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

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Job Market Paper

October 22, 2022

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Abstract

Concepts of a Universal Basic Income (UBI) have received increasing attention over the past years, but evidence of their effects, especially their interactions with automation decisions, are still scarce. I develop a quantitative theory with labor market frictions and endogenous automation to provide a new framework in which such policies can be assessed and compared to other proposals. I find a negative relationship between the investment in automation and the generosity of the unconditional transfers. When transfers are low, firms increase their investment in automation, since they face a higher probability of being matched with low-skilled workers, while the opposite happens when transfers are high. Also, while future generations would prefer being born into the benchmark equilibrium without a UBI, workers from the current generation can expect welfare gains during the transition to the new equilibrium, hence creating a generational conflict. Lastly, an inexpensive evaluation of the optimal tax regime reveals that a negative income tax together with subsidies to capital income could lead to welfare gains.

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

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

*I have greatly benefited from the seminars at VGSE and the discussions with my colleagues. I am especially thankful for the comments from Michael Reiter, Alejandro Cuñat, Florian Exler, Gerhard Sorger, Monika Gehrig-Merz, Paul Pichler, Nawid Siassi and Daniel Garcia. Furthermore, I gratefully acknowledge the financial support of the DOC Fellowship program of the Austrian Academy of Sciences and the support of the Vienna Graduate School of Economics.

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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). Atkinson (1995), in contrast, discusses 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[2] analyzing the effects of unconditional transfers in the form of a negative income tax. In an overview of the results, Munnell (1986) states that reductions in work effort were only moderate, while school attendance increased.

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 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

[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, 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 time of the referendum).

thresholds.

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.[4] This leads to an increased fear of job-loss due to the displacement of low skilled workers by the adoption of robots and many believe that programs such as a UBI might be necessary to counteract the resulting rise in inequality. A basic income could provide much needed insurance and give people the freedom to learn new skills according to their talents. And since the trend toward 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 Permament Fund). However, one should be careful before extrapolating the results of such experiments, since their ability to provide insights on general 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 with 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

[4]See, for example, Kindberg-Hanlon (2021), for structural vector autoregressions using a large global sample of economies.

none of them consider the interaction with endogenous automation decision.

The aim of this paper is therefore to add to the discussion about the effecots of basic income programs by endogenizing the interaction between the provision of unconditional transfers, firms' decisions to automate jobs and workers' decisions about labor force participation. In doing so, I am providing a new model framework in which basic income programs and similar policies can be analyzed quantitatively to address some of the open questions regarding macroeconomic effects. I introduce a segregated labor market in which workers have to decide between participating in one of two sectors. One sector will feature endogenous automation, allowing firms to invest in robots instead of hiring a worker if an open vacancy has to be filled. Workers in the second sector do not face this additional job risk, but need to acquire a college degree. Additionally, labor market frictions are incorporated via Nash-Bargaining which determines work contracts. This setup allows for an inexpensive evaluation of basic income programs when automation decisions are endogenous.

This paper is organized as follows. The next section describes relevant literature and highlights the contributions to the ongoing discussion. Section 2 then presents the model setup, while the parameterization, calibration strategy and relevant statistics of the benchmark economy are described in Section 3. In Section 4 I discuss the general effects of different UBI policies of varying generosity, while Section 4.1 provides a deeper analysis of a specific UBI proposal. Section 5 then briefly discusses the effects of a Negative Income Tax, while Section 6 analyses an optimal tax and transfer system. Section 7 concludes.

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 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 very complementary of 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) find 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.

Next, 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. This paper contributes to these existing studies by adding a new macroeconomic framework which can shed light on some of the advantages as well as the challenges of UBI policies.

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 elasticity is close to zero. Lastly, 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 for the explanation of general equilibrium effects on a broader population, as mentioned by Zellner and Rossi (1986), among others. Hence, this paper provides a quantitative framework to embed these insights within a model setup which allows for the analysis of general equilibrium effects and the evaluation of counterfactual policies.

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-wokrer firms and are used in the competitive final goods production.

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

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

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

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 or not 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 sector 2 uses only 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 $h \cdot f(\theta_m)$. Note that in market 1, the automation sector, the number of open vacancies is also determined by the automation decision of the firms, as some vacancies can be filled with robots before entering the labor market. 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. The wage rate is determined by Nash-Bargaining when an open vacancy is matched with an unemployed worker. Also, gross income is subject to a progressive income tax given by

$$T(\tilde{y}) = \tilde{y} - \lambda_0 \tilde{y}^{1-\lambda_1} \tag{2}$$

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. Net income, y, is therefore given as $y = \tilde{y} - T(\tilde{y}) = \lambda_0 \tilde{y}^{1-\lambda_1}$

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 will be decided by Nash-Bargaining and are therefore functions of s, $w = w(s)$.

Then, a worker's decision problem is given by

$$\begin{aligned} W(s) = &\max_{c \geq 0, h \in [0,1]} \; u(c, h) + \beta \mathbb{E}\Big[(1-\psi)W(s') + \psi U(s')\Big] \\ &s.t \quad y(s) \leq (1 + \tau_c)c \end{aligned} \tag{3}$$

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 $\bar{b}$.

With s again denoting the worker's state, the decision problem for short-term unemployed is

$$\begin{aligned} U(s) = &\max_{c \geq 0, h \in [0,1]} \; u(c,h) + \beta \mathbb{E}\Big[hf(\theta_m)W(s') + (1 - hf(\theta_m))\bar{U}(s')\Big] \\ &s.t \quad b(s) \leq (1+\tau_c)c \end{aligned} \tag{4}$$

where $\bar{U}(\cdot)$ is the value function of long-term unemployed and $hf(\theta_m)$ the probability of being matched with a firm in market m with market tightness θ_m when exerting search effort h.

If a worker continues being unemployed for two or more periods, the decision problem changes to

$$\begin{aligned} \bar{U}(s) = &\max_{c \geq 0, h \in [0,1]} \; u(c,h) + \beta \mathbb{E}\Big[hf(\theta_m)W(s') + (1 - hf(\theta_m))\bar{U}(s')\Big] \\ &s.t \quad \bar{b} \leq (1+\tau_c)c \end{aligned} \tag{5}$$

Universal Basic Income. If the government provides a certain level of unconditional subsistence to everyone, the problem of unemployed workers is simplified 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

$$y^{disp} = \begin{cases} \tilde{y} + b^{UBI} - T(\tilde{y}) & u = 0 \\ b^{UBI} & u \in \{1,2\} \end{cases} \tag{6}$$

with $T(\cdot)$ again being tax on labor income.[6]

Market Decision For sake of simplicity 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

[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.

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

$$V(z,z_c,2) > V(z,z_c,1). \tag{7}$$

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

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 from sector 1 and sector 2, respectively. Intermediate goods are produced according to a cobb-douglas technology

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

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

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

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

with ζ following a first-order Markov process.

The final good Y is then produced using the 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.

Automation. Firms in the automation sector ($m=1$) who have created an open vacancy can decide to invest in robots instead of searching for a worker. If a robot is adopted, the vacancy is no longer available. However, adopting a robot requires an investment x^a which is drawn from the iid distribution $G(x^a)$ and influences the probability,

q^a, with which an open vacancy is automated. Let $\tilde{v}_1$ denote the stock of open vacancies before firms decide going to the labor market.[7] Then the stock of automated jobs evolves according to

$$A_{t+1} = (1-\delta^a)A_t + q^a\tilde{v}_{1,t}$$

with δ^a being the probability with which a robot becomes obsolete or breaks down at the end of the model period.

In the stationary equilibrium, with $A_t = A_{t+1} = A^*$ and $\tilde{v}_{1,t} = \tilde{v}_{1,t} = \tilde{v}_1^*$, we get

$$A^* = \frac{q^a\tilde{v}_1^*}{\delta^a}$$

Also, maintaining a robot necessitates flow costs κ^a and hence, the value of automation with a robot of productivity ζ is given by

$$J^a(\zeta) = \max_k \; p_1 \cdot k^\alpha\zeta^{1-\alpha} - \kappa^a - (r+\delta)k + \frac{(1-\delta^a)}{1+r}\mathbb{E}\Big(J^a(\zeta')\Big), \tag{8}$$

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

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

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

$$\begin{aligned} J(s,m) = \max_k \; & p_m \cdot k^\alpha(hze_j)^{1-\alpha} - (r+\delta)k - whze_j \\ & + \frac{1}{1+r}\Big[\psi J^v + (1-\psi)\mathbb{E}\Big(J(s',m)\Big)\Big], \end{aligned} \tag{9}$$

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

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

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

[7] With v_1 being the number of open vacancies in the labor market, we have $\tilde{v}_1 = v_1/(1-q_a) = \theta_1\mathcal{H}_1/(1-q_a)$, with θ_1 being the market tightness in sector 1 and $\mathcal{H}_1$ aggregate search effort

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 for firms in sector 2 (the college sector) is given by

$$J_2^v = -\kappa_2^v + \frac{1}{1+r}\bigg(g(\theta_2)\mathbb{E}\Big(J(s,2)\Big) + \Big(1-g(\theta_2)\Big)J_2^v\bigg). \tag{10}$$

In the automation sector, however, the value of a vacancy is also influenced by the possibility to automate a job before being matched with a worker. Consequently, in sector 1 the value of a vacancy is given by

$$\begin{aligned} J_1^v = -\kappa_1^v + \frac{1}{1+r}\bigg(& q^a\Big[\mathbb{E}(J^a) - \mathbb{E}(x|x \leq x^*)\Big] \\ & + (1-q^a)\Big[g(\theta_1)\mathbb{E}\Big(J(s,1)\Big) + \Big(1-g(\theta_1)\Big)J_1^v\Big]\bigg) \end{aligned} \tag{11}$$

were $\mathbb{E}(x|x \leq x^*)$ denotes the expected costs of automation given that automation occurs.

The threshold cost x^* up until which an open vacancy is automated is simply pinned down by the expectation of the labor market outcome: Firms will automate jobs as long as they can expect the value from automating being higher than keeping the vacancy open and going to the labor market. Hence, automation occurs if and only if,

$$\mathbb{E}(J^a) - x > g(\theta_1)\mathbb{E}\Big(J(s,1)\Big) + \Big(1-g(\theta_1)\Big)J_1^v.$$

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 $J_m^v = 0$. Hence, in equilibrium the cutoff cost x^* is given as

$$x^* = \mathbb{E}(J^a) - g(\theta_1)\mathbb{E}\Big(J(s,1)\Big) \tag{12}$$

Wage determination. When a firm is matched with a worker, a contract specifying the wage rate w 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 $W(w,s)$ the value function for an employed worker in state s with wage rate w, the bargaining solution is given by

$$w = \arg\max_{w \geq 0}\Big(W(w,s) - U(s)\Big)^{\xi} \cdot \Big(J(w,s) - J^v\Big)^{1-\xi}, \tag{13}$$

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 investment costs for automation are realized. Based on the investment costs a fraction of open vacancies in sector 1 are automated. Afterwards, remaining 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 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.

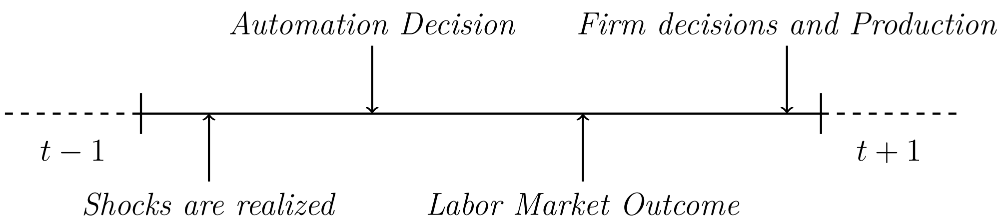


Figure 1: The timing of events in period t

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

$$(1+r-\delta)K_t^s + (1-\tau_a)\Pi_t - \kappa^v v_t - \bar{x}\Delta A_{t+1} - (1+\tau_c)c_t^{\text{cap}} = K_{t+1}^s \tag{14}$$

with $\kappa^v v_t$ being the total costs of vacancies, $\bar{x}\Delta A_{t+1}$ 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

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

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

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

$$R_\ell + R_c + R_\pi = B + G \tag{15}$$

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 productiviry, 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 unemplyoment). 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 $U(s)$, policy functions (consumption $c(s)$ and working hours $h(s)$), prices (wages $w(s)$ and intermediated goods p_1 and p_2), a distribution over states $\Phi(s)$, social transfers and taxes such that:

1. The value functions and optimal decision rules $c(s)$ and $h(s)$ solve the optimization problems of the households (3) and (4) given the factor prizes and initial conditions.

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

3. Wages $w(s)$ solve the bargaining problem (13)

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

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

3 Parameterization

This section presents the parameter values used to numerically solve the benchmark economy.[8] 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), while others are estimated using a Simulated Method of Moments approach to match important labor market outcomes (cf. Table 2). Lastly, Table 3 provides a brief overview of the benchmark economy, before introducing a Universal Basic Income.

3.1 Households

Households enter the model at age 21 and die with certainty at age 80. One model period corresponds to one year. There is no formal retirement, but the households' age-dependent experience premium drops after the age of 65. The experience premium 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 $\beta = 0.985$ 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 autocorrelation parameter is set to $\bar{\rho} = 0.95$ and the variance of the iid shock chosen to be $\bar{\sigma}^2 = 0.025$. All of these values are within the range of standard literature.

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

Table 1: Directly specified parameters

	Parameter	Value	Target/Source
Preferences			
Risk aversion	σ	2	standard
Frisch elasticity	γ	0.7	Hall (2009)
Discount factor	β	0.98	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)
Depreciation	δ	0.01	standard
Intermediate Input	μ	0.5	standard
Automation			
Autocorr. efficiency	ρ_a	0.86	Leduc and Liu (2021)
Std. dev. efficiency	σ_a	0.028	Leduc and Liu (2021)
Probability of obsolescence	δ^a	0.02	see text
Maintenance costs	κ^a	0.18	see text
Labor Market			
Job finding probability	χ	0.99	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)

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 33%.

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 annual depreciation rate, δ, is set to 1% and the annual nominal interest rate is given by $r = 1/\beta - 1 = 1.04\%$.

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 annual values and set $\rho_a = \hat{\rho}^4$ and $\sigma_a = (1 + \hat{\rho}^2 + \hat{\rho}^4 + \hat{\rho}^6) \cdot \hat{\sigma}$.

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 vacancy and is chosen endogenously to match an automation rate in sector 1 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 2%. In equilibrium, this leads to a situation in which the match between a firm and a workers breaks down twice as often as an automated job. Lastly, following the estimation in Leduc and Liu (2021), maintenance costs of robots are given by $\kappa^a = 0.18$, which yields annual profits of 2% of annual revenue by adopting a robot.

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 annual flow arrival rate of job offers equals $1 - (1 - 0.45)^{12} = 0.99$ and with an equilibrium market tightness of $\theta = 1$, this pins down the value $\chi = 0.99$.[9]

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.[10]

[9] 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.

[10] 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 2: Jointly calibrated parameters

	Parameter	Value	Target
Disutility of college	δ_c	6.3	33% college attendance
Investment costs	$\bar{x}$	0.89	30% automation rate
Labor disutility	ϕ	341	Avg. labor hours 0.33
Average taxation	λ_0	0.63	Avg. taxation 22%

Table 3: Benchmark Outcomes

College Share	31%
Automation Rate	30%
Consumption/Output	55%
Unemployment Rate	7.5%
autom. sector	8.7%
college sector	4.9%
Mean Net Income[1]	1.5
autom. sector	0.94
college sector	2.78
Average Taxation	21.9%

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

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 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.

3.5 The Benchmark Economy

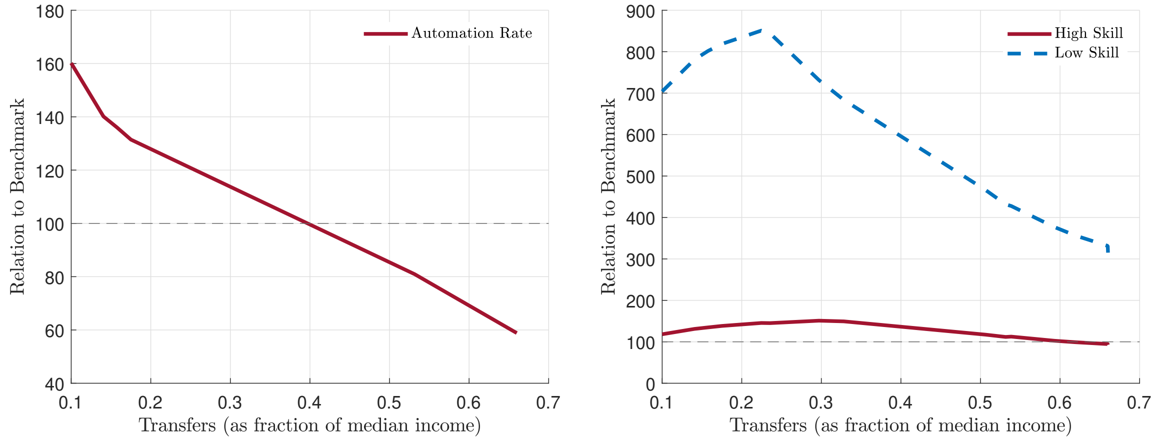
Before introducing a universal basic income, Table 3 summarizes the outcome of the benchmark equilibrium with the parameterization as described above. As targeted in the calibration, the equilibrium college share is 33% and the the automation sector sees a share of 30% of automated jobs. Also, we can see sizable differences between the markets. While the overall unemployment rate is given by 4.4%, it is higher in the automation sector than in the college sector with 4.6% against 4.1%, respectively. The probability to replace workers with robots also has implications for wages. Average income is about 50% higher in sector 2, with workers earning 137% of median income on average, while the average worker in the automation sector only earns 89% of median income. Lastly, employed workers face an average tax rate of roughly 22%, as was the target of the calibration.

4 Introducing a UBI

This section describes the effects of replacing unemployment benefits by a UBI policy which keeps the government budget balanced. To do so, I introduce universal transfers of varying generosity which are paid to everyone and which replace all unemployment benefits. Hence, disposable income is now given as in Equation 6. All other exogenous parameters are held constant (including government consumption) and only the shift parameter of the labor income tax, λ_0, is adjusted to keep the government budget balance.[11] This might lead to a higher tax burden, but at the same time everyone receives lump-sum transfers. Hence, it is not immediately clear who wins and who looses from such a policy.

Effects on Automation. To see how universal transfers would affect the automation sector, Figure 2 compares the outcomes from an economy with universal transfers to the benchmark economy. Transfers from the UBI policy are measured as fractions of median income and the outcomes are given in relation to the benchmark equilibrium. Looking at Figure 2a we can see how the generosity of the transfer level drastically changes the impacts on automation. When transfers are below 40% of median income, firms start to invest more in automation, while the investment is discouraged when transfers become higher. This effect is mostly driven by the labor market. In the benchmark economy the lowest productive workers did not see a sizeable difference between their wages and unemployment benefits. Switching to a new regime with lower transfers raises the costs of unemployment and lower productive workers drastically increase their search effort relative to the benchmark economy, as seen in Figure 2b. High skilled workers, in contrast,

[11] This leads to a slight change in the computational solution method: The parameter λ_0 is now an equilibrium outcome. 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.



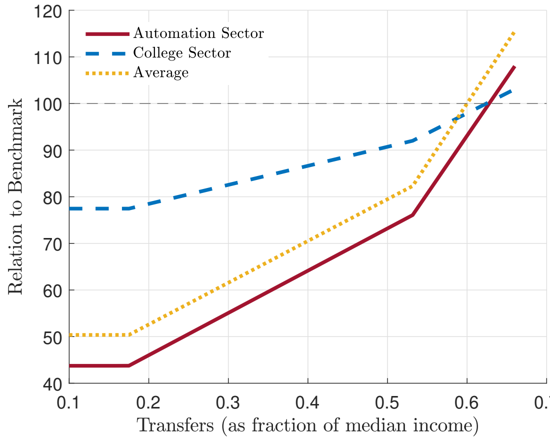
(a) Automation Rate

(b) Search Effort in automation Sector

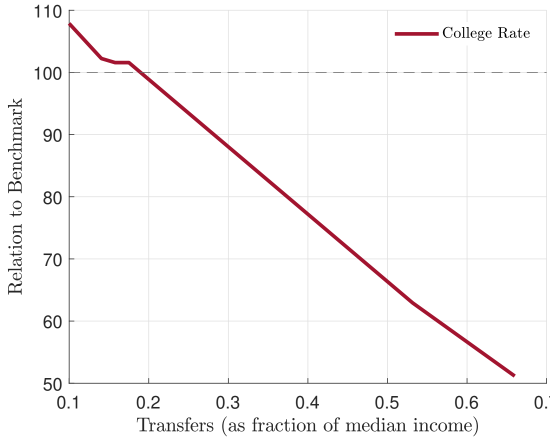
Figure 2: Effects of different levels of UBI transfers on investment in automation and search effort of workers in the automation sector (low skill refers to workers with the lowest productivity level, while high skill refers to workers with the highest productivity level).

have already exerted high effort for finding a job in the benchmark economy and thus, are not affected by the change in policy. Consequently, firms face higher probabilities of being matched with low-skilled workers which reduces the expected profit of filling a vacancy with a worker. Hence, automation rises. When transfers become larger, however, search effort of low productive workers falls together with the college rate. Since higher transfers are financed by higher taxes on labor income, less workers are inclined to obtain a college degree (college attendance drops to nearly 50% of benchmark levels with higher transfers, cf. Figure 3b). Both effects lead to an increase in labor supply from high productive workers relative to the situation with lower transfers. Consequently, the expected profits on the labor market rise and automation decreases.

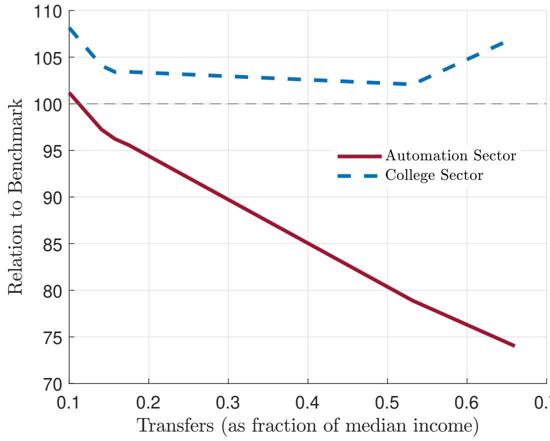
Labor Market. Concerning labor supply, Figure 3c shows the effects of a UBI on average hours worked in both sectors. First, average working hours in the college sector are nearly unaffected by the generosity of the transfer level and always lie roughly 5% above the level from the benchmark economy. This increase mostly stems from the higher taxation needed for financing the universal transfers, which incentivises high income earners to supply more labor to make up for the loss in net income. Workers in the automation sector, in contrast, drastically reduce their labor hours as transfers become more generous. A transfer level above 60% of median income leads to a reduction in average working hours of 25%. At the same time, the number of workers who find a job also decreases with more generous transfer levels (cf. Figure 3a). Also, note that with the large drop in the college rate, total labor supply in the college sector falls considerably, even though average working hours are above their benchmark levels. Overall, we can see a clear adverse



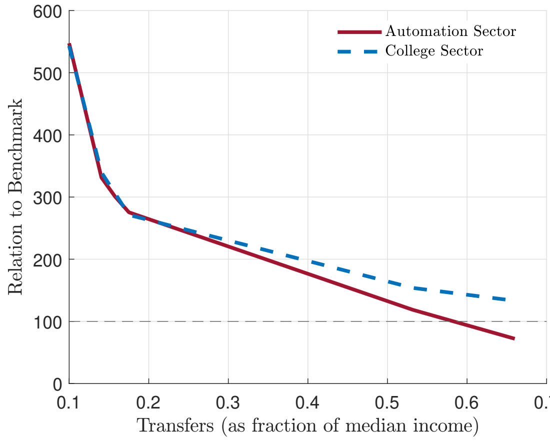
(a) Unemployment Rate



(b) College Rate



(c) Average Working Hours



(d) Market Tightness

Figure 3: Effects of different levels of UBI transfers on labor market outcomes.

relationship between the generosity of the transfer system and labor supply.

Production. Turning to Figure 4 reveals that total output in the economy follows the same pattern as investment in automation. With lower transfers the supply of labor increases in both sectors together with investment in automation which leads to higher output. As transfers get higher, however, output falls to nearly 60% of the benchmark level. This is driven by two results: First, total labor supply falls in both markets as discussed above. Second, due to the high tax payments needed to finance the universal transfers, average disposable income of high productive workers falls relative to the benchmark economy which also leads to a reduction in consumption. Both effects lead to a reduction in output.

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

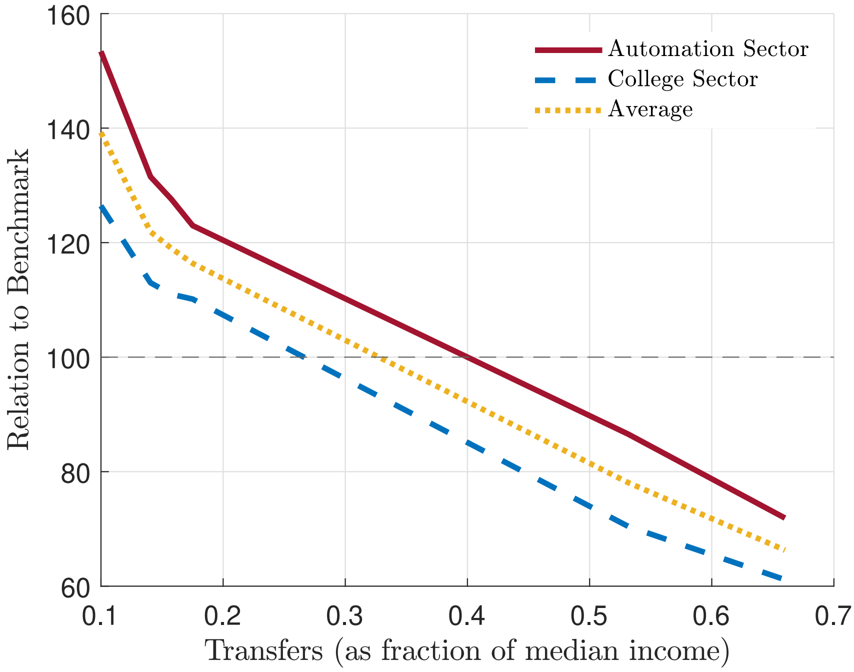


Figure 4: Effects of different levels of UBI transfers on output.

consumption of an individual has to be increased in order to make the household indifferent between the benchmark economy and the economy with a UBI. Specifically, for an individual in state s, the CEV is calculated by

$$V^B((1 + CEV)c(s), h(s)) = \tilde{V}(c(s), h(s)) \tag{16}$$

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 UBI given their state s.

Figure 5 shows the expected welfare gains or losses of a newborn under the veil of ignorance for all transfer levels and both sectors. Looking first at the average welfare, the graph reveals a slight u-shape, showing that very low transfer levels are equally bad for the workers as exceedingly generous ones. However, even with the transfer levels which lead to the lowest welfare loss workers still experience a loss in consumption equivalence of about 20%. The reason for the strong negative effects of a UBI 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, while working hours remain the same. Overall, workers experience a welfare loss. With a more generous UBI, the reason for the strong negative effects is different. Unemployed workers can now enjoy a fixed amount of high transfers, which especially favors low productive workers. High productive workers, in contrast, stem most of the tax burden, as their higher

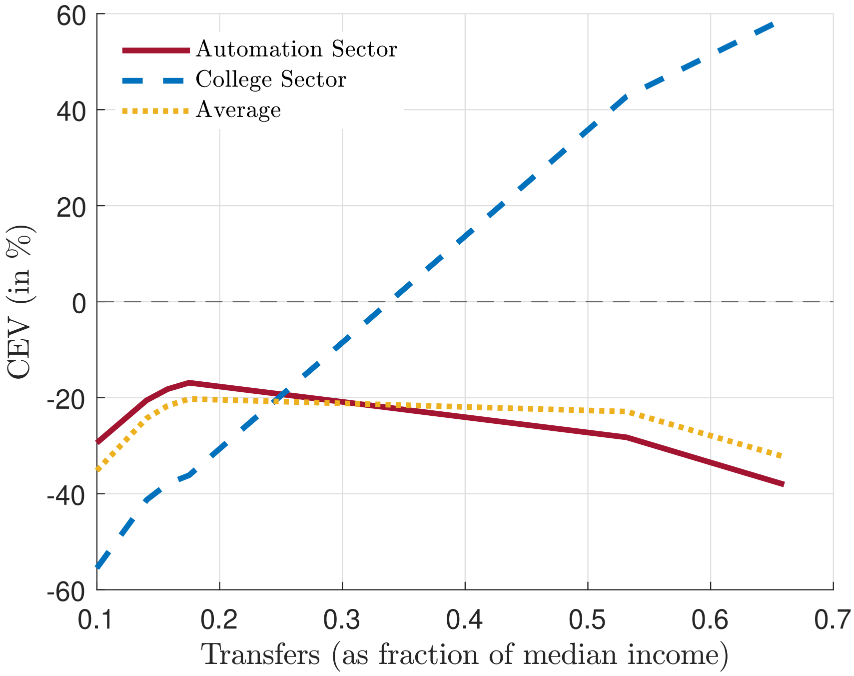


Figure 5: Welfare effects of UBI in terms of consumption equivalence

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, however, reveals a vast difference between workers in the college sector and workers in the automation sector. While low transfers are bad for everyone, a more generous UBI scheme actually leads to a welfare gain in the college sector. This effect is mostly driven by the drop in college attendance. With less people participating in sector 2, the price for the intermediate good rises and workers can enjoy higher wages. Overall, even though their high tax payments finance most of the UBI policy, workers in the college sector can still enjoy more consumption than in the benchmark economy. Hence, the introduction of a generous UBI scheme leads to an increase in the college premium.

4.1 The case for a specific UBI policy

While Figure 4 and Figure 5 already show that the introduction of a UBI which is solely financed by income taxation does not seem desirable, it is still worthwhile to disentangle the equilibrium effects by analyzing the transitional dynamics and to compare the new equilibrium to the benchmark economy in more detail. This section therefore analyzes the introduction of a specific transfer level. A natural starting point is a UBI policy 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.[12] Hence, in this exercise I introduce a UBI

[12]Compare, for example, Eurostat.

Table 4: Effects of UBI on aggregates

Variable		Benchmark	UBI
Output		100	69
Profits		100	79
College Rate		100	57
Automation		100	56
Avg. taxation		22%	62%
Intermediate Goods Prices			
	autom. sector	100	90.7
	college sector	100	103.6
Avg Working Hours		100	85.1
	autom. sector	100	77.5
	college sector	100	106.5
Avg. Consumption		100	57.8
	autom. sector	100	70.0
	college sector	100	64.7
Unemployment Rate		100	100
	autom. sector	100	93.9
	college sector	100	98.4
Disposable Income		100	57.9
	autom. sector	100	71.3
	college sector	100	65.1
Gini		0.37	0.29

which pays exactly 60% of median income to everyone and present a deeper analyze of the effects such a policy would have on the economy.

First, Table 4 provides a detailed overview of the effects of a UBI of 60% of median income by comparing the benchmark equilibrium and the equilibrium after the introduction of the UBI. We can see how output in the new economy drops to only 69% of the benchmark level. Looking at the values for automation and labor supply, this drop in output seems to mostly stem from a reduction in investment in robots and reduced working hours. This also results in lower firm profits.

Next, the college rate drops to 57% of the benchmark level. This is because the incentive to join sector 2 is mostly driven by higher job security. However, for lower skilled workers the disutility of obtaining a college degree now outweighs the potential gains due to the additional insurance provided by UBI. The drop in the college sector and higher labor force participation in the automation sector also lead to a change in factor prizes. The price for the intermediate goods in sector 1 drops by nearly 10%, whereas the price for intermediate goods in sector 2 rises by roughly 4%.. Consequently, gross wages in the college sector increase, while the wage rates in the automation sector drop. However, The lump-sum transfers of the UBI are mainly financed by higher taxes on labor income, thereby increasing marginal tax rates for high-income workers. Hence, average net income falls in both sectors. This also leads to a significant drop in average consumption, which decreases by 30% in the automation sector and by nearly than 40% in the college sector.

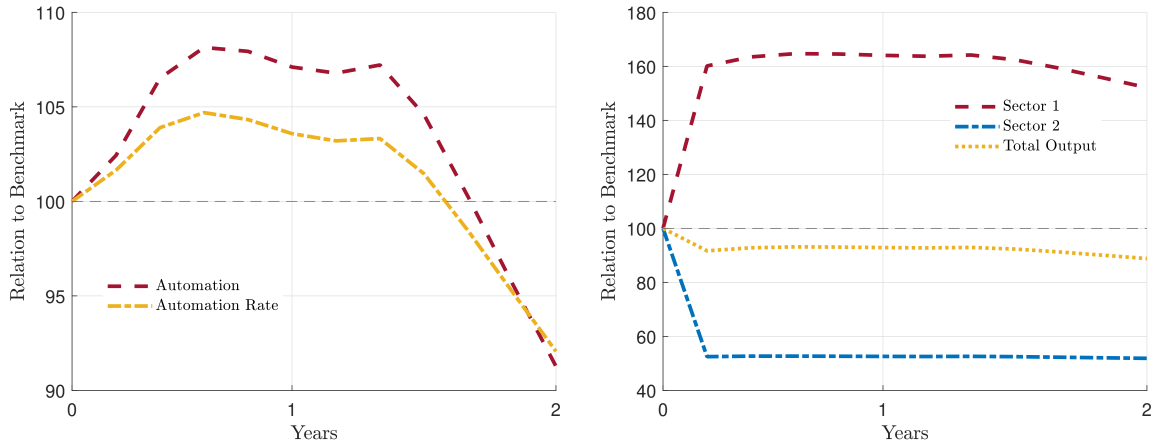
Lastly, the introduction of a UBI has significant consequences on the income distribution. The percent of overall income earned by top income earners falls drastically and the Gini coefficient drops from 0.37 in the benchmark economy to 0.29 in the economy with a UBI. Details on the income distribution can be found in Table B1 in appendix B.

Overall, combining the insights from the change in the income distribution with Table 4 we seemingly can conclude that the introduction of a universal basic income would mostly lead to a large redistribution from high income earners to low income earners. The insight for this becomes immediately clear when comparing the average tax payments in both economies. While the average taxation in the benchmark economy was targeted to be roughly 22%, the need for additional funding in the economy with a UBI leads to an increase of average tax payments to 62%. To run a balanced budget the government taxes higher-income workers more heavily, thereby introducing additional redistribution.

Transitional Dynamics. This section describes the dynamics which occur during the transition to the new equilibrium.[13] First, Figure 6 shows how the investment in automation and total output are effected during the transitional periods. Looking at Figure 6a we can see how initially firms react by increasing the stock of robots until it lies roughly 8% above the benchmark level after the first year. Then, investment slows down until the stock of robots even falls below the benchmark level and only lies at nearly 90% of the benchmark level. A similar path can also be observed for the automation rate, which is the fraction of jobs in the automation sector which are occupied by robots. Again, the automation rate initially rises and starts falling after the first year. However, the initial increase is less pronounced than for total automation, indicating that the number of jobs occupied by workers also rises.

Turning to Figure 6b reveals that this increase in automation leads to a surge in production in the automation sector and output of the intermediate good from sector 1 rises by roughly 60% and stays at this level throughout the transition period. Hence, the

[13]For details on the computational method see appendix E.



(a) Investment in Automation

(b) Evolution of Output

Figure 6: Transitional Dynamics of Investment in Automation and Output. Note: Automation Rate is the fraction of jobs in automation sector occupied by robots. Sector 1 refers to the automation sector, while sector 2 refers to the college sector.

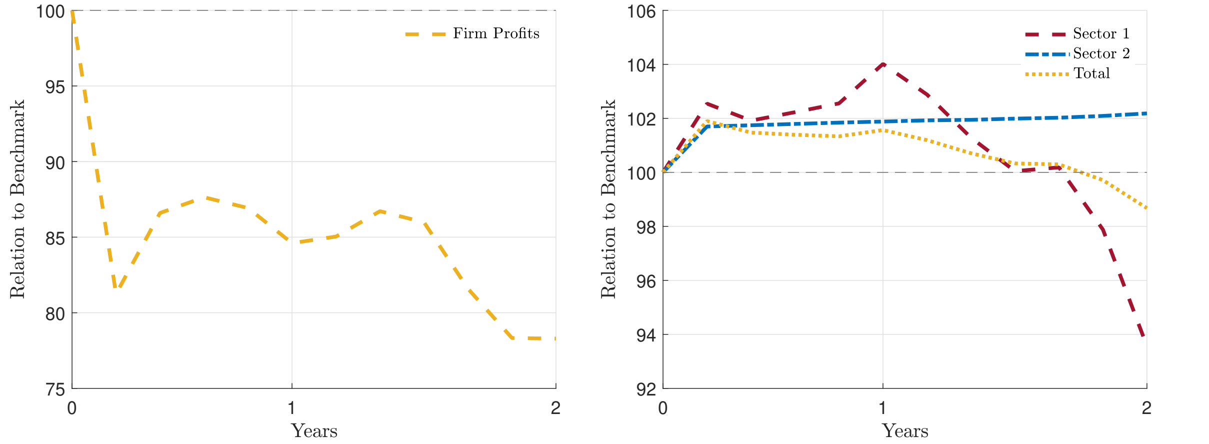
decline in automated jobs after the first year of transition is outweighed by the increase in jobs done by workers. In contrast, output in the college sector falls drastically and remains at roughly 50% of the benchmark level. This considerable drop in production in sector 2 stems from the reduced labor supply in sector 2. First, the amount of workers with a college degree drops and second, the remaining workers in sector 2 reduce their working hours. This is shown in Figure 8a and Figure 8c.

How firms are affected by these transitions is shown in Figure 7. We can see how despite the increase in output in sector 1 the profit of firms decreases. This is partly due to increased wage rates[14] demanded by workers as seen in Figure 7b. There are two reasons why the introduction of a universal basic income leads to higher wage rates: First, a guaranteed transfer of 60% of median income is an improvement for most unemployed workers and consequently, improves the outside option of the workers and their bargaining position. Second, the introduction of the UBI is solely financed through an increase in the average tax on labor income. Hence, workers request higher compensation per unit of nominal labor supply since a higher fraction of their income is used for redistribution. Lastly, firm profits are also affected by the prices of intermediate goods and as the production in sector 1 rises, the price for the intermediate good falls.

Next, Figure 8 shows transitional paths for several statistics regarding the labor market. In Figure 8a we can see how the introduction of a UBI leads to a slight reduction in the college Rate. With the guaranteed income provided by UBI, workers who face a high disutility of attending college and only decided to do so due to the higher expected life-time income are now dropping out of the college sector.

Regarding labor force participation, Figure 8b reveals that unemployment rates fall

[14]Note that the wage rate refers to the payment per unit of effective labor supply and is not equivalent to the worker's income



(a) Change in Profits

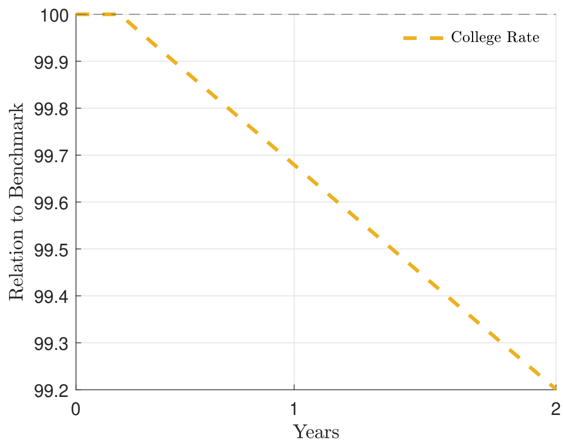
(b) Average Wage Rate

Figure 7: Transition paths for firm profits and wage rates. Note: Sector 1 refers to the automation sector, while sector 2 refers to the college sector.

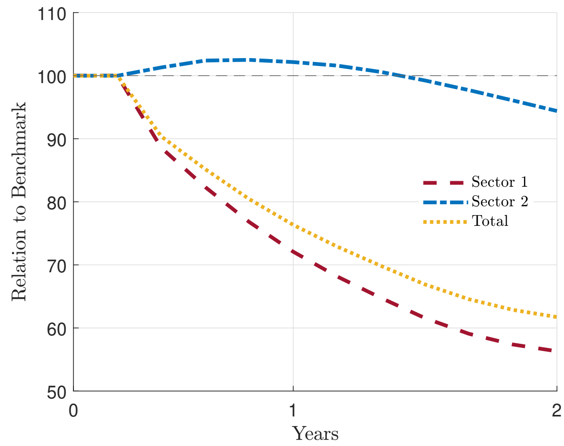
throughout all sectors, while the average effort to search for a job increases (see Figure 8d). At the same, the average amount of working hours falls drastically in the automation sector and stays fairly constant in the college sector. Overall, more people are finding a job but are spending less time at work.

Lastly, since a universal basic income is a lump-sum transfer, it is worthwhile to look at the evolution of disposable income as well as average tax burden during the transition to the new equilibrium. Figure 8e therefore shows the average disposable income of workers. Immediately, we see that the money an average worker in the automation sector can spend on consumption has increased by nearly 70% compared to the benchmark economy. This stems in part from higher wages paid in the automation sector but is mainly due to the additional transfer provided by the introduction of a UBI. The college sector, in contrast, sees a decline in disposable income of nearly 10%. Despite the increase in wages paid by firms and the additional transfers from the government, workers in the college sector have less money at their disposal than in the benchmark economy. Looking at Figure 8f reveals that the reason for this decline lies in the funding of the universal transfers. Average taxation in the economy rises by more than 100% and while both sectors are affected similarly by this increase, workers in the automation sector earn much less income and therefore pay much less taxes in absolute terms. Overall, for workers in the automating sector the increase in taxation is being outweighed by the additional funding provided by a universal basic income. Workers in the college sector, in contrast, loose as it is mostly their income which finances the additional transfers.

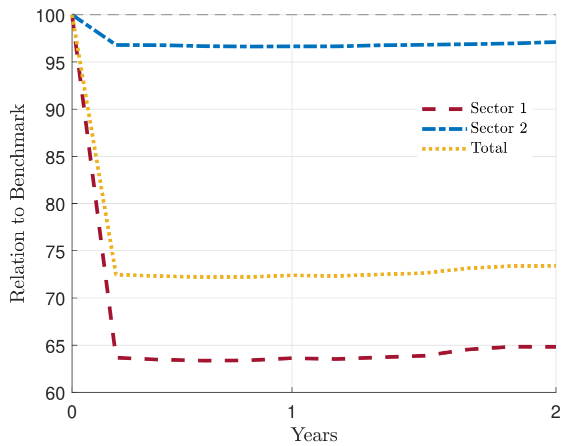
Welfare Comparison. Lastly, the transitional dynamics are also important for the welfare implications of the new policy, since current cohorts experience different welfare effects than future generations who are immediately born into the new stationary equilibrium. Hence, Figure 9 reports the welfare gains and losses of cohorts who are born before



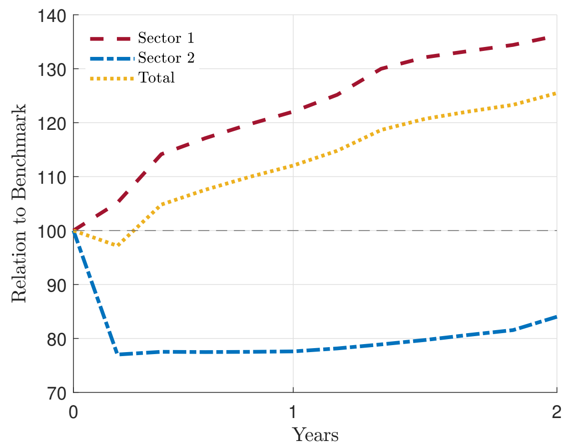
(a) Change in College Attendance



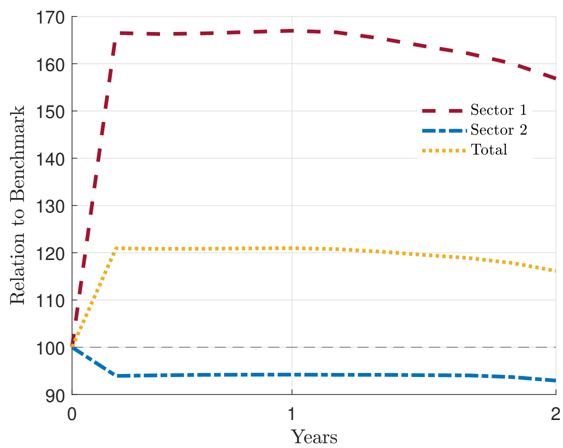
(b) Change in Unemployment Rates



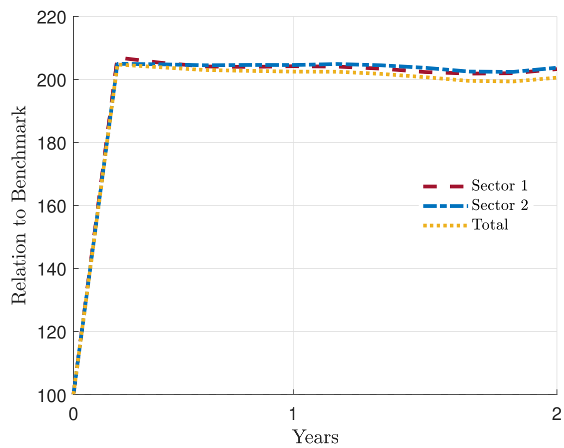
(c) Average Working Hours



(d) Average Search Effort

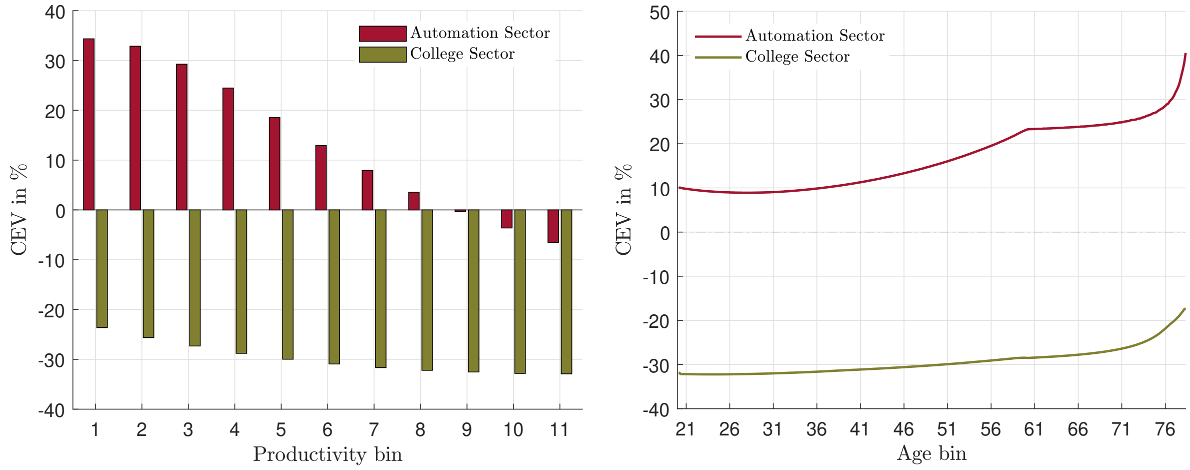


(e) Mean Disposable Income



(f) Average Income Taxation

Figure 8: Transitional Dynamics in the labor market. Note: Sector 1 refers to the automation sector, while sector 2 refers to the college sector



(a) Welfare Effects per Skill Group

(b) Welfare Effects per Age Group

Figure 9: Change in expected life-time utility of current generation when introducing the UBI policy next period.

the introduction of the UBI. 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[15].

Turning to Figure 9a reveals the different effect the introduction of a UBI has on workers of different productivity levels and between sectors. Mostly all of the workers in the automation sector experience large welfare gains (up to 34% for the least productive workers) and only the workers with the highest productivity are adversely affected (with welfare losses up to -8%). Workers in the college sector, in contrast, experience welfare losses throughout all skill groups with the highest productive workers loosing roughly 32% in terms of CEV.

Next, Figure 9b 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 a clear upward trend with older workers being less adversely affected, they still experience welfare losses throughout all age groups. Only the oldest people, who are already at the end of their working life, are indifferent between the two equilibria. In the automation sector, in contrast, all workers from the current generation can expect welfare gains. Similarly to the college sector, older workers are better off than younger workers, but this difference seems to be steeper as the welfare gains of people near the end of their model life is nearly 4 times as high as the welfare gains expected by the youngest workers. These accentuated positive welfare effects for older people in the automation sector are mainly due to the fact that firms can invest in robots. Since aging workers will soon leave the workforce, firms might want to

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

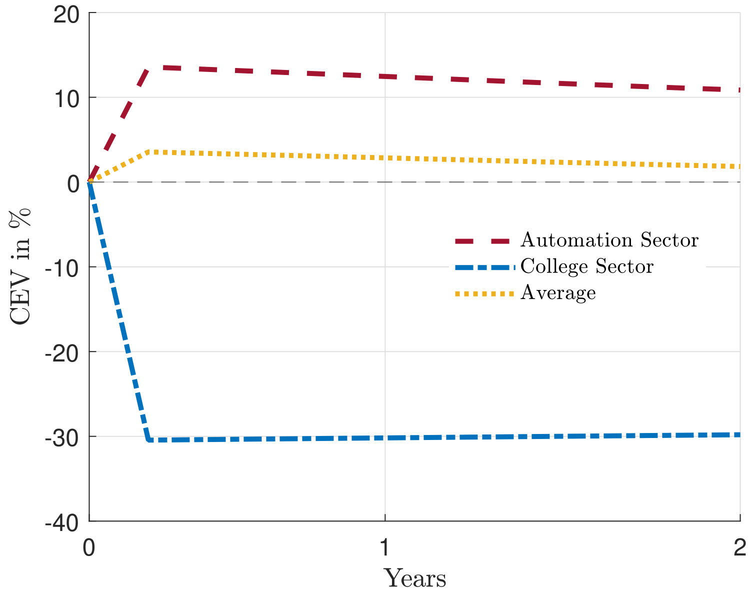
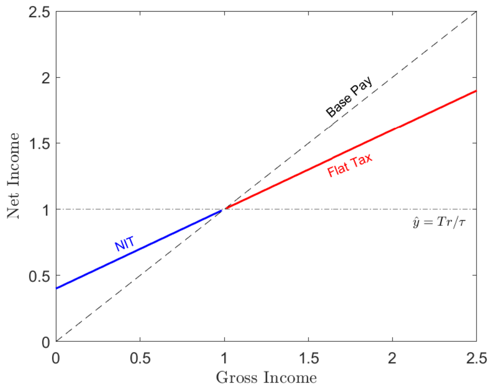


Figure 10: Welfare effects for cohorts who are born after the introduction of a a UBI

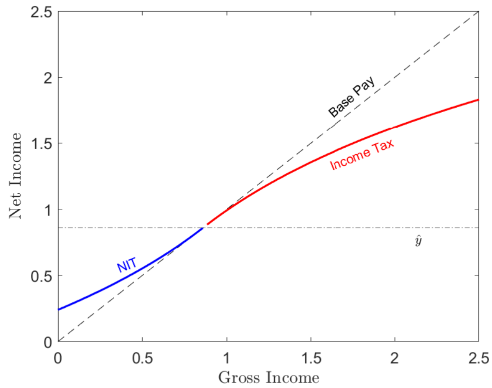
automate their tasks and hence, older people face poorer contracts. The introduction of a UBI can now provide additional insurance against this rationalization.

Together these figures suggest that the introduction of a UBI would mainly yield large 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 62.49% of workers would vote in favor of the reform.

This can also be seen in Figure 10 which plots the welfare effects of cohorts who are born after the introduction of a UBI. Again, workers in the automation sector are better off during the transition period than in the benchmark equilibrium, while workers entering the college sector experience substantial welfare losses. However, the overall welfare effect is slightly positive, indicating that the welfare gains experienced by workers in the automation sector slightly outweigh the large losses experienced in the college sector. However, as we converge to the new equilibrium the welfare gains in the automation sector shrink until the overall welfare effect turns negative. In the end, computing the expected life-time utility under the veil of ignorance for the benchmark economy and the counterfactual economy reveals that future generations who are born into the new equilibrium would experience a welfare loss of -5% in terms of CEV. Hence, while current generations would vote in favor of a UBI, 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.



(a) Flat Tax Schedule



(b) Progressive Tax Schedule

Figure 11: Negative Income Tax

To see how future generations would fare under a regime with a universal basic income, I compute welfare under the veil of ignorance. This analysis reveals that future generations would also prefer the benchmark economy, as they would require an increase of 1.34% of consumption in order to be as good off in the economy with UBI as they were in the benchmark economy.

5 Negative Income Tax

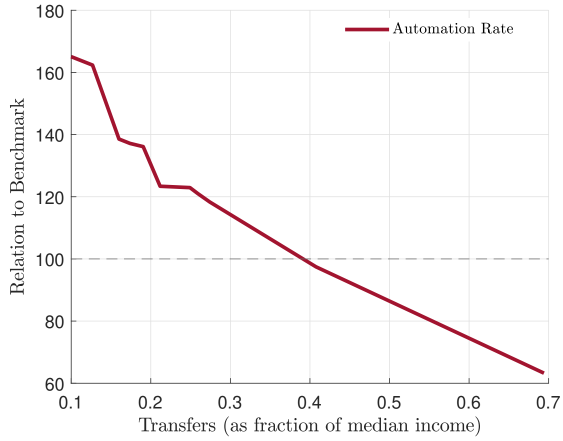
Another natural experiment is to compare the benchmark economy and the effects of UBI with a negative income tax as proposed, among others, by Friedman (1962). The idea of a NIT is very similar to a UBI, as people are guaranteed a basic income, regardless of their employment status, their wealth or their education. The difference, however, is that the transfers of a negative income tax face out as households start to earn labor income until they completely vanish above a given income threshold, $\hat{y}$.

In this exercise, I replace the taxation scheme and the unemployment benefits from the benchmark economy with a linear negative income tax. With $\tilde{y}$ denoting gross income (0 in case of unemployed), τ denoting the flat tax and Tr the amount of transfers to unemployed, after-tax income is now given by

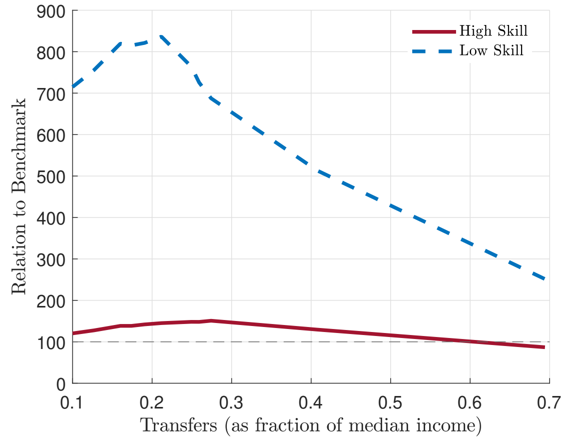
$$y = \tilde{y} + Tr - \tau\tilde{y}, \tag{17}$$

such that households receive transfers until their income exceeds $\hat{y} = Tr/\tau$. Figure 11a shows an example of how such a tax can look like, when households are guaranteed transfers in the amount of median income and transfers face out at a rate of 40%.[16]

[16] I also conducted an experiment with a progressive tax schedule as depicted in Figure 11b, 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.



(a) Automation Rate



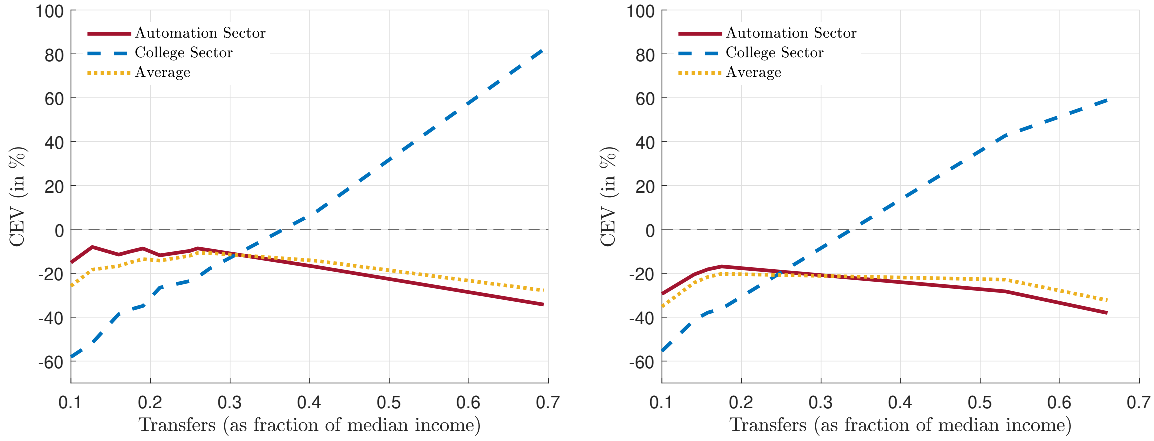
(b) Search Effort in automation Sector

Figure 12: Effects of different NIT schemes on the automation sector (ordered by guaranteed income as fraction of median income).

As in section 4, I vary the generosity of the unconditional transfers and measure them as fraction of median income. The flat income tax, τ, which is also the face-out rate of the transfers, is then chosen to keep the government budget fixed 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, since transfers are not distributed in a lump-sum manner but face out for higher income earners.

As shown in Figure 12 the equilibrium effects of an NIT are very similar to the effects of a UBI. We can see the same patterns in investment in automation and the search effort of workers in the automation sector. The reasoning for this effect is the same as described above in the case of UBI. Switching to a new regime with lower transfers raises the costs of unemployment which affects the search effort of low skilled workers, while the search effort of high skilled workers is nearly unaffected. Again, firms face higher probabilities of being matched with low-skilled when transfers are low and consequently, automation rises. The effect reverses with higher transfers as the probability of being matched with high productive workers increases. Also, note, that search effort nearly always lies above the benchmark level. This is because starting to work does not lead to a loss of all transfers, but rather to a gradual facing out, so that workers can start earning income while still enjoying part of their benefits. More figures on the effects of an NIT, which also reveal qualitatively similar effects as the introduction of a UBI, can be found in appendix C.

Lastly, Figure 13 compares the welfare implications of NIT schemes and UBI policies which provide the same amount of unconditional transfers. Again, we can see that the effects of a negative income tax are qualitatively the same as those of universal transfers. However, there is a slight quantitative difference as the negative welfare effects of an NIT



(a) Welfare Effects of NIT

(b) Welfare Effects of UBI

Figure 13: Comparing the welfare effects of an NIT to a UBI.

seem to be less pronounced for lower transfers. For example, providing an unconditional income at the amount of 30% of median income leads to an average welfare loss of -20% in terms of CEV in the case of a UBI, but only to roughly -10% in the case of an NIT. Also, for higher transfers the welfare gains expected by workers in the college sector after the introduction of an NIT exceed the expected gains from a UBI. This difference stems from the taxes needed to finance the system. With an NIT the transfers face out until high income earners do not get any benefits at all, while a UBI provides lump-sum transfers which are always the same for everyone. Hence, the average tax burden in an economy with an NIT is far smaller than in an economy with a UBI, thereby leading to less adverse effects on high income earners.

This result of qualitatively similar effects together with less pronounced negative consequences of an NIT are also confirmed in appendix F which analyses a specific NIT scheme in more detail. Overall, we seemingly can conclude that an NIT provides the same safety measures for low income earners as a UBI, while resulting in a far smaller tax burden.

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 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.

Table 5: 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 face-out rate of transfers.
[2] Transfers are measured as percent of median income.
[3] Welfare is measured in relation to the benchmark economy.

Considering the results of section 5, the introduction of a negative income tax 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 face-out rate of the transfers (cf. Equation 17), 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 5.

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 exceed 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 6 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 face-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

Table 6: Comparing model outcomes from optimal NIT to benchmark

	Benchmark	Optimal NIT
College Share	31%	52.8%
Automation Rate	30%	74.5%
Average Taxation	21.9%	−10%
Output	100	217
Unemployment Rate	7.5%	3.8%
autom. sector	8.7%	3.8%
college sector	4.9%	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

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 5 and 6 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.

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 a Universal Basic Income with varying degree of generosity which is 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 UBI with very low transfer levels increases the costs of unemployment and therefore also increases search effort of low productive workers, while high productive workers are nearly unaffected. This affects the expected profits on the labor market, since firms are now more likely to be matched with low productive workers and consequently, investment in automation rises. When transfer levels are higher, in contrast, the reduced search effort of low-skill workers increases expected profits of firms on the labor market and discourages automation. At the same time, labor supply falls in both markets and due to higher taxation disposable income also decreases. Overall, the equilibrium effects on output are strongly negative and a welfare analysis suggests that under the veil of ignorance workers would prefer being born into the benchmark equilibrium without a basic income.

A subsequent analysis of one specific UBI program which provides unconditional transfers in the amount of 60% of median income to everyone reveals additional insights on the effects of basic income programs. The analysis shows that such a policy has mainly adverse affects on macroeconomic outcomes. Output, consumption and college attendance fall, while average taxation rises drastically. Since the additional funding needed to finance the unconditional transfers is provided by higher taxation of labor income, the effect of a UBI is mainly 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 a UBI simply redistributes income from the college sector to the automation sector. Consequently, workers in the college sector experience large welfare losses, while the average worker in the automation sector can expect welfare gains. However, after the transition to the new equilibrium the expected life-time utility of a newborn under veil of ignorance is lower than in the benchmark equilibrium and thus, future generation would prefer being born into an economy without UBI. The majority of the current generation, in contrast, can expect to experience welfare gains during the transition and would vote in favor of a reform, thereby creating a conflict between current and future generations.

The results of this exercises seem to be robust with respect to the specific regime with which an unconditional transfer is provided. For example, introducing a negative income tax which provides the same subsistence level of 60% of median income to unemployed households leads to the same qualitative result as the introduction of a UBI. Quantitatively, however, the effects slightly less pronounced. Since the transfers are facing out with higher incomes, the overall tax burden is much lower. Hence, while leading to similar results, a negative income tax requires a far smaller budget. The natural next step is therefore to analyze whether an NIT together with a completely new tax regime to 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 face-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 effects on automation decisions and while the introduction of a UBI and an NIT lead 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

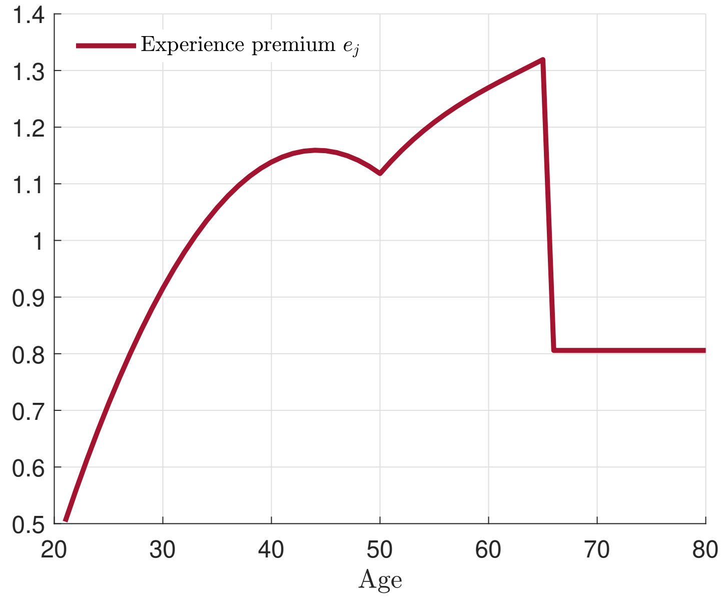


Figure A1: Experience premium to wages

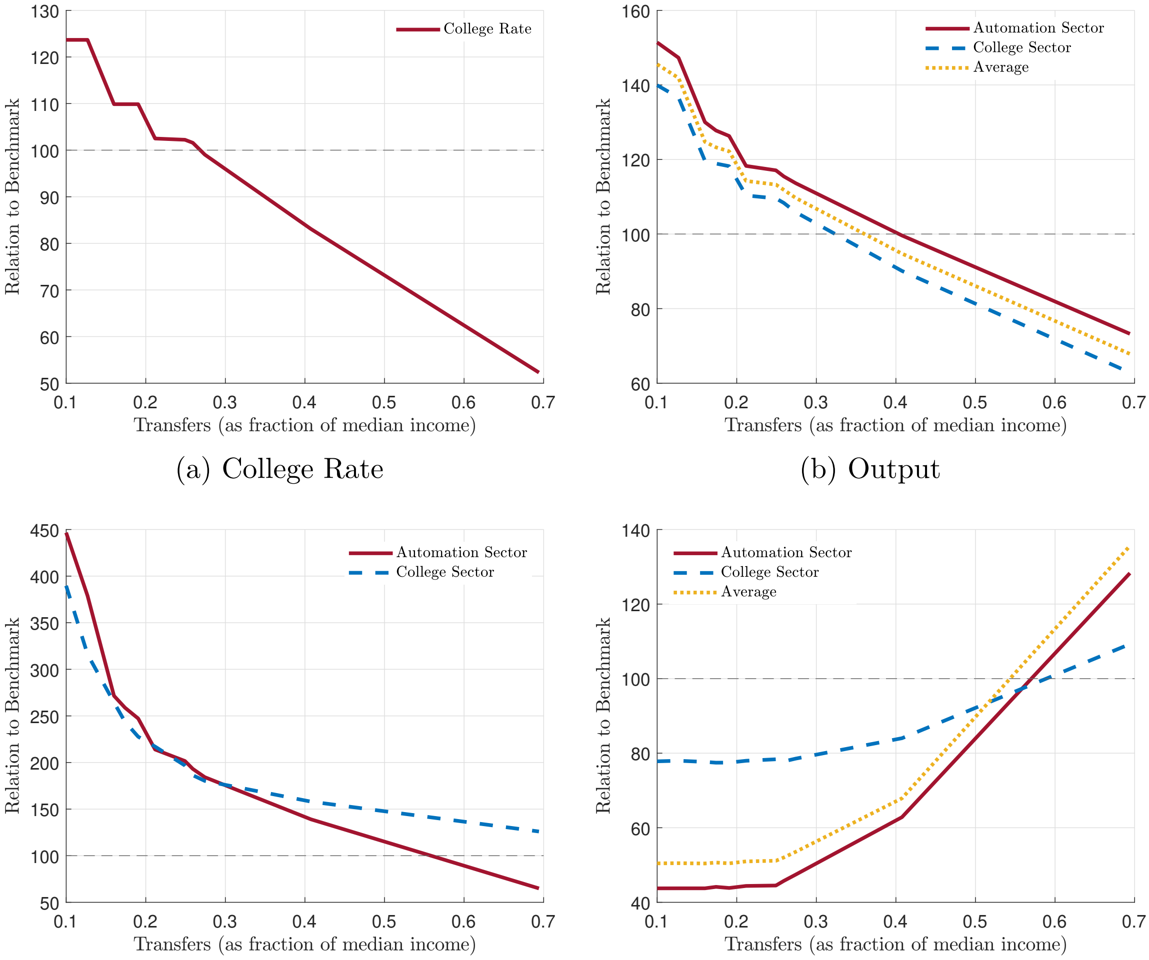
B Effects of UBI on Income Distribution

Table B1: Earnings Distribution

Quintile	**Benchmark**	**UBI**[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	0.29

[1] UBI refers to the policy which pays exactly 60% of median income as described in subsection 4.1.

C Effects of a Negative Income Tax: Additional Figures



(a) College Rate (b) Output

(c) Market Tightness (d) Unemployment Rate

Figure C1: Effects of different NIT schemes (ordered by guaranteed income as fraction of median income)

D 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 life-span 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:

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:

$$S(\mathcal{P}) = \left(\sum_i \omega_i (M_i(\mathcal{P}) - D_i)^2 \right)^{1/2} \tag{18}$$

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. $\forall i : \omega_i = 1$)

E Computing Transitional Dynamics

To compute the dynamics which 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 costs of posting vacancies, κ_1^v and κ_2^v, and the average wage rates, $\bar{w}_1$ and $\bar{w}_2$, during all periods. That is, I need to solve for the values of $\{p_{1,t}, p_{2,t}, \kappa_{1,t}^v, \kappa_{2,t}^v, \bar{w}_{1,t}, \bar{w}_{2,t}\}_{t=1}^T$, which satisfy the conditions for the 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 $\{p_{1,t}, p_{2,t}, \kappa_{1,t}^v, \kappa_{2,t}^v, \bar{w}_{1,t}, \bar{w}_{2,t}\}_{t=1}^T$, which is a matrix of dimension $7 \times T$.

III. Given the guess for $\{p_{1,t}, p_{2,t}, \kappa^v_{1,t}, \kappa^v_{2,t}, \bar{w}_{1,t}, \bar{w}_{2,t}\}_{t=1}^T$ recursively compute decision rules for all periods 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 $\{p_{1,t}, p_{2,t}, \kappa^v_{1,t}, \kappa^v_{2,t}, \bar{w}_{1,t}, \bar{w}_{2,t}\}_{t=1}^T$

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.

F Effects of an NIT providing 60% of median income

Similar to the experiment in subsection 4.1, I introduce a negative income tax which provides exactly 60% of median income as unconditional transfers to analyze the effects of such a policy in more detail. Table F1 shows the effects of a NIT on aggregate variables by comparing the new stationary equilibrium to the benchmark equilibrium and the outcome from the introduction of a UBI as described in section 4. Again, overall output drops, while profits see a slight increase. However, output falls by less percent when compared to the effects of a UBI and profits rise by more. Similar patterns can be seen with Investment in Automation and College attendance. Both variables see the same effect qualitatively as in the experiment with the UBI as they fall below the values from the benchmark equilibrium. However, quantitatively the effects are less pronounced and the college rate only drops by 4% as compared to 12% after the introduction of a UBI. The biggest difference, however, is the average tax burden. As transfers are now not distributed equally among all workers but face out with higher income, the tax rate which balances government budget lies drastically below the tax rate from both, the benchmark equilibrium and the equilibrium after the introduction of a UBI. Overall, the average worker only sees a tax burden of 4%.

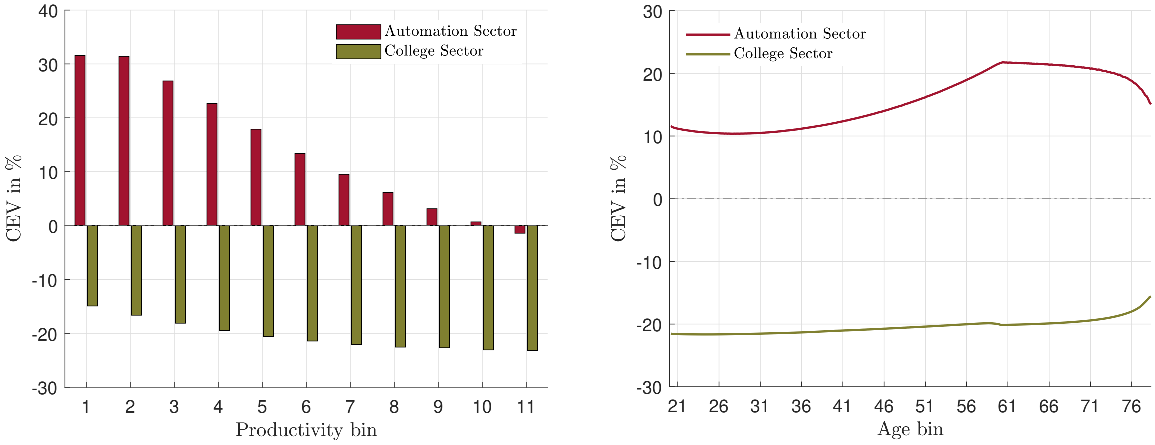
The difference in tax payments also leads to a considerable difference in disposable income for workers in the college sector. While disposable income dropped to 66% of the benchmark level after the introduction of a UBI, a negative income tax only leads to a drop to 81%. Similarly, workers in the automation sector also see a less pronounced decline, which mostly stems from the high productive workers. With this less pronounced drop in disposable income the Gini coefficient also does not react as strongly as in the equilibrium with a UBI. It only drops to 0.3 as compared to 0.15.

Table F1: Comparison of UBI and NIT schemes which both provide 60% of median income as unconditional transfers

Variable	Benchmark	UBI	NIT
Output	100	69	88.5
Profits	100	79	105.5
College Rate	100	57	77.3
Automation	100	56	96
Avg. taxation	22%	62%	4%
Intermediate Goods Prices			
autom. sector	100	90.7	92.5
college sector	100	103.6	108.7
Avg Working Hours	100	85.1	80.9
autom. sector	100	77.5	72.4
college sector	100	106.5	102.4
Avg. Consumption	100	57.8	77.5
autom. sector	100	70.0	90.2
college sector	100	64.7	80.8
Unemployment Rate	100	100	62.4
autom. sector	100	93.9	53.6
college sector	100	98.4	98.4
Disposable Income	100	57.9	76.4
autom. sector	100	71.3	89.5
college sector	100	65.1	81
Gini	0.37	0.29	0.3

In summary, a negative income tax seems to be very similar to the introduction of a UBI, but its effects are less pronounced and it leads to considerable less redistribution between the sectors. However, to see who wins and who looses, the next section again looks at welfare levels.

Welfare Comparison. As in subsection 4.1, I again compute the welfare implications of this reform to see who wins and who loses in the current generation of workers, who are already born before the introduction of the NIT reform. Hence, Figure F1 again shows



(a) Skill groups (b) Age Groups

Figure F1: Welfare effects of a NIT policy

welfare gains and losses in terms of CEV when compared to the benchmark equilibrium. As with Table F1 above, the resulting graphs look very similar to the introduction of a UBI and differences lie only in the size of the effects. Again, mostly all of the workers in the automation sector experience large welfare gains (up to 31% for the least productive workers) and only the workers with the highest productivity are adversely affected (with welfare losses of roughly -2%). This is the same pattern that we already saw in Figure 9a after the introduction of a UBI, but the effects are again less pronounced. For example, introducing a UBI leads to a welfare loss of -8% for the highest productive workers in the automation sector compared to only -2% in this case of a NIT. Also, workers in the college again experience welfare losses throughout all skill groups, but the highest productive workers only loose about 22% in terms of CEV compared to roughly 32% in the exercise with a UBI.

Next, Figure F1b again shows the change in welfare for current cohorts for different age groups in both sectors. Qualitatively we can see no difference to Figure 9b and the effects of a UBI. However, quantitatively the changes in welfare are roughly 10 percentage points less pronounced compared to the effects of a UBI, meaning that workers in the college sector experience lower welfare losses, while workers in the automation sector enjoy lower welfare gains. Nonetheless, the picture stays the same: Older households are less adversely affected than younger households and redistribution mainly occurs between the two sectors.

Lastly, since workers in the automation sector outnumber workers in the college sector, a majority of 71.2% of current households would vote in favor of the reform. However, as with the introduction of a UBI, computing the expected life-time utility under the veil of ignorance reveals that households would prefer being born into the benchmark equilibrium than into the counterfactual equilibrium with a NIT. As with all the results int his section, the welfare loss is less pronounced than under a regime with a UBI and the expected welfare loss of a newborn is -2.13% in terms of CEV, compared to roughly -5% with a UBI. Nevertheless, the welfare change is still negative and the same problem arises as in with the introduction of a UBI: While current generations would vote in favor of an NIT, future generations are worse off and would prefer being born into the benchmark equilibrium. This might potentially create generational conflict.