% of median disposable income.[14] Consequently, in this exercise I introduce an NIT which provides exactly 60% of median income as unconditional transfers and present a deeper analysis of the effects such a policy would have on the economy.

Before talking about the transitional periods, Table 1.5 provides a detailed overview of the effects of a basic income of 60% of median income by comparing the benchmark equilibrium and the equilibrium after the introduction of the NIT. As already discussed above (cf. Figure 1.7), output in the new stationary equilibrium will be lower than in the benchmark economy and drops by roughly 20%. This decline is driven by three mechanisms: The college rate drops by nearly 40% and this decrease in labor supply in the college sector is not offset by the moderate increase in average working hours. Also, while the participation in the automation sector rises, workers decrease their average working hours by nearly 25% and overall labor supply in the automation sector falls. At the same time, firms do not invest more in automation to counteract this loss in labor supply and consequently, output in both sectors and the economy as a whole decreases. This also results in lower firm profits, which drop by nearly 30%.

One of the arguments of opponents of a basic income relates to unemployment rates. The fear is that an unconditional basic income will significantly decrease the incentive for unemployed to search for a job. Here, we can see that the overall unemployment rate indeed rises to 8.1%, compared to 7% in the benchmark economy. This increase is only driven by the automation sector, where the unemployment rate rises from 7.9% to 9.1%. The college sector, in contrast, sees a decline in unemployment from 5.1% to 4.4%. This difference lies in the difference between average wages. Introducing a basic income improves the outside option of low productive workers who mostly join the automation sector. As a result, the automation sector sees a decline in search effort and average working hours. High-income earners, however, are adversely affected by the basic income since they received a fraction of their past income as unemployment benefits before the introduction of the NIT. Since the highest productive workers mostly join the college sector, we see a rise in search effort and average working hours.

[14]Compare, for example, Eurostat.

Table 1.5: Effects of NIT on macroeconomic outcomes

Variable		Benchmark	NIT
Output		100	79.5
Profits		100	72.5
College Rate		31%	22.6%
Automation		35%	34.4%
Avg. taxation		23%	10%
	Phase-out rate		65%
Intermediate Goods Prices			
	autom. sector	100	92.2
	college sector	100	107.7
Avg Working Hours		100	80.9
	autom. sector	100	76.4
	college sector	100	105.4
Avg. Consumption		100	68.8
	autom. sector	100	77.3
	college sector	100	79.9
Unemployment Rate		7%	8.1%
	autom. sector	7.9%	9.1%
	college sector	5.1%	4.4%
Disposable Income		100	70.4
	autom. sector	100	78.6
	college sector	100	79.9
Gini		0.37	0.3
Welfare change (CEV)			−14%

Looking more closely into college attendance, we see a drop in the college rate from 31% to only 22.6%. As discussed in section 1.4, this is because the incentive to join the college sector is mostly driven by higher job security and a wage premium. However, for lower productive workers the disutility of obtaining a college degree now outweighs the potential gains due to the additional insurance provided by the basic income. At the same time, high-income earners stem most of the tax burden from financing the NIT reform. As a result, human capital in the new stationary equilibrium is lower than in the benchmark equilibrium, which also leads to a decline in the number of high-income earners. Therefore, the revenue required to finance the basic income will be higher ex-post than when calculating the funding requirements in the old equilibrium. This also results in higher tax rates.

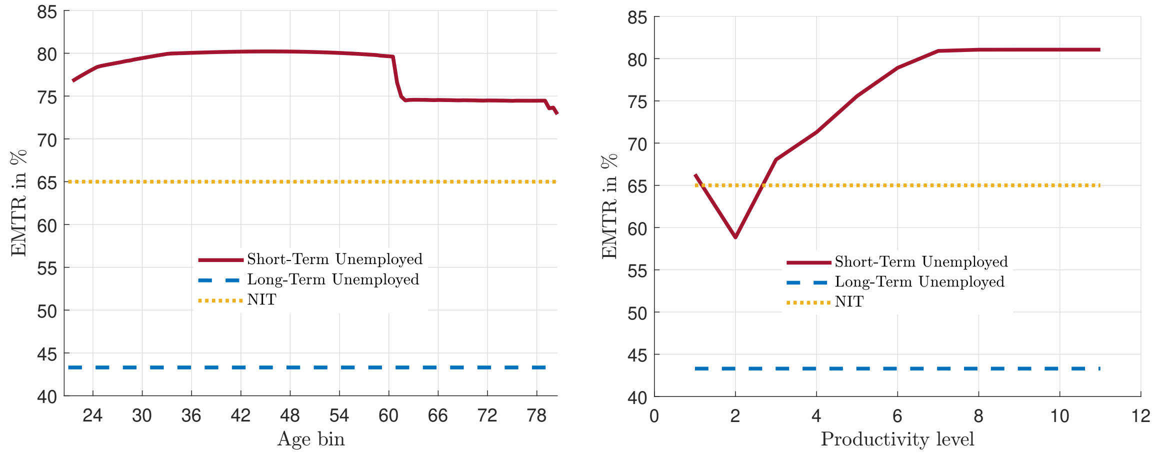
The drop in the college sector and the subsequent decline in output of the intermediate good from the college sector leads to a change in factor prizes. The price for the intermediate good in the automation sector drops by nearly 10%, whereas the price for the intermediate good in the college sector rises by roughly 8%. Consequently, gross wages in the college sector increase, while the wage rates in the automation sector decline. Hence, introducing a basic income leads to a considerable increase in the wage premium for college educated workers. However, average disposable income still falls in both sectors. In the automation sector, workers enjoy more leisure and their foregone earnings from lower wages and lower labor supply outweigh the additional income from the NIT reform. In the college sector, workers actually increase their average working hours, while firms pay higher wages. However, the tax burden for financing the NIT reform is mostly carried by high-income earners and thus, the after-tax income is still lower on average than in the benchmark economy. This also leads to a significant drop in average consumption, which decreases by more than 20% in both sectors.

Furthermore, the introduction of an NIT policy has significant consequences for the taxation scheme in the economy. Average taxation on labor income drops to only 10%, compared to 23% in the benchmark economy. This is due to the high number of workers who now receive transfers from the government instead of paying taxes on their earnings. At the same time, the phase-out rate required to ensure a balanced budget is 65%. Hence, in the new stationary equilibrium all workers face a constant marginal tax rate of 65%, irrespective of their employment status, their income, or other characteristics. This phase-out rate might appear high compared to the discussion by Friedman (1962) who used a rate of 50% for illustrative purposes and claimed that this should be the highest tax rate to be considered. However, a tax rate of 65% is still in line with some of the past experiments on a basic income. The New Jersey Graduated Work Incentive Experiment and the Rural Income-Maintenance Experiment in Iowa and Carolina, for example, both analyzed tax rates up to 70%. Consequently, the NIT reform also greatly impacts the income distribution. The percent of overall income earned by top income earners falls drastically and the Gini coefficient drops from 0.37 in the benchmark economy to 0.3 in the economy with an NIT. Details on the income distribution can be found in Table B1 in appendix B.

Overall, combining the insights from the change in the income distribution with Table 1.5 we seemingly can conclude that the introduction of a basic income via a Negative Income Tax would mostly lead to a redistribution from high income earners to low income earners. However, this redistribution does not lead to welfare gains in the economy and the average expected welfare of a newborn under the veil of ignorance drops by 14% in terms of consumption equivalence.

Effective Marginal Tax Rates. Another important point in the discussions about basic income programs relates to the effective marginal rates faced by unemployed workers. Effective marginal tax rates (EMTR) measure the amount of additional income that the recipient loses due to income taxes and any decline in welfare entitlements. When households are eligible to certain welfare benefits such as unemployment benefits, the effective marginal tax rate might be higher than the marginal tax rate when looking at income taxes only. Households not only lose the part of their additional income that is being taxed, but also lose out on some welfare benefits. This is especially important for unemployed workers who lose all their unemployment benefits when taking up a job. This can lead to very high EMTRs for unemployed workers which might discourage them from exerting considerable effort for finding a job.

Basic income programs are often thought to mitigate this problem, since unemployment benefits do not vanish when people find a job. In the case of the NIT regime discussed above and specified in Equation 1.14, workers face a flat income tax whose marginal tax rate is constant and the same for everyone, irrespective whether workers



(a) EMTR by age group

(b) EMTR by skill group

Figure 1.11: Average effective marginal tax rates in the benchmark economy and under the NIT regime per age group and productivity level. Note: Short-term unemployed and long-term unemployed refer to the situation in the benchmark economy.

are currently unemployed or already high-income earners. However, since the government runs a balanced budget, this resulting flat tax could still be higher than the effective marginal tax rates before the introduction of the NIT, depending on the generosity of the transfers to unemployed. In the case of UBI, the basic income is a lump-sum transfer given to everyone irrespective of income or employment status. In theory, this could lead to a lower marginal tax rate for unemployed since they do not lose any unemployment benefits. However, similarly to the NIT regime, the introduction of a UBI might require additional funding through higher income taxes. Hence, again it is not immediately clear whether the introduction of a UBI would yield a reduction or an increase in the effective marginal tax rates.

Figure 1.11 shows the average effective tax rates for unemployed workers who find a job which pays mean income. Tax rates are compared between the benchmark equilibrium and the new equilibrium with an NIT.[15] Average tax rates in the benchmark economy vary by age and skill group, as well as between short-term and long-term unemployed, while the NIT regime introduces a constant marginal tax rate which is equal among all workers. Figure 1.11 compares the benchmark economy with the constant EMTR faced by workers after the introduction of the NIT which provides 60% of median income as transfers to unemployed. First, we can see that in the benchmark economy short-term

[15]Effective marginal tax rates under a UBI regime are shown in Figure E1 in appendix E.

unemployed face EMTRs up to 80% on average throughout most age bins. This means that the loss of unemployment benefits after finding a job together with the taxes paid on income amount to roughly 80% of the additional income earned. Long-term unemployed, in contrast, mostly face EMTRs slightly below 45%. This difference stems from the different treatment of short-term unemployed and long-term unemployed. While short-term unemployed receive benefits which partially depend on their past productivity, long-term unemployed only receive a fixed subsistence level. This leads to a situation in which short-term unemployed still receive a sizable fraction of their past income as benefits and losing those benefits hurts them relatively more than losing the low subsistence benefits when transitioning to long-term unemployment. Under the NIT regime, however, this difference disappears, and everyone faces the same marginal rate of 65%, which is both, the phase-out rate of the transfers and the tax rate for high-income earners. Hence, introducing the NIT policy can significantly reduce the EMTR faced by short-term unemployed, while slightly raising the EMTR faced by long-term unemployed. However, since the benefits for long-term unemployed in the benchmark economy are very low, the incentive to find a job is already very high and is not deeply affected by the change in EMTRs after the introduction of the NIT. Also, note that the dip in EMTRs after the age of 60 is due to the drop in the experience premium for older age groups which reduces expected profits by firms and therefore also wages.

Lastly, Figure 1.11b shows the average EMTRs faced within different skill groups. Similarly to above, the EMTR faced by short-term unemployed in the benchmark economy is always higher than the EMTRs under the NIT regime. Also, note that EMTRs are increasing with higher skill groups. This is because that benefits for short-term unemployed are partially based on their past productivity. Hence, higher skill groups receive higher benefits which increases their effective tax rates when taking up a job. Again, the EMTRs faced by long-term unemployed lie below the tax rates after the NIT reform. Since benefits for long-term unemployed do not depend on either age or productivity, they are constant for all workers.

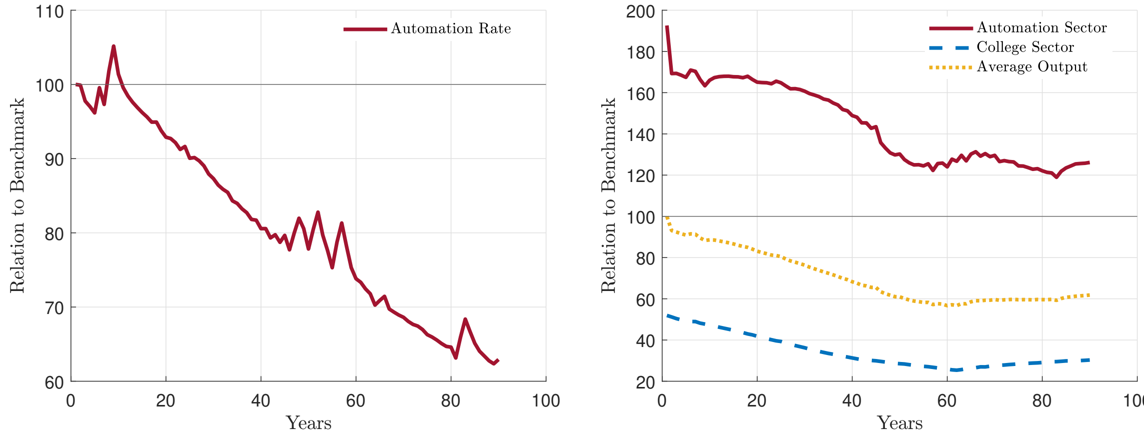
1.5.1 Transition Dynamics

This section therefore describes the dynamics which occur during the transition from the benchmark equilibrium to the new equilibrium, when introducing the specific NIT reform as discussed in section 1.5 above.[16] First, Figure 1.12 shows how the investment in automation and total output are affected during the transitional periods. Looking at Figure 1.12a we can see how firms initially react by increasing their investment in the adoption of robots until it lies roughly 8% above the benchmark level. Then, investment slows down, gradually falls below the benchmark level and continues to fall for the next years. Turning to Figure 1.12b reveals that this change in automation does not immediately result in a change in output. While output of the intermediate good in the automation sector is also falling during the transition to the new equilibrium, production lies above the benchmark for more than one generation (60 years). In contrast, output in the college sector falls drastically and remains at roughly 40% of the benchmark level. This considerable drop in production in the college sector stems from the reduced labor supply in this sector as the amount of workers with a college degree drops.

As mentioned above, introducing a new social welfare system would first lead to a transitional period, during which the economy transitions from the old benchmark equilibrium to the new stationary equilibrium. This transitional period can take several years or even decades and hence, when discussing the effects of a reform towards a basic income, analyzing these transition dynamics might be even more important than simply looking at a comparison of stationary equilibria, particularly when talking about the consequences for workers' welfare. Current cohorts will be affected by the reform in a very different way than future generations.

This considerable decline in the college rate is depicted in Figure 1.13c. After the introduction of the NIT reform, new cohorts are discouraged from obtaining a college degree and the college rate drops by more than 60% over the span of one generation. Thereafter, the fraction of workers with a college degree slowly starts to rise again due to the increase in the college premium with the concurring fall of disposable income in the automation sector. As the economy transitions to the new equilibrium, the fall in output and profits in the automation sector make obtaining a college degree more attractive.

[16]For details on the computational method see appendix D.

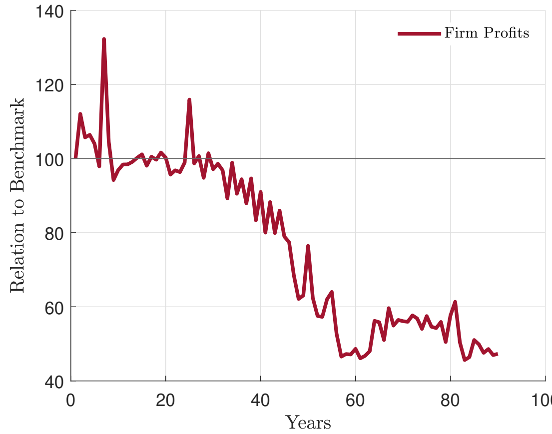


(a) Investment in Automation (b) Evolution of Output

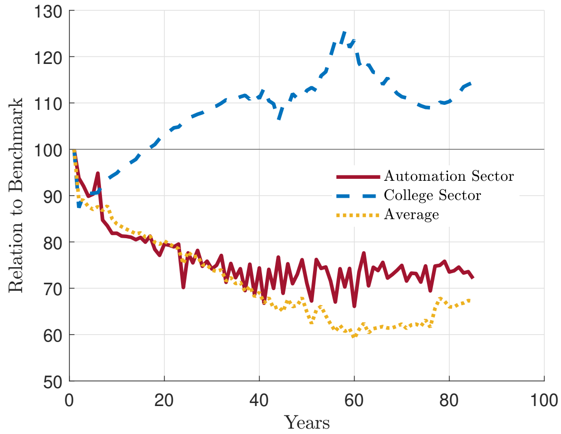
Figure 1.12: Transition Dynamics of Investment in Automation and Output.

Regarding labor force participation, Figure 1.13d reveals that unemployment rates rise throughout all sectors. While the college sector is only moderately affected, the automation sector reacts strongly to the transition dynamics and the unemployment rate rises by up to 300%. This difference results from the endogenous selection of workers into one of the two sectors. Workers who obtain a college degree do so because they can expect higher wages and higher consumption on average. Consequently, workers who enter the college sector are actively searching for a job in order to be able to enjoy these expected gains. Workers entering the automation sector, in contrast, do not necessarily prefer working in this sector over the college sector. Some of them, particularly the workers with the lowest productivity, simply enjoy the better insurance provided by the basic income. As a result, some of the workers in the automation sector reduce their search effort and unemployment rises. The same is true for average working hours. Figure 1.13f reveals a similar pattern to Figure 1.4 in section 1.4. Workers in the college sector increase their hourly labor supply, while average working hours in the automation sector drop drastically. Overall, in the automation sector a smaller fraction of workers is getting a job and those who do are spending less time at work.

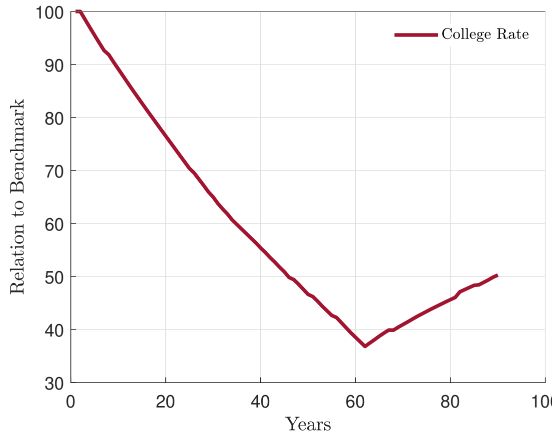
Concerning wage rates, Figure 1.13b shows the average wage rates paid in both sectors and on average in the whole economy. Seemingly, the introduction of the NIT reform positively affects the college sector, while workers in the automation sector lose. The fall in overall labor supply and production in the college sector leads to an increase in the price for the intermediate good from this sector and as a result, firms pay higher wages.



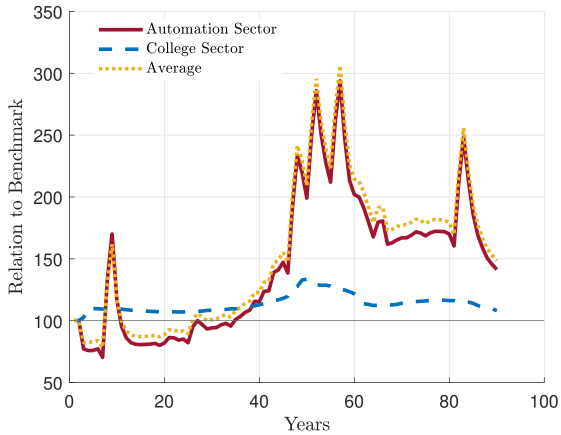
(a) Change in Profits



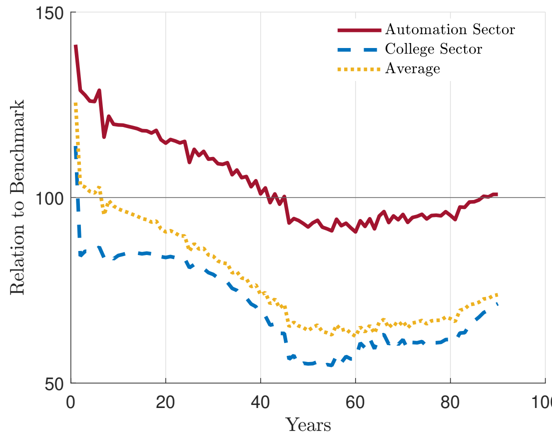
(b) Average Wage Rate



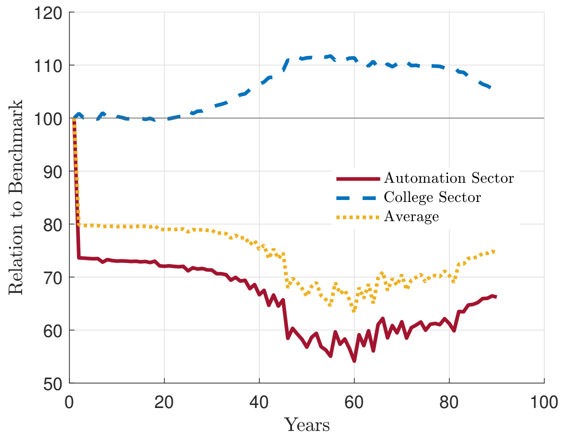
(c) Change in College Attendance



(d) Change in Unemployment Rates



(e) Mean Disposable Income



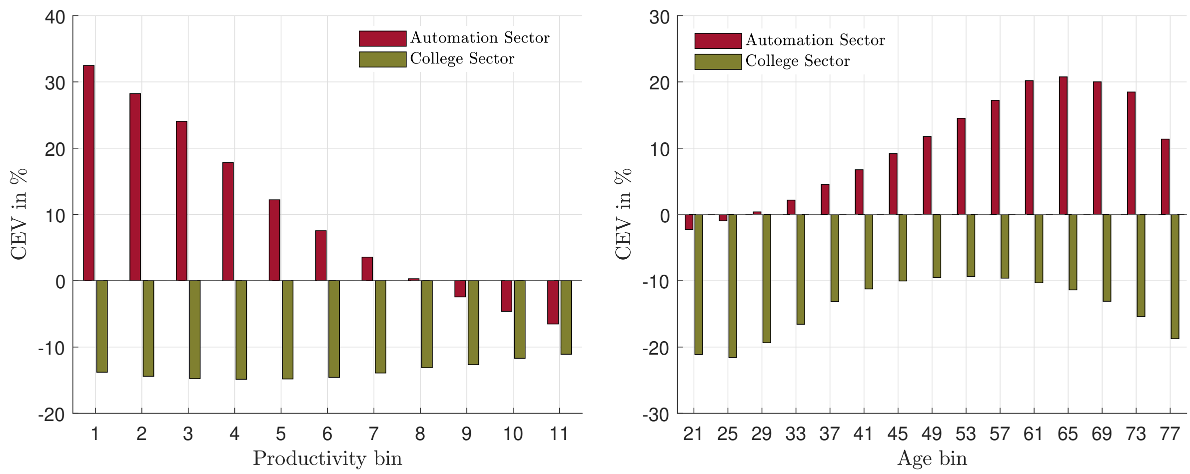
(f) Average Working Hours

Figure 1.13: Transition Dynamics in the labor market.

In the automation sector, in contrast, more workers are joining the labor force and the price for the intermediate good falls. Both effects depress the wage rates paid to workers in the automation sector. Also, we can see how wages in the college sector start to decline again after one generation when the college rate starts to rise, and the college sector sees an increase in labor force participation.

The change in wages, however, does not directly translate into a change in disposable income, as shown in Figure 1.13e. As with most other variables, we see a downward pattern as after-tax income declines in the years following the introduction of a basic income. Interestingly, despite the increase in average wages in the college sector, workers with a college degree are affected more deeply than workers in the automation sector. In the first four decades after the NIT reform, average disposable income in the automation sector even lies above the benchmark level, even though average wages have decreased. Afterwards, we see a slight drop below the benchmark level before average disposable income starts rising again. This has several reasons: Workers in the automation sector are on average less productive than workers in the college sector and face lower wage rates. As a result, the NIT reform provides an additional source of income and in the first couple of years after the introduction of the NIT, workers are better off on average. Thereafter, however, the economy transitions towards the new stationary equilibrium and output and wages start to fall. Consequently, disposable income also falls, until it reaches a level below the benchmark equilibrium. Now, workers start to increase both, their search effort, and their hourly labor supply, which leads to a rise in average disposable income. Also, after one generation, more workers start to obtain a college degree, which has positive effects on the wage rate in the automation sector. The college sector, in comparison, is adversely affected throughout all transitional periods. The phase-out rate of 65% leads to a high average tax burden for high-income earners and even though wages and average working hours are increasing, after-tax income still falls.

Lastly, Figure 1.13a depicts the evolution of firm profits during the transition to the new equilibrium. We can see how despite the increase in output in the automation sector, the profit of firms decreases. This is due to two reasons: First, the price of the intermediate good in the automation sector falls. This depresses average profits per job. Second, output in the college sector falls drastically and even though this leads to an increase in the price for the intermediate good from this sector, the higher wages demanded by workers offset



(a) Welfare Effects per Skill Group (b) Welfare Effects per Age Group

Figure 1.14: Change in expected life-time utility of current generation when introducing the NIT policy next period.

any additional profits. Overall, output and profits in the economy decrease.

Welfare Comparison. As mentioned above, considering the transition dynamics can have different consequences for the evaluation of welfare than simply comparing stationary equilibria. Figures 1.12 and 1.13 show that the transition to the new equilibrium will take almost two generations. Consequently, current cohorts will experience vastly different welfare effects than future generations who are immediately born into the new stationary equilibrium. Thus, Figure 1.14 reports the welfare gains and losses of cohorts who are born before the introduction of the NIT. The reported values for the consumption equivalence are calculated by comparing the life-time utility of remaining in the benchmark equilibrium to experiencing the transitional periods towards the new equilibrium[17]. The CEV is calculated as describe in subsection 1.4.1.

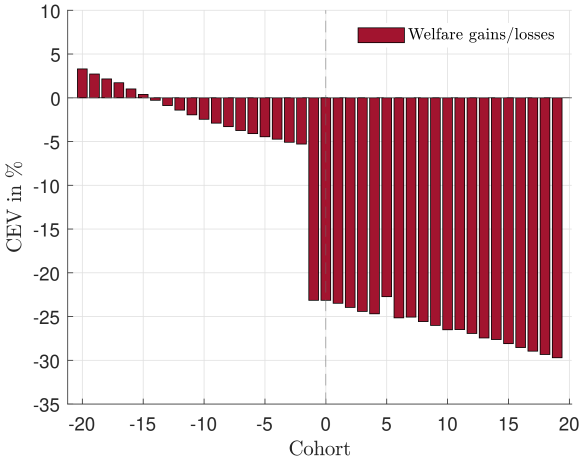
Turning first to Figure 1.14a reveals the different effects the introduction of the NIT reform has on workers of different productivity levels and between sectors. A considerable fraction of workers in the automation sector experience large welfare gains (up to 33% for the least productive workers) and only the workers with the highest productivity are adversely affected (with welfare losses up to −8%). The increase in average disposable income during the first couple of years after the introduction of the reform benefits low

[17]This means that this comparison is not simply between expected welfare in the old economy and the new economy. The transition dynamics which current cohorts would experience upon the introduction of the new policy are taken into account.

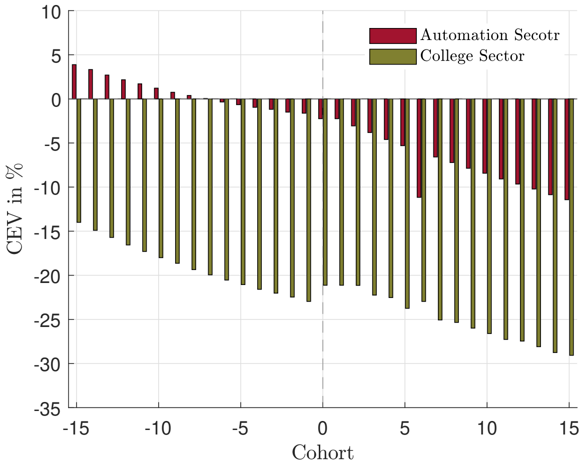
productive workers in the automation sector. The subsequent decline in the capital stock and aggregate output during the transition to new equilibrium is slow enough not to erode these expected welfare gains. Workers in the college sector, in contrast, experience welfare losses throughout all skill groups. Already during the first periods after the introduction of the reform, the disposable income in the college sector falls and the negative effects are only getting stronger in the periods thereafter.

Next, Figure 1.14b again shows the change in welfare for current cohorts, but this time reported for different age groups in both sectors. Again, the reform is clearly worse for workers who enter the college sector. Although there seems to be an upward trend with older workers being less adversely affected, they still experience welfare losses throughout all age groups. Even the oldest people, who are already at the end of their working life, would prefer staying in the benchmark economy. In the automation sector, in contrast, nearly all workers from the current generation can expect welfare gains when averaged by age group. Similarly to the college sector, older workers are better off than younger workers. The highest welfare gains can be expected by workers who enter the later phase of their working life around the age of 65. At this age, their age-efficiency profile starts to decline in order to mimic retirement and the additional insurance provided by the NIT leads to an expected welfare gain of up to 21% in terms of CEV. These accentuated positive welfare effects are mainly driven by the fact that firms can invest in robots. Since aging workers become less productive, firms might be inclined to automate their tasks. Hence, older people face poorer contracts. The introduction of the NIT can now provide additional insurance against this rationalization.

Together these figures suggest that the introduction of the NIT would mainly yield redistributional effects from the college sector towards the automation sector and an overall assessment of welfare is mainly driven by the weights given to both groups. However, when looking purely at a potential voting outcome where every worker is assigned one vote in favor or against the reform based on whether they can expect welfare gains or welfare losses, the higher number of workers in the automation sector would be able to overrule the objections from workers in the college sector. Overall, in this experiment a majority of 56% of workers would vote in favor of the reform.



(a) Average welfare effects



(b) Welfare effects per sector

Figure 1.15: Welfare Effects of NIT on different cohorts. Period 0 refers to introduction of NIT.

Effects on different cohorts. Lastly, the transition dynamics also reveal huge differences in the effects a reform towards an NIT would have on cohorts who are born before and after the introduction of the new policy. Figure 1.15a plots the average expected life-time welfare of a newborn under the veil of ignorance for several periods before and after the introduction of the NIT. First, for cohorts who are born before the introduction of the NIT, older people can expect welfare gains, while younger households suffer welfare losses, which is consistent with the finding in Figure 1.14b. Cohorts who are born during or after the introduction of the NIT reform, in contrast, experience huge welfare losses. Seemingly, even though the transitional periods can be beneficial for some workers who are already alive before the reform, cohorts who are born thereafter all lose and would prefer being born into the benchmark economy. Hence, future generations are not only worse off after the new equilibrium has been reached, but face welfare losses starting from the very first period after the introduction of the NIT.

Turning to Figure 1.15b again reveals that the welfare effects differ greatly between sectors. Workers in the automation sector can benefit from the reform when being born more than eight years prior to the introduction of the NIT policy, while workers entering the college sector experience substantial welfare losses throughout all cohorts. Still, the effects on welfare show a clear downward trend for both sectors and after the introduction of the reform, workers in the automation would prefer being born into benchmark economy as well. Apparently, workers in the automation sector who are already alive during the

Table 1.6: Optimal Tax and Transfer System

	Parameter	Value
Consumption Tax	τ_c	30%
Capital Income Tax	τ_a	−10%
Labor Income Tax[1]	τ	10%
Unconditional Transfers[2]	Tr	15%
Welfare gains[3]	CEV	+19%

[1] Note: The income tax rate is also the phase-out rate of transfers.
[2] Transfers are measured as percent of median income.
[3] Welfare is measured in relation to the benchmark economy.

introduction of the NIT policy, profit from the decisions made by workers who entered the college sector. After the introduction of the NIT, however, workers can take the new tax system into account and are discouraged from obtaining a college degree. This lowers the welfare gains in the automation sector, which are mostly financed by the high-income earners in the college sector, and consequently, cohorts who are born after the introduction of the NIT are worse off than in the benchmark economy.

Note that as we converge to the new equilibrium, the average welfare of future generations does not become positive. In the new stationary equilibrium with the NIT, average welfare of a newborn under the veil of ignorance drops by 13.5% in terms of CEV. Hence, while current generations would vote in favor of the NIT, since the welfare gains in the automation sector outweigh the losses in the college sector, future generations are worse off and would prefer being born in the benchmark equilibrium.

1.6 Optimal Tax and Transfer System

So far, all the experiments have assumed the tax system to stay the same and only the tax on income was shifted upwards to finance the additional transfers. However, a more comprehensive policy analysis should consider possible changes in other tax rates as well. Hence, in this section I also vary the tax on consumption, τ_c, and the tax on profits, τ_a, to

Table 1.7: Comparing model outcomes from optimal NIT to benchmark

	Benchmark	**Optimal NIT**
College Share	31%	52.8%
Automation Rate	35%	74.5%
Average Taxation	23%	−10%
Output	100	217
Unemployment Rate	7%	3.8%
autom. sector	9.1%	3.8%
college sector	5.1%	3.8%
Mean Net Income	100	173
autom. sector	100	115
college sector	100	144
Average Consumption	100	143
autom. sector	100	94
college sector	100	119

try and find the optimal tax and transfer system with regards to the expected welfare of a newborn under the veil of ignorance. Again, welfare is calculated in terms of consumption equivalence.

Considering the results discussed in appendix of subsection E, the introduction of an NIT seems to be preferable over the introduction of a UBI in terms of CEV for any given level of unconditional transfers. Thus, in this exercise I vary the tax on consumption and the tax on profits and introduce an NIT of varying generosity to find the optimal combination of $\{\tau_c, \tau_a, Tr\}$. Note that the flat income tax, which is also the phase-out rate of the transfers (cf. Equation 1.14), is not a variable of choice, since it has to be adjusted to keep the government budget balanced under the given tax and transfer regime. The result of this exercise is shown in Table 1.6.

First, we can see how changing the whole tax and transfer system can lead to an improvement of average expected welfare by nearly 20% in relation to the benchmark economy. Next, while the optimal tax on labor income is very low with only 10%, the tax on consumption vastly exceeds the benchmark value with 30% against only 0.075%, respectively. Also, the unconditional transfer to unemployed only amounts to 15% of median income, while profits of firms are actually being subsidized by a negative tax on capital income. Overall, this tax and transfer system vastly reduces tax rates on production, while putting a higher burden on unemployed and consumption. Seemingly, the average worker prefers the additional income when employed by a firm over better insurance provided by higher taxes and higher transfers.

Table 1.7 compares the equilibrium outcome of some macroeconomic variables from the optimal tax and transfer system to the benchmark equilibrium. We can see how the subsidy on profits leads to a surge in automation, while more people are obtaining a college degree. Consequently, output in both sectors rises and the production of the final good increases by more than 100%. At the same time, lower taxes and the slow phase-out rate of transfers leads to a considerable increase in average disposable income which rises by 73% compared to the benchmark economy. This also leads to an increase in average consumption by roughly 43%. However, this is mostly driven by the higher consumption in the college sector and the fact that more people are now obtaining a college degree. Workers in the automation sector, however, experience a slight decrease in average consumption of about 6%. Lastly, since an NIT introduces transfers for employed workers, the average taxation in the economy is negative, with the average employed worker receiving transfers in the amount of 10% of their income. Hence, with capital income also being subsidized the government budget is nearly exclusively financed by the tax on consumption.

Overall, looking at tables 1.6 and 1.7 reveals that in this model setup the optimal tax and transfer system is simply a subsidy to capital and labor income, which increases labor supply in both sectors - unemployment drops to 3.8% in both markets -, while also encouraging further investment in automation. Both effects drastically increase production and on average workers can expect welfare gains. However, note that this tax regime harshly punishes unemployed workers who only receive 15% of median income as subsistence level, which lies way below every common indicator for poverty. Hence, workers who face involuntary unemployment are punished harshly in comparison to the benchmark economy.

1.7 Conclusion

This paper develops a quantitative framework to study the effects of different basic income policies when there exist segregated labor markets which differ in the possibility of automation induced job-loss. I use this framework to analyze the adoption of two popular basic income policies with varying degree of generosity which are financed solely by adjusting income taxation. The analysis reveals that the effects on automation are highly dependent on the transfer level and that including search frictions in the labor market matters greatly for the outcome. A basic income with very low transfer levels increases the costs of unemployment and therefore increases search effort and labor supply of workers. At the same time, workers are encouraged to obtain a college degree to insure themselves against automation induced job-loss. The increased production in both sectors also raises expected profits in the automation sector and thus automation. With higher transfers, in contrast, the opposite happens. With the fall in the college rate, production in the college sector decreases and consequently, the price for the intermediate good from the college sector increases. Meanwhile, the price for the intermediate good from the automation sector falls which depresses expected profits from investing in robots. At the same time, unemployed workers face lower effective marginal tax rates since they do not lose all their unemployment benefits when taking up a job. Both effects lead to a sharp increase in participation and search effort in the automation sector. Consequently, firms can expect higher profits in the labor market and investment in automation is discouraged even further while employment increases.

To look at the impact of a basic income policy on current generations and on the effects during the transition to the new equilibrium, I analyze a specific NIT program which provides 60% of median income as unconditional transfers to everyone. This refers to a common poverty threshold and is often mentioned among proponents of such a reform. The results of this exercise show that such a policy has mainly adverse effects on macroeconomic outcomes. Output, consumption, and college attendance fall, while unemployment rates rise. Concerning welfare, the effects are slightly ambiguous. Since the basic income is mostly financed through income taxes, the introduction of a basic income leads to a redistribution from high income earners to low income earners. Wages in the college sector are higher than in the automation sector and hence, the introduction of the

NIT mostly redistributes income from the college sector to the automation sector. During the transitional periods towards the new equilibrium, current cohorts in the automation sector can expect welfare gains. In particular, low productive workers benefit from the basic income, as they receive additional transfers without being hurt by the higher tax rates needed to fund the basic income. Overall, a majority of the current generation would vote in favor of the reform. Comparing the stationary equilibria under the veil of ignorance, in contrast, reveals that most workers would prefer being born into the benchmark economy without a basic income. Also, in the new equilibrium, college rates, output and average consumption are lower.

The results of these exercises seem to be robust with respect to the specific regime with which an unconditional transfer is provided. For example, introducing a UBI which provides the same subsistence level of 60% of median income to unemployed households leads to the same qualitative result as the introduction of the NIT. Quantitatively, however, the effects are far more pronounced. Since the transfers are paid in a lump-sum fashion to everyone, the overall tax burden is much higher than under the NIT regime. Hence, while leading to similar results, an NIT requires a far smaller budget. The natural next step is therefore to analyze whether an NIT together with a completely new tax regime could lead to welfare gains in relation to the benchmark equilibrium. I find that within this model setup a subsidy to capital income together with a high tax on consumption and a low phase-out rate of transfers which leads to a negative average tax burden on income can lead to higher expected welfare of workers in terms of CEV. However, the subsistence level of income provided for unemployed workers is way below common poverty thresholds.

Overall, the analysis in this paper suggests that unconditional transfers can have counterintuitive implications for automation decisions, and while the introduction of both, UBI and NIT, leads to comparable results, the latter requires only a fraction of the budget of a UBI and can actually lead to welfare gains together with a subsidy on profits and labor income.

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Appendices

A Experience Premium

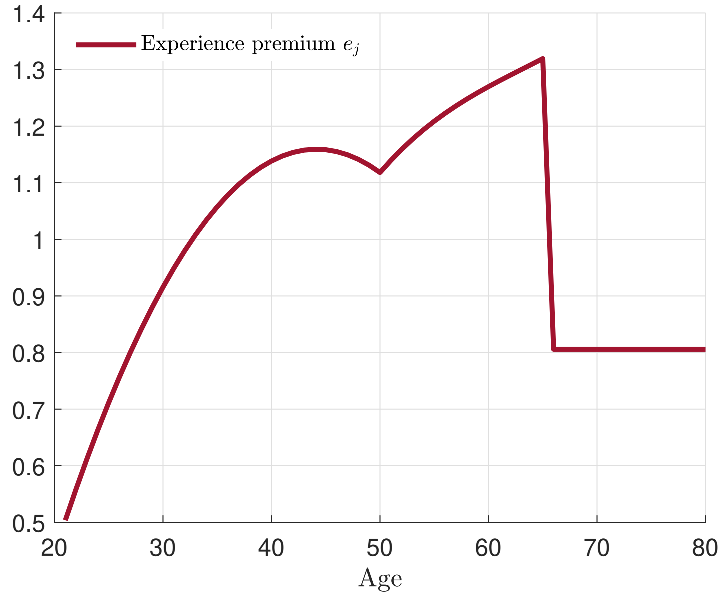


Figure A1: Experience premium to wages

B Effects of NIT on Income Distribution

Table B1: Earnings Distribution

Quintile	**Benchmark**	**NIT**[1]
Bottom 20%	6.1%	8.4%
20% to 40%	12.0%	15.1%
40% to 60%	14.6%	16.9%
60% to 80%	23.5%	18.7%
Top 20%	43.9%	40.9%
Gini	0.37	0.3

[1] NIT refers to the policy which pays exactly 60% of median income as described in section 1.5.

C Computational Solution Method

The model is solved numerically in MATLAB R2021b by using value function iteration on the discretized state space given by $S = Z \times Z \times m \times J \times u$. Where Z is the set of possible productivity levels, m the set of markets ($\{1, 2\}$), J the maximum lifespan and u the possible employment status ($\{0, 1, 2\}$). The stochastic process for productivity level z is discretized into 11 states by using Rouwenhorst's method as described in Kopecky and Suen (2010).

Algorithm to compute competitive equilibrium[18]

I. Make guess on initial values for prices, p_1 and p_2, the costs of posting vacancies, κ_1^v and κ_2^v and the average wage rates, $\bar{w}_1$ and $\bar{w}_2$.

II. Solve model using the guess from I.

III. Given the solution for the value functions of employed and unemployed, W and U, and the optimal decision rules compute the invariant distribution over states $\Phi(z, z_{-1}, m, j, u)$.

IV. Update $(p_1, p_2, \kappa_1^v, \kappa_2^v, \bar{w}_1, \bar{w}_2)$

1. Calculate the implied parameters using the solution from II.
2. Compare implied values to initial guess. If difference is larger than 10^{-9}, update $(p_1, p_2, \kappa_1^v, \kappa_2^v, \bar{w}_1, \bar{w}_2)$ with appropriate root finding procedure (for this paper, Broyden's method has been used) and go to II.
   Else, end.

Model calibration: In order to fit the model to the data, the following objective function is minimized:

$$S(\mathcal{P}) = \left(\sum_i \omega_i (M_i(\mathcal{P}) - D_i)^2 \right)^{1/2} \tag{1.16}$$

[18]Note that this algorithm refers to the competitive equilibrium of the benchmark economy. After the introduction of the NIT or UBI policy, this algorithm changes slightly: Instead of varying the costs of posting a vacancy, those costs are assumed to be the same as in the benchmark equilibrium, while the market tightness adjusts until posting a vacancy again yields an expected value of 0. Also, since there are no unemployment benefits after the reform, we do not need equilibrium values for the average wage rates. However, under the new regime the average tax becomes a new equilibrium parameter as it is adjusted to yield a balanced government budget.

where D_i are the data moments sought to be matched and $M_i(\mathcal{P})$ are the moments calculated from the model for a given set of structural parameters $\mathcal{P}$. The parameters to be jointly determined are $\mathcal{P} = \{\kappa_a, \phi, \delta_c, \lambda_0\}$ and deviations are weighted equally (i.e. $\forall i : \omega_i = 1$)

D Computing Transition Dynamics

To compute the dynamics which occur during the convergence to the new equilibrium after the introduction of a new policy, I need the transition paths for the prices, p_1 and p_2, the market tightness, θ_1 and θ_2, and the income tax rate which keeps the government budget balance, λ_0.[19] That is, I need to solve for the values of $\{p_{1,t}, p_{2,t}, \theta_{1,t}, \theta_{2,t}, \lambda_{0,t}\}_{t=1}^{T}$, which satisfy the conditions for the new competitive equilibrium in every period t, given the optimal decision rules in this period. To solve for these parameters, the following algorithm has been used:

Algorithm to compute transitional Dynamics:

I. Compute decision rules and distribution over states for the old equilibrium and the new equilibrium and save the outcome.

II. Decide on a number of transitional periods T and make a guess on initial values for $\{p_{1,t}, p_{2,t}, \theta_{1,t}, \theta_{2,t}, \lambda_{0,t}\}_{t=1}^{T}$, which is a matrix of dimension $5 \times T$.

III. Given the guess for $\{p_{1,t}, p_{2,t}, \theta_{1,t}, \theta_{2,t}, \lambda_{0,t}\}_{t=1}^{T}$ recursively compute decision rules for all periods $t \in \{1, .., T\}$ given the next periods value functions (starting from the value function from the new equilibrium obtained in I).

IV. Given the decision rules obtained in III, start from the distribution over states in the old equilibrium obtained in I to compute distributions over states during all the transitional periods

V. Update $\{p_{1,t}, p_{2,t}, \theta_{1,t}, \theta_{2,t}, \lambda_{0,t}\}_{t=1}^{T}$

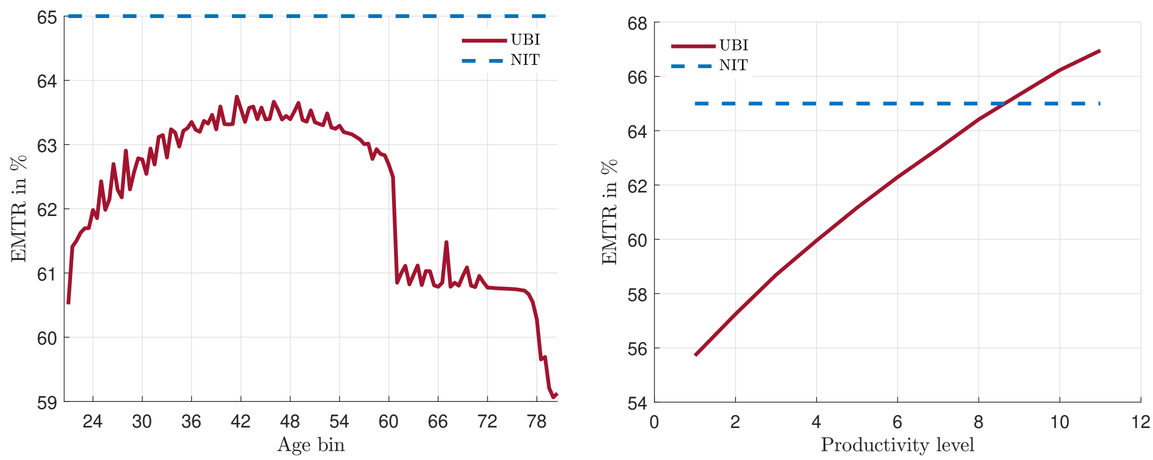
[19] Note that this parameter has different implications depending on whether UBI or NIT is introduced. Under the UBI regime, the income tax is still progressive and λ_0 only adjusts the average taxation. Under the NIT, regime λ_0 determines the flat income tax, which is also the face-out rate of the transfers.

1. Calculate the implied parameters during every transitional period using the solutions from III and IV.
2. Compare implied values to initial guess. If difference is larger than 10^{-9}, update the parameters with appropriate root finding procedure (for this paper, Broyden's method has been used) and go to III.
   Else, end.

E Marginal Tax Rates with UBI

To compare the effects of UBI on the effective marginal tax rates (EMTR) faced by unemployed workers to the effects of an NIT as described in section 1.5, I introduce a UBI which yields 60% of median income as unconditional transfers to everyone. This yields the same amount of transfers to unemployed as the NIT reform in section 1.5. Figure E1 shows the average effective tax rates for unemployed workers who find a job which pays mean income.

Since transfers in a UBI regime do not face out when people start to work, the EMTRs faced by unemployed are nearly always lower with UBI than with the NIT reform (cf. Figure E1a). Only when looking at workers within the highest productivity groups do we see that EMTRs under the UBI reform exceed those after the NIT reform. The reason for this is the vast difference in revenue needed for funding the reform. While the NIT



(a) EMTR by age group

(b) EMTR by skill group

Figure E1: Effective marginal tax rates with a UBI policy and NIT.

actually leads to a reduction in average tax rates on income, introducing a UBI requires a considerable increase in average taxes, since the transfers are paid in lump-sum fashion to everyone (indeed, the average taxation rises to 62% compared to 23% in the benchmark economy). And since the taxation is progressive under the UBI regime, higher incomes are taxed more heavily. This leads to an upward trend of EMTRs by skill group, whereas in the benchmark economy EMTRs are falling with productivity (cf. Figure 1.11b). Hence, introducing a UBI increases the incentive for low-skilled workers to find a job, while decreasing the incentive for high-skilled workers. This effect might undesirable and does not occur with the NIT regime, since EMTRs with an NIT are constant for everyone.

Chapter 2

Naïve Consumers and Financial Mistakes

(with Florian Exler)

Financial contracts are complicated and consumers often do not grasp them in their entirety. This may lead to financial mistakes. We develop a quantitative theory of unsecured credit and equilibrium default where borrowers can sign debt contracts that trade off interest rates for penalty fees. These fees make unforeseen financial shocks—such as paying late or borrowing over limit—costly. The economy is populated with sophisticated and naïve borrowers. Naïves face higher financial uncertainty without internalizing this fact. They make financial mistakes as they choose inefficiently high penalty fees. In equilibrium, these fees cross-subsidize interest rates for sophisticates. We use this framework to analyze two unexplored features of the CARD act: transparency requirements and penalty fee limits. More transparency leads to less financial uncertainty for naïve borrowers, while fee limits constrain everyone. Both policies reduce financial mistakes and increase the welfare of naïves. The effects on sophisticates, in contrast, are negative: If naïves make fewer mistakes due to clearer language, sophisticates lose cross-subsidization and experience welfare losses. The same holds true in the case of fee limits. When high-fee contracts are banned, expected revenue from naïve fee payments falls and interest rates rise. As a result, sophisticates experience a welfare loss.

JEL Codes: E21, E43, G18, G41, G51, K12

Keywords: Consumer Credit, Naïveté, Financial Mistakes, Bankruptcy, CARD Act, Cross-Subsidization

This chapter is based on a joint paper with Florian Exler from the University of Vienna

2.1 Introduction

Financial contracts can be quite complicated. According to the Wall Street Journal, credit card contracts in 2013 are up to 50 times longer than in 1980—20,000 words in 2013 versus 400 words in 1980.[1] Complicated contracts are harder to understand. Indeed, many cardholders fail to understand key aspects of their contracts, including when late payments trigger penalty fees (GAO, 2006).[2]

Despite not being fully internalized, penalty fees constitute a significant part of the cost of banking to consumers. In 2011, nearly 28% of US consumer checking accounts experienced non-sufficient funds or overdraft fees. Nearly one third of those accounts accrued more than 10 penalty items with an average fee of $225 (CFPB, 2014). Besides paying interest, credit card borrowers incur penalty fees for repaying financial obligations too late or for exceeding lines of credit. With late fees and over limit fees constituting the largest items, Agarwal et al. (2015) document that the average credit card holder paid $58 in fees per year.

While some of these penalty fees are certainly the consequence of a rational optimization of one's financial situation, some of these fees seem to occur by mistake. Missing important aspects of their credit contract,[3] consumers can lose track of financial commitments, misunderstand minimum payments, or forget to pay bills on time. These financial mistakes are quite common. For example, 52% of borrowers that were charged overdraft fees do not recall opting in to overdraft at all (PEW, 2014). Besides leading to unexpected penalty fees, financial mistakes can cause financial distress. According to Warren et al. (2000), "credit card debt out of control" and "trouble in managing money" are the third and fourth most common reasons given for a consumer bankruptcy. Only job loss and medical reasons rank higher.

Due to their potentially high cost and severe consequences, financial mistakes are at the center of many pieces of regulation. The 2009 Credit Card Accountability Responsibility and Disclosure (CARD) Act in the U.S. is the most prominent recent example. Policy makers tackle financial mistakes along two dimensions: firstly, transparency requirements

[1] See `https://www.wsj.com/articles/SB10001424127887324000704578386652879032748`.

[2] According to the United States Government Accountability Office, this lack of understanding is a consequence of lenders deliberately complicating their contracts.

[3] See GAO (2006).

and reporting standards make contracts easier to understand, lowering the likelihood of incurring penalty fees by mistake. Secondly, the CARD Act caps penalty fees, reducing the cost of financial mistakes that trigger a penalty fee.

Despite the importance of penalty fees and financial mistakes for consumers and policy makers, state-of-the-art quantitative research cannot inform regulators about their costs and consequences. Standard models of consumer debt simply abstract from penalty fees and have no roll for financial mistakes. Without these important ingredients, transparency requirements or fee limits as mandated by the CARD act seem futile. We address this gap in the literature and answer the following questions: What are the consequences of financial mistakes for credit market outcomes? Can regulation similar to the CARD act achieve better outcomes? How do these policies influence the interaction between consumers that make more and less mistakes?

In a framework where some borrowers make financial mistakes due to their lack of understanding, we explore the implications on interest rates and welfare when consumers borrow on credit contracts that trade off interest rates and penalty fees. Building on the theory of Naïveté,[4] we set up a heterogeneous agents model of unsecured debt and default that is inhabited by two types of agents: sophisticates and naïves. While all borrowers are subject to financial shocks that trigger penalty fees, naïve borrowers are unaware of their increased exposure to these shocks and the ensuing penalty fees. Being naïve, these consumers behave just like sophisticated consumers (as is standard in the literature) and choose contracts that carry too high penalty fees. This is what we term financial mistakes. Behaving identically, both types of consumers are indistinguishable to lenders. Lenders maximize profit and offer a menu of loan contracts. Conditional on a requested amount and borrower characteristics, lenders offer a continuum of interest rate and penalty fee combinations for both types of borrowers to choose from.

In equilibrium, lenders only offer contracts that yield equal expected revenue. Hence, debt contracts trade off lower interest rates for lower penalty fees. When choosing from the menu of loan contracts, naïve borrowers do not understand the true expected cost of penalty fees and consequently choose contracts that carry too high penalty fees (that they are naïve about) because they prefer low interest rates. Naïve borrowers make financial mistakes: on average, they pay more for credit than they would if they knew their true

[4] Cf. Armstrong and Vickers (2012), Gabaix and Laibson (2006), and Heidhues and Kőszegi (2010).

exposure to financial shocks. Sophisticated consumers are less prone to financial shocks and incur fewer penalty fees. Being pooled with naïve agents, they benefit from the same set of contracts where low interest rates are subsidized by high penalty fees. These high penalty fees are mainly carried by naïve consumers. Thus, sophisticated consumers face cheaper credit in the presence of naïve consumers than if they were by themselves.

We use this framework to analyze two important aspects of the 2009 CARD Act: (1) The CARD Act defines how late fees, interest rates, and minimum payments are to be reported and communicated to consumers. With stringent transparency requirements, standardized language, and clearer reporting standards contracts are easier to understand. More understandable contracts reduce the risk of financial mistakes. (2) The CARD Act limits how lenders can reset interest rates in response to missed payments and restricts the amount of penalty fees to be charged. Limiting penalty fees for borrowers reduces the cost of financial mistakes. We find that both pieces of legislation have a similar impact on credit contracts offered in equilibrium. Revenues from penalty fees shrink, either because (1) consumers make fewer mistakes and thus pay fees less often or because (2) lenders are banned from offering high penalty fees. Consequently, interest rates rise for the equilibrium contracts and cross-subsidization from naïves to sophisticates is reduced under both policies.

Naïve consumers benefit from both reforms. Their lack of understanding become less consequential either (1) because they make fewer mistakes per se due to simpler contracts or (2) because they are protected from choosing too high penalty fees. Naïves pay too much for their credit prior to the reform and both policies reduce their cost of credit. Because sophisticated agents lose cross-subsidization, they stand to lose from these reforms. While inconsequential to their understanding of credit contracts, sophisticates lose out on cross-subsidization as a consequence of (1) transparency requirements. With naïves committing fewer financial mistakes and paying lower penalty fees, sophisticates face higher interest rates. They consequently suffer from transparency requirements. Similarly, (2) limiting penalty fees also reduces sophisticate welfare. Penalty fee limits force naïve borrowers to choose contracts with lower fees, thereby reducing the size of their mistakes. Similar to before, this leads to welfare losses.

2.1.1 Related Literature

This paper contributes to three strands of literature. First, it relates to empirical studies which try to evaluate the 2009 CARD act. Agarwal et al. (2015) use panel data to analyze the effects of the 2009 CARD Act and estimate that regulations lead to a decrease in overall borrowing costs. Nelson (2020) also considers the CARD Act and finds that lower markups and limited ability to raise borrowers' interest rates based on new information lead to a fall in average transacted prices. However, he also reports that prices rose in some parts of the market, thereby unveiling possible cross effects which might mitigate the legislator's intent. We add to this literature by proposing a structural model to evaluate two main components of the reform. Besides identifying the importance of financial mistakes, a structural quantitative model allows to identify key mechanisms, gauge effects through equilibrium pricing, and estimate welfare.

Second, our paper extends Naïveté in credit markets to setups with imperfect enforcement and equilibrium default. Furthermore, it quantitatively gauges the relevance of Naïveté in the credit market and for credit market regulation. Naïveté has long been the focus of theoretical contributions. Armstrong and Vickers (2012) show that in markets with sophisticated and naïve consumers a pooling equilibrium may exist and that competition can work to subsidize the sophisticated at the expense of the naïve. This exploitation of naïve consumers is also present in the work by Heidhues and Kőszegi (2015), who study Naïveté-based discrimination and find that firms lend more than is socially optimal to increase unexpected payments of naïve consumers. Heidhues and Kőszegi (2010) develop a model of loan-repayment in competitive credit markets with consumers who value immediate gratification. They show that non-sophisticated consumers take on credit which is cheap in the short term, but would then go on to overborrow and pay large penalties, thereby suffering considerable welfare losses. In Eliaz and Spiegler (2006), agents have dynamically inconsistent preferences and the principal offers a menu of loan contracts in order to screen for sophistication. Gabaix and Laibson (2006) propose a framework in which firms offer cheap baseline contracts in order to hook naïves and earn profits from shrouded prices for additional payments.

Besides constituting an important theoretical tool to study credit markets and contract design, Naïveté also seems to be relevant empirically. DellaVigna and Malmendier (2004) study how firms respond to partially naïve time-inconsistent consumers. They show that contract design targets consumers' misperception of future behavior. Using transaction data of retail funds, Gao et al. (2020) document that naïve investors cross-subsidize sophisticated investors. Relative to simple non-structured funds, this subsidization is especially pronounced when trading more complex structured funds.

Third, we expand the standard framework of unsecured credit and equilibrium default based on the seminal work by Chatterjee et al. (2007) and Livshits et al. (2007).[5] We introduce naïve agents that misunderstand financial contracts and make financial mistakes. This notion of Naïveté creates a natural role for information requirements and penalty fee limits, which are an integral component of the 2009 CARD Act. To the best of our knowledge, we are the first to quantitatively assess the importance of Naïveté in the credit market. Furthermore, we employ our new framework to investigate central components of the CARD Act that have not been studied before.

There have been other approaches to incorporate behavioral consumers into a model of unsecured credit and equilibrium default. Nakajima (2017) introduces hyperbolic discounters but does not allow for any interactions between consumer types. Exler et al. (2020) model over-optimistic consumers that interact with rational consumers through pricing. Chatterjee et al. (2018) develop a framework where agents hold heterogeneous discount factors. Both papers focus on how lenders learn about consumer types and do not have a role for information requirements or fee limits. Raveendranathan and Stefanidis (2020) analyze the ability to pay check mandated by the 2009 CARD Act, but also have no role for assessing transparency regulations.

The remainder of this paper is structured as follows: Section 2.2 presents the framework, Section 2.3 describes the calibration, Section 2.4 explores the benchmark properties and mechanisms of the model before Section 2.5 investigates two important components of the 2009 CARD Act. Section 2.6 concludes.

2.2 The Model Framework

We propose a quantitative theory which allows for the interaction of Naïveté and default and has an explicit role for information requirements and penalty fee limits which are often

[5] See Exler and Tertilt (2020) for a recent survey.

formulated in credit market legislations. We study an incomplete-market heterogeneous-agent model of unsecured debt and idiosyncratic uncertainty about earnings. Furthermore, the model features equilibrium default and endogenous borrowing interest rates.

2.2.1 Households

We set up a standard overlapping generations model with an economy which is populated by a continuum of households, with one model period representing one year. Individuals enter the model at age 21 and die with certainty at age 80. They derive utility from consumption in each period, c_t, and maximize expected lifetime utility:

$$\mathbb{E}_0 \left\{ \sum_{j=1}^{J} \beta^t u(c_t) \right\},$$

where $\beta < 1$ is the time discount factor.

Each agent decides on consumption, whether to save or borrow and can file for bankruptcy. The model features equilibrium bankruptcy and abstracts from secured lending like mortgages. Instead, we focus on unsecured credit such as credit card debts. Households face idiosyncratic risk in labor productivity and financial shocks, while wages and the risk-free interest rate are set exogenously.

Labor Productivity. Households are subject to idiosyncratic shocks to their labor productivity p, which represents the wage risk they are facing. Income y_j is given by $y_j = p \cdot e(j)$, with $e(j)$ being an age-dependent efficiency premium as in Livshits et al. (2007). Individual labor productivity is modeled as a persistent AR(1) process $z_{i,t}$ with transitory white noise $\eta_{i,t}$. Hence, for a household i at age j, productivity evolves according to

$$\begin{aligned} \log(p_{i,j}) &= z_{i,j} + \eta_{i,j} \\ z_{i,j} &= \rho z_{i,j-1} + \zeta_{i,j}, \end{aligned} \tag{2.1}$$

where $\rho \in [0, 1]$, $\eta \sim \mathbb{N}(0, \sigma_\eta^2)$ and $\zeta \sim \mathbb{N}(0, \sigma_\zeta^2)$.

Financial Shocks. Households are prone to unforeseen financial shocks ε. For example, these shocks can be thought of as unanticipated bills or repaying one's credit too late. If a household incurs such a financial shock and does not have the assets to pay for it, a lender will provide them with the funds in exchange for a fee ϕ (e.g.: overdraft fees, late payment fees, etc.). Thus, for indebted households the costs of a financial shock are given by $\phi \cdot \varepsilon$, while households who are holding assets can pay ε out-of-pocket.

There are two types of households in the economy: Rational, sophisticated consumers (S) and naïve consumers (N), whose shocks share the same support: $\varepsilon \in \Omega_N = \Omega_S$. However, naïve borrowers face higher probabilities that a nonzero shock occurs:

$$p_N(\varepsilon = \omega_i) > p_S(\varepsilon = \omega_i) \quad \text{for all} \quad \omega_i > 0. \tag{2.2}$$

Sophisticated borrowers know the distribution of their shock and take it into account when making decisions. In contrast, naïve consumers do not understand their higher exposure to financial shocks and expect the same distribution that sophisticates face:

$$\tilde{\mathbb{E}}_N(\varepsilon_N) = \tilde{\mathbb{E}}_S(\varepsilon_S) = \mathbb{E}(\varepsilon_S) \tag{2.3}$$

where $\tilde{\mathbb{E}}_i(\cdot)$ denotes the perceived expectation of consumers (which might differ from the true expectation in case of a naïve agent).

Consequently, given their perceived expectation over financial shocks, naïve agents behave exactly like sophisticated consumers, conditional on their state. Hence, lenders cannot distinguish between the two types and offer the same loan contract to everyone. Furthermore, we abstract from learning in the sense that even if a consumer keeps experiencing bad shocks, the lenders do not update their belief about the borrower's type - they can only observe the total debt, not the history of shocks which led to that level.[6] This means that we are only analyzing a pooling equilibrium, in which prices depend on the share of naïve and sophisticated consumers in the market, but do not vary between the types. However, in later sections and especially when talking about policy experiments, we compare the results from such a pooling equilibrium to the outcomes in a market where lenders always know the type of their customers.

[6] In subsection 2.2.3 we discuss how the total debt can hold some information on whether the lender deals with a sophisticate or a naïve and how this is accounted for in equilibrium.

Financial Mistakes. Due to underestimating their true proneness to financial shocks, naïve borrowers might miscalculate their expected payments resulting from fees, that is $\tilde{\mathbb{E}}_N(\phi \cdot \varepsilon) < \mathbb{E}(\phi \cdot \varepsilon)$. Therefore, naïve borrowers might fail to choose an optimal debt contract and opt for contracts which yield lower interest rates but higher fees. Consequently, their true expected total cost of credit will exceed the optimal costs associated with an optimal contract which a social planner would choose for them. The extent of this over-payment is called a financial mistake.

Bankruptcy. Households can choose to default and not repay their debt and financial mistakes. Bankruptcy is modeled as a Fresh Start according to Chapter 7 meaning that upon default all outstanding debt is discharged and the household enters the next period without any obligations.

However, default is costly since a fraction γ of current income is garnished and distributed to the creditors. Furthermore, the household incurs a utility cost χ which can be thought as stigma costs.

Decision Problem. A household's decision variables are consumption c, debt level d (where $d < 0$ are positive asset holdings) and a financial contract when taking on a loan. A financial contract is a combination of loan prizes q and fees for financial shocks ϕ. Lenders will offer different loan prizes for different fees and the borrowers choose a contract by deciding on a fee level. Note, however, that this fee choice will only be important in the next period, when the borrower might be faced with a financial shock ε and then has to pay $\phi \cdot \varepsilon$.

Let $V(d, \phi; s)$ denote the value function of a consumer in state $s = (z, \eta, j)$, who is holding debts d and chose a fee ϕ last period. If a consumer declares bankruptcy, all debt charges are dismissed ($d = 0$ and $\varepsilon = 0$), but a fraction γ of income is garnished and the household experiences a disutility χ. Also, no saving is allowed for next period, the household simply consumes all income that is not garnished.

With $q(d', \phi'; s)$ being the loan prize for a loan of size d' with fees ϕ' for an individual in state s, the consumer's decision problem reads

$$V(d,\phi;s) = \max_{c,d',\phi'} \left[u(c) + \beta \mathbb{E} \max \left\{ V(d',\phi';s'), B(s') \right\} \right] \tag{2.4}$$
$$\text{s.t. } c + d \leqslant y(s) + q(d',\phi';s)d' - \phi \cdot \varepsilon$$

where B is the value of filing for bankruptcy:

$$B(s) = u(c) - \chi + \beta \mathbb{E} \left\{ V(0,\phi';s') \right\} \tag{2.5}$$
$$\text{s.t. } c = (1-\gamma)y(s)$$

Note that this decision problem is the same for both sophisticated and naïve consumers since the latter do not realize their higher proneness to financial shocks. Consequently, the decisions of sophisticates and naïves will be the same based on their observable state.

2.2.2 Credit Market

Let $s = (z, \eta, j)$ denote a household's current state, with z being the persistent component of labor productivity, η the transitory shock and j age. If an individual seeks out a loan, the lender sets the loan prize depending on loan size and the individual's current state s. Furthermore, banks offer different loan prizes depending on an additional fee, ϕ. There is no asymmetric information as lenders observe the current state of a household and the loan size. Also, whether a household is naïve or sophisticated is unknown by all. However, lenders know the fraction of naïves μ in the economy.

Loan Contracts. Loans are only sought out for one period and households have a limited commitment to repay. A loan contract consists of the face value of the debt, $d' \in (0, \infty)$, the loan prize, $q \in [0, 1]$, and penalty fees for financial mistakes, $\phi \in [1, \infty)$. Households can choose which contract to take and decide to simply repay their financial shocks without additional fees ($\phi = 1$) or to gamble by accepting higher fees in exchange for lower interest rates ($\phi > 1$). Also, note that in equilibrium the endogenous loan price depends on d', s, and ϕ.

Lenders. When deciding on the bundle of contracts the lenders take as given the exogenous interest rate r. Revenue consists of two components: The expected revenue from the issued loan and the expected revenue from additional payments due to the fee ϕ. If a household is hit by a shock ε, which is interpreted as unexpected financial mishandling, the bank's revenue is simply given by:

$$(\phi - 1) \cdot \varepsilon$$

Furthermore, households can default on their debts. In this case, a fraction γ of the household's current income is garnished to repay parts of outstanding debt. We assume that garnished income is split equally among all creditors and hence, the recovery from a defaulted loan for the bank is given by

$$\rho(d', s, \varepsilon) = \gamma y(s) \cdot \frac{d'}{d' + \varepsilon}$$

Let $\theta(d', s, \varepsilon, \phi)$ denote a household's decision to default depending on loan size d', current state s, financial shock ε and fee ϕ. Then a bank's expected profit is given by:

$$\Pi = -q(d', \phi, s)d' + \frac{1}{1+r} \int \theta(d', s', \varepsilon, \phi)\rho(d', s', \varepsilon) + \Big(1 - \theta(d', s', \varepsilon, \phi)\Big)\Big(d' + (\phi - 1)\varepsilon\Big)\, \mathrm{d}\mu(s', \varepsilon)$$

with $\mu(s', \varepsilon)$ being the probability measure over next period's possible states s' and financial shocks ε.

We assume perfect competition and free entry for lenders, which leads to zero profits conditional on observables d' and s and hence,

$$\begin{aligned} q(d', \phi, s) = \frac{1}{1+r} \int \theta(d', s', \varepsilon, \phi) & \frac{\rho(d', s', \varepsilon)}{d'} \\ & + \Big(1 - \theta(d', s', \varepsilon, \phi)\Big)\left(1 + \frac{(\phi - 1)\varepsilon}{d'}\right) \mathrm{d}\mu(s', \varepsilon). \end{aligned} \tag{2.6}$$

Equation 2.6 is the implicit functional relationship between $q(\cdot)$ and ϕ, $q = q(\phi, \cdot)$, which holds in equilibrium. Figure 2.1 shows an example contract space and the relationship between interest rates and fees at different debt levels.

There are two interesting cases to distinguish. If agents choose $\phi = 1$, they decide to

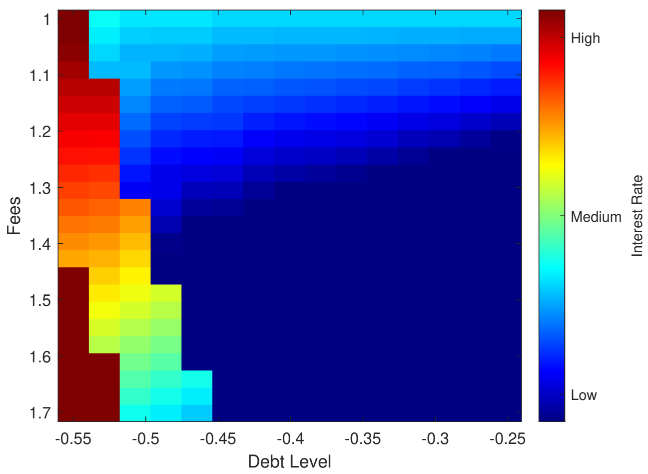


Figure 2.1: Example contract space

fully insure against financial shocks and never have to pay an additional fee if they occur. This comes at the cost of higher interest rates. A choice of $\phi > 1$ relates to positive penalty fees that lenders charge in the case of financial shocks. This choice might lead to lower interest rates as lenders can expect more revenue from fees. Lastly, note that there exists an endogenous limit on penalty fees, since too high fees always cause default: $\exists\ \bar{\phi} \in \mathbb{R}^+ \colon \forall\ \phi > \bar{\phi} : \mathbb{E}[\theta(\cdot)] = 1$. Thus, $q(\phi > \bar{\phi}, \cdot) = 0$.

2.2.3 Distribution of naïve consumers

When creating the bundle of contracts as defined in Equation 2.6, the lender takes as given the debt level d' without knowing whether the borrower is naïve or sophisticated. However, since naïve agents are more prone to financial shocks, the lender might deem it more likely that they are dealing with a naïve borrower for very high debt levels. In this case, the lender might attribute a probability $\hat{\mu} > \mu$ to the chance of dealing with a naïve agent, where μ again denotes the fraction of naïves in the economy. Figure 2.2 shows an example of an assumed distribution over asset holdings, where the fraction of naïves might vary for different debt levels. We can see how the expectation of dealing with a naïve borrower rises for the highest debt levels, while the fraction of naïves at debt levels close to zero is even smaller than the economy wide average.

Hence, when calculating expected repayment and default probabilities for the debt contracts in Equation 2.6, the lender uses a prior belief of naïves over debt levels d', $\hat{\mu}(d')$. This belief $\hat{\mu}(\cdot)$ might differ from the true ex-post distribution $\mu(\cdot)$, whereupon the lender

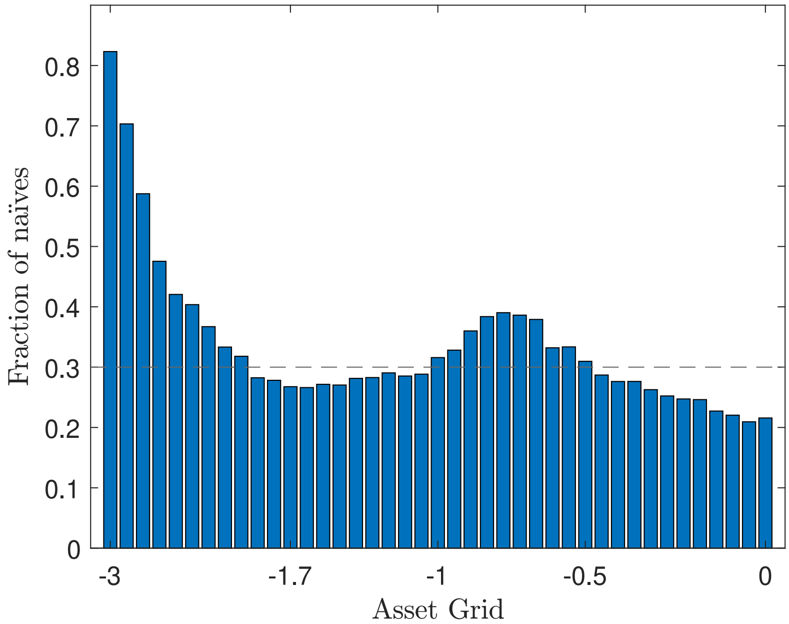


Figure 2.2: Example of distribution of naïve consumers over different debt levels (share of naïves in whole economy $\mu = 0.3$).

updates their prior belief. Thus, in equilibrium we have $\hat{\mu} = \mu$ and the lender uses all the information entailed in the debt level d' chosen by the borrower.

2.3 Calibration

This section presents the parameter values used to numerically solve the benchmark economy. Some parameters are set externally, while others are estimated using a Simulated Method of Moments approach to match important credit market data. We use data of the consumer credit card market from the Consumer Financial Protection Bureau (CFPB, 2014) and credit card account data from the Office of the Comptroller of the Currency in the US (OCC) as reported in Agarwal et al. (2015). Although the current calibration strategy is limited with respect to variable selection and model outcomes, it still provides a meaningful foundation to solve the model and gauge the importance of our proposed mechanisms. Future versions will include a more intricate simulated methods of moments approach to determine the model's parameters.

Households live for 60 periods and one period represents one year. Individuals enter the model at age 20 and die with certainty at age 80. There is no formal retirement, but households' age-dependent experience premium drops after the age of 65. Per-period

Table 2.1: Directly specified parameters

Economic Parameters		Value
CRRA consumption	σ	2
Persistent Wage Autocorrelation	ϱ	0.95
Persistent Wage Var	σ_ζ^2	0.025
Transitory Wage Var	σ_η^2	0.05
Risk Free Rate	r	1%
Garnishment rate	γ	0.15
Cost of default	χ	1.5
Financial Mistakes		
Size of mistakes	ε	$(0, 0.018, 0.126)$
Sophisticates	$Pr^S(\varepsilon)$	$(0.88, 0.084, 0.036)$
Naïves	$Pr^N(\varepsilon)$	$(0.28, 0.504, 0.216)$
Share of naïves	μ	0.3

utility takes the form of a CRRA utility function

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma},$$

where the risk-aversion parameter, σ, is set to 2, which is standard in the literature. The discount factor β is chosen to match an average interest to debt ratio of 14.3% and the risk-free rate is set exogenously to 1%.

Persistent labor productivity follows a simple AR(1) process where the autocorrelation parameter is set to $\rho = 0.95$ and the variance of the iid shock chosen to be $\sigma_\zeta^2 = 0.025$. The variance of the transitory shock is $\sigma_\eta^2 = 0.05$. All these values are within the range of standard literature.

A household who decides to file for bankruptcy experiences stigma costs in the form of a disutility of $\chi = 1.5$ in the period of default and a fraction $\gamma = 0.15$ of current income is garnished.

Financial Shocks. Financial shocks are modeled to take on only three different values: $\varepsilon \in \{0, \omega_1, \omega_2\}$. These values are meant to represent no occurrence of a financial shock within a year, only one such occurrence, and repeated occurrences. We use data on overdraft from the CFPB (2014) to estimate that a fraction of 21% of borrowers experiences only one item per year, while 9% of borrowers experience two or more items. Hence, we set $p(\omega_1) = 0.21$ and $p(\omega_2) = 0.09$.

These values represent the economy wide average and have to be split into different processes for naïve and sophisticated consumers. The size of these shocks is pinned down by two parameters. First, we look at the data to estimate the average ratio of payments for repeated occurrences in relation to payments for only one occurrence. This means that we are looking at the average ratio of ω_2/ω_1 and estimate a value of 7. By doing so, the value ω_2 is now simply determined by the value of ω_1 which is chosen to match an average ratio of fee payments to debt of 7.1%, as observed in the OCC data. The value to do so is $\omega_1 = 0.018$, with median income normalized to 1.

Naïveté. Lastly, the most important part concerns our choice of modelling Naïveté. The first parameter to pin down is the fraction of naïves in the economy. Looking at data from the OCC we find that a share of 30% of borrowers have a FICO score of 660 or less. Typically, a FICO score above 660 is considered favorable and since naïve agents in our model are those who experience more financial shocks we relate them to the people with lower FICO scores. Consequently, we set the share of naïves, μ, equal to 30%.

To determine the extent of Naïveté, we define a probability spread ψ which denotes how much more likely a naïve agent is to receive a non-zero financial shock:

$$\psi = \frac{p(\varepsilon_N = \omega_1)}{p(\varepsilon_S = \omega_1)} = \frac{p(\varepsilon_N = \omega_2)}{p(\varepsilon_S = \omega_2)} \tag{2.7}$$

where $p(\varepsilon_N = \omega_i)$ is the probability that a naïve agent experiences a shock of $\omega_i > 0$ and $p(\varepsilon_S = \omega_i)$ the corresponding probability of a sophisticate.

If $\psi = 1$, there is no naïveté in the economy and all consumers experience the same shocks. If $\psi > 1$, naïve consumers experience financial shocks more often but are not aware of this fact (as discussed in section 2.2).

We choose $\psi = 5.14$ to obtain a ratio of average fee payments of naïves over average

Table 2.2: Jointly-Targeted Moments

	Data (OCC)	Model
Avg. Interest / Debt	14.30%	13.89%
Avg. Fees / Debt (AFD)	7.10%	4.77%
AFD naïve / AFD sophisticated	6	7.57
	Parameter	Value
Discount factor	β	0.77
Size small financial shock	ω_1	0.57
Relative likelihood of financial shock	ψ	5.46

fee payments of sophisticates equal to 6. This ratio corresponds to the differences in fee payments seen in the data from the OCC for borrowers with low and high FICO scores. The specific probability processes for naïves and sophisticated are then constructed in such a way that their weighted mean (with the share of naïves, μ, used as weight) results in the economy wide probabilities determined above.

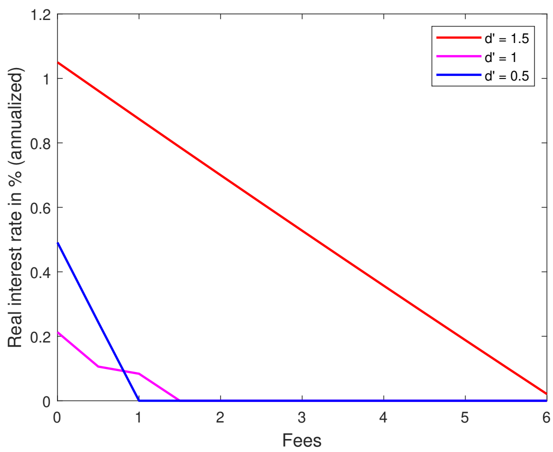
Parameters and targets are summarized in tables 2.1 and 2.2.

2.4 Results

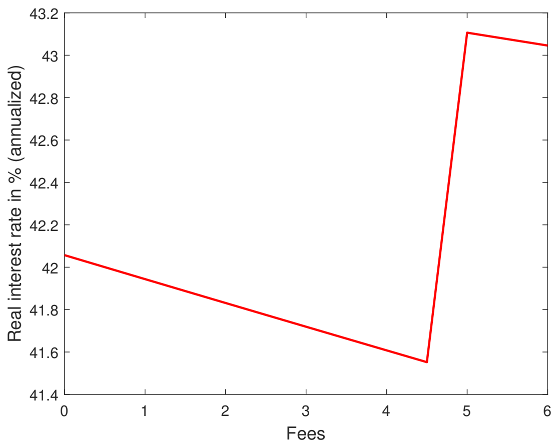
With the previously defined parameters, we solve the model quantitatively by backward iteration on the value function. Before turning to the benchmark outcomes in Section 2.4.2, Section 2.4.1 illustrates the effects of naïveté on the design of credit contracts and life cycle outcomes. Section 2.4.3 discusses cross-subsidization and its welfare effects and Section 2.4.4 highlights the importance of default for the mechanisms.

2.4.1 Illustration of Mechanism

Figure 2.3 shows an example of possible $(q(\phi, \cdot), \phi)$ schedules as defined in Equation 2.6 for different loan sizes d' with median income being normalized to 1. For the high income earner in Figure 2.3a we can see how a choice of higher fees can reduce the real interest



(a) High income earner



(b) Low income earner, ($d' = 1.6$)

Figure 2.3: Example of Equilibrium Credit Contracts (q,ϕ) for a high and low income earner, aged 45-50 (median income normalized to 1).

rate. However, the $(q(\phi, \cdot), \phi)$ schedule does not have to be monotonic as can be seen in Figure 2.3b. There, the lender faces a low income earner who might default on future debts. Hence, at some point higher fees lead to an increase in default risk. Thus, the lender expects lower profits and consequently increases the interest rates. Note, however, that all the $(q(\phi, \cdot), \phi)$ schedules to the right of the first jump are strictly inferior to all the points to left. They combine higher fees with higher interest rates and would therefore never be chosen by the consumer. This finding ensures that – conditional on a loan size d' and consumer characteristics – the optimal contract is uniquely defined.

These $(q(\phi, \cdot), \phi)$ schedules become important when analyzing a market in which sophisticated and naïve borrowers are pooled together. Since lenders issue one contract for both types, balancing revenue from interest payments and penalty fees, the $(q(\phi, \cdot), \phi)$ schedules become steeper. This means that interest rates are falling more rapidly with the choice of higher fees, since the foregone interest payments are financed by the higher fee payments resulting from naïveté. Later sections will further elaborate on this cross-subsidization effect and show that sophisticates are indeed choosing different contracts in a pooling equilibrium when compared to a separating equilibrium.

To gauge the importance of misunderstanding the risk of financial shocks and fee payments in this framework, Figure 2.4 shows an example of a naïve consumer's life-time decisions concerning assets, consumption, fees ϕ and bankruptcy. While the red line shows actual decision taken by the naïve consumer, the dotted blue line shows how the

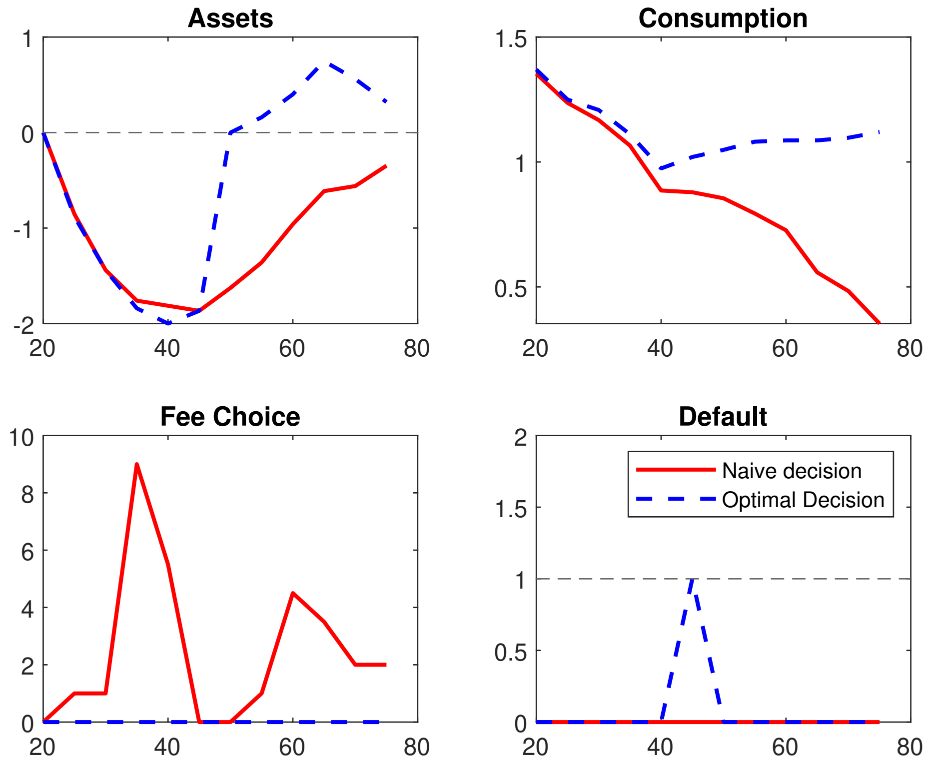
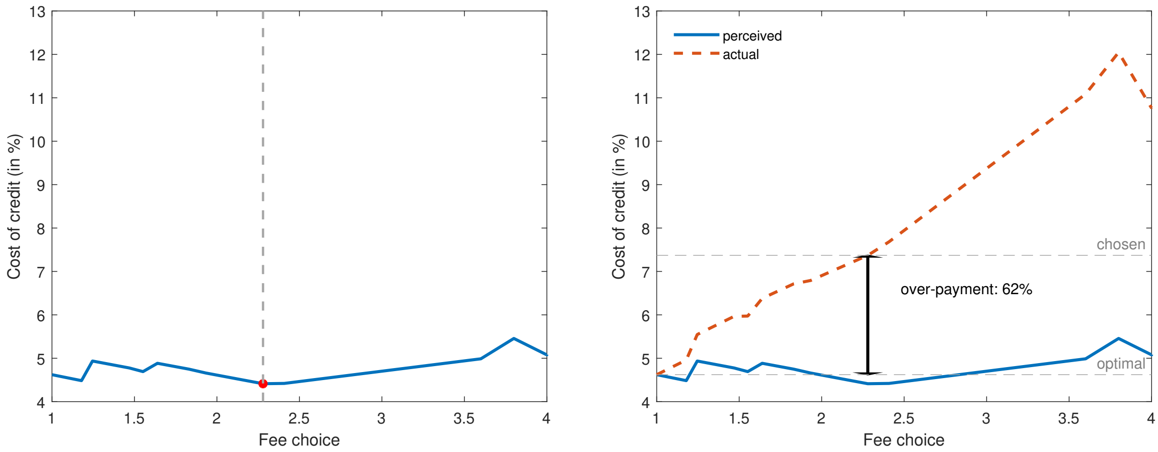


Figure 2.4: Optimal (dotted blue) and actual decisions (red) of a naïve consumer. Cost of Naïveté 22.5% CEV.

optimal behavior would look like if the consumer was aware of the actual probabilities of making financial mistakes but faced the same prices. We call this hypothetical agent *informed naïve*. One can see how the naïve consumer chooses significantly higher fees than the informed self, resulting in over-accumulation of debts. At age 45, the optimal behavior would be to default, but since the naïve household does not understand his true probabilities, he does not file for bankruptcy. He continues rolling over debt and enjoys significantly lower consumption in all periods thereafter. The difference leads a loss in consumption equivalence of 22.5%.

Financial Mistakes. In our setting a financial mistake is a contract which yields higher expected costs for a given credit than the optimal one. The total costs of a credit, TCC, are all the payments resulting from interest and fees, that is

$$TCC = d' - qd' + (\phi - 1)\varepsilon \tag{2.8}$$



(a) Fee Choice based on perceived costs

(b) Actual costs and over-payment

Figure 2.5: Over-payment of a naïve consumer based on chosen contract compared to optimal contract

where $d' - qd'$ are interest payments and $(\phi - 1)\varepsilon$ are fee payments. Note that $\phi = 1$ means that no extra fees have to be paid. Hence, the cost of credit only exceeds interest payments if $\phi > 1$.

Since naïves underestimate their true proneness to financial shocks, they also miscalculate the expected costs of a given credit contract. For a given level of current borrowing let TCC^N denote the costs of a contract chosen by a naïve consumer and let TCC^* denote the costs of a contract chosen by an informed naïve in the same state for the same amount of current borrowing (i.e. both contracts lead to the same consumption in the current period, but might differ in expected costs next period).

A financial mistake is now the relative amount of over-payment, that is the relative amount the naïve consumer has to pay more in expectation than if he had chosen the optimal contract. Hence, in our setting a financial mistake is defined as

$$Mistake = \frac{\mathbb{E}(TCC^N) - \mathbb{E}(TCC^*)}{\mathbb{E}(TCC^*)}, \tag{2.9}$$

where the expectation $\mathbb{E}(\cdot)$ is formed with respect to the true risks.

This mechanism is illustrated in Figure 2.5. Part 2.5a shows the total costs of a given credit in percent of the amount borrowed as perceived by a representative naïve consumer. The naïve borrower chooses a fee of about 2.3, since this leads to the lowest expected costs for the given borrowing level. However, as shown in Figure 2.5b the actual expected costs (formed by an informed agent) considerably exceed the naïve expectations. This leads to

Table 2.3: Benchmark Outcomes

	Sophisticated	Naïve	Average
Debt-to-income ratio	48%	55%	50%
Default Rate	0.78%	2.25%	1.22%
Interest Rates	14.90%	11.54%	13.89%
Fraction Borrowing	11%	6%	9%

a situation in which the naïve consumer would have liked to choose a different contract (one with $\phi = 1$), had he known the true underlying risk. In fact, the actual costs of the chosen contract exceed the costs of the optimal contract by 62%, which can be classified as a financial mistake, since both contracts yield the same level of current borrowing and only differ in expected repayment next period. Hence, the naïve borrower could have chosen a cheaper credit contract, had he known about the true underlying risk. Note, however, that this counterfactual is always given in comparison to an atomistic informed agent whose decisions do not affect prices.

2.4.2 Benchmark Outcomes

Table 2.3 presents benchmark outcomes in the economy with the parameterization as described in Section 2.3. Without a full calibration, we do not focus on the levels of these outcomes. However, the differences between sophisticated and naïve consumers are informative: Naïveté leads to higher debt (along the intensive and extensive margin), higher average interest rates, and higher default rates.

2.4.3 Cross-subsidization and Welfare

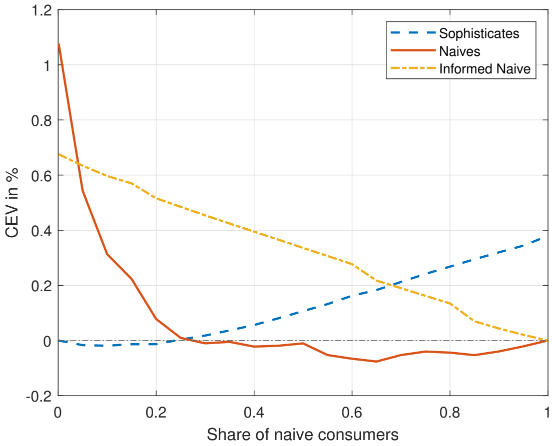
Since lenders cannot separate naïve from sophisticated borrowers, they only issue one set of credit contract for both types. Lenders only offer contracts – i.e. interest rate and penalty fee combinations – that yield the same expected revenue. However, dealing with sophisticates only would lead to contracts with higher interest rates for each level of fees, since sophisticated consumer are less prone to mistakes. Furthermore, in equilibrium, sophisticates understand their exposure to financial shocks and want to insure against this risk, hence they will pick contracts with lower fees.

In contrast, dealing with naïve borrowers would lead to lower interest rates for each level of fees, since they are more likely to experience bad financial shocks and incur these fees. Furthermore, naïves underestimate their true proneness to these shocks and thus, in equilibrium they choose contracts with higher fees and lower interest rates than they should were they aware of their risk.

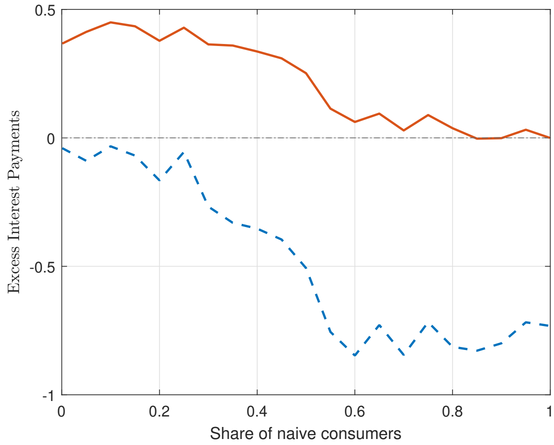
In an economy where sophisticates and naïves are pooled, lenders have to price credit in such a way as to balance those two mechanisms according to the share of naïves in the market. The welfare effects of both types interacting through pooled credit prices are represented in Figure 2.6a, which plots welfare of sophisticated and naïve agents depending on the share of naïve consumers in the economy. Welfare changes are measured in consumption equivalence variation in percent and computed relative to the separating equilibrium in which banks can offer different contracts to naïve and sophisticated borrowers. In other words, the point of reference for sophisticated (naïve) borrower is on the left (right). The third line in Figure 2.6a depicts welfare for an atomistic *informed naïve* agent, i.e. an agent that faces the same prices and the same risk of financial shocks as every naïve but understands her true exposure to these shocks and consequently picks optimal fee levels.

To gauge the importance of cross-subsidization for the observed welfare patterns, Figure 2.6b plots excess interest payments of both types of agents. Excess interest payments are defined as the difference in expected interest ($r(\cdot)d'$) paid by an agent in the pooling equilibrium relative to a separating equilibrium.

Sophisticate welfare level increases as the share of naïve consumers increases. Sophisticates profit from the presence of naïve agents in the economy. They profit from cross-subsidization, since pooled interest rates will fall more rapidly as fees increase because more naïves are around. Figure 2.6b shows that this effect manifests in decreasing average interest rates (or, equivalently, increasingly negative excess interest payments) compared to the absence of naïves. Average interest paid falls as the share of naïves in the pooled market rises. This happens because lenders shift larger parts of their revenue to fees for the financial mistakes made by naïves, thereby increasing fees and lowering interest rates. Since the decisions made by sophisticates are optimal regarding their risk



(a) Welfare Change



(b) Excess interest paid in pooling economy

Figure 2.6: The amount of cross-subsidization in dependence of the share of naïve consumers

of financial shocks, they benefit relatively more from lower interest rates than being hurt by higher fees.

In contrast, welfare of naïves is highest in an economy where there are only sophisticates and falls sharply as the share of naïves rises. This might seem counter-intuitive because excess interest payments drop as the fraction of naïves increase and fewer sophisticates enjoy cross-subsidization (cf. Figure 2.6b).

However, there is a strong opposing effect reducing naïve welfare. Banks shift their focus from interest payments to punishment fees as the probability of dealing with a naïve agent increases. Abstracting from Naïveté and suboptimal fee choices, we first focus on an informed naïve. Her welfare is highest in an economy with only sophisticates because she can self-insure against her higher risk of mistakes by accepting the loan contracts of sophisticates with relatively low penalty fees. As more naïves enter the market, the set of equilibrium contracts shifts towards higher fees.[7] Thus, insurance for the informed naïve against mistakes gets worse and welfare drops.

These suboptimal fee choices are exacerbated by naïveté. Low interest-high fee contracts are tempting naïves because they underestimate their proneness to financial shocks. Thus, they choose inferior contracts and their welfare drops more steeply than that of an informed naïve. However, at higher shares of naïves in the economy, the cross-

[7]Both, sophisticates and naïves are happy to accept these contracts. Sophisticates gain cross-subsidization and naïves wrongfully think they gain cross-subsidization but actually pay more.

subsidization effect dominates for high fee contracts, leading to a small increase of naïve welfare above a share of 60%.

The total welfare effect of ca. 1.1% CEV for naïves that live in an economy with only sophisticates can be attributed to a better set of contracts being available even in the absence of Naïveté (ca. 0.7 percentage points, the gain of an informed naïve) and forced insurance since there are only contracts with lower penalty fees on offer (0.4 percentage points, the difference between naïves and informed naïves). Naïves are forced to insure against their risk, making them ex-post better off, although they themselves would prefer lower interest rates.

Overall, this discussion clearly shows that if the fraction of naïve consumers is high enough, sophisticated borrowers are being cross-subsidized by the mistakes made by naïve individuals. Naïves suffer from insufficient insurance against their higher risk of mistakes.

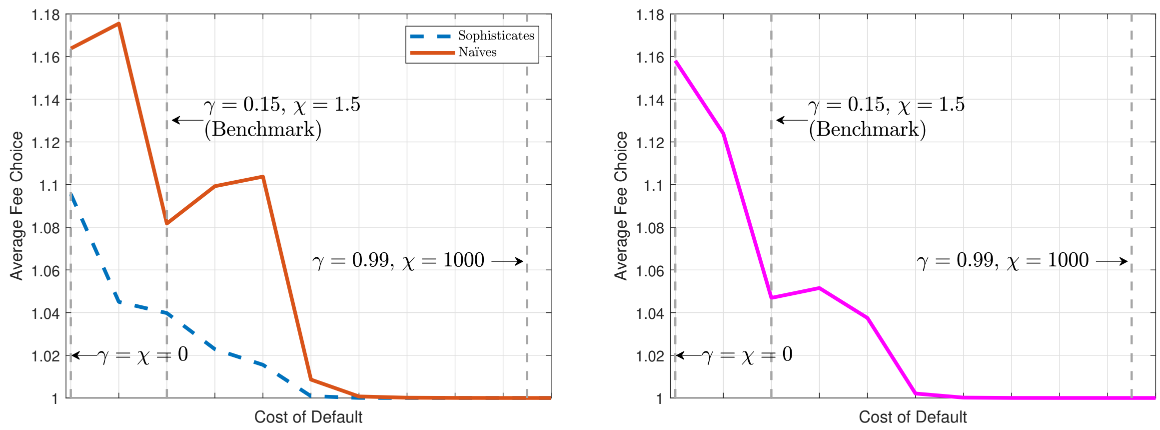
2.4.4 Default Matters

When analyzing credit contracts and the interaction between sophisticated and naïve agents, default is important.[8] Default arises because agents have less than perfect commitment to repay. Agents only repay their debts if it is *ex-post* rational to do so. This limits the amount of late fees a lender can charge and consequently limits cross-subsidization. This has important welfare consequences.

With lower default costs households face less commitment to repay their debts which is taken into account by creditors when pricing the loans. If filing for bankruptcy is completely free, only very low levels of debt can be sustained in equilibrium and lenders will charge high interest rates. In contrast, if bankruptcy is costly enough to ensure nobody ever wants to default, households can take on loans only if they are sure they will be able to repay. This leads to an equilibrium where default is theoretically possible, yet never occurs. Hence, borrowing interest rates are risk-free.

Sophisticates can only profit from lower interest rates due to the presence of naïves if a positive amount of debt can be sustained in equilibrium. Hence, if the costs of default are so high that nobody ever wants to file for bankruptcy, households will always try to insure themselves against possible default risks and thus choose debt contracts without

[8] We extend Heidhues and Kőszegi (2010) to incorporate default and better gauge the magnitude of cross-subsidization and its welfare effects.



(a) No pooling

(b) Pooling

Figure 2.7: Effects of default costs on average fee choice.

fees ($\phi = 1$). This leads to a situation without cross-subsidization since sophisticates can only profit from the presence of naïves if the lender expects additional revenue from fee payments. If, in contrast, default is costless, only a small amount of debt can be sustained at very high interest rates. Now, sophisticates can profit from higher fee choices to reduce the amount of interest payments.

Figures 2.7 and 2.8 show the effects of different levels of default on average fee choice and excess interest payments. To that end, we interpolate between zero default cost and prohibitively high default cost. Default cost have two components: the fraction of garnished income γ and the utility cost χ. Costless default corresponds to $\gamma = \chi = 0$, while in the benchmark we set $\gamma = 0.15$ and $\chi = 1.5$ which leads to an average default rate of 1.15%. Prohibitively high default costs are $\gamma = 1$ and $\chi = 1,000$.

Figure 2.7a shows the effects of higher defaults costs on average fee choice in an economy without pooling where there is no interaction between sophisticated and naïve households. We can see how both choose contracts with high fees if default is costless. This happens because only a small amount of debt can be sustained in equilibrium and relative to the level of borrowing interest payments are higher than the expectations of possible fee payments. Because of limited commitment to repay debts, lenders can expect to sometimes profit from the decisions naïves make and hence offer contracts with low interest rates and high fees. Since naïves underestimate their proneness to mistakes, they choose high fees to benefit from the low interest rates. Sophisticates, in contrast, understand that lower interest rates come with the risk of high penalty fees and thus always accept lower fees than naïve consumers. Since there is no cross-subsidization

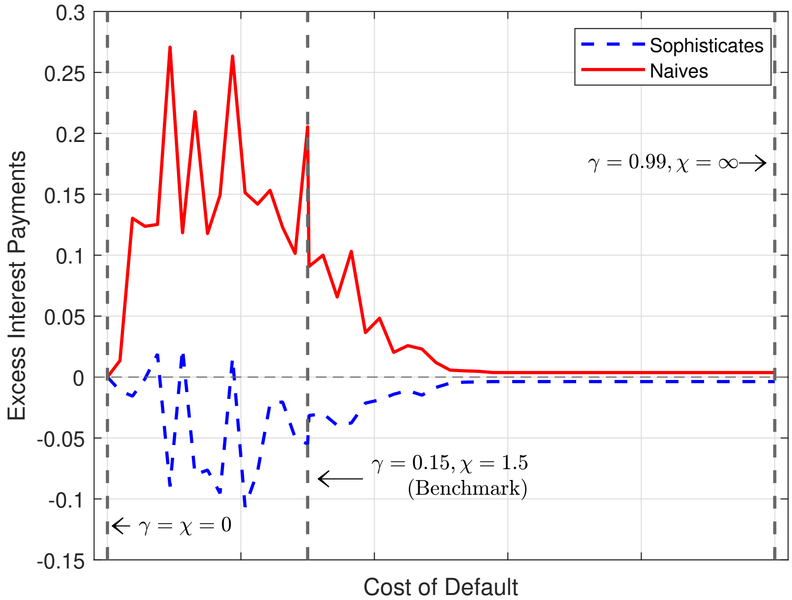


Figure 2.8: Difference in interest payments between mixed and isolated economy

without pooling, sophisticates don't profit from higher fees chosen by naïves. As the costs of filing for bankruptcy are increasing the average chosen fees decrease, since costly default translates to higher risks associated with higher fees.

Figure 2.7b again shows the effects of changing default costs, but here sophisticates and naïves are pooled and face the same contracts. One striking difference to Figure 2.7a is that now sophisticates always choose contracts with higher fees than in the separating economy, exposing themselves to higher costs associated with financial shocks. Due to pooling, however, sophisticates can profit from these contracts. Also, note how higher default costs again lead to a decrease in average fee choice. If default becomes so costly that nobody wants to file for bankruptcy anymore the average chosen fee in the economy even drop to 1, meaning that consumers want to insure against financial shocks. Agents ensure that unexpected financial costs cannot lead to a situation in which they cannot repay and have to default.

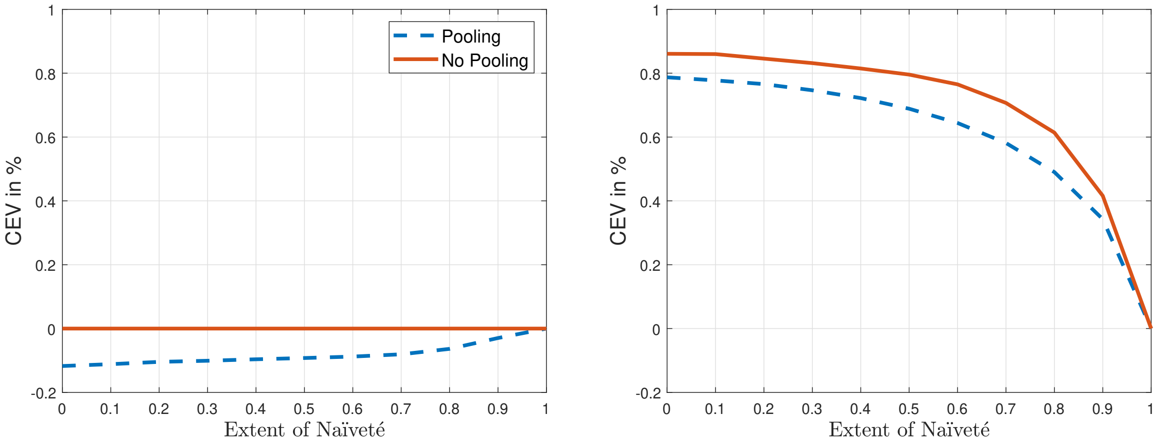
The effect of default costs on cross-subsidization is depicted in Figure 2.8. It plots the costs of default against the excess interest payments compared to an economy without pooling, taking as given the penalty fee choices discussed before. We can see that as long as there is default in the economy, naïves cross-subsidize sophisticates. This supports the idea that sophisticates choose higher fees when pooled together with naïves only to profit from the lower interest rates. If default becomes too expensive, average penalty fees drop sharply and cross-subsidization all but vanishes. Thus, cross-subsidization crucially hinges on the occurrence of default in equilibrium. In a model with a continuum of credit contracts that trade off interest rates for penalty fees, naïve agents would otherwise self-insure against their perceived risk of mistakes and break the cross-subsidization between them and sophisticates.

2.5 Policy Experiments

Policy makers often pass legislations to reduce the likelihood that financial mistakes occur (e.g. standardized language, information requirements or transparency rules for contracts). Such policies have not been studied in previous quantitative models, because they have no effect on perfectly informed rational agents. In the model, however, we can easily simulate such policies by scaling the extent of naïveté, i.e. reducing the difference between the likelihood of financial shocks of sophisticated and naïve consumers. Another policy which is easily studied within our framework is imposing a limit on possible fee charges. In the following we therefore discuss these two policies and assess them in terms of their effects on welfare which is calculated as consumption equivalence relative to the benchmark. Also, we always compare our benchmark economy, where naïve and sophisticated borrowers are pooled together, with a hypothetical economy in which markets are separated and lenders can offer different contracts to naïve and sophisticated borrowers. This enables us to disentangle the direct effects these policies might have on consumers from the effects on cross-subsidization.

2.5.1 Transparency Requirements

Credit market regulations and legislations which are aimed at reducing the likelihood of financial shocks by making contracts easier to understand should have an effect on naïve consumers, since they will become better at understanding the true underlying risks they are facing. Sophisticated consumers, in contrast, will not be affected since they are already aware of the true risks. Hence, we model an improvement in the transparency of financial contracts as a reduction in the spread between the probabilities of financial shocks of sophisticates and naïves. With ψ denoting this spread as defined in Equation 2.7, we



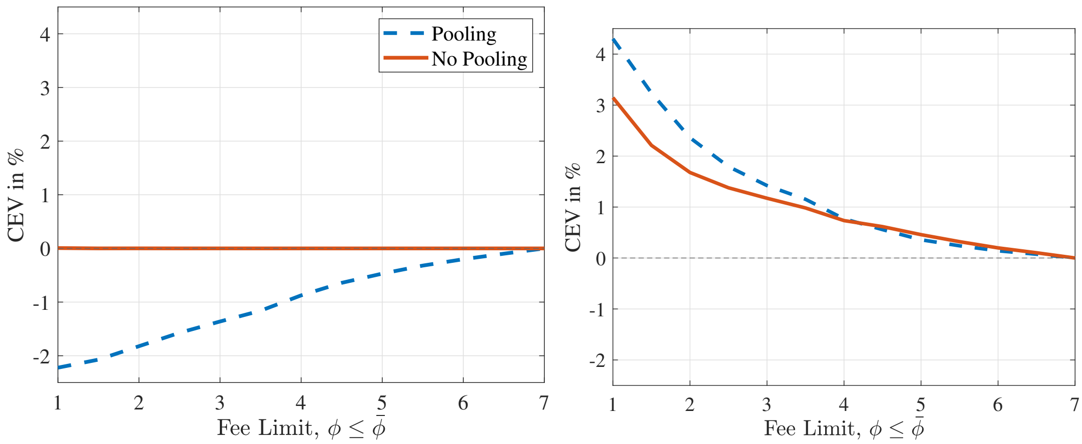
(a) sophisticates (b) naïves

Figure 2.9: Welfare Effects of Fewer Mistakes.

vary the extent of naïveté by scaling down $(\psi - 1)$, such that an economy with 0 naïveté corresponds to a spread of $\psi = 1$, meaning that naïves now face exactly the same shocks as sophisticates. The results of this experiment are shown in Figure 2.9, where welfare is given as consumption equivalence (CEV) relative to the benchmark in percent.

Focusing first at Figure 2.9b shows that the effect of improving the transparency of financial contracts is unambiguously positive for naïves, whose welfare in terms of consumption equivalence can be improved up to nearly 1%. Also, note that these welfare gains rise sharply at the beginning, while becoming flatter as transparency reaches the optimal level. Improving transparency by only 30%, for example, already leads to welfare gains between 0.6% and 0.7% in CEV. Further improvements, however, only lead to slightly higher welfare gains. Furthermore, comparing the effects of transparency requirements in the pooling equilibrium to an equilibrium with separated contracts reveals that welfare gains are always higher for naïves when they are operating in separated markets. In the pooling equilibrium some of their welfare gains are counteracted by the cross-subsidization of sophisticates.

Looking at Figure 2.9a shows that the effects of higher transparency requirements have vastly different effects on sophisticates depending on being in an economy with or without naïves. The policy has no effect in the economy without pooling, since lenders can perfectly distinguish between sophisticated and naïve borrowers. Sophisticated borrowers have already considered their true risks when deciding on a credit contract and thus, their decisions are unaffected by the extent of naïveté, because banks do not change



(a) sophisticates (b) naïves

Figure 2.10: Welfare effect of fee limits. Benchmark: $\bar{\phi} = 7$.

their offers to sophisticates. Looking at the pooling equilibrium, in contrast, reveals that sophisticates are hurt by the new policies when they are in an economy with naïves. Since improved transparency of financial contracts reduces the revenue banks can expect from fee payments from naïve borrowers, sophisticates lose some cross-subsidization on their interest payments. Hence, a legislation aimed at reducing the likelihood of financial mistakes will help naïves while hurting sophisticates, meaning that overall welfare effects are ambiguous and depend on the fraction of naïves in the economy.

2.5.2 Limiting Fees

Another possible intervention by policy makers concerns restrictions on the maximum amount of fees which can be charged for financial mistakes. Again, such policies can easily be simulated within our model by imposing an upper bound $\bar{\phi}$ on possible fees ϕ.

The results of such policies are shown in Figure 2.10 which plots the effects on welfare of a variety of different fee limits, $\bar{\phi}$, on possible credit contracts. Again, the effects are calculated for an economy with and without pooling and measured as consumption equivalence relative to the benchmark in percent.

Focusing first on Figure 2.10a we can see that a limit on fees has no effects on sophisticated borrowers in an economy without pooling. Since sophisticates already like to insure themselves against the risk of financial mistakes, they are not affected by restrictions. However, if sophisticates are pooled together with naïves, the effects of an upper bound become strongly negative, up to a welfare loss of 2% CEV. This is because lower fees also lower the unexpected payments of naïves and consequently, lenders have to offer higher interest rates when compared to the benchmark economy in order to keep the same expected revenue as before. Hence, sophisticates lose cross-subsidization and end up paying more for their credit then in the benchmark economy.

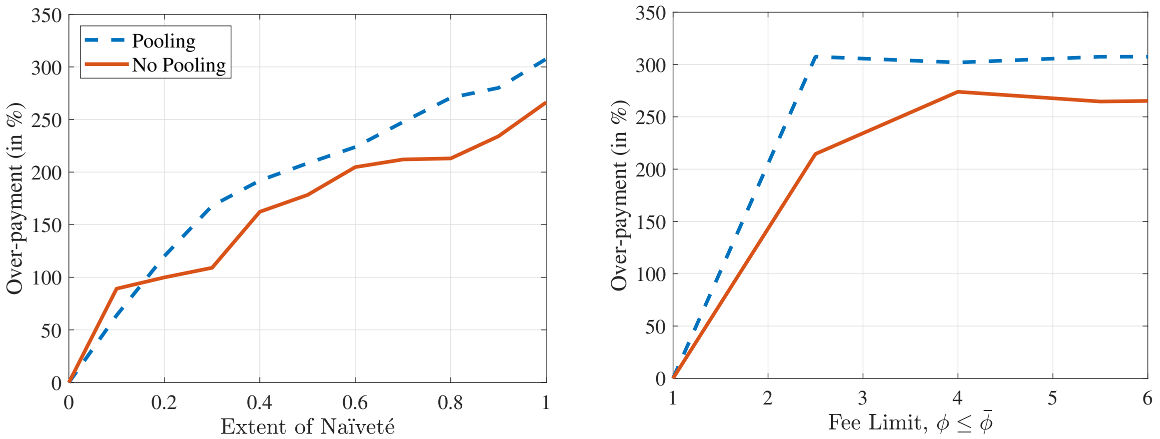
Turning to Figure 2.10b we see that while the effects of a fee-limit are unambiguously positive for naïves, they profit relatively more if they are pooled together with sophisticates than if they face separated contracts. This is because in the pooling equilibrium naïve borrowers are also cross-subsidizing lower interest rates for sophisticates. With tighter fees naïves are not only profiting from better insurance against financial shocks, but also from less cross-subsidization. In the separated economy, in contrast, naïves are simply profiting from the fact that upper bounds on fees reduce the size of their potential mistakes. Stricter fee limits force them to choose credit contracts which are closer to the optimal contracts which they would choose if they knew their true risks.

Lastly, comparing Figure 2.10a and Figure 2.10b shows that welfare effects are evolving at different rates for sophisticated and naïve consumers. While the loss of welfare for sophisticates is nearly linear in the fee limit, welfare gains for naïves rise slowly at first but very sharply at tighter limits. The overall welfare effects of such a policy therefore crucially depend on the specific choice of the fee limit. For example, prohibiting all contracts with possible fee choices above $\phi = 4$ leads to comparable losses for sophisticates and gains for naïves (about -1% CEV vs $+1\%$ CEV, respectively). When the limit is lowered even further, however, the gains of naïves quickly overtake the losses of sophisticates.

2.5.3 Policy Interventions and Costs of Mistakes

We have shown that both policies are successful at making naïve borrowers better off. However, policy makers might not only care about improving overall outcomes but also about helping naïve borrowers avoid mistakes. We therefore analyze the effects of different policies on the average size of mistakes of naïve borrowers. Mistakes are measured as the amount by which the expected total costs of a chosen credit contract exceed the expected costs of the optimal contract (cf. Equation 2.9 and Figure 2.5 in subsection 2.4.1).

Figure 2.11 shows the change in average financial mistakes (i.e. the average overpayment in percent) of naïves for both policies presented in Section 2.5, reducing the



(a) Improving transparency requirements

(b) Imposing fee limit

Figure 2.11: Policy effects on average size of over-payment by naïves.

likelihood of financial shocks or limiting fees. In the extreme case of completely avoiding mistakes – either by directly abolishing naïveté or by prohibiting lenders to charge any fees – the cost of mistakes is zero.

However, improving transparency of financial contracts and thereby reducing the extent of naïveté in the economy (see Figure 2.11a) is more effective than limiting fees (see Figure 2.11b). While the average over-payment falls steadily with the extent of naïveté in the economy, it remains relatively constant with lax fee limits and only decreases if the limit becomes very tight. For example, reducing naïveté in the economy by 40% leads to a decrease in average over-payment of about 30% (from 300% to 200%). To achieve the same improvement in the average mistake through fee limits requires a reduction in the maximum fee of 60%. This suggests that imposing a limit on possible fees is not as effective at reducing mistakes due to Naïveté as is working to reduce the shock itself.

Lastly, note that average mistakes are always lower in the hypothetical separated economy. This does not mean that naïves are necessarily better off if they are not pooled together with sophisticates. It merely shows that the difference between the optimal contract and the contract which was actually chosen is smaller in a separating economy than in a pooling economy. This happens because contracts in the separating economy exhibit higher fees than in the pooling economy, since lenders do not have to account for the choice of sophisticates. Hence, the optimal contract in this separated world will yield higher expected costs than the one in the pooled economy, thereby lowering the difference to the actually paid costs.

2.6 Conclusion

We propose a novel quantitative theory of Naïveté in the credit market. We incorporate Naïveté in a standard framework of unsecured credit and equilibrium default. The model gives rise to policy interventions as naïve borrowers misunderstand their contracts and make financial mistakes. In equilibrium, they pay high penalty fees that benefit sophisticated borrowers through cross-subsidized interest rates.

We find that the 2009 CARD Act tackles two important dimensions of financial mistakes. Firstly, it makes contracts easier to understand and thereby reduces financial mistakes. Through the lens of our model, the welfare effects of such a policy are ambiguous as sophisticated consumers are hurt by higher interest rates, while naïves make less mistakes. The overall welfare effect therefore crucially hinges on the fraction of naïve consumers in the economy.

Secondly, the CARD Act limits the amount of penalty fees that lenders can charge. This limit has a clear and considerably positive impact on naïve borrowers. They are forced to accept contracts with lower fees, which also lowers the size of potential mistakes from wrong contract choices. Hence, by banning high-fee contracts that naïves might have otherwise wrongfully chosen, the limit insures them against their future risks, while they themselves would not have done so. Sophisticates, in contrast, are again hurt by such a policy. By reducing the possible size of mistakes made by naïves, cross-subsidization of lower interest rates is also reduced and sophisticates end up paying more for their credit than in the benchmark economy. Also, the welfare gains of naïves and losses of sophisticates rise at different rates. Hence, the overall welfare effects of such a policy can be highly ambiguous and not only depend on the fraction of naïves in the economy, but also on the tightness of the limit.

Lastly, comparing the effects of these two policies on the size of the mistakes made by naïve consumers, we find that transparency requirements are more effective as sizable results are more easily achieved. Also, in light of the welfare effects, transparency requirements seem to have a less strong negative impact on sophisticates. Hence, while limiting fees might be the easier policy, improving the language used in financial contracts and raising standards for transparency and information requirements seems to be the better solution.

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Appendix

Computational Solution Method

The consumer optimization problem described in Equation 2.4 and Equation 2.5 is solved numerically in MATLAB R2021b by using value function iteration on the discretized state space given by $S = \mathcal{E} \times \mathcal{A} \times \mathcal{F} \times \mathcal{N} \times \mathcal{Z} \times J$. Where $\mathcal{E}$ is the set of possible financial shocks ε, $\mathcal{A}$ the set of asset holdings, $\mathcal{F}$ the set of fee payments, $\mathcal{N}$ the realizations of the transitory shock to labor productivity, $\mathcal{Z}$ the realizations of persistent labor productivity, and J the life-span of agents. The stochastic process for persistent productivity $\mathcal{Z}$ is discretized by using Rouwenhorst's method as described in Kopecky and Suen (2010) and the transitory white noise is discretized into 3 values (negative, zero, positive).

The households' decision problem is solved by backwards iteration on the value function. The decision problem has to be solved only for sophisticates, since naïves do not realize their Naïveté and make the same decisions as sophisticates given they are in the same state. At any period t, the lender knows the decisions of households at time $t+1$ for any given state s_{t+1}. Hence, prices for credit contracts at time t for a given state s_t are computed by forming an expectation over the household's decision in period $t+1$, where the lender internalizes the probability of dealing with a naïve. This expectation is given in Equation 2.6.

Paternalistic Welfare. To analyze the financial mistakes made by naïves and compute the resulting welfare loss, we compare the decisions of naïves with the decision which is made by a hypothetical informed agent. This informed agent solves the consumer optimization problem as described in Equation 2.4 and Equation 2.5, but forms expectations with regards to the real process of financial shocks, $\tilde{\mathbb{E}} = \mathbb{E}(\varepsilon_N)$, instead of believing to be prone to the same process as sophisticates (i.e. $\tilde{\mathbb{E}} = \mathbb{E}(\varepsilon_s)$). The resulting value function is called the paternalistic welfare (the decision is not made by the naïve but by an informed paternalistic figure) and allows to compare life-time utility between naïve and informed decisions.

Separating Equilibrium. To disentangle the direct effects different policies might have on consumers from the effects on cross-subsidization we compute hypothetical equilibria for separated markets in which lenders can offer different contracts to naïve and sophisticated. The numerical solution method is still the same. However, we now need to solve the households' decision problem separately for naïves and sophisticated, since they might face different prices for borrowing (while naïves still form expectations over the same process for financial stocks as sophisticates). From the lender's perspective, the profit maximization is also split into two separated calculations: one with forming expectations over next period's decisions when being sure to deal with a sophisticate, and one with forming expectations over next period's decisions when being sure to deal with a naïve. This yields potentially differing bond prices q_S and q_N for both types of agents and eliminates cross-subsidization.

Chapter 3

The Distributional Effects of Tax Evasion

This paper investigates the aggregate and distributional effects of tax evasion using a general equilibrium model with heterogeneous households. In the model, households invest in their own businesses and pay capital gains taxes on realized gains. However, these capital taxes can be evaded by under-reporting the real tax base, which bears the risk of being detected and having to pay a punishment fee. The model parameters are first calibrated to Scandinavia to exploit the rich estimates on tax evasion for Scandinavia and is then taken to the US. The benchmark economy exhibits high wealth inequality as reported for the US and leads to a realistic evasion behavior. The findings suggest that if individuals can try to evade some of their tax payments, wealth inequality is higher under a tax regime with positive capital gains taxes. Moreover, a counterfactual analysis shows that replacing capital gains taxes with a general tax on wealth could potentially enhance welfare.

JEL Codes: E21, E22, E62, H21, H26.

Keywords: Capital Gains Tax, Tax Evasion, Rate of Return Heterogeneity, Wealth Inequality, General Equilibrium

3.1 Introduction

The taxation of capital has always been a widely debated topic among both academics and policy makers, and often fuels public discussions. Proponents of capital taxation have brought up many reasons to support their arguments. First, the observed rise in the inequality of wealth makes redistribution based solely on labor income taxation a fruitless task. Wealth holdings can be passed on to newer generations through inheritances, and the heterogeneity in returns on capital investment benefits a relatively small group of highly productive entrepreneurs. These observations lead to substantial differences in wealth and capital holdings between workers with the same labor income and drastically reduce the power of labor income taxation as an instrument of redistribution. Also, high marginal tax rates on labor income could potentially lead to higher distortions than moderate taxes on capital, if saving and physical investment are exceedingly more profitable than supplying labor and accumulating human capital. Lastly, high wealth and capital income can also be the result of circumstances which lie outside of individual control. Inheriting large amounts of wealth or the ownership of a highly productive enterprise are not linked to individual productivity. Also, sometimes luck can play an important role in the rapid growth of capital investment. In these cases, arguments in favor of capital taxation revolve around the need for a tool to balance such vastly different initial conditions.

Proponents of a tax-free capital market, in contrast, mostly cite two main reasons why capital taxation would lead to adverse effects on the economy: The discouragement of saving and the mobility of capital, both of which could drastically reduce the capital stock and harm the economy. A rarely discussed aspect, however, is the possibility of avoiding or evading tax payments through legal and illegal measures. While recent developments and the emergence of leaked micro-date have shown the efforts undertaken by some wealthy individuals to reduce their tax burden, the academic literature mainly considers perfect tax compliance, which has serious implications for studies on optimal taxation.

Hence, the aim of this paper is to shed light on two important questions which have been neglected in the macroeconomic literature so far: What are the consequences of tax evasion on the aggregate economic outcomes? And should capital be taxed if the rich have access to the means of evading their tax payments while the poor do not?

These questions are not easily answered and while the quantitative literature concerning capital taxation is constantly growing, the role of tax evasion has not yet been studied. This seems particularly pitiable given the growing evidence of its empirical relevance. Aaron and Munnell (1992), for example, find that in the U.S. resources spent to avoid wealth transfer taxes are of the same magnitude as the yield. Furthermore, recent micro-data leaked from offshore financial institutions[1] proved once more how widespread the desire to avoid tax payments seems to be, especially among the very wealthy. Alstadsaeter et al. (2019) combine these micro-data with random audits to estimate that the wealthiest households in Scandinavia evade about 25 percent of their tax obligations. Apparently, the use of legal and illegal measures to reduce the tax burden is a predominant problem among the very rich. Similarly, Seim (2017) shows that the behavioral responses to a wealth tax in Sweden are mostly driven by evasion and avoidance rather than by changes in savings. In fact, households seem to only react in real terms if avoidance and evasion opportunities prove limited.

These findings have significant effects on our understanding of the role of capital taxation. In the past, the seminal contributions by Judd (1985) and Chamley (1986) have led to the general opinion that capital income should not be taxed in the long run. This result, however, has since been contested and shown to be invalid under different modeling choices. If consumers face tight borrowing constraints and are subject to uninsurable idiosyncratic risks, for example, the optimal tax system should include strictly positive capital gains taxes (Aiyagari, 1995). More studies trying to assess the optimal tax on capital have since emerged, but none takes into account the distorting effects of tax evasion. In light of the growing empirical evidence of its prevalence, as discussed above, this could result in misleading conclusions about actual economic consequences.

Hence, discussions about optimal tax systems should also incorporate the effects of tax evasion. Since it seems unlikely that evasion opportunities will cease to exist in the near future, neglecting their existence leads to economic models whose policy implications are highly implausible. First, tax evasion among the very rich has considerable effects on the distribution of wealth, which should be reflected in our models. Second, in a framework of consumer heterogeneity and incomplete markets the aggregate implications of tax evasion involve general equilibrium effects on wages and interest rates, which could drastically

[1]The most prominent being the HSBC Switzerland, the so-called "Swiss Leaks", and Mossack Fonseca, for which the term "Panama Papers" has been coined by the media.

change the quantitative results. Therefore, how to design an optimal tax system does not only depend on the objective of the government, but also on the behavioral responses of the households.

Consequently, this paper aims to incorporate this dimension and to re-evaluate the effects of capital taxation from this point of view. The analysis is conducted in the context of a quantitative model populated by infinitely lived households, who make decisions about labor supply, investment in intermediate goods and tax evasion and are subject to uninsurable idiosyncratic risk. The government raises revenue by taxing consumption, labor income and realized capital gains and uses a progressive labor tax schedule to redistribute between richer and poorer households. Tax evasion is only relevant for capital taxes, as individuals can decide how much of their assets they want to declare. The government randomly audits households to find out the true tax base and punishes individuals who are found evading some of their tax payments. For simplicity, the punishment only consists of a pecuniary penalty, while in reality evading a certain amount of taxes might even be punished with jail. However, the non-pecuniary costs are captured in a specification of the disutility of tax evasion. Following the theoretical literature (e.g. Sandmo 2005), this disutility is modeled as an increasing and convex function, which can be thought of as the effort needed to hide the true tax base from the government or as social costs due to moral considerations or due to the associated negative stigma after being caught.

The rest of this paper is organized as follows. The next subsection elaborates on the literature related to this work. Section 3.2 describes the full model setup and the definition of a competitive equilibrium. Section 3.3 then discusses the parameterization of the model and the calibration to jointly targeted moments while section 3.4 discusses the performance of the benchmark model. Section 3.5 then describes several policy experiments regarding the distributional effects of tax evasion and the optimal tax rates. Finally, section 3.6 concludes.

3.1.1 Related Literature

This project contributes to different strands of the economic literature. First, it relates to the existing studies on capital taxation. A comprehensive review of the broader literature is out of the scope of this section, but Chari and Kehoe (1999) or Golosov et al. (2006) provide useful surveys. This work is most closely related to the quantitative literature which uses incomplete markets frameworks in which the famous results by Atkinson and Stiglitz (1976) and Judd (1985) and Chamley (1986) about zero capital taxation no longer hold. Among others, Aiyagari (1995) showed that a strictly positive tax on capital income is optimal in the presence of uninsured idiosyncratic risks and tight borrowing constraints. Similarly, Erosa and Gervais (2002) find that taxing capital is desirable in life cycle models, if explicitly conditioning the tax code on the age of the household is not possible. Other studies include Conesa et al. (2009), who employ an overlapping generations model to calculate an optimal capital income tax rate of 36 percent. Kitao (2010), in contrast, studies the implications of a capital income tax that is negatively correlated with labor supply and finds that such a scheme would improve long-run welfare. Lastly, using a model which features heterogeneous returns to capital, Guvenen et al. (2023) find the optimal tax on net wealth to be strictly positive. There are, however, no quantitative papers which incorporate the means to evade tax payments into their models.

Second, this project builds on the empirical and theoretical literature on tax evasion. The importance of resources being spent in order to reduce tax payments has already been pointed out in the past. Aaron and Munnell (1992) report that overall compliance costs of the wealth transfer tax system in the U.S. are almost as high as the yield and similar findings are reported by other studies. Brülhart et al. (2016) and Seim (2017) use evidence from Switzerland and Sweden to show that responses to wealth taxes are mostly driven by behavioral responses, while real decisions like savings remain unchanged. A more comprehensive look at actual tax evasion is provided by Alstadsaeter et al. (2019). The authors combine stratified random audits and new micro-data leaked from offshore financial institutions to analyze the behavior of Scandinavian households. In combination with administrative wealth records they can show that offshore tax evasion is highly concentrated at the top, implying that the wealthiest households evade about 25 percent of their tax payments. This project connects these empirical findings with the quantitative literature discussed above, thereby bridging two important economic topics.

To incorporate tax evasion in my framework, I draw from the theoretical formulations which started with the seminal work of Allingham and Sandmo (1972), who provide a natural starting point with their simple yet useful model of underreported income.

Several extensions of their formulation have since been studied, but the basic concept remained generally unchanged (see, e.g, Yitzhaki 1974, 1987, Scotchmer and Slemrod 1989, Andreoni et al. 1998, Sandmo 2005 or Alm 2012).

Lastly, this project borrows heavily from the quantitative literature on wealth inequality in the spirit of Aiyagari (1994). The model framework with heterogeneous agents and incomplete markets leads to heterogeneity in endogenous choices due to exogenous differences between households and hence enables economists to replicate inequality in economic outcomes. Since tax evasion seems to be highly prevalent among the very rich, reproducing a skewed wealth distribution is important for talking about relevant policy implications of capital taxation. Nowadays, there exist several papers which employ dynamic quantitative models to reproduce highly skewed wealth distributions. Among the most influential mechanisms are the introduction of uninsured idiosyncratic risk and aggregate saving by Aiyagari (1994), voluntary bequests and the transmission of human capital (e.g. De Nardi 2004) and out-of-pocket medical expenditures as an additional source of future uncertainty (Hubbard et al. 1994).

This paper, however, is especially influenced by the literature on heterogeneity of returns to capital, since this mechanism has been shown to have strong implications for the desired level of capital taxation. Empirically, Fagereng et al. (2020) find strong evidence that differences in rates of returns are large and persistent across households. In this regard, another important factor for modeling wealth inequality is the role of entrepreneurship as noted by Quadrini (1999) and several studies have been able to simulate highly skewed distributions of wealth by explicitly modeling entrepreneurial ability. In the models by Quadrini (2000) and Cagetti and De Nardi (2006) return heterogeneity results from productivity differences in the entrepreneurial sector. Furthermore, Guvenen et al. (2023) developed a model that can match some important features of the U.S. wealth distribution by including an additional sector for intermediate goods. This paper uses similar modeling frameworks and solution methods but adds to the existing literature by incorporating behavioral responses, which allows for quantifying the aggregate and distributional consequences of tax evasion.

3.2 The Model

I study a general equilibrium model with infinitely lived households and two sectors of production, one for intermediate goods and one for the final goods production. To reproduce a highly skewed wealth distribution I include high returns to investment for entrepreneurial activity in the intermediate goods sector following the specification by Guvenen et al. (2023). Households supply labor and can decide how much to invest in intermediate goods production. The government raises revenues through various taxes and uses a progressive labor income tax for redistribution. Furthermore, households can try to evade parts of their capital gains taxes and then face an additional uncertainty due to the possibility of being detected.

3.2.1 Households

The economy is populated by infinitely lived households of measure 1 and without population growth. The model period is one year long and households derive utility from consumption, c, and disutility from supplied working hours, h. However, per period utility is also affected by the fraction of evaded taxes, e. This approach follows a strand in the theoretical literature on tax evasion, which found that realistic evasion behavior cannot be explained with punishment fees only and therefore introduced a disutility of evasion (e.g. Sandmo 2005).

Households then maximize expected lifetime utility:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, e_t) \right\}$$

where $\beta < 1$ is the time discount factor.

Furthermore, households differ in labor productivity and entrepreneurial skill, both of which follow a stochastic process. Every period households decide how much labor to supply to the final goods production, how much to invest in intermediate goods production, what fraction of taxes owed to evade and how much to consume. I now describe the skills which govern these decisions and the production technologies and then spell out each of the four decisions in more detail.

Entrepreneurial Productivity

To match the high concentration at the top of the wealth distribution I model return heterogeneity as in Guvenen et al. (2023). Let θ_t denote the entrepreneurial productivity of a given individual at time t. There are two different components to θ_t: $\bar{\theta}_t$ denotes the 'permanent' component, while Θ_t denotes the 'life-cycle' component. The permanent ability changes with probability π (on average every generation) and according to an AR(1) process, that is

$$\log(\bar{\theta}_t) = \begin{cases} \log(\bar{\theta}_{t-1}) & \text{with probability} \quad 1-\pi \\ \rho_\theta \log(\bar{\theta}_{t-1}) + \varepsilon_\theta & \text{with probability} \quad \pi \end{cases}$$

where ε_θ is an iid normal innovation with mean zero and variance σ_θ^2. Also, note that in this specification $\bar{\theta}_{t-1}$ can be thought of as the ability of the parent, since permanent skills change on average every generation. This might lead to a situation in which an individual with high (low) entrepreneurial ability transitions to a state of low (high) productivity, thereby mimicking a situation in which unsuccessful children inherit a large amount of wealth from their successful parents and vice versa.

The second component of entrepreneurial ability, Θ_t, captures the possibility that skills can be augmented with or hampered by external factors. As in Guvenen et al. (2023), I therefore allow individuals with permanent ability $\bar{\theta}_t$ to be in different phases of productivity, characterized by a three-state Markov chain that can take on the values high, low and zero: $\Theta_t \in \{\mathbb{H}, \mathbb{L}, 0\}$ with the transition matrix $\Pi_\Theta \in \mathbb{R}^{3x3}$ given by

$$\Pi_\Theta = \begin{pmatrix} 1-p_1-p_2 & p_1 & p_2 \\ 0 & 1-p_2 & p_2 \\ 0 & 0 & 1 \end{pmatrix}$$

Overall, entrepreneurial skill is then determined by:

$$\theta_t = f(\bar{\theta}_t, \Theta_t) = \begin{cases} (\bar{\theta}_t)^\omega & \text{for} \quad \Theta_t = \mathbb{H} \\ \bar{\theta}_t & \text{for} \quad \Theta_t = \mathbb{L} \\ 0 & \text{for} \quad \Theta_t = 0 \end{cases}$$

with $\omega > 1$. Finally, individuals who transition to a permanent ability above the median level, i.e. $\bar{\theta}_t > \bar{\theta}_{med}$, immediately enter the high state of productivity, $\Theta_i = \mathbb{H}$. This is done to model the fact that many individuals who are extremely wealthy go through a very high growth phase especially in the early stages of their business, followed by a slowdown as their business matures or their competitors catch up.

This stochastic variation in productivity allows for a more realistic calibration of the model to the wealth dynamics of the very wealthy and it provides an additional precautionary savings motive for individuals. As shown by Guvenen et al. (2023), the model falls short in matching some key wealth moments without this stochastic component.

Labor Productivity

Households decide how much labor to supply to the final goods producing sector. At a given point in time individuals differ in their labor productivity y_t, which evolves according to an AR(1) process:

$$\log(y_t) = \rho_y \log(y_{t-1}) + \varepsilon_y,$$

where ε_y is an iid normal shock with mean zero and variance σ_y^2. Hence, total labor supply is given by Let $h(a, y, \theta)$ denote the labor hours supplied to the market by an individual in state $s = (a, y, \theta)$ and let $\Phi_t(a, y, \theta)$ be the distribution over households at time t. Aggregate labor supply for period t is given by

$$L_t = \int y h(a, y, \theta) \, \mathrm{d}\Phi_t(a, y, \theta) \tag{3.1}$$

The equilibrium wage rate w is determined in the competitive final goods producing sector and a given individual's labor income at time t is then given by $w y_t h_t$.

3.2.2 Technology

There are two sectors of production in the economy: The final goods producer and producers of intermediate goods. The final good X is produced according to a Cobb-Douglas technology:

$$X_t = Q_t^{\alpha} L_t^{(1-\alpha)}, \tag{3.2}$$

where L_t is aggregate labor supply and Q_t is the effective capital stock composed of intermediate inputs x. The intermediate inputs are produced by entrepreneurs who decide to invest capital k. The production function is linear and given by

$$x(a,\theta) = \theta \cdot k(a,\theta), \tag{3.3}$$

where $k(a,\theta)$ is the amount of capital invested in the production by an individual with assets a and entrepreneurial skill θ. The effective capital stock then consists of these intermediate inputs by a CES relationship:

$$Q_t = \left(\int x(a,\theta)^{\nu} \, \mathrm{d}\Phi_t(a,y,\theta) \right)^{1/\nu} \tag{3.4}$$

Capital for intermediate production can be borrowed or lent to another entrepreneur at the risk-free rate r in a one-period bond market. However, borrowing constraints are imposed to capture some frictions that are not modeled explicitly. As in Guvenen et al. (2023), I allow firms with higher productivity to borrow more. Formally, an entrepreneur with assets a can only borrow an amount of

$$k \leq \xi(\bar{\theta}) \cdot a$$

with $\xi(\bar{\theta}) \in [1, \infty]$. When $\xi(\bar{\theta}) = 1$ this would lead to an extreme borrowing limit, where individuals can only use their own assets in production. $\xi(\bar{\theta}) = \infty$, in contrast, would lead to an environment without any frictions and there would be no limit on the amount an entrepreneur can borrow. Also, capital depreciates at rate δ.

Lastly, the final goods producing sector is competitive and therefore prices of the intermediate goods (and hence the profits of the entrepreneurs) and the wage rate are determined by

$$p_t(x(a,\theta)) = \alpha x(a,\theta)^{\nu-1} Q_t^{(\alpha-\nu)} L_t^{(1-\alpha)} \qquad w_t = (1-\alpha) Q_t^{\alpha} L_t^{-\alpha} \tag{3.5}$$

3.2.3 Government

The role of the government is to raise taxes in order to finance transfers to low income households to ensure a certain level of consumption. The government has three instruments to finance these expenditures: Taxes can be imposed on consumption (τ_c), on labor income (τ_y) and realized capital gains (τ_a).

While taxes on consumption and capital income are flat, the tax on income is progressive. Following Bénabou (2002) and Heathcote et al. (2017), among others, the income tax function τ_y is defined by

$$\tau_y(y) = y - \lambda_0 y^{1-\lambda_1} \tag{3.6}$$

The parameter λ_1 then determines the degree of progressivity, while λ_0 shifts the tax function and determines the average level of taxation in the economy. This specification also allows for the modeling of government transfers, since every individual with an income below λ_0^{1/λ_1} will pay negative taxes.

The government runs a balanced budget at any time. Hence, it will choose the parameter λ_0 in a way that transfers to low income households are exactly offset by revenues from consumption taxes, labor income taxes, capital taxes and the punishment fees from detected evaders. Also, note that since there is a measure 1 of individuals, the fraction of detected evaders will be always the same in the stationary equilibrium.

3.2.4 Tax Evasion

Individuals face a tax rate on capital income of τ_a, but can decide to evade some of their tax payments. The evasion mechanisms are very simple in order to facilitate calibration and follow the intuition of the seminal formulation by Allingham and Sandmo (1972) and the comment thereof by Yitzhaki (1974). The government does not know the true tax base and individuals can try to lower it by understating their capital income. Hence, the tax authority must enforce compliance by randomly auditing taxpayers and imposing a penalty if someone is found evading. The enforcement policy is to audit taxpayers with an exogenous and publicly known probability $\phi \in (0,1)$, which is independent of the evaded amount. If the government audits a report, the true tax base becomes known and in the event of evasion behavior the convicted individual has to pay the loss of tax revenue and an additional punishment, ψ, proportional to the amount of evaded taxes.

Let a^T be the true amount of capital income subject to taxation and a^R the amount of capital reported to the government. Then $E = (a^T - a^R)$ denotes the amount by which the tax base is underreported. If the taxpayer is not subject to a random audit, her after tax capital gains are given by $a^T - \tau_a a^R = a^T(1-\tau_a) + \tau_a E$, which is $\tau_a E$ more than if the taxpayer would have been truthful and reported her whole amount of capital income. If an audit occurs, in contrast, the after tax capital is given by $a - \tau_a a^R - (\tau_a E + \psi \tau_a E) = a(1-\tau_a) - \psi \tau_a E$, which is $\psi \tau_a E$ less than if the taxpayer would have been truthful.

Disutility of evasion. If there are no other costs to evasion, the theoretical literature on tax evasion reports an empirical puzzle, where optimal tax evasion is way higher than what can be observed in reality (often even 100 percent). One way to resolve this puzzle is to introduce a disutility of tax evasion. Let therefore T denote the total amount of taxes owed and $e = \tau_a E/T$ the fraction of evaded taxes. Following Sandmo (2005) I now introduce a strictly increasing function $B(e)$, which represents the disutility of evasion. The per period flow of utility of a household is then given by:

$$u(c, h, e) = u(c, h) - B(e)$$

with $B'(e) > 0$ and $B''(e) > 0$.

The function $B(e)$ can be thought of as a measure of the non-pecuniary effort which is needed to evade a certain amount of taxes and hence naturally depends on the fraction of evaded taxes relative to taxes owed rather than the total amount. The insight for this becomes clear when we think about the differences in evasion between the wealthy and the poor. Trying to evade the same amount of taxes can be very different for different households depending on whether it is only a negligible part of taxes owed or already a sizable fraction of the tax base. Furthermore, note that the function $B(\cdot)$ can also be interpreted as the disutility resulting from a bad conscience or from a social stigma after being caught, as briefly discussed in Allingham and Sandmo (1972).

The Timing of Events. The decision to evade taxes is made at the end of the period and lowers the individual's tax base. Before taxes are levied, the government might detect the evasion and impose the punishment. This introduces an additional source of uncertainty in the household's optimization problem regarding next periods capital holdings. However, the government is myopic in the sense that it cannot detect evasion that has taken place in a previous period. Therefore, an individual who has been hiding some of her wealth and is not found evading by the government before the start of the next period does not have to worry about any repercussions thereafter. The timing of events is illustrated in Figure 3.1.

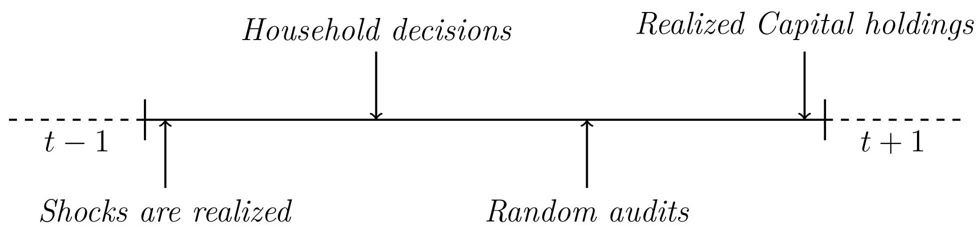


Figure 3.1: The timing of events in period t

3.2.5 The decision problem of the Households

For simplicity, time subscripts are dropped in the following subsection and next period values are denoted with a prime. At the beginning of each period the current ability levels are known with certainty, while next period's levels are uncertain. An individual starts the period with assets a, entrepreneurial ability θ, and worker ability y and decides how much to consume, how much labor to supply to the market and how much to invest in their own business. Furthermore, individuals can decide to lower their tax base by underreporting their capital income.

First, as an entrepreneur the individual wants to maximize her profits given by

$$\pi(k, \theta) = p(x(k, \theta)) \cdot x(k, \theta) - (r + \delta) \cdot k$$

with $p(\cdot)$ being the price of the intermediate good, $x(\cdot)$ the provided amount of that good, $\delta < 1$ the depreciation rate, r the interest rate and k investment.

This problem is static and can therefore be solved without considering the other decisions. Maximizing the expression with respect to invested capital and accounting for the borrowing constraint yields the solution

$$k(a,\theta) = \min\left\{\xi(\theta)a, \left(\frac{\nu\theta^{\nu}P}{r+\delta}\right)^{\frac{1}{1-\nu}}\right\} \tag{3.7}$$

with $P = \alpha Q^{(\alpha-\nu)}L^{(1-\alpha)}$. Note that maximized profits only depend on entrepreneurial ability θ and assets a and can therefore be denoted by $\pi(a,\theta) = \max\{\pi(k,\theta)|k \leq \xi(\theta)a\}$.

Also, let $\Phi(e)$ denote the change in capital holdings after a potential auditing has occurred, that is

$$\Phi(E) = \begin{cases} +\tau_a E & \text{if not audited} \\ -\tau_a E - \psi\tau_a E & \text{otherwise} \end{cases}$$

with E being the amount of underreported capital. Furthermore, for notational reasons it is convenient to denote with Y the after tax labor income

$$Y = wyh - \tau_y(wyh)$$

Then the individuals dynamic programming problem can be written recursively as:

$$V(a,y,\theta) = \max_{c,k,h,e,a'}\{u(c,h) + \beta\mathbb{E}[V'(a',y',\theta')]\} \tag{3.8}$$

$$\text{s.t.} \quad (1+\tau_c)c + a' = Y + a + [ra + \pi(a,\theta)](1-\tau_a) + \Phi(e) \tag{3.9}$$

$$a' \geq 0, \quad c \geq 0, \quad h \in [0,1], \quad e \in [0,1] \tag{3.10}$$

3.2.6 Equilibrium Definition

Let $s = (a,y,\theta)$ denote the vector of states of a given individual. The competitive stationary equilibrium is defined by the following conditions:

1. Given the risk-free interest rate r, pricing function $p(x)$ and wage rate w, the optimal decision rules $c(s)$, $h(s)$, $e(s)$ and $a'(s)$ solve the maximization problem for an individual in state s.

2. The solution in the competitive final goods producing market yields wage rate w and prices $p(x)$.

3. The measure of households over states $\Phi(a, s, \theta)$ is constant.

4. Given $\Phi(\cdot)$, r, $p(x)$, w and taxes τ_y, τ_a and τ_c

   - The markets clear:

$$\int a(s)\,\mathrm{d}\Phi(s) = \int k(s)\,\mathrm{d}\Phi(s)$$

$$L = \int yh(s)\,\mathrm{d}\Phi(s)$$

   - The government runs a balanced budget:

$$\int \tau_y(wyh(s))\,\mathrm{d}\Phi(s) + \int \tau_c c(s)\,\mathrm{d}\Phi(s) + \int \tau_a(ra + \pi(s))\,\mathrm{d}\Phi(s) + \int \phi\psi\tau_a E(s)\,\mathrm{d}\Phi(s) = 0$$

3.3 Parameterization

Since the aim of this paper is to analyze the distributional and aggregate consequences of tax evasion, the most important part is to pin down the relevant parameters. This is done by first calibrating the model to Scandinavia and using the estimates on tax evasion by Alstadsaeter et al. (2019). Then the model is taken to the US and recalibrated to match relevant moments, while the parameters for tax evasion remain unchanged.

Preferences. In the benchmark economy I assume an additively separable utility function:

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} - \chi\frac{h^{1+\gamma}}{1+\gamma} \tag{3.11}$$

Note that with this specification the Frisch elasticity of labor supply is given by γ^{-1}. As parameter for relative risk aversion for consumption I choose a standard value of $\sigma = 2$ following, among others, Conesa et al. (2009). The coefficient of labor supply is chosen to match a Frisch elasticity of labor supply of 0.7. This value has been reported by Hall (2009) and is a conservative estimate, since I abstract from external margins. The discount factor β and the parameter χ are then chosen to match a wealth-output-ratio of 2.7 and to produce average labor supply of 0.4, which requires $\beta = 0.944$ and $\chi = 12.01$.

Tax Evasion. The probability of being found evading in the model, ϕ, is not perfectly equivalent to audit rates in reality, because in the model audits are costless and immediately unveil the true tax base. Thus, the parameter is chosen to match the average amount of people who are found evading at least some of their tax payments per period. Alstadsaeter et al. (2019) report this to be 1.33 for Norway and this leads to $\phi = 0.022$.

Since it seems natural that evading one more unit would become harder, the higher the fraction of evaded taxes already is, the function $B(e)$ is assumed to be strictly increasing and specified as:

$$B(e) = \mu e^{\eta} \tag{3.12}$$

where η and μ are chosen to match an average tax evasion of 3% for the whole population and an average tax evasion of 9.19% among the wealthiest 10%, which leads to $\mu = 1.1$ and $\eta = 2.13$. Finally, pinning down the punishment rate ψ is not easy, since in reality tax

Table 3.1: Calibrated parameters

Directly specified parameters			
Parameter		Value	Source
CRRA consumption	σ	2	Standard
Frisch elasticity	γ	0.7^{-1}	Hall (2009)
Autocorr. labor efficiency	ρ_y	0.9	Guvenen et al. (2023)
Std. dev. labor efficiency	σ_y	0.2	Guvenen et al. (2023)
Autocorr. entrepreneurial skill	ρ_θ	0.1	Fagereng et al. (2020)
Capital income tax	τ_a	25%	McDaniel (2007)
Consumption tax	τ_c	7.5%	McDaniel (2007)
Income tax progressivity	λ_1	0.137	Holter et al. (2019)
Curvature of CES Prod. func.	ν	0.9	Guvenen et al. (2023)
Jointly calibrated parameters			
Parameter		Value	Target
Discount factor	β	0.944	$K/Y = 2.7$
Std. dev. entrepreneurial skill	σ_θ	0.11	Top 1% Wealth share
Leisure scale	χ	12.01	Avg. Hours = 0.4
Disutility of evasion	μ	3.7	avg. evas. 3%
	η	2.6	evas. of top 1%
Auditing rate	ϕ	0.022	Detecting 1.3%

evasion can also be punished with non-pecuniary penalties like imprisonment. However, the exact rate of the fee does not seem to change the quantitative results and was chosen to be 0.62.

Tax System. There are three different tax parameters to be chosen. Tax rates on consumption and capital gains are taken from McDaniel (2007), who reports $\tau_c = 7.5\%$ and $\tau_a = 25\%$. The parameter λ_1, which measures the rate of progressivity, is based on Holter et al. (2019) who find an estimated value for the US of 0.137.

Labor Productivity. Idiosyncratic labor productivity follows a simple AR(1) process, whose parameters are chosen to be $\sigma_y = 0.2$ and $\rho_y = 0.9$. This parameterization is standard in the literature and broadly consistent with different estimates.

Entrepreneurial Ability. As discussed in the model setup, the persistent part of entrepreneurial ability can be thought of as the transmission of skills from parents to children. Therefore, I set the persistence of the AR(1) process to $\rho_\theta = 0.1$. This value is taken from Fagereng et al. (2020), who document intergenerational correlation of individual-level average rates of return for Norway. The authors also show that despite the lower income inequality in Norway, the top wealth shares are very similar to those for the US. Therefore, while not being ideal, using Norwegian data still seems justifiable. The same argument is given by Guvenen et al. (2023) who also use this value for intergenerational persistence. The probability of a change in the persistent component, π, is set to 0.97 so that the average length of unchanged persistent skill is 30 years, which means that persistent productivity changes on average every generation.

The remaining parameter σ_θ^2 and the transition probabilities of the stochastic component of entrepreneurial ability are then calibrated jointly to match not only the wealth share of the top 1% but also the fraction of self-made billionaires, which Guvenen et al. (2023) calculate to be 54% for the US.

Financial constraints. As explained above, entrepreneurs face exogenous borrowing limits based on their permanent ability as in Guvenen et al. (2023). I discretize the distribution of $\bar{\theta}$ into 3 mass points using Rouwenhorst's method as described in Kopecky and Suen (2010) and set $\xi(\bar{\theta}_i) = 1 + 1.5(i-1)/3$. Note that since entrepreneurial activity is also subject to a stochastic component, the overall number of different skill levels is higher.

Production. The labor share is set to 0.64 by choosing $\alpha = 0.36$. Following Guvenen et al. (2023), the parameter ν in CES aggregator is set to 0.9. The authors report that the value of ν has only mild effects on the wealth distribution and the implications from the tax system up until a value of 0.75. For lower values the diminishing return for entrepreneurs makes matching the high skewness of the wealth distribution impossible.

Table 3.2: Jointly-Targeted Moments

	Target	Model
Wealth-to-output ratio	2.7	2.71
Average labor hours	0.4	0.39
Top 1% wealth share	0.36	0.36
Average evasion	3%	3%
Evasion of top 1%	9.2%	9.1%
Detected evaders	1.33%	1.30%

Note: The six parameters chosen to match these moments are $\{\beta, \chi, \sigma_\theta^2, \phi, \mu, \eta\}$. Values for evasion are compared to Scandinavia.

The depreciation rate δ of capital is chosen to be 0.05.

3.4 Benchmark

Before discussing the effects of tax evasion and how the heterogeneity in tax evasion affects the economy and the implications of capital taxation, this section describes the benchmark economy and how well the model does at matching relevant moments. In the following, I therefore present the outcome of the stationary equilibrium with the benchmark calibration as discussed in section 3.3 and show that is indeed a plausible description of the US economy concerning the most important dimensions.

First, Table 3.2 reports the targets of the calibration and compares the data moments with the model output. Note, however, that data concerning evasion is taken from Scandinavia, while the other moments correspond to the US. The model values of the wealth-to-output ratio and average labor supply are reasonably close to their empirical counterparts. Moreover, the share of wealth held by the top 1% and the average evasion in the economy are matched perfectly. Evasion at the top 1% of the wealth distribution and the fraction of caught evaders are slightly off, but still reasonably close.

Wealth Inequality. Turning to a more thorough comparison of the wealth distribution, Table 3.3 compares the share of total wealth held by different wealth groups in the US with the wealth shares in the model's stationary equilibrium. The wealth holdings of the

Table 3.3: Share of aggregate wealth held by the top x%

	US Data	Model
Top 0.1%	0.14	0.10
Top 0.5%	0.27	0.25
Top 1%	0.36	0.36
Top 10%	0.75	0.81
Top 50%	0.99	0.99
Wealth Gini	0.85	0.86

Note: Wealth shares are taken from Guvenen et al. (2023) who use data for the United States from Vermeulen (2018). The wealth Gini is based on the Global Wealth Report by Credit Suisse (2019).

top 1% have been target and thus match perfectly. The other values are slightly off, but still very close to their empirical counterparts. The model understates the wealth holdings at the very top of the distribution and overstates the wealth share of the top percentile. However, the wealth Gini simulated by the model is very close to the reported one for the US with 0.86 against 0.85. Overall, the model seems to do reasonably well in replicating the observed inequality in wealth.

An important empirical feature of the wealth distribution is its thick right tail and being distributed in a way that can be described by a Pareto distribution. This observation has been reported for many countries (see, e.g., Vermeulen 2018). Such a Pareto distribution cannot be generated by precautionary savings alone, as shown by Benhabib et al. (2017). Hence, matching some relevant moments is not sufficient in showing how well the model does at replicating the skewed wealth distribution. Figure 3.2 therefore plots the log-counter CDF of wealth against log wealth for wealth holdings above \$1M. If this right tail follows a Pareto distribution, the log-log plot will be linear. The blue line in Figure 3.2 represents the model output, while the solid line is the linear fit. Both lines are very close to each other for wealth holdings below \$100, while the model output gets visibly flatter for wealth holdings of \$1B and above. This is in line with Table 3.3, where the wealth shares at the top 0.5% are smaller than their empirical counterparts. Overall, however, the model distribution exhibits a thick right tail and thus, the model plausibly replicates wealth inequality by matching important moments and the most prominent

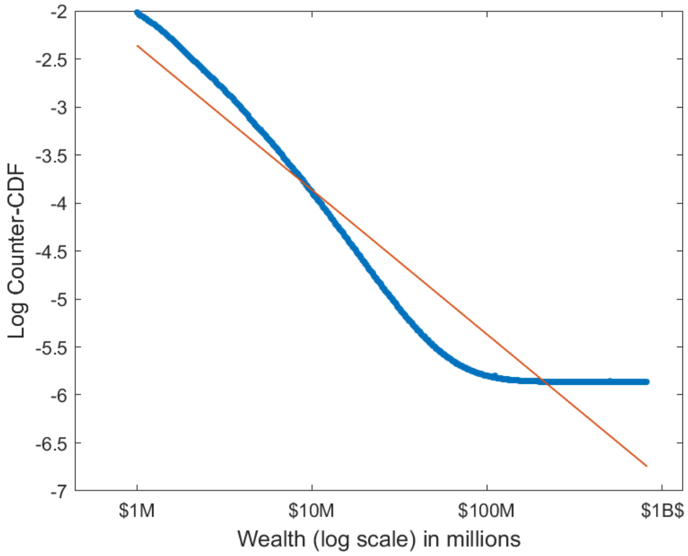


Figure 3.2: Pareto right tail of the wealth distribution

feature of the wealth distribution.

Tax Evasion. Concerning tax evasion, Figure 3.3 reports the average fraction of evaded taxes by wealth group (assorted by percentiles). Overall, the average evasion rate in the model economy is about 2.5%, but the fraction of evaded taxes rises steeply with the position in the wealth distribution. The average evasion rate in the first two percentiles is practically zero, mostly because households in the lower part of the wealth distribution are not subject to any capital gains taxes. Also, while households who find themselves between the third and the eighth percentile of the wealth distribution do evade some of their capital gains taxes, the average amount is still below the economy wide average. The main evasion behavior only takes place at the top two percentiles, thereby confirming that tax evasion is especially prominent among the very rich. Households in the top percentile evade on average about 9%, while the overall maximum even reaches values of 23% for some individuals. This heterogeneous evasion behavior is well in line with reports of real evasion and also matches the estimates by Alstadsaeter et al. (2019). Overall, the model can replicate a highly skewed wealth distribution as observed in most countries and also produces a highly heterogeneous evasion behavior.

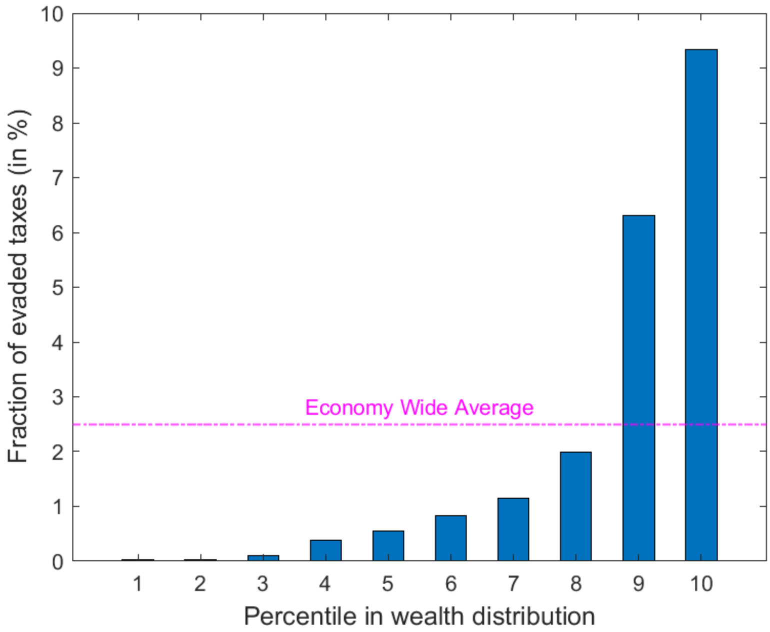


Figure 3.3: Average tax evasion by position in the wealth distribution

3.5 Policy Experiments

Analyzing the effects of capital taxation has a long tradition in the literature. The model presented in this paper allows for the addition of a new channel that has been missing so far: the effects of tax evasion. In this section, I discuss how tax evasion can affect economic outcomes and welfare analyses. To do so, subsection 3.5.1 presents the outcome of a hypothetical policy experiment in which the government can prevent all evasion (i.e. detecting evaders at a rate of 100%) and compares it to the benchmark economy presented above. Also, to see how the consideration of tax evasion could change the implications of capital taxation, subsection 3.5.2 subsequently discusses the consequences of abolishing such taxes.

3.5.1 The Effects of Tax Evasion

The amount of tax evasion appears to be very heterogeneous throughout the wealth distribution. It is therefore a noteworthy exercise to analyze what would happen, could the government enforce perfect tax compliance and thus eliminate all evasion behavior. To do this, I set the auditing rate to 100%, which is costless within the model, and then solve

Table 3.4: Share of aggregate wealth held by the top x% with and without evasion

	US Data	Model	
		with evasion	without evasion
Top 0.1%	0.14	0.10	0.10
Top 0.5%	0.27	0.25	0.25
Top 1%	0.36	0.36	0.35
Top 10%	0.75	0.81	0.80
Top 50%	0.99	0.99	0.97
Wealth Gini	0.85	0.86	0.84

Note: Data moments and wealth Gini are the same as in Table 3.3 .

for the new stationary equilibrium. Table 3.4 shows the result of this exercise by comparing the wealth shares held by a certain wealth group with and without evasion. If the government can enforce perfect tax compliance, the wealth shares held by the wealthiest individuals surprisingly stay the same. Only the share of the top 10% and the top 50% decreases. Also, the wealth Gini drops to 0.84. Seemingly, wealth inequality does decrease if people cannot evade their tax payments, but it does so very moderately. While this result might not be surprising in itself given the heterogeneous evasion rates throughout the wealth distribution, it still has implications for the modeling of wealth inequality, since quantitative models often target specific wealth shares. Without considering tax evasion, however, this can lead to misleading results. Moreover, quantifying theses effects can help policy makers in justifying additional costs for higher auditing rates.

Another important aspect of tax evasion, which is missing in the macroeconomic literature so far, are its effects on the aggregate outcome of the economy. Table 3.5 compares the two stationary equilibria by using the benchmark economy as index and displaying the changes if tax evasion is prevented. We can see that without evasion the interest rate rises by 3%, while the wage rate and the effective capital stock decrease by 2% and 7%, respectively. Also, the average tax on labor income increases by 1%, since the drop in the capital stock leads to less tax revenue from capital taxation. However, since the decrease in the capital stock mostly stems from preventing evasion behavior, the reduction in government revenue also mostly comes from foregone punishment fees rather

Table 3.5: Economic aggregates with and without evasion

	with evasion	without evasion	Δ
Interest Rate	100	103	+3%
Wage Rate	100	98	-2%
Effective Capital Stock	100	93	-7%
Average Labor Tax	100	101	+1%
Output	100	98	-2%
Average labor hours	100	99.5	-0.5%

Note: Numbers represent percentages. The benchmark economy is taken as 100% .

than actual tax payments. Hence, the average tax on labor increases only slightly. Lastly, the fall in the capital stock and the wage rate also affect output and labor hours, which drop by 2% and 0.5%, respectively.

These numbers reveal several interesting facts. First, the very wealthy are discouraged from accumulating more wealth if they are subject to taxation without the means of avoiding parts of their taxes. Consequently, the capital stock in the economy drops significantly. This has adverse effects on other economic outcomes. Simply looking at Table 3.5 might suggest that the economy is worse off if tax evasion is abolished. The reason for that might be that capital gains taxes are distortionary and actions to avoid these payments therefore desirable. However, these figures only represent aggregates and the average worker in the economy might still prefer an equilibrium in which the very wealthy cannot evade their tax payments, especially seeing how some of the foregone revenue leads to higher taxes on labor income.

3.5.1.1 Welfare Implications

While Table 3.5 presents an interesting comparison of economic aggregates, the overall welfare implications might not be clear. Especially low income households might profit from perfect tax compliance, even if the capital stock and output fall. Therefore, I start with a simple welfare analysis by looking at a social welfare function as in Conesa et al. (2009). Assuming that the government wants to maximize ex-ante lifetime utility of an

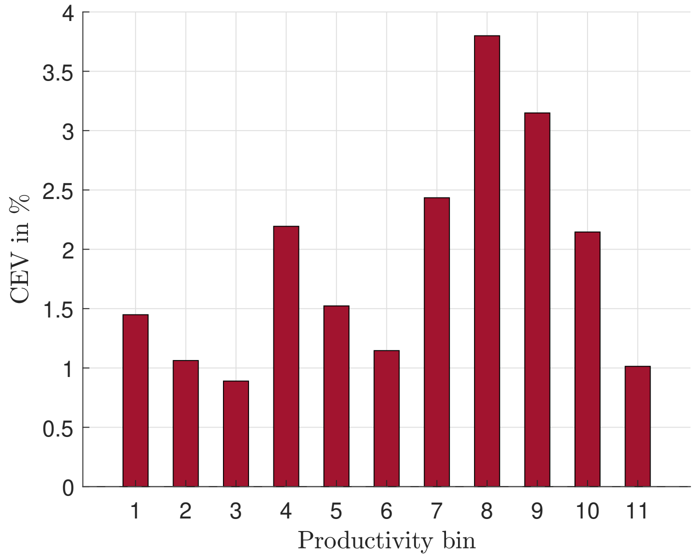


Figure 3.4: Average welfare change for workers at different skill levels (CEV in percent).

agent born into the stationary equilibrium yields the following objective function:

$$SWF^i = \int V^i(a,s)\,\mathrm{d}\Phi^i(a,s) \tag{3.13}$$

with $V^i(a,s)$ denoting the value function of an individual with assets a in state s, $\Phi^i(a,s)$ the invariant distribution over assets and states and $i \in \{1,0\}$ the equilibrium with and without evasion, respectively.

Calculating the social welfare for both stationary equilibria reveals that an economy without tax evasion would lead to a slight welfare increase of 1.5%. Thus, even though evasion leads to a higher effective capital stock and an increase in wages, the average individual seems to be better off if the government can enforce perfect tax compliance.

This result, however, leaves several aspects unconsidered. The social welfare function defined in Equation 3.13 only considers the expectation over value functions given the stationary distribution. However, the per-period utility streams also include labor supply and the disutility from tax evasion. Hence, some of the welfare improvements might simply stem directly from abolishing tax evasion and consequently from abolishing all disutility related to such behavior. Also, the numbers themselves cannot be interpreted and are not easily disentangled to analyze the issue more thoroughly.

Next, I therefore computed the consumption equivalence value (CEV) for both stationary equilibria, where the economy with evasion is taken to be the benchmark. Since the CEV measures the factor by which the consumption of an individual has to be increased in order to make the household indifferent between the benchmark economy and the economy without evasion, these values are straightforward to interpret and allow for a more detailed analysis of who loses and who wins with perfect tax compliance.

Specifically, for an individual with assets a in state s, the CEV is given by

$$V^B((1+CEV)c(a,s),\ell(a,s),e(a,s)) = \tilde{V}(c(a,s),\ell(a,s),e(a,s)) \tag{3.14}$$

where V^B and $\tilde{V}$ indicate the value functions in the benchmark economy and the counterfactual economy, respectively. Hence, if $CEV > 0$ households prefer the economy without tax evasion given their states (a, s).

Figure 3.4 shows the average welfare change for workers with different persistent labor productivity if perfect tax compliance can be enforced. We can immediately see that everyone would prefer the new equilibrium to the old equilibrium with welfare improvements ranging from nearly 1% to nearly 4% in terms of CEV. Individuals with higher persistent productivity seem to be gaining relatively more from perfect tax compliance than workers in the lower productivity bins. There are several reasons for these welfare gains. First, individuals who gain their income from labor only profit from the rise in the interest rate, since they can accumulate more savings. At the same time, they provide slightly less labor and enjoy more leisure. Hence, the decrease in the wage rate and the increase in the labor income tax do not outweigh the gains from higher savings. These reasons, however, apply more to workers with higher productivity, thus explaining why individuals in the lower productivity bins experience relatively less welfare gains.

Next, to see how enforcing perfect tax compliance affects entrepreneurs Figure 3.5 shows the welfare gains for entrepreneurs at different productivity levels. Again, we can see how most individuals would prefer the new equilibrium to the old one, with welfare gains of almost up to 4% in terms of CEV. Only for entrepreneurs in the highest productivity group do we see welfare losses of roughly -1.3%. The entrepreneurs with the highest productivity in the model gain nearly all their income by renting capital and producing intermediate goods at a high rate. They translate to the top 1% in the wealth distribution and are the individuals who evade the largest fraction of their tax payments in the benchmark economy (up to 23%). These people accumulate less wealth than before

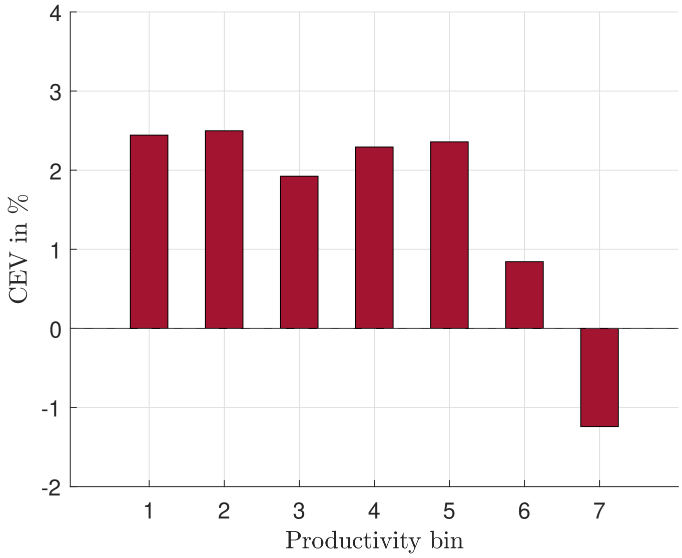


Figure 3.5: Average welfare change for entrepreneurs at different productivity levels (CEV in percent).

and pay more taxes, without experiencing any gains through altered economic outcomes. In fact, they have to rent capital at a much higher rate than before. Hence, they prefer the old economy in which they were able to evade a significant fraction of their tax payments.

Entrepreneurs in the lower productivity bins, in contrast, are far less productive and also gain some of their income from working and saving. For them the same logic applies as for the workers and they experience welfare gains, since they can lend their capital at a higher rate to the most productive entrepreneurs. Also, the welfare gains in Figure 3.5 are mostly higher than in Figure 3.4, since individuals are always both, workers and entrepreneurs, at the same time. taxpayer the two figures are related and cannot be interpreted entirely separately. In particular, Figure 3.4 also includes the welfare losses of the most productive entrepreneurs, while Figure 3.5 shows them separately at the highest productivity bin.

Overall, the new stationary equilibrium without tax evasion seems to be preferred by nearly every individual. Only the most productive entrepreneurs who have been evading a significant fraction of their tax payments in the benchmark economy would prefer to go back to the old equilibrium. In fact, looking at the average overall change in welfare in terms of CEV, computed as

$$\overline{CEV} = \int CEV(a, s) \, \mathrm{d}\Phi(a, s) \tag{3.15}$$

Table 3.6: Economic aggregates with and without capital taxation

	$\tau_a = 25\%$	$\tau_a = 0\%$	Δ
Interest Rate	100	61	-39%
Wage Rate	100	109	+9%
Effective Capital Stock	100	126	+26%
Average Labor Tax	100	104	+4%
Output	100	108	+8%
Average labor hours	100	98.5	-1.5%

Note: Numbers represent percentages. The benchmark economy is taken as 100% .

with $\Phi(a, s)$ being the invariant distribution over states, we can see a welfare improvement of 2%. Also, looking at the fraction of people who would experience welfare gains by enforcing perfect tax compliance reveals that nearly 93% would vote in favor of transitioning to the new stationary equilibrium.

3.5.2 Abolishing Capital Gains Taxes

In the benchmark economy the very wealthy engage in significant tax evasion to reduce their tax burden. As seen in subsection 3.5.1, enforcing perfect tax compliance therefore leads to a considerable reduction in the capital stock. Nonetheless, most people still prefer the economy without evasion behavior. Consequently, a natural question is to analyze the effects of abolishing capital taxation. Without capital taxation the rich can build a higher capital stock without having to use illegal measures like tax evasion. Hence, abolishing capital taxes could also abolish possible distortions and maybe lead to an even better outcome than simply enforcing perfect tax compliance. This section therefore discusses the aggregate and distributional implications of setting $\tau_a = 0$, while still forcing the government to run a balanced budget. As in section 3.5.1, I first solve for the new stationary equilibrium and then compare the aggregate and distributional outcomes with the benchmark model.

First, Table 3.6 again shows some interesting statistics by comparing economic aggregates from the new stationary equilibrium with the benchmark economy. The most striking differences are the capital stock, which increases by 26%, and the interest rate, which drops by nearly 40%. Without the tax on capital income, entrepreneurs are able to accumulate much more wealth than in the benchmark economy. This also leads to an increase in output and the wage rate. However, the foregone tax revenue from capital taxation has to be compensated for by an increase in the average tax on labor income. Lastly, people slightly reduce their labor supply as the average labor hours fall by 1.5%. Overall, abolishing capital gains taxes seemingly benefits entrepreneurs and wealthy individuals, while people whose income mainly stems from labor have to pay higher taxes and can only save at a much lower rate than before. These adverse effects are partially counteracted by an increase in the wage rate. Thus, whether people experience gains or losses in the new equilibrium remains to be studied in more detail.

Before turning to a simple welfare analysis, Table 3.7 shows the effects of abolishing capital taxation on the distribution of wealth. The columns again present the share of total wealth held by a certain wealth group, where the third column now displays the shares without a tax on realized capital gains. Note that the economy with capital gains taxes is again the benchmark economy, where people engage in evasion behavior. We can see that wealth inequality has increased considerably, with the top 1% now holding 40% of overall wealth in the economy. The wealth share held by the top 10% also rose from 81% to 84% and only for the top 50% nothing changed. Lastly, these changes in the wealth distribution also lead to an increase in the Gini coefficient, which rose to 0.88, an increase of over 2%. This result seems to suggest that capital taxes are an effective tool of redistribution even in the presence of tax evasion.

This shows that capital taxation is still a valuable tool for the redistribution of wealth and for reducing the gap between lower productive and higher productive individuals, even if the rich can evade part of their tax payments, while the poor cannot. Since these differences in productivity and wealth can be the result of circumstances which lie outside of individual control - like inheriting a successful business or simply luck in investing capital - redistribution through capital taxation might be a desirable tool for policy makers.

Table 3.7: Wealth shares of the top x% with and without capital taxation

	US Data	Model	
		$\tau_a = 25\%$	$\tau_a = 0\%$
Top 0.1%	0.14	0.10	0.11
Top 0.5%	0.27	0.25	0.28
Top 1%	0.36	0.36	0.40
Top 10%	0.75	0.81	0.84
Top 50%	0.99	0.99	0.99
Wealth Gini	0.85	0.86	0.88

Note: Data moments and wealth Gini are the same as in Table 3.3. The equilibrium with $\tau_a = 25\%$ corresponds to the benchmark economy in which households engage in evasion behavior.

3.5.3 Welfare Implications

Finally, to compare the new stationary equilibrium to the old one in terms of welfare I again calculate the consumption equivalence value as defined in Equation 3.14. Figure 3.6 shows the welfare change in terms of CEV in percent for entrepreneurs at different productivity levels. The most productive entrepreneurs - who are also the wealthiest - experience huge welfare gains of up to 24% if capital gains taxes are abolished. This is no surprise as these entrepreneurs manage to get the highest return to their investment and thus, also paid the most capital gains taxes in the benchmark economy. In contrast, lower productive entrepreneurs, who gain a considerable fraction of their income from labor, do not profit as much from abolishing capital taxation and only experience welfare gains of up to 5% in terms of CEV.

Regarding worker welfare, the result is very different. With the higher tax on labor needed to keep the government budget balanced, some workers experience welfare losses. In particular, the highest productive workers are now punished for their productivity, since the progressive tax system considerably raises their marginal tax rates. Hence, high productive individuals who are not entrepreneurs would prefer the benchmark economy with capital gains taxes. Overall welfare under the veil of ignorance, however, increases by about 4% in terms of CEV - largely driven by the huge welfare gains for entrepreneurs.

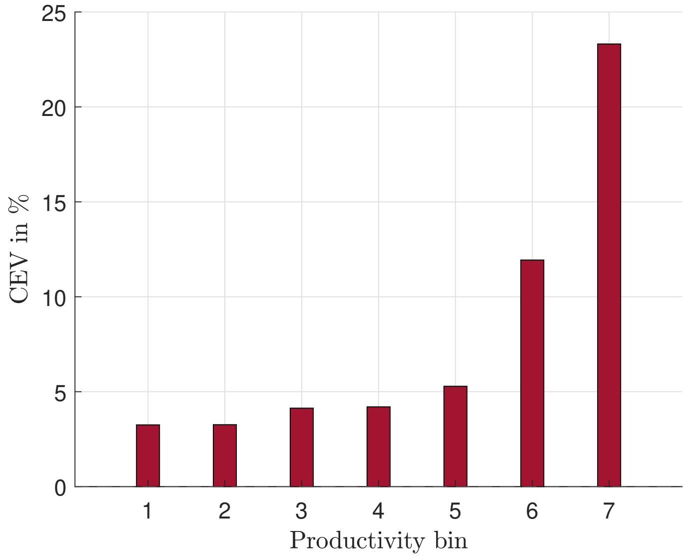


Figure 3.6: Average welfare change for entrepreneurs at different productivity levels without capital gains taxes (CEV in percent).

This shows that the relatively high tax on capital income in the benchmark economy is not optimally from the perspective of overall welfare. This finding contrasts with earlier results from the literature (e.g. Conesa et al., 2009) may be attributed to tax evasion, a factor that macroeconomic models have previously overlooked. Also, this simple exercise does not prove that capital should not be taxed. There might be an optimal rate of capital gains taxes which is lower than the benchmark rate but still strictly positive. The next question therefore would be how an optimal tax schedule should be designed in the presence of tax evasion.

3.5.4 Replacing Capital Gains Taxes with a Wealth Tax

As discussed above, a tax on capital income appears to be distortionary and removing it could result in welfare gains. However, this conclusion may be affected by the presence of return heterogeneity, as highly productive entrepreneurs are penalized for their productivity and discouraged from investing as much capital as would be optimal for them. To address this issue, a natural experiment involves replacing the distorting tax with a general tax on total wealth. Guvenen et al. (2023) demonstrate that a tax on wealth can increase welfare in the presence of return heterogeneity. Unlike a tax on capital gains, a tax on wealth would punish nonproductive entrepreneurs, while potentially encourag-

Table 3.8: Economic aggregates in the benchmark economy and with $\tau_w = 0.9\%$

	Benchmark	$\tau_w = 0.9\%$	Δ
Interest Rate	100	82	-19%
Wage Rate	100	105	+5%
Effective Capital Stock	100	113	+13%
Average Labor Tax	100	99	-1%
Output	100	104	+4%
Average labor hours	100	99	-1%

Note: Numbers represent percentages. The equilibrium with $\tau_w = 0.9\%$ corresponds to revenue neutral reform to capital taxation, where τ_w replaces τ_a. The benchmark economy is taken as 100%.

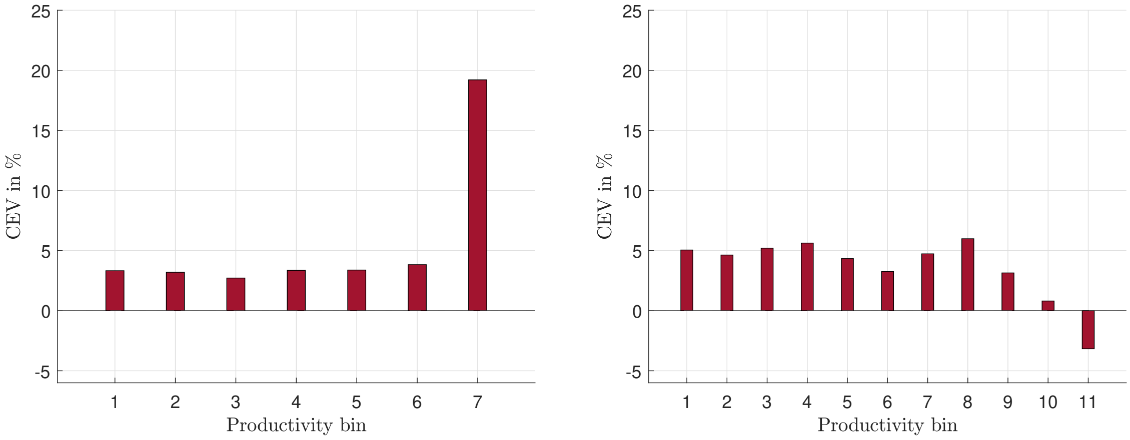
ing more investment from highly productive households, thereby possible reducing any distortionary effects.

In this section, I therefore discuss the aggregate and distributional implications of replacing the tax on capital gains with a tax on total wealth, τ_w. This means that total wealth is now mapped to after tax wealth by the relationship

$$a \quad \rightarrow \quad (1-\tau_w)(1+r)a.$$

To compare the wealth tax to the tax on capital income, I set the value of τ_w to be revenue neutral, meaning that the revenue from the tax on wealth is the same as the revenue from the capital gains taxes in the benchmark economy. The government still runs a balanced budget and adjust the tax on labor accordingly. Note that even though the revenue from the wealth tax is the same as the revenue from the capital gains taxes, the difference in incentives and distortions might still lead to large differences in economic aggregates and thus, also in the equilibrium tax on labor income. As in the exercises above, I first solve for the new stationary equilibrium and then compare the aggregate and distributional outcomes with the benchmark model.

The tax rate on total wealth found to be revenue neutral is $\tau_w = 0.9\%$. Table 3.8 compares the counterfactual economy with this reform the tax system to the benchmark economy by presenting important statistics on economic aggregates. The first thing to



(a) Entrepreneurs (b) Workers

Figure 3.7: Average welfare change for entrepreneurs and workers at different productivity levels after the tax reform where τ_w replaces τ_a (CEV in percent).

notice is that the effects of the tax reform on economic aggregates are very similar to the effects of simply abolishing the tax on capital gains, but only less pronounced. As before, the capital stock increases, while the interest rate drops. The wage rate and output slightly increase, while average labor hours are reduced. Only the average tax on labor displays the opposite behavior than when abolishing capital gains taxes: Before it increased by 4%, now it drops slightly by about 1%. Overall, Table 3.8 reveals that even though households still pay a tax on their assets, highly productive entrepreneurs are not discouraged from investment, since the tax is not linked to their returns. This suggests that the distortionary effects from the wealth tax are far less pronounced than those of a capital income tax.

Figure 3.7a shows how these findings translate to the welfare of entrepreneurs in terms of CEV. As in subsection 3.5.3, entrepreneurs seem to profit throughout all productivity bins, with the highest productive households again seeing the biggest welfare increase compared to the benchmark economy with capital gains taxes. Since the tax on capital income was higher for entrepreneurs who achieved a better return to investment, those households profit relatively more and experience welfare gains of up to 20%, compared to only 4% for the less productive households. The effect on worker welfare, as depicted in Figure 3.7b, is very different. Replacing the capital income with a tax on total wealth hurts the most productive workers who are able to save a considerable amount of their income. In the benchmark economy, they only paid very limited capital taxes, while now they have to pay a tax on their total wealth. This negative effect is not outweighed by the increase in the wage rate and overall, the most productive workers experience a welfare loss of roughly -4% in terms of CEV. Less productive workers, in contrast, profit from the fall in the average tax on labor and the increase in the wage rate and can expect welfare gains of roughly 5% in terms of CEV.

Combining all these insights and looking at the life-time utility of a newborn under the veil of ignorance reveals that the new equilibrium with a tax on wealth would increase total welfare by 4.4% in terms of CEV. Hence, even if some people lose from the transition to a new tax system, overall welfare is still expected to increase. The tax on wealth is less distortionary than a tax on capital gains, since it does not discourage investment from highly productive entrepreneurs. This exhibits positive effects on the economy, and one might assume that an optimal taxation scheme should include some form of tax on total wealth.

3.6 Conclusion

Tax evasion has long been a topic of public interest and recent empirical evidence points to the fact that it is not only a considerable problem, but also especially prominent among the wealthiest households. Hence, discussions about tax evasion should take into account the unequal distribution of wealth. Wealth inequality has seen an increase over the past few decades, while taxation of wealth or capital income has decreased considerably. A reason for this could be that public discussions often revolve around capital outflow and the observed fact that the very rich tend to find ways to reduce their tax payments. This has led politics to lose faith in capital taxation, especially since we lack academic research on its effects in the presence of tax evasion. This paper contributes to closing this gap in the literature by quantitatively evaluating the effects of tax evasion on aggregate and distributional outcomes and by showing that even in the presence of tax evasion a strictly positive tax on capital income is still desirable.

The benchmark model plausibly replicates relevant moments of the US economy and produces a highly skewed wealth distribution as observed in many countries. Due to the inclusion of return heterogeneity the model even produces a thick right tail, an important feature of empirical wealth distributions which is not easily obtained. Furthermore, the model produces realistic evasion behavior with the amount of evaded taxes depending on the position in the wealth distribution. Hence, tax evasion raises inequality, even if only moderately, since wealthier households tend to evade more of their taxes. More important are the effects of tax evasion on the aggregate economy. While evasion behavior leads to higher wage rates and a higher effective capital stock, low income households still profit relatively more from the lower labor income taxes in the presence of perfect tax compliance. In this regard, tax evasion works like transfers from the poor to the rich, since the government has to adjust the tax on labor income in response to foregone payments from the tax on realized capital gains. This finding is also strengthened by the welfare analysis showing that most households prefer the economy with perfect tax compliance.

A subsequent analysis of abolishing capital gains taxes, however, showed that the counterfactual economy exhibits mostly positive effects on economic aggregates. Wages and capital in the economy rise significantly and so does output. The moderate increase in the tax on labor income needed to keep the government budget balanced does not seem to outweigh these positive effects. Especially high productive entrepreneurs experience huge welfare gains and are encouraged to increase their investment which seems to be a socially desirable behavior. This shows that the distortions from capital gains taxes have adverse effects on the economy. Comparing this result to earlier literature tax evasion might play a role in this assessment. However, in replacing the tax on capital income with a tax total wealth might still be desirable. Also, the analysis only shows that an economy without capital gains taxes is to be preferred over the benchmark economy. Nevertheless, there might still be a strictly positive rate of capital gains taxes that is socially preferable over both economies studied in this paper.

Next, a brief exercise with a tax reform of replacing capital income taxes with a revenue neutral tax on total wealth revealed possible welfare gains. The effects of a wealth tax are very similar to the effects of abolishing capital gains taxes, with a higher capital stock and higher output, while still bringing in additional revenue for the government which can lead to a reduction in the average tax on labor income. Thus, both workers and entrepreneurs can profit from this new equilibrium. Consequently, a natural next step is to analyze this issue more closely and to find how an optimal taxation scheme - possibly with a combination of wealth taxes and capital income taxation - should look like.

Lastly, some issues remain which have to be resolved in future work. First, robustness checks regarding the parameterization are required. Tax evasion seems to be very sensitive with respect to the specific model parameters. This could potentially change some of the results and have further impact on the optimal tax rate. Also, the amount of evaded taxes seems to decline again at the very top (the 0.1%) of the wealth distribution. Further checks should uncover whether this is a desired feature of individual optimization behavior or a downside of the model. Second, while this paper already shows that capital taxation is desirable even in the presence of tax evasion, finding the optimal tax rate still remains to be done.

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Appendix

Computational Solution Method

The model is solved numerically in MATLAB 2021b by using value function iteration on a discretized state space, given by $\mathcal{S} = A \times \mathcal{Y} \times \mathcal{T}$, denoting the set of asset holdings, realizations of stochastic labor productivity and realizations of stochastic entrepreneurial skill, respectively. The stochastic processes are discretized by using Rouwenhorst's method as described in Kopecky and Suen (2010).

Algorithm to compute competitive equilibrium:

I. Set initial values for interest rate r_0, wage w_0 and effective capital stock Q_0.

II. Do Value Function Iteration given (r_0, w_0, Q_0):

   1. Start with initial guess for the value function V_0
   2. Calculate optimal decision rules given V_0 by maximizing over c, ℓ, a' and e for each state $s \in \mathcal{S}$.
   3. Calculate new value function V_{new} and check difference to initial guess V_0
   4. If difference is larger than 10^{-9}, set $V_0 = V_{new}$ and go to 2.
      Else, end.

III. Given the solution for the value function V^* and the optimal decision rules c^*, ℓ^*, a^* and e^* compute the invariant distribution over states $\Phi(a, y, \theta)$.

IV. Update (r, w, Q)

   1. Use $\Phi(a, y, \theta)$, c^*, ℓ^*, a^* and e^* to calculate the implied capital stock Q_{new}, implied wage w_{new} and excess demand or supply for assets.
   2. Compare implied values to initial guess. If difference is larger than 10^{-9}, update (r_0, w_0, Q_0) using an appropriate root finding procedure and go to II.
      Else, end.

Model calibration: In order to fit the model to the data, the following objective function is minimized:

$$S(\mathcal{P}) = \sum_i \omega_i (M_i(\mathcal{P}) - D_i)^2 \tag{3.16}$$

where D_i are the data moments sought to be matched and $M_i(\mathcal{P})$ are the moments calculated from the model for a given set of structural parameters $\mathcal{P}$. The parameters to be jointly determined are $\mathcal{P} = \{\beta, \chi, \sigma_\theta^2, \phi, \mu, \eta\}$ and deviations are weighted equally (i.e. $\forall i : \omega_i = 1$)

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