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

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Abstract

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

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

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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). Later, Atkinson (1995) discussed the replacement of the social security system by a guaranteed basic income which provides transfers to everyone irrespective of their age, income, or other personal characteristics.

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

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

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

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

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

lation it would yield a 100 percent coverage and avoid frictions from stigma or eligibility. Lastly, providing an unconditional income is thought to yield a minimum of distortions as it is a lump-sum transfer which avoids problems from bunching below certain costly thresholds. This is particularly relevant with regard to the effective marginal tax rates faced by unemployed. If welfare benefits are being retracted when people start working, they might be discouraged from actively searching for jobs. An unconditional income is thought to reduce this friction and could even lead to higher labor force participation.

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

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

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

While the literature on the effects of unconditional transfers is already extensive and still growing, studies mostly rely on empirical data or contained field experiments (see,

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

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

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

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

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

This paper is organized as follows. The subsequent section describes relevant literature and highlights the contributions to the ongoing discussion. Section 2 then presents the model setup, while the parameterization and calibration strategy of the benchmark economy are described in Section 3. In Section 4, I discuss the effects of a basic income of varying generosity and compare the two most common proposal, a Negative Income Tax and Universal Basic Income. Section 5 then provides a deeper analysis of one specific basic income program. Section 6 briefly analyses an optimal tax and transfer system, and 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 complementary to the existing literature and provide insights into new channels through which basic income programs affect the economy.

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

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

Lastly, assessing UBI policies also relates to the empirical literature concerning the effects of unconditional transfers. Beginning in the end of 1960s, four pilot studies using a negative income tax were conducted in the US and showed only moderate reductions in work effort in response to the treatment (see, e.g., Munnell, 1986). The long-term effects of one of these experiments[5] were studied by Price and Song (2018). The authors caught up with participants four decades after the program and found that reductions in earnings in response to the cash assistance were mainly related to retirement. Similar modest results were found more recently in studies exploiting lottery wins. Cesarini et al. (2017), for example, used evidence from Swedish lotteries to show that a monetary win only leads to a moderate reduction in earnings, while the uncompensated labor supply elasticity is close to zero. Similarly, Jones and Marinescu (2022) exploit data from the Alaska Permanent Fund, which pays a yearly dividend to all residents, and find no effect on employment. While all these empirical studies provide partial insights on the effects of a guaranteed income, their results cannot simply be extrapolated on a broader population, as mentioned by Zellner and Rossi (1986), among others. Such low-scale experiments cannot provide insights on general equilibrium effects as they only focus on the responses of a small sub-population, while ignoring reactions by firms. Moreover, they often even fail to explain partial equilibrium effects, since they do not capture decisions over the whole life-cycle. Hence, this paper provides a quantitative framework to test these results within a model setup which allows for the analysis of general equilibrium effects and the evaluation of counterfactual policies.

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

2 Model Setup

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

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 a college degree is obtained. Both markets share the same capital stock and produce intermediate goods for final production. In the first market, which does not require a college degree, workers can be replaced by robots, while production in sector 2 always requires labor input.

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

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

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

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

where the parameter λ_1 determines the degree of progressivity, while λ_0 shifts the tax function and determines the average level of taxation in the economy. This specification has been introduced into dynamic macroeconomic models with heterogeneous agents by Bénabou (2002) and allows for closely mimicking existing tax systems with only two variables. Net income, y, is then given as $y = \tilde{y} - T(\tilde{y}) = \lambda_0 \tilde{y}^{1-\lambda_1}$. Also, note that this specification does not provide transfers for unemployed, since $T(0) = 0$. Unemployment benefits are described below and subsection 2.5 discusses the possible forms of UBI.

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

Then, a worker's decision problem is given by

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

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

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

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

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

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

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

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

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

Hence, a worker decides to enter sector 2, iff

$$V(z, z_c, 2) > V(z, z_c, 1). \tag{5}$$

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 of one firm from sector 1 and sector 2, respectively. Intermediate goods are produced according to a Cobb-Douglas technology within a firm:

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

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

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

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

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

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

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

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

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

One-Worker Firms. All firms in sector 2 as well as those firms in sector 1 who do not adopt a robot are randomly matched with unemployed workers in their respective market. The value of a job filled with a worker in state s in sector m is given by

$$\begin{aligned} J(s, m) = \max_k \; & p_m \cdot k^\alpha (hze_j)^{1-\alpha} - (r+\delta)k - whze_j \\ & + \frac{1}{1+r}\Big[\psi J_m^v + (1-\psi)\mathbb{E}\Big(J(s', m)\Big)\Big], \end{aligned} \tag{6}$$

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

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

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

$$J_m^v = -\kappa_m^v + \frac{1}{1+r} \Big(g(\theta_m) \mathbb{E}\Big(J(s,m)\Big) + \Big(1 - g(\theta_m)\Big) J_m^v \Big), \tag{7}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$(w, h) = \underset{w \geq 0, h \in [0,1]}{\arg\max} \Big(W(w, h, s) - U(s) \Big)^{\xi} \cdot \Big(J(w, h, s) - J^v \Big)^{1-\xi}, \tag{9}$$

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

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

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

$$(1 + r - \delta)K_t^s + (1 - \tau_a)\Pi_t - \kappa^v v_t - \bar{x} q_t - (1 + \tau_c)c_t^{\text{cap}} = K_{t+1}^s \tag{10}$$

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

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

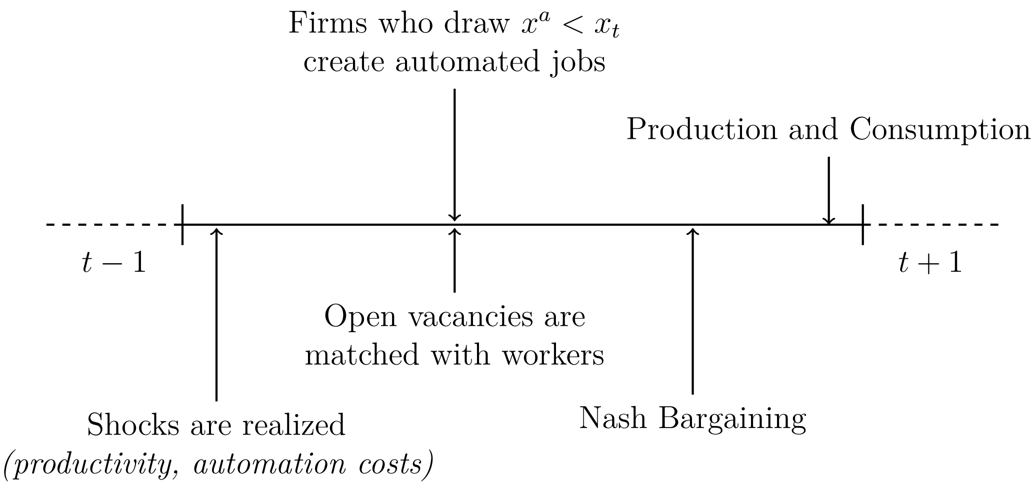


Figure 1: The timing of events in period t

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

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

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

$$R_\ell + R_c + R_\pi = B + G \tag{11}$$

2.4 Stationary Equilibrium

At each point in time an agents state is given by $s = (z, z_{-1}, m, j, u)$, with z being persistent productivity, z_{-1} last period's persistent productivity, $m \in \{1, 2\}$ the market, j age and $u \in \{0, 1, 2\}$ the unemployment status (0 meaning employed, 1 indicating short-term unemployment and 2 denoting long-term unemployment). Let the space of possible states be denoted by $S = Z \times Z \times m \times J \times u$.

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

1. The value functions and the optimal decision rule for consumption $c(s)$ solve the optimization problems of the households (3) and (4) given the factor prizes, bargaining outcomes, and initial conditions.

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

3. Wages $w(s)$ and labor supply $h(s)$ solve the bargaining problem (9)

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

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

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

6. The government runs a balanced budget

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

2.5 Basic Income

Section 4 will discuss the effects of introducing a basic income which is provided by the government and financed through labor income taxes. There are several concepts of how to provide unconditional transfers to everyone which are often used interchangeably in the public discussion. However, most of them can be described as a combination of two ideas which theoretically yield the same outcome, but diverge conceptually in their approach. The first refers to a policy as proposed by Atkinson (1995) and provides a fixed amount of lump-sum transfers to every individual irrespective of their age, income or other personal characteristics. The other is a tax system as discussed by Friedman (1962), where everyone again receives a fixed amount of transfers, but these transfers slowly phase out when people start earning income. Although the two concepts can often be designed to achieve the same result and are thus not always distinguishable, for the purposes of this paper, the former will be referred to as Universal Basic Income (UBI), and the latter will be called Negative Income Tax (NIT).

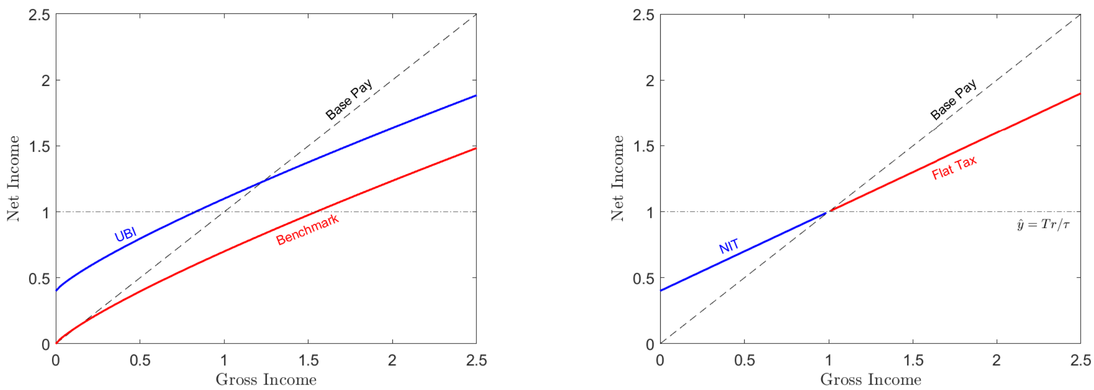
A reform towards UBI simplifies the problem of unemployed workers as they only receive the lump-sum transfer b^{UBI} irrespective of their individual state. However, employed workers also receive this transfer. Hence, with gross income of employed workers being denoted by $\tilde{y}$, net disposable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

$$y^{disp} = \begin{cases} \tilde{y} + b^{UBI} - T(\tilde{y}) & u = 0 \\ b^{UBI} & u \in \{1, 2\} \end{cases} \tag{12}$$

with $T(\cdot)$ being the progressive tax on labor income as specified in Equation 2.[6] Within this paper, I focus on the case where the UBI is introduced without changing the progressivity of the tax schedule. Figure 2a shows how the introduction of a UBI which provides transfers in the amount of median income to everyone would shift disposable income compared to a given benchmark economy when the degree of progressivity remains unchanged.

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



(a) UBI

(b) Linear NIT

Figure 2: Universal Basic Income and Negative Income Tax

by

$$y^{disp} = \begin{cases} \tilde{y} + Tr - \tau\tilde{y} & \tilde{y} \leq \hat{y} \\ \tilde{y} - T(\tilde{y} - \hat{y}) & \tilde{y} > \hat{y}, \end{cases} \tag{13}$$

where $\tilde{y}$ denotes gross income, Tr the transfers to households with no income, and τ the phase-out rate of the transfers. Hence, once the household's income surpasses the threshold $\hat{y}$, they start paying taxes on the additional income above $\hat{y}$ according to a tax schedule $T(\cdot)$.[7] Here, the threshold level is determined by the transfer level and the phase-out rate, i.e. $\hat{y} = Tr/\tau$. For this paper, I focus on the simplest case where income is taxed linearly at the same rate τ as the transfers phase out. Thus, the tax schedule in Equation 13 can be simplified to

$$y^{disp} = (1 - \tau)\tilde{y} + Tr. \tag{14}$$

Figure 2b shows an example of how such a tax can look like when households are guaranteed transfers in the amount of median income and transfers phase out at a rate of 40% (which is also equal to the tax rate above the threshold level).[8] In this special case with a linear tax that is equal to the phase-out rate, introducing a UBI alongside a flat tax would be equivalent to implementing an NIT. However, this equivalence only holds with regard to the disposable income of the household. From the government side there are still differences in the amount of taxes and transfers that are being paid. These difference are summarized in Table 1. In the case of UBI, everyone receives the same amount of transfers and also faces the same average tax rate, τ. In the case of NIT, in contrast, transfers phase out, while taxes are only paid on income exceeding the threshold level.

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

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

Table 1: Difference between linear NIT and linear UBI

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

Thus, the average tax rate is $\tau - Tr/\tilde{y}$, which is increasing in $\tilde{y}$. Hence, despite having the same gross income and resulting net income, households under the NIT system are subjected to lower average tax rates and receive fewer transfers compared to households in the UBI system.

Within the scope of this paper, I analyze two opposing regimes: A UBI as in Equation 12, and an NIT as in Equation 14. Thus, the former refers to a tax system where a basic income is introduced without changing the progressivity of the tax system, while the latter refers to the introduction of basic income together with a reform towards a linear tax system in the form of an NIT. Unless otherwise specified, all subsequent analyses in this paper refer to these two cases when mentioning UBI and NIT.

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

Other reforms towards a basic income can often be realized as a convex combination of the two programs shown in Figure 2. For example, one could imagine a Negative Income Tax with varying tax rates for different income groups. This would lead to a situation which closely resembles UBI as discussed above. At the same time, one could also imagine a reform towards UBI in which the transfers are included in the tax base. This would lead to a situation in which tax rates for employed and unemployed workers become more equal. Hence, such a reform would closely resemble an NIT with a progressive tax schedule. Consequently, in this paper I only discuss the two boundary cases and highlight their possible benefits as well as their expected disadvantages. The effects of other programs can then often be inferred from the results presented in this paper.

3 Parameterization

This section presents the parameter values used to numerically solve the benchmark economy.[9] I calibrate the model to certain moments of the U.S. economy in order to provide an insightful analysis of the possible effects of different basic income programs. Some parameters are set externally (cf. Table 2), while others are estimated using a Simulated Method of Moments approach to match important labor market outcomes (cf. Table 3). Lastly, Table 4 provides a brief overview of the benchmark economy, before the effects of introducing a basic income are discussed in section 4.

3.1 Households

Households enter the model at age 21 and die with certainty at age 80. One model period corresponds to six months. There is no formal retirement, but the households' age-dependent experience premium drops after the age of 65. The experience premium is set exogenously and normalized to yield a life-time mean of 1. The evolution of the experience premium is plotted in Figure A1 in appendix A.

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

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

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

Persistent labor productivity follows a simple AR(1) process where the annual 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 these values are within the range of standard literature. To map these values into biannual numbers, I set $\rho = \bar{\rho}^{1/2}$ and $\sigma^2 = \bar{\sigma}^2/(1+\rho^2)$.

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

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

Table 2: Directly specified parameters

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

3.2 Production

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

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

The costs of automating an open vacancy, x^a, are drawn from a uniform distribution with support $[0, \bar{x}]$. The upper bound $\bar{x}$ determines the probability of automating an open vacancy and is chosen endogenously to match an automation rate in the economy of 30% as reported in Leduc and Liu (2021). The probability with which a robot becomes obsolete or breaks down, δ^a, is set exogenously to 8%. This leads to a situation in which the average annual lifespan of a robot is in line with the data reported by the International Federation of Robotics (IFR) as used in Leduc and Liu (2021). Lastly, following the estimation in Leduc and Liu (2021), maintenance costs of robots are given by $\kappa^a = 0.34$, which yields annual profits of 2% of annual revenue by adopting a robot.

3.3 Labor market.

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

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

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

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

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

Table 3: Jointly calibrated parameters

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

Table 4: Benchmark Outcomes

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

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

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 4 summarizes the outcome of the benchmark equilibrium with the parameterization as described above. The equilibrium college share is 31% and the automation sector sees a share of 35% of automated jobs. Also, we can see sizable differences between the markets. While the overall unemployment rate is given by 7%, it is higher in the automation sector than in the college sector with

7.9% against 5.1%, respectively. The probability to invest in robots instead of workers also has implications for wages. Average income is nearly three times higher in sector 2 than in sector 1. Workers who obtained a college degree earn 278% of median income on average, while the average worker in the automation sector only earns 94% of median income. Lastly, employed workers face an average tax rate of roughly 23%,

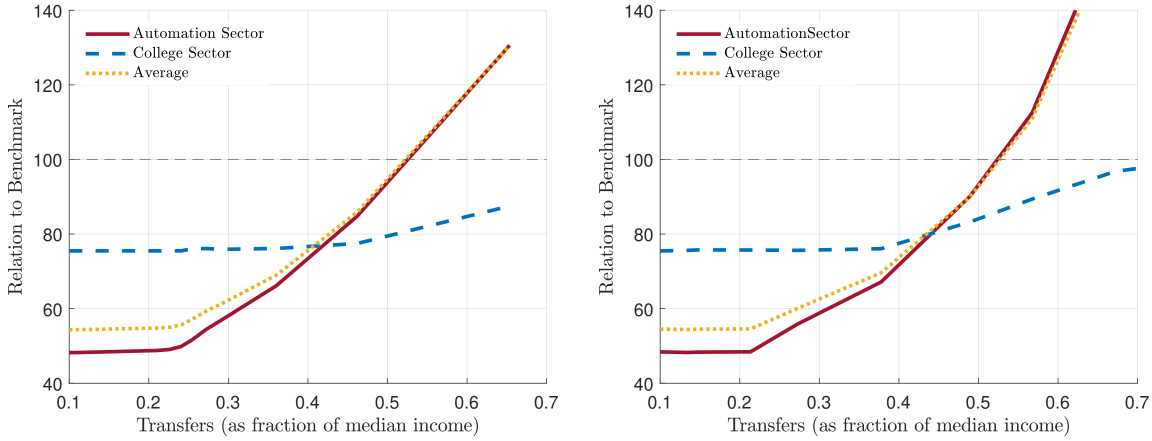
4 The Effects of a Basic Income

As discussed in subsection 2.5, most popular concepts for an unconditional income can be thought of as a combination of UBI and NIT. This section therefore describes the effects of replacing unemployment benefits with a UBI program or an NIT scheme as described in Equations 12 and 14 and shown in Figure 2. I introduce unconditional transfers of different amounts and measure their generosity in terms of their fraction of the median income in the new stationary equilibrium. Exogenous parameters, including government consumption, are kept constant at their benchmark level. To still ensure a balanced budget, the average taxation of income in the economy is adjusted upwards or downwards. All other tax rates remain unchanged.[12]

Hence, introducing a UBI only changes the parameter λ_0 which determines the average tax on income. The progressivity of the tax system remains unchanged. The NIT program, in contrast, replaces the benchmark tax system with a flat tax schedule as given in Equation 14. The flat income tax, τ, which is also the phase-out rate of the transfers, is then chosen to keep the government budget balanced with regards to the exogenous parameters. Note that the break-even income at which households receive no transfers and pay no taxes is immediately determined by the transfer level and the tax rate, $\hat{y} = Tr/\tau$, so that it cannot be used as additional policy variable. All else equal this scheme should result in a smaller tax burden for the households than the introduction of UBI, since transfers are not distributed in a lump-sum manner but phase out for higher income earners. However, as discussed in subsection 2.5, the different incentives of the two programs might have different consequences for the economy and thus, it is not clear in advance whether one of these programs should be strictly preferred.

Labor Market. First, Figure 3 shows how the introduction of a basic income would affect unemployment rates in the economy, when the basic income is provided either by the NIT or the UBI proposal. We can see that the relationship between unemployment and the generosity of the transfers is increasing in both cases. If transfers are low, staying in unemployment becomes so costly that unemployed workers increase their search effort

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



(a) NIT (b) UBI

Figure 3: Effects of a basic income on unemployment rates

and also accept lower wages. These channels have a positive effect on employment and with both, NIT and UBI, the unemployment rate in the automation sector falls below 50% of the benchmark level for exceedingly low transfer levels. As the welfare benefits become more generous, in contrast, the workers' outside option improves and they lower their search effort while demanding higher wages. Consequently, unemployment rates rise until they exceed the benchmark level.

Concerning the different sectors, Figure 3 reveals sizable differences between workers in the automation sector and the college sector. Workers who obtained a college degree earn higher wages on average and thus, unemployment has already been very costly for them in the benchmark economy. They react less strongly to a reduction in the transfer level, as they have already made exerted high effort for finding a job in the benchmark economy. As transfer levels get higher, workers in the college sector bear most of the additional tax burden, which slightly reduces their incentive to work. However, comparing Figure 3a and Figure 3b reveals differences between NIT and UBI. As transfers become more generous, the additional revenue required for financing the reform leads to higher tax rates on labor income. The NIT reform introduces a flat tax which distributes the tax burden evenly among the income groups, since everyone faces the same average tax rate. The UBI reform, in contrast, keeps the progressivity of the benchmark tax system unchanged and increases the tax burden of high income earners. Consequently, the UBI reform has stronger effects on workers in the college sector, as they face higher marginal tax rates than in the benchmark economy. The NIT reform, in comparison, has a greater impact on workers in the automation sector since the flat tax leads to higher marginal tax rates for low-income earners.

Next, Figure 4 shows the effects of an NIT and a UBI on the overall college rate in the economy and average working hours in both sectors. Both reforms lead to a sharp decrease in the fraction of people who are obtaining a college degree. Higher transfers are financed

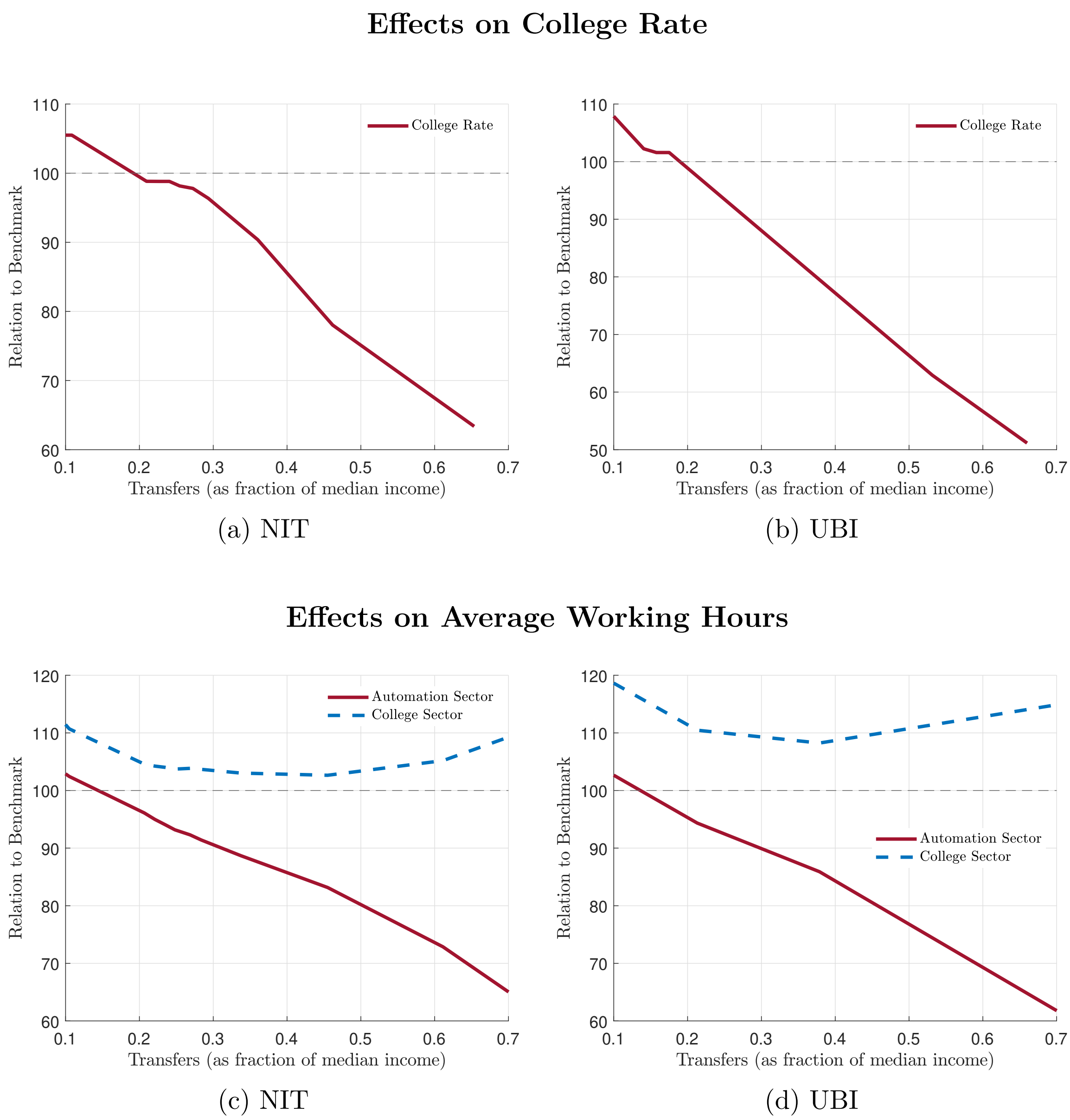
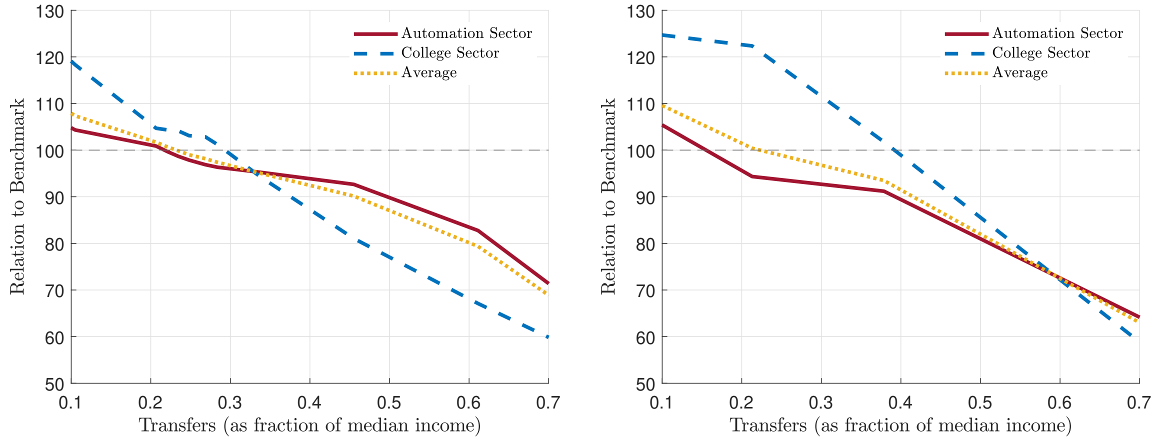


Figure 4: Effects of a basic income on the college rate and average Working hours.

by higher income taxes. At the same time, the insurance against automation induced job loss provided by a college degree is partially offset by the unconditional transfers provided by the higher basic income. Together, these channels reduce the incentive to join the college sector and discourage workers from obtaining a degree early in life. Hence, human capital is adversely affected by the introduction of a basic income. Overall, college attendance drops to nearly 60% of the benchmark level under the NIT regime and to nearly 50% with a UBI.

With regards to average working hours, we can see that the college sector is positively affected by both reforms. There are two channels which drive this result: When transfers are low, more people are obtaining a college degree and firms pay lower wages. Lower



(a) NIT

(b) UBI

Figure 5: Effects of a basic income on total labor supply.

wages together with lower tax rates which are needed for funding the transfer system incentivize workers in the college sector to increase their hourly labor supply. When transfers are high, in contrast, the fraction of people in the college sector drops and firms pay higher wages. Again, this leads to an increase in the average labor supply by college educated workers. Concerning workers in the automation sector, Figure 4 reveals a clear negative trend in the amount of average hours worked. In both reforms, the NIT and the UBI, higher transfers reduce the work incentives for low income earners. With a UBI, all the workers receive additional transfers which are mostly financed through higher tax rates at higher income levels. Hence, low income earners can enjoy more leisure with comparable levels of disposable income. With the NIT reform, transfers phase out as workers earn more income and consequently, low income earners are again discouraged from supplying more hours of labor. Overall, low income earners seem to gain from both reforms. Also, both reforms seem to provide the same incentives for labor supply, since the differences between Figure 4c and Figure 4d seem to be negligible.

Lastly, combining the insights from above, Figure 5 shows the effects of a basic income on total labor supply in the economy and in both sectors. Again, we can see a clear negative trend with more generous transfer systems. However, the reason for the reduction in overall labor supply is very different. In the college sector the decline is only driven by the fall in the college rate, while average working hours actually increase (cf. Figure 4). In the automation sector, the opposite happens: more workers are entering the automation sector, but they reduce their average working hours. Overall, the reduction in working hours is much stronger than the increase in the participation rate and total labor supply drops by roughly 30% with the highest transfer schemes. Also, comparing Figure 5a and Figure 5b shows that the effects on the college sector are stronger with a reform towards UBI. Funding a UBI usually requires more revenue than funding an NIT reform and seemingly, this difference in tax rates for the high income earners is large enough to yield

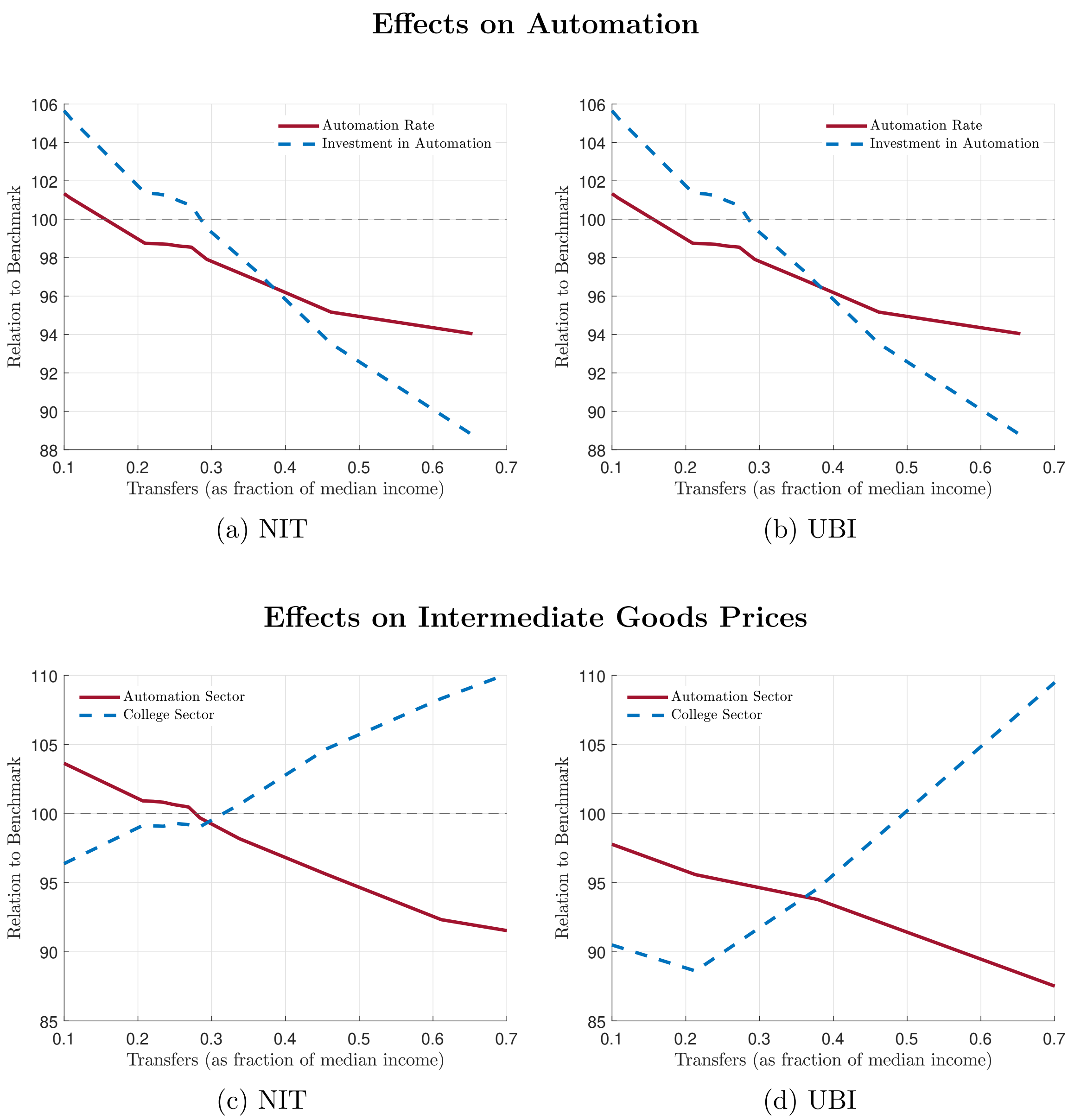
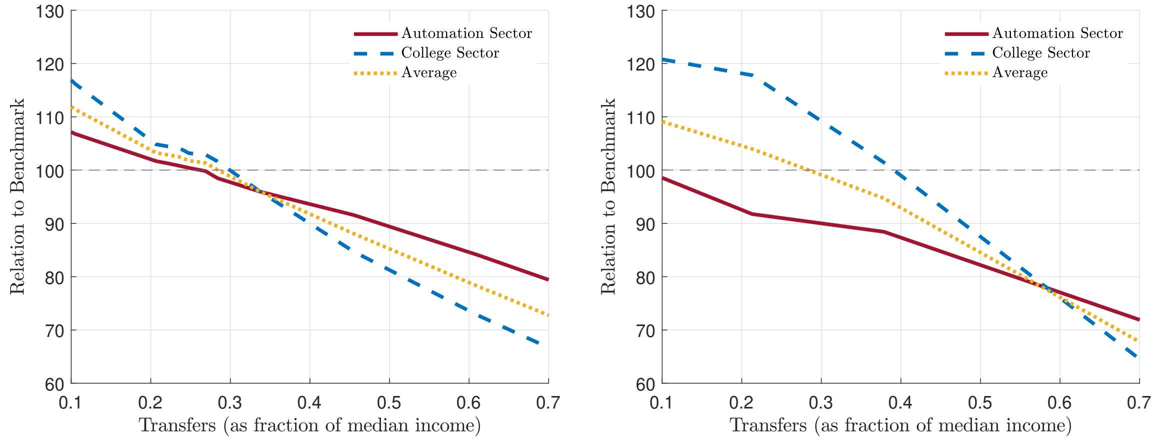


Figure 6: Effects of a basic income on automation and intermediate goods prices.

considerably stronger effects with a UBI.

Effects on Automation. Seeing how labor supply decreases with higher transfers poses the natural question whether firms will react by increasing their investment in automation. Figure 6, however, reveals that automation is also negatively affected by more generous transfer systems. When transfers are below 30% of median income, firms start to invest more in automation, while the investment is discouraged when transfers become higher. This effect is driven by the responses in the labor market which also deeply impact the prices for the intermediate goods (cf. Figure 6c and Figure 6d). With the fall in the college rate, production in the college sector decreases and consequently, the price for



(a) NIT

(b) UBI

Figure 7: Effects of a basic income on output.

the intermediate good from the college sector increases. Meanwhile, the price for the intermediate good from the automation sector falls, which depresses expected profits from investing in robots. Also, with a more generous basic income unemployed workers face lower effective marginal tax rates since they do not lose all their unemployment benefits when taking up a job. Together with the decline in the college rate, this leads to a sharp increase in participation and search effort in the automation sector. Consequently, firms can expect to fill their vacancies on the labor market more easily, and investment in automation is discouraged while employment increases.

This result reveals two things: First, introducing a basic income does not lead to a surge in unemployment rates due to the displacement of costly labor by cheap robots. The insurance effect of a basic income against automation induced job-loss is far greater than even proponents of such reforms might have thought. Not only are workers not being displaced by robots, but firms actually decrease their investment in automation and the labor share in the economy rises. Second, the fall in total labor supply is not offset by investment in automation. If low-skill jobs are being automated, overall output might remain unchanged, while low productive workers could enjoy welfare gains from their improved outside option. However, investment in automation follow the same pattern as total labor supply, and overall output in the consumption falls.

This can be seen in Figure 7, which plots output in both sectors and the economy as a whole for both the NIT and the UBI reform. We can see that under the NIT regime the college sector reacts more strongly to the generosity of the transfer system, while under the UBI regime both sectors seem to react in the same way. The overall pattern, however, is again only negative. An NIT policy which provides more than 60% of median income as unconditional transfers leads to a fall in overall output by more than 20% relative to the benchmark level. With the UBI reform, the output even falls by more than 30%. With lower transfers, however, the supply of labor increases in both sectors together with

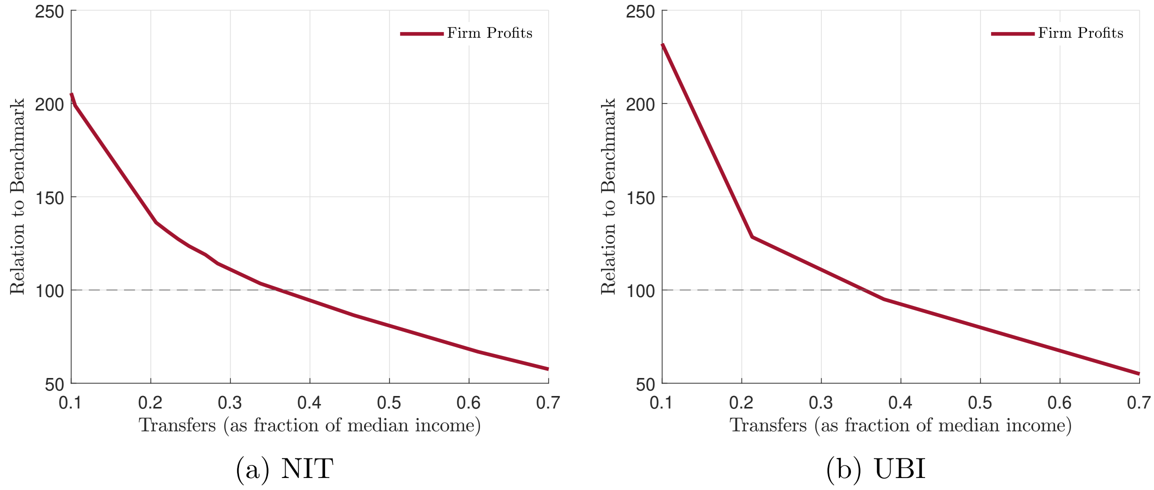


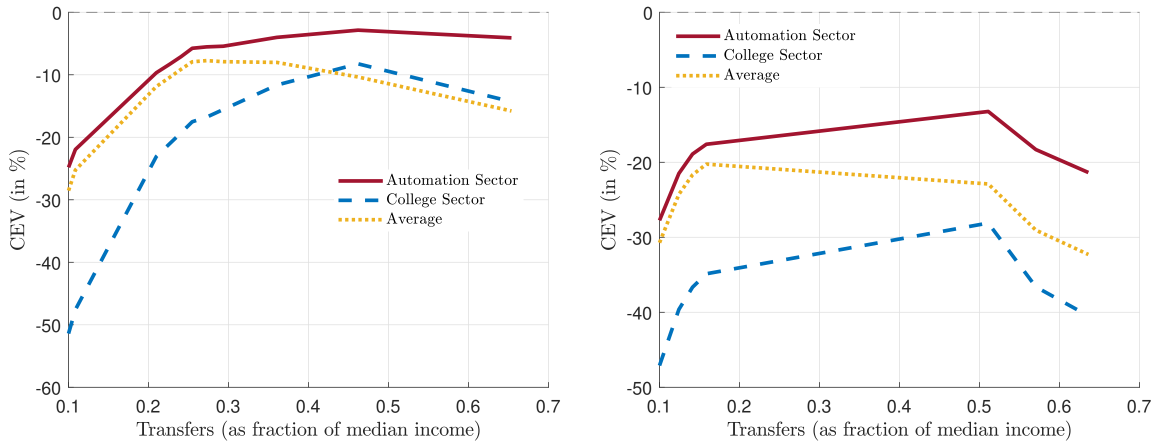
Figure 8: Effects of a basic income on firm profits.

investment in automation which leads to higher output. And again, the effect is stronger under the UBI regime.

Capitalists. Lastly, it is also worthwhile to look at the effects the basic income has on capitalists. How does the change in the labor share affect firm profits? Figure 8 shows the relationship between average profits before and after the introduction of the basic income. Once again, we can see a downward pattern with falling profits when the transfer system becomes more generous. However, for transfer schemes which provide less than 40% of median income as unconditional subsistence to everyone, profits are considerably higher than in the benchmark economy. With lower benefits for unemployed, workers accept lower wages and supply more labor (cf. Figure 5). Together this leads to higher profits in both sectors and also a higher output. As the basic income gets more generous, in contrast, labor falls while workers demand higher wages. At the same time, the price for the intermediate good in the automation sector falls, which further depresses expected profits. Hence, capitalists stand to lose from more generous reforms an NIT policy which provides unconditional transfers of about 60% of median income leads to a fall in profits by more than 20%. Note that the fall in profits also means less tax revenue for the government from capital gains taxes and consequently, income taxes will rise even more.

4.1 Welfare Implications

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



(a) NIT (b) UBI

Figure 9: Effects of a basic income on worker welfare.

an individual in state s, the CEV is calculated by

$$V^B((1 + CEV)c(s), h(s)) = \tilde{V}(c(s), h(s)) \tag{15}$$

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

Figure 9 shows the expected welfare gains or losses of a newborn, where the comparison is between the benchmark economy and the new stationary equilibrium after the reform. No transition dynamics are considered[13]. Expected welfare is shown for both, an NIT and a UBI reform, and between sectors. The average welfare effect depicted in Figure 9 is the expected change in life-time utility of a newborn under the veil of ignorance. The welfare gains or losses within one specific sector refer to the average expected change in life-time utility for newborn workers who will enter one of the two sectors.

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

[13] A discussion of the effects of a reform towards basic income on the periods preceding the new stationary equilibrium follows in section 5.

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

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

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

4.2 Robustness Checks

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

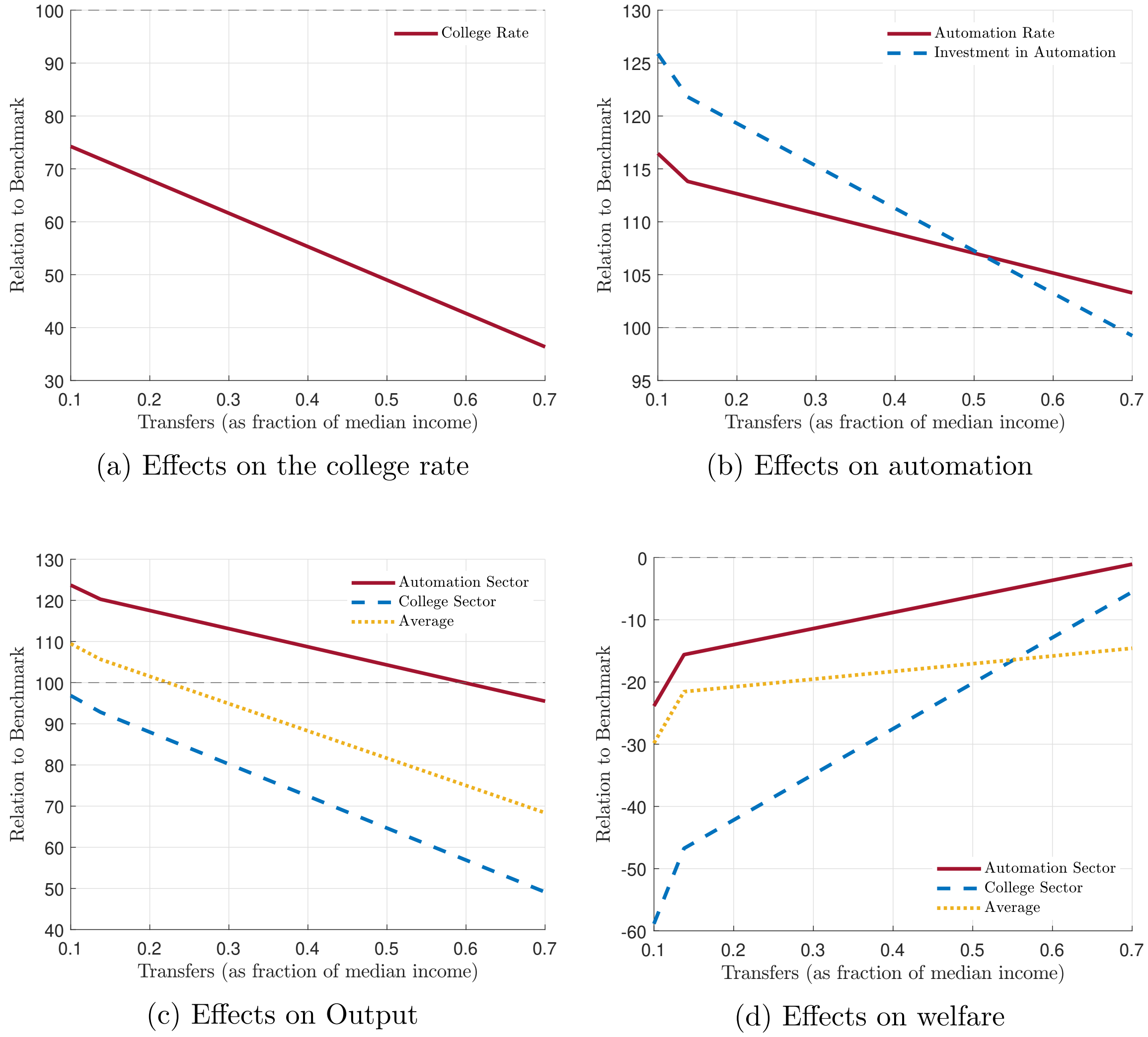
$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} - \phi \frac{h^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}}$$

First, in the benchmark economy, the risk aversion parameter for consumption in the CRRA utility function, σ, was chosen to be 2. When changing the functional form of the utility derived from consumption to a log-utility specification, all the results from section 4 still hold and remain mostly unchanged. Second, the Frisch elasticity in the benchmark economy was chosen to be 0.7. The results above have shown that this parameterization can lead to strong reactions in the labor market. To see how much of these effects was driven by the parameter γ, Figure 10 shows some of the same statistics as discussed in section 4, but this time an even lower Frisch elasticity of $\gamma = 0.2$ was used. We can see that the overall patterns remain mostly the same. More generous transfer systems lead to a fall in labor market related variables. However, quantitatively a big difference can be seen in the automation sector. While with a Frisch elasticity of 0.7 investment in automation falls by roughly 10% in relation to the benchmark for higher transfer schemes (cf. Figure 6a), with a Frisch elasticity of 0.2 the automation rate lies above its benchmark level throughout most transfer levels. This also leads to a slightly different picture of the drop in output. Output in the automation sector does not decline as much as with the benchmark parameterization, while output in the college sector reacts even stronger. However, effects on welfare are still exclusively negative. Overall, changing the parameterization does not change the qualitative pattern of the results, but only the quantitative interpretation.

5 The case for a specific NIT policy

So far, the analysis has focused only on a comparison of stationary equilibria. However, introducing a reform towards a basic income would first lead to a transitional period, in which current cohorts might be affected differently than future generations. This might be especially important when talking about the welfare implications of the new policy. Hence, while the discussion in section 4 indicates that the introduction of a basic income policy which is solely financed by adjusting average income taxation does not seem desirable, it is still worthwhile to disentangle the equilibrium effects by analyzing the transition dynamics and to compare the new equilibrium to the benchmark economy in more detail.

This section therefore analyzes the introduction of a specific policy. Seeing how the NIT scheme seems to be strictly preferable over the UBI proposal in terms of worker welfare (cf. Figure 9), a natural starting point is an NIT scheme which at least provides an income of the level of the at-risk-of-poverty threshold which is commonly set around



(a) Effects on the college rate

(b) Effects on automation

(c) Effects on Output

(d) Effects on welfare

Figure 10: Effects of an NIT reform with lower Frisch elasticity 0.2

60% of median disposable income.[14] Consequently, in this exercise I introduce an NIT which provides exactly 60% of median income as unconditional transfers and present a deeper analysis of the effects such a policy would have on the economy.

Before talking about the transitional periods, Table 5 provides a detailed overview of the effects of a basic income of 60% of median income by comparing the benchmark equilibrium and the equilibrium after the introduction of the NIT. As already discussed above (cf. Figure 7), output in the new stationary equilibrium will be lower than in the benchmark economy and drops by roughly 20%. This decline is driven by three mechanisms: The college rate drops by nearly 40% and this decrease in labor supply in the college sector is not offset by the moderate increase in average working hours. Also, while the participation in the automation sector rises, workers decrease their average working hours by nearly 25% and overall labor supply in the automation sector falls. At

[14]Compare, for example, Eurostat.

Table 5: Effects of NIT on macroeconomic outcomes

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

the same time, firms do not invest more in automation to counteract this loss in labor supply and consequently, output in both sectors and the economy as a whole decreases. This also results in lower firm profits, which drop by nearly 30%.

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

Looking more closely into college attendance, we see a drop in the college rate from 31% to only 22.6%. As discussed in section 4, this is because the incentive to join the college sector is mostly driven by higher job security and a wage premium. However, for lower productive workers the disutility of obtaining a college degree now outweighs the potential gains due to the additional insurance provided by the basic income. At the same time, high-income earners stem most of the tax burden from financing the NIT reform. As a result, human capital in the new stationary equilibrium is lower than in the benchmark equilibrium, which also leads to a decline in the number of high-income earners. Therefore, the revenue required to finance the basic income will be higher ex-post than when calculating the funding requirements in the old equilibrium. This also results in higher tax rates.

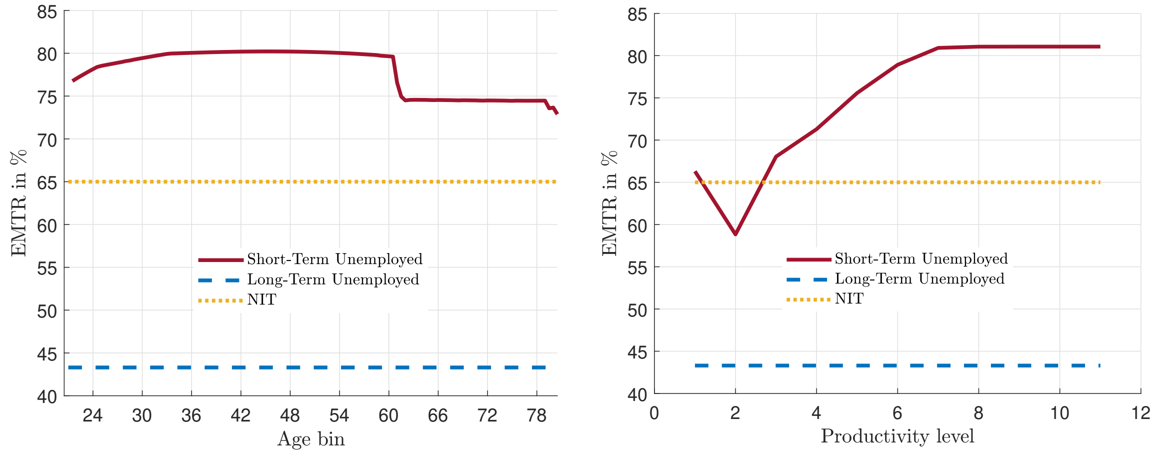
The drop in the college sector and the subsequent decline in output of the intermediate good from the college sector leads to a change in factor prizes. The price for the intermediate good in the automation sector drops by nearly 10%, whereas the price for the intermediate good in the college sector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

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

Overall, combining the insights from the change in the income distribution with Table 5 we seemingly can conclude that the introduction of a basic income via a Negative Income Tax would mostly lead to a redistribution from high income earners to low income earners. However, this redistribution does not lead to welfare gains in the economy and the average expected welfare of a newborn under the veil of ignorance drops by 14% in terms of consumption equivalence.

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

Basic income programs are often thought to mitigate this problem, since unemployment benefits do not vanish when people find a job. In the case of the NIT regime discussed



(a) EMTR by age group

(b) EMTR by skill group

Figure 11: Average effective marginal tax rates in the benchmark economy and under the NIT regime per age group and productivity level. Note: Short-term unemployed and long-term unemployed refer to the situation in the benchmark economy.

above and specified in Equation 14, workers face a flat income tax whose marginal tax rate is constant and the same for everyone, irrespective whether workers are currently unemployed or already high-income earners. However, since the government runs a balanced budget, this resulting flat tax could still be higher than the effective marginal tax rates before the introduction of the NIT, depending on the generosity of the transfers to unemployed. In the case of UBI, the basic income is a lump-sum transfer given to everyone irrespective of income or employment status. In theory, this could lead to a lower marginal tax rate for unemployed since they do not lose any unemployment benefits. However, similarly to the NIT regime, the introduction of a UBI might require additional funding through higher income taxes. Hence, again it is not immediately clear whether the introduction of a UBI would yield a reduction or an increase in the effective marginal tax rates.

Figure 11 shows the average effective tax rates for unemployed workers who find a job which pays mean income. Tax rates are compared between the benchmark equilibrium and the new equilibrium with an NIT.[15] Average tax rates in the benchmark economy vary by age and skill group, as well as between short-term and long-term unemployed, while the NIT regime introduces a constant marginal tax rate which is equal among all workers. Figure 11 compares the benchmark economy with the constant EMTR faced by workers after the introduction of the NIT which provides 60% of median income as transfers to unemployed. First, we can see that in the benchmark economy short-term unemployed face EMTRs up to 80% on average throughout most age bins. This means that the loss of unemployment benefits after finding a job together with the taxes paid on

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

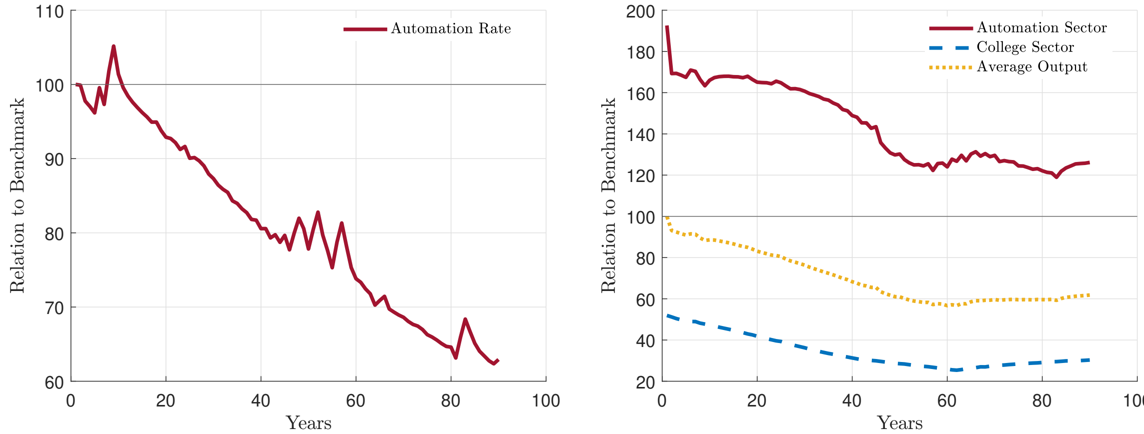
income amount to roughly 80% of the additional income earned. Long-term unemployed, in contrast, mostly face EMTRs slightly below 45%. This difference stems from the different treatment of short-term unemployed and long-term unemployed. While short-term unemployed receive benefits which partially depend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

Lastly, Figure 11b shows the average EMTRs faced within different skill groups. Similarly to above, the EMTR faced by short-term unemployed in the benchmark economy is always higher than the EMTRs under the NIT regime. Also, note that EMTRs are increasing with higher skill groups. This is because that benefits for short-term unemployed are partially based on their past productivity. Hence, higher skill groups receive higher benefits which increases their effective tax rates when taking up a job. Again, the EMTRs faced by long-term unemployed lie below the tax rates after the NIT reform. Since benefits for long-term unemployed do not depend on either age or productivity, they are constant for all workers.

5.1 Transition Dynamics

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

This section therefore describes the dynamics which occur during the transition from the benchmark equilibrium to the new equilibrium, when introducing the specific NIT



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

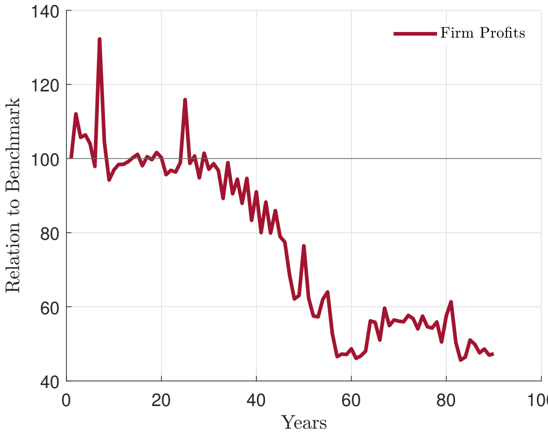
Figure 12: Transition Dynamics of Investment in Automation and Output.

reform as discussed in section 5 above.[16] First, Figure 12 shows how the investment in automation and total output are affected during the transitional periods. Looking at Figure 12a we can see how firms initially react by increasing their investment in the adoption of robots until it lies roughly 8% above the benchmark level. Then, investment slows down, gradually falls below the benchmark level and continues to fall for the next years. Turning to Figure 12b reveals that this change in automation does not immediately result in a change in output. While output of the intermediate good in the automation sector is also falling during the transition to the new equilibrium, production lies above the benchmark for more than one generation (60 years). In contrast, output in the college sector falls drastically and remains at roughly 40% of the benchmark level. This considerable drop in production in the college sector stems from the reduced labor supply in this sector as the amount of workers with a college degree drops.

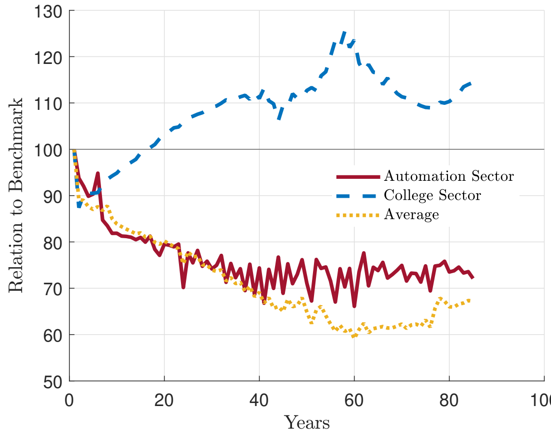
This considerable decline in the college rate is depicted in Figure 13c. After the introduction of the NIT reform, new cohorts are discouraged from obtaining a college degree and the college rate drops by more than 60% over the span of one generation. Thereafter, the fraction of workers with a college degree slowly starts to rise again due to the increase in the college premium with the concurring fall of disposable income in the automation sector. As the economy transitions to the new equilibrium, the fall in output and profits in the automation sector make obtaining a college degree more attractive.

Regarding labor force participation, Figure 13d reveals that unemployment rates rise throughout all sectors. While the college sector is only moderately affected, the automation sector reacts strongly to the transition dynamics and the unemployment rate rises by up to 300%. This difference results from the endogenous selection of workers into one of the two sectors. Workers who obtain a college degree do so because they can expect higher wages and higher consumption on average. Consequently, workers who enter the college

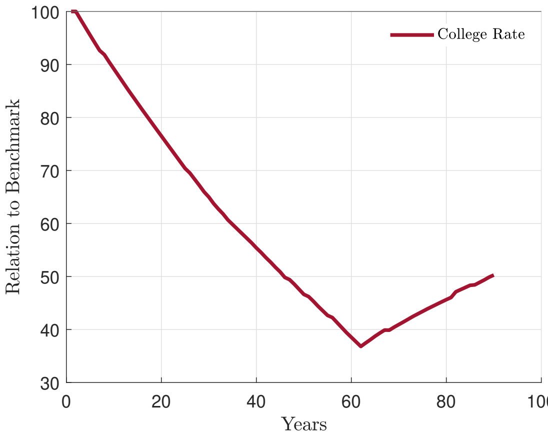
[16] For details on the computational method see appendix D.



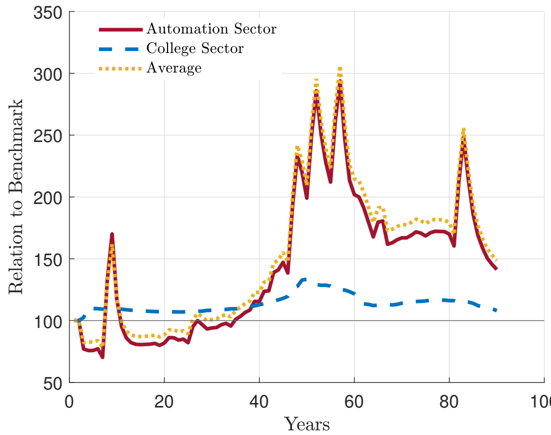
(a) Change in Profits



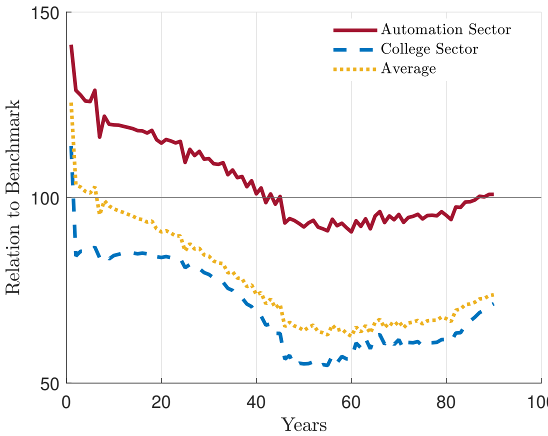
(b) Average Wage Rate



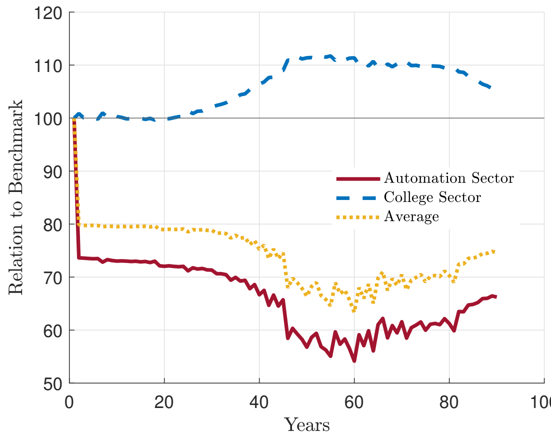
(c) Change in College Attendance



(d) Change in Unemployment Rates



(e) Mean Disposable Income



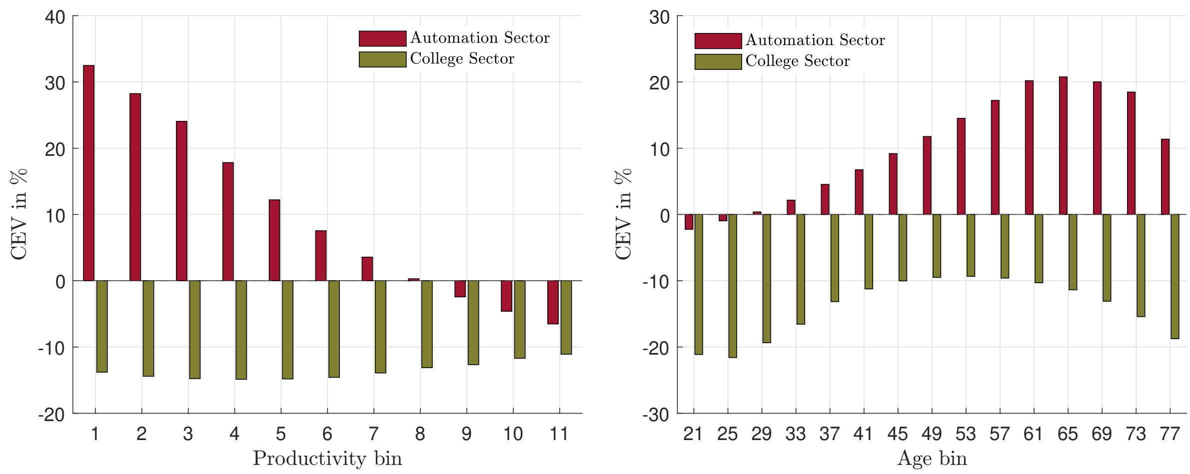
(f) Average Working Hours

Figure 13: Transition Dynamics in the labor market.

sector are actively searching for a job in order to be able to enjoy these expected gains. Workers entering the automation sector, in contrast, do not necessarily prefer working in this sector over the college sector. Some of them, particularly the workers with the lowest productivity, simply enjoy the better insurance provided by the basic income. As a result, some of the workers in the automation sector reduce their search effort and unemployment rises. The same is true for average working hours. Figure 13f reveals a similar pattern to Figure 4 in section 4. Workers in the college sector increase their hourly labor supply, while average working hours in the automation sector drop drastically. Overall, in the automation sector a smaller fraction of workers is getting a job and those who do are spending less time at work.

Concerning wage rates, Figure 13b shows the average wage rates paid in both sectors and on average in the whole economy. Seemingly, the introduction of the NIT reform positively affects the college sector, while workers in the automation sector lose. The fall in overall labor supply and production in the college sector leads to an increase in the price for the intermediate good from this sector and as a result, firms pay higher wages. In the automation sector, in contrast, more workers are joining the labor force and the price for the intermediate good falls. Both effects depress the wage rates paid to workers in the automation sector. Also, we can see how wages in the college sector start to decline again after one generation when the college rate starts to rise, and the college sector sees an increase in labor force participation.

The change in wages, however, does not directly translate into a change in disposable income, as shown in Figure 13e. As with most other variables, we see a downward pattern as after-tax income declines in the years following the introduction of a basic income. Interestingly, despite the increase in average wages in the college sector, workers with a college degree are affected more deeply than workers in the automation sector. In the first four decades after the NIT reform, average disposable income in the automation sector even lies above the benchmark level, even though average wages have decreased. Afterwards, we see a slight drop below the benchmark level before average disposable income starts rising again. This has several reasons: Workers in the automation sector are on average less productive than workers in the college sector and face lower wage rates. As a result, the NIT reform provides an additional source of income and in the first couple of years after the introduction of the NIT, workers are better off on average. Thereafter, however, the economy transitions towards the new stationary equilibrium and output and wages start to fall. Consequently, disposable income also falls, until it reaches a level below the benchmark equilibrium. Now, workers start to increase both, their search effort, and their hourly labor supply, which leads to a rise in average disposable income. Also, after one generation, more workers start to obtain a college degree, which has positive effects on the wage rate in the automation sector. The college sector, in comparison, is adversely affected throughout all transitional periods. The phase-out rate



(a) Welfare Effects per Skill Group

(b) Welfare Effects per Age Group

Figure 14: Change in expected life-time utility of current generation when introducing the NIT policy next period.

of 65% leads to a high average tax burden for high-income earners and even though wages and average working hours are increasing, after-tax income still falls.

Lastly, Figure 13a depicts the evolution of firm profits during the transition to the new equilibrium. We can see how despite the increase in output in the automation sector, the profit of firms decreases. This is due to two reasons: First, the price of the intermediate good in the automation sector falls. This depresses average profits per job. Second, output in the college sector falls drastically and even though this leads to an increase in the price for the intermediate good from this sector, the higher wages demanded by workers offset any additional profits. Overall, output and profits in the economy decrease.

Welfare Comparison. As mentioned above, considering the transition dynamics can have different consequences for the evaluation of welfare than simply comparing stationary equilibria. Figures 12 and 13 show that the transition to the new equilibrium will take almost two generations. Consequently, current cohorts will experience vastly different welfare effects than future generations who are immediately born into the new stationary equilibrium. Thus, Figure 14 reports the welfare gains and losses of cohorts who are born before the introduction of the NIT. The reported values for the consumption equivalence are calculated by comparing the life-time utility of remaining in the benchmark equilibrium to experiencing the transitional periods towards the new equilibrium[17]. The CEV is calculated as describe in subsection 4.1.

Turning first to Figure 14a reveals the different effects the introduction of the NIT reform has on workers of different productivity levels and between sectors. A considerable

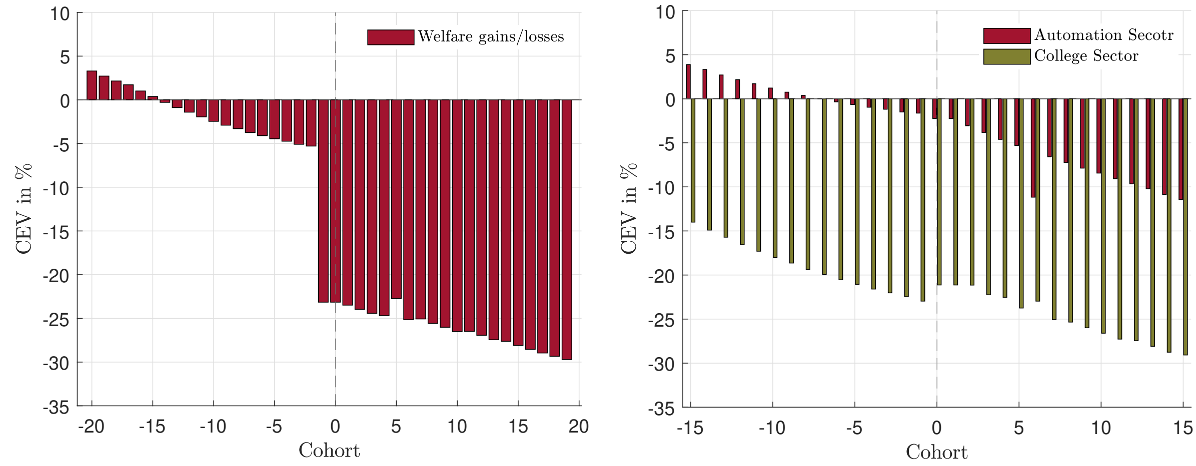
[17] This means that this comparison is not simply between expected welfare in the old economy and the new economy. The transition dynamics which current cohorts would experience upon the introduction of the new policy are taken into account.

fraction of workers in the automation sector experience large welfare gains (up to 33% for the least productive workers) and only the workers with the highest productivity are adversely affected (with welfare losses up to -8%). The increase in average disposable income during the first couple of years after the introduction of the reform benefits low productive workers in the automation sector. The subsequent decline in the capital stock and aggregate output during the transition to new equilibrium is slow enough not to erode these expected welfare gains. Workers in the college sector, in contrast, experience welfare losses throughout all skill groups. Already during the first periods after the introduction of the reform, the disposable income in the college sector falls and the negative effects are only getting stronger in the periods thereafter.

Next, Figure 14b again shows the change in welfare for current cohorts, but this time reported for different age groups in both sectors. Again, the reform is clearly worse for workers who enter the college sector. Although there seems to be an upward trend with older workers being less adversely affected, they still experience welfare losses throughout all age groups. Even the oldest people, who are already at the end of their working life, would prefer staying in the benchmark economy. In the automation sector, in contrast, nearly all workers from the current generation can expect welfare gains when averaged by age group. Similarly to the college sector, older workers are better off than younger workers. The highest welfare gains can be expected by workers who enter the later phase of their working life around the age of 65. At this age, their age-efficiency profile starts to decline in order to mimic retirement and the additional insurance provided by the NIT leads to an expected welfare gain of up to 21% in terms of CEV. These accentuated positive welfare effects are mainly driven by the fact that firms can invest in robots. Since aging workers become less productive, firms might be inclined to automate their tasks. Hence, older people face poorer contracts. The introduction of the NIT can now provide additional insurance against this rationalization.

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

Effects on different cohorts. Lastly, the transition dynamics also reveal huge differences in the effects a reform towards an NIT would have on cohorts who are born before and after the introduction of the new policy. Figure 15a plots the average expected lifetime welfare of a newborn under the veil of ignorance for several periods before and after



(a) Average welfare effects

(b) Welfare effects per sector

Figure 15: Welfare Effects of NIT on different cohorts. Period 0 refers to introduction of NIT.

the introduction of the NIT. First, for cohorts who are born before the introduction of the NIT, older people can expect welfare gains, while younger households suffer welfare losses, which is consistent with the finding in Figure 14b. Cohorts who are born during or after the introduction of the NIT reform, in contrast, experience huge welfare losses. Seemingly, even though the transitional periods can be beneficial for some workers who are already alive before the reform, cohorts who are born thereafter all lose and would prefer being born into the benchmark economy. Hence, future generations are not only worse off after the new equilibrium has been reached, but face welfare losses starting from the very first period after the introduction of the NIT.

Turning to Figure 15b again reveals that the welfare effects differ greatly between sectors. Workers in the automation sector can benefit from the reform when being born more than eight years prior to the introduction of the NIT policy, while workers entering the college sector experience substantial welfare losses throughout all cohorts. Still, the effects on welfare show a clear downward trend for both sectors and after the introduction of the reform, workers in the automation would prefer being born into benchmark economy as well. Apparently, workers in the automation sector who are already alive during the introduction of the NIT policy, profit from the decisions made by workers who entered the college sector. After the introduction of the NIT, however, workers can take the new tax system into account and are discouraged from obtaining a college degree. This lowers the welfare gains in the automation sector, which are mostly financed by the high-income earners in the college sector, and consequently, cohorts who are born after the introduction of the NIT are worse off than in the benchmark economy.

Note that as we converge to the new equilibrium, the average welfare of future generations does not become positive. In the new stationary equilibrium with the NIT, average

Table 6: Optimal Tax and Transfer System

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

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

welfare of a newborn under the veil of ignorance drops by 13.5% in terms of CEV. Hence, while current generations would vote in favor of the NIT, since the welfare gains in the automation sector outweigh the losses in the college sector, future generations are worse off and would prefer being born in the benchmark equilibrium.

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.

Considering the results discussed in appendix of subsection E, the introduction of an NIT seems to be preferable over the introduction of a UBI in terms of CEV for any given level of unconditional transfers. Thus, in this exercise I vary the tax on consumption and the tax on profits and introduce an NIT of varying generosity to find the optimal combination of $\{\tau_c, \tau_a, Tr\}$. Note that the flat income tax, which is also the phase-out rate of the transfers (cf. Equation 14), is not a variable of choice, since it has to be adjusted to keep the government budget balanced under the given tax and transfer regime. The result of this exercise is shown in Table 6.

First, we can see how changing the whole tax and transfer system can lead to an

Table 7: Comparing model outcomes from optimal NIT to benchmark

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

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

Table 7 compares the equilibrium outcome of some macroeconomic variables from the optimal tax and transfer system to the benchmark equilibrium. We can see how the subsidy on profits leads to a surge in automation, while more people are obtaining a college degree. Consequently, output in both sectors rises and the production of the final good increases by more than 100%. At the same time, lower taxes and the slow phase-out rate of transfers leads to a considerable increase in average disposable income which rises by 73% compared to the benchmark economy. This also leads to an increase in average consumption by roughly 43%. However, this is mostly driven by the higher consumption in the college sector and the fact that more people are now obtaining a college degree. Workers in the automation sector, however, experience a slight decrease in average consumption of about 6%. Lastly, since an NIT introduces transfers for employed workers, the average taxation in the economy is negative, with the average employed worker receiving transfers in the amount of 10% of their income. Hence, with capital income also being subsidized the government budget is nearly exclusively financed by the tax on consumption.

Overall, looking at tables 6 and 7 reveals that in this model setup the optimal tax and transfer system is simply a subsidy to capital and labor income, which increases labor supply in both sectors - unemployment drops to 3.8% in both markets -, while also encouraging further investment in automation. Both effects drastically increase production and on average workers can expect welfare gains. However, note that this tax regime harshly punishes unemployed workers who only receive 15% of median income as subsistence level, which lies way below every common indicator for poverty. Hence, workers who face involuntary unemployment are punished harshly in comparison to the benchmark economy.

7 Conclusion

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

To look at the impact of a basic income policy on current generations and on the effects during the transition to the new equilibrium, I analyze a specific NIT program which provides 60% of median income as unconditional transfers to everyone. This refers to a common poverty threshold and is often mentioned among proponents of such a reform. The results of this exercise show that such a policy has mainly adverse effects on macroeconomic outcomes. Output, consumption, and college attendance fall, while unemployment rates rise. Concerning welfare, the effects are slightly ambiguous. Since the basic income is mostly financed through income taxes, the introduction of a basic income leads to a redistribution from high income earners to low income earners. Wages in the college sector are higher than in the automation sector and hence, the introduction of the NIT mostly redistributes income from the college sector to the automation sector. During the transitional periods towards the new equilibrium, current cohorts in the automation sector can expect welfare gains. In particular, low productive workers benefit from the basic income, as they receive additional transfers without being hurt by the higher tax rates needed to fund the basic income. Overall, a majority of the current generation would vote in favor of the reform. Comparing the stationary equilibria under the veil of ignorance, in contrast, reveals that most workers would prefer being born into the benchmark economy without a basic income. Also, in the new equilibrium, college rates, output and average consumption are lower.

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

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

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Appendices

A Experience Premium

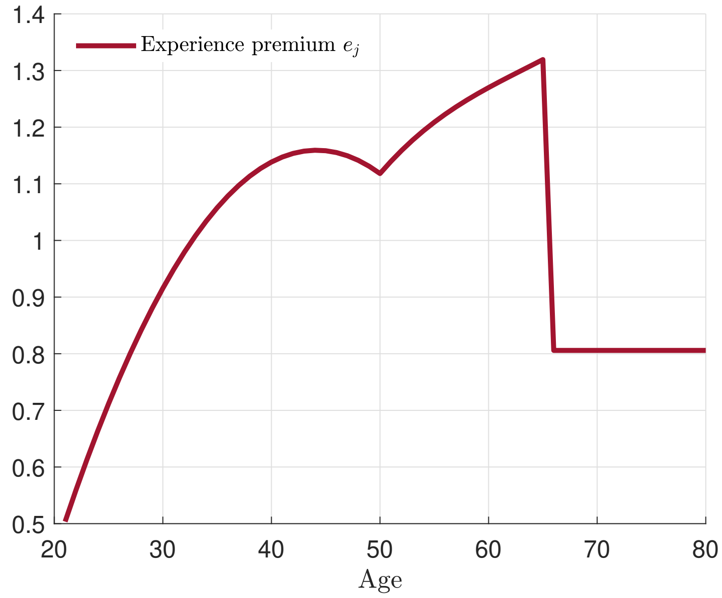


Figure A1: Experience premium to wages

B Effects of NIT on Income Distribution

Table B1: Earnings Distribution

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

[1] NIT refers to the policy which pays exactly 60% of median income as described in section 5.

C Computational Solution Method

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

Algorithm to compute competitive equilibrium[18]

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

II. Solve model using the guess from I.

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

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

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

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

$$S(\mathcal{P}) = \left(\sum_i \omega_i (M_i(\mathcal{P}) - D_i)^2 \right)^{1/2} \tag{16}$$

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

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

D Computing Transition Dynamics

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

Algorithm to compute transitional Dynamics:

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

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

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

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

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

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

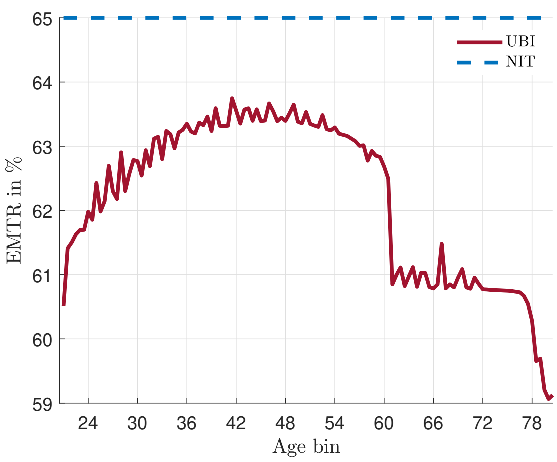
E Marginal Tax Rates with UBI

To compare the effects of UBI on the effective marginal tax rates (EMTR) faced by unemployed workers to the effects of an NIT as described in section 5, I introduce a UBI which yields 60% of median income as unconditional transfers to everyone. This yields

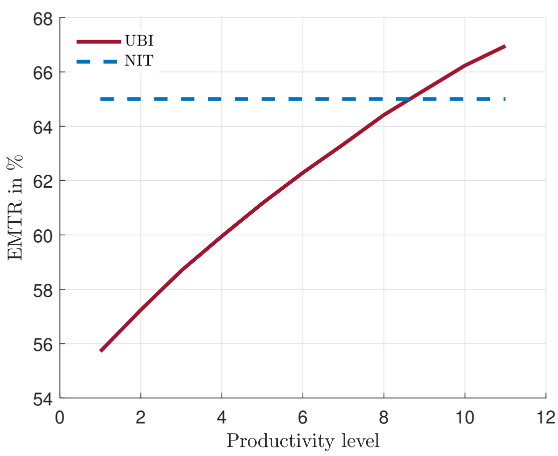
[19]Note that this parameter has different implications depending on whether UBI or NIT is introduced. Under the UBI regime, the income tax is still progressive and λ_0 only adjusts the average taxation. Under the NIT, regime λ_0 determines the flat income tax, which is also the face-out rate of the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

the same amount of transfers to unemployed as the NIT reform in section 5. Figure E1 shows the average effective tax rates for unemployed workers who find a job which pays mean income.

Since transfers in a UBI regime do not face out when people start to work, the EMTRs faced by unemployed are nearly always lower with UBI than with the NIT reform (cf. Figure E1a). Only when looking at workers within the highest productivity groups do we see that EMTRs under the UBI reform exceed those after the NIT reform. The reason for this is the vast difference in revenue needed for funding the reform. While the NIT actually leads to a reduction in average tax rates on income, introducing a UBI requires a considerable increase in average taxes, since the transfers are paid in lump-sum fashion to everyone (indeed, the average taxation rises to 62% compared to 23% in the benchmark economy). And since the taxation is progressive under the UBI regime, higher incomes are taxed more heavily. This leads to an upward trend of EMTRs by skill group, whereas in the benchmark economy EMTRs are falling with productivity (cf. Figure 11b). Hence, introducing a UBI increases the incentive for low-skilled workers to find a job, while decreasing the incentive for high-skilled workers. This effect might undesirable and does not occur with the NIT regime, since EMTRs with an NIT are constant for everyone.



(a) EMTR by age group



(b) EMTR by skill group

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