Labor Market Polarization with Hand-to-Mouth Households*

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Abstract

I argue that borrowing constraints are important for understanding the welfare and output consequences of labor market polarization. I document empirically that i) a large fraction of routine workers who switched to manual and abstract occupations suffered short-term wage losses, ii) one third of routine workers are hand-to-mouth (hold few liquid assets), and iii) being hand-to-mouth predicts a low probability of leaving routine occupations. I build a general equilibrium incomplete markets model featuring three occupations, a continuum of skill types, occupation-specific human capital and a realistic share of hand-to-mouth households. A fall in the price of capital causes the routine wage to decline relative to wages in the other occupations. The presence of a large share of households close to the borrowing constraint inefficiently protracts the reallocation of labor away from the declining routine occupation. Policies that alleviate the borrowing constraint upon switching the occupation raise social welfare and output, speeding up the reallocation of workers away from the declining routine occupation. While disadvantageous for the high-skilled, the policies benefit medium- and low-skilled workers.

JEL Codes: D31, E21, E24, J24, J62

Keywords: Wealth distribution, Technological change, Labor markets, Borrowing constraints

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1 Introduction

Technological change has had a major impact on labor markets in recent decades. Many jobs that were previously performed by humans have become automated and are now completed by machines. This trend has benefited workers in some occupations while harming those in others. On the one hand, jobs intensive in routine, i.e. easily codifiable tasks (e.g. assembly line workers, bookkeepers), have increasingly become automated. On the other hand, jobs intensive in manual tasks (e.g. taking care of the elderly or children) and abstract tasks (e.g. teachers, managers) have remained and often profited from technological change, as they are difficult to master for machines. Consequently, wages and employment shares in occupations intensive in routine tasks have declined in recent decades compared to those in manual and abstract occupations.[1]

In this paper, I argue that borrowing constraints and the ability to smooth consumption are important to understand the output and welfare consequences of this technological change and the labor market reallocation it has caused. To share in the benefits of technological growth, many routine workers have left their old jobs and switched into occupations in which wages have been rising (Cortes, 2016). I show that these switches, while providing benefits in terms of higher wages in the medium to long term, were often accompanied by initial wage losses. This pattern, which can be rationalized by the presence of occupation-specific human capital, makes occupational choice a dynamic investment decision. The ability to smooth consumption, i.e. the distance from the borrowing constraint, is therefore an important determinant of whether a worker decides to switch or stay in her old job.

The main contribution of this paper is to embed routine-biased technological growth into a general equilibrium model of the US economy featuring incomplete markets and occupation-specific human capital. I use the model to demonstrate that borrowing constraints play an important role in shaping the reallocation of labor away from jobs in routine occupations. The aggregate labor market transition is impeded by the presence of hand-to-mouth households, i.e. those with few or no liquid assets. The closeness to the borrowing constraint makes them unwilling to invest in future earnings growth at the cost of bearing short-term wage losses. This gives rise to an inefficiency, as the discounted gains from switching can outweigh the initial costs. Building on this insight, I use the model to ask how government policies aimed at alleviating the borrowing constraint of occupational switchers affect output and welfare. In particular, I study the introduction of a government loan program and the payment of transfers, both targeted at formerly routine workers who leave their occupation.

To assess whether the friction I propose is empirically relevant, I build on and extend

[1] These empirical patterns have been documented, among others, by Acemoglu and Autor (2011), Autor and Dorn (2013), Autor, Levy, et al. (2003), Cortes, Jaimovich, and Siu (2017), and Goos et al. (2014).

previous empirical findings. Using panel data from the Panel Study of Income Dynamics (PSID), Cortes (2016) shows that, compared to those workers who stayed in routine occupations, workers who switched to either abstract or manual occupations saw faster wage growth and thus enjoyed long-term wage gains. Adding to this, I show that a large share of switchers did, however, suffer wage losses in the short run, i.e. in the year immediately following the switch. Next, I use data from the Survey of Consumer Finances (SCF) to demonstrate that a third of routine workers fall under common definitions of being hand-to-mouth, i.e. hold very few liquid assets. This shows that potential short-term wage losses might have posed an important obstacle to an occupational switch for a large fraction of routine workers. Lastly, I bring these two pieces of information together, turning again to recent waves of the PSID, which provide information on asset holdings. I ask whether the current hand-to-mouth status is predictive of leaving the routine occupations for a new job, and find that, in line with the mechanism described above, hand-to-mouth households are less likely to make such a switch.

I then build a heterogeneous agent model with idiosyncratic labor income risk and incomplete markets, that takes account of these empirical findings. On the supply side, there exists a representative firm that uses two types of capital (Information and Communication Technology (ICT) and non-ICT capital) and three types of labor (manual, routine and abstract labor) as inputs. The driving force of technological change is an exogenous fall in the price of ICT capital relative to the consumption good. The prices of all production factors are endogenous. On the demand side the model features households that die stochastically and are then replaced by newborns (perpetual youth). Households are heterogeneous in several ways. They have a fixed skill type, which affects their optimal occupational choice. In line with the data, low-skill types work in low-wage manual jobs, medium-skilled in routine jobs in the middle of the wage distribution, and high-skilled workers sort into the high-paying abstract occupation. While working in either of the three occupations, households accumulate occupation-specific human capital, which depreciates once they switch to another occupation. On top of this, households are exposed to uninsurable idiosyncratic productivity risk, causing them to engage in precautionary saving. Households can use two assets for saving, a liquid and an illiquid one. This enables the model to generate a share of hand-to-mouth agents that matches the data.

I calibrate the model to the US economy, targeting the employment shares in each occupation and the share of income accruing to labor in 1980 and 2020, the share of hand-to-mouth households, as well as the average wage changes of routine workers who switch to either the abstract or to the manual occupation. I solve for the steady state when the price of ICT capital is relatively high (representing 1980) and relatively low (representing today), and compute the perfect foresight transition path between the two steady states. The calibrated production function implies that ICT capital is relatively easy to substitute with routine work and complementary to manual and especially abstract work. This leads to a lower routine employment share in the new steady state compared to the old one.

Consistent with the empirical evidence and the proposed mechanism the model predicts an important role of liquid assets and hence the ability to smooth consumption for the switching behavior of routine workers. I demonstrate this, first, by zooming in on individual policy functions. Conditional on skill and occupation-specific human capital, routine workers leave the occupation earlier if they possess liquid asset savings than if they are hand-to-mouth. Second, I conduct counterfactual simulations of the economy in which I assume that all households choose their occupation like the ones who are well insured against shocks, in particular those with liquid assets above the 70th (90th) percentile of the liquid asset distribution. In these counterfactuals, the employment share in the abstract occupation would have been two (three) percentage points higher on average along the transition than in the baseline. Third, I conduct the same regressions of hand-to-mouth status on future switching decisions as before in the PSID, only now in a synthetic panel of households simulated from the model. I find the same negative association as in the data.

Next I ask how the policymaker can address the inefficiency introduced by the borrowing constraint by studying policies that target routine workers who leave their former occupation. First, I study the introduction of a government loan program, which provides switchers with additional liquidity upon leaving the routine occupation. Second, the government pays a recurrent transfer to the switchers, partly covering the temporary wage loss they endure while building up occupation-specific human capital in their new occupation. Both policies are financed via distortionary labor income taxation.

Focusing on policies targeting the routine to abstract switchers, I find that both programs increase aggregate welfare vis-à-vis the baseline transition without any policy. They do so both because households who become eligible directly benefit from the programs, and because of general equilibrium effects. The optimal policies lead to a more efficient allocation of the labor force across occupations, and hence output and average labor productivity increase. The majority of the population enjoys wage gains: as more households switch to the abstract occupation with the policies in place, wages of abstract workers decline while wages of manual and routine workers rise. The growing employment share in the abstract occupation further leads to the crowding-in of complementary ICT capital, which increases by up to 1.0% (3.0%) under the optimal loan (transfer) program compared to the baseline transition. The clear winners of the policies are medium-skilled workers, who are predominantly employed in the routine occupation. Their expected lifetime consumption increases by 0.3% (1.0%).

The rest of the paper is structured as follows. I first discuss the related literature. In Section 2 I use a small, highly stylized model of dynamic occupational choice to develop the intuition for the key mechanism. In Section 3 I present empirical evidence that motivates the quantitative model. The full quantitative model is presented in Section 4. In Section 5 I study the transition between two steady states, while in Section 6 I conduct the policy experiments. Section 7 concludes.

Related Literature This study relates to three strands of the literature. The first is the empirical literature exploring labor market polarization. Acemoglu and Autor (2011) point out that a notable polarization both of wage growth and of jobs has taken place in the US since the 1980s. Sorting occupations by hourly wage, long-run changes in wages and employment shares exhibit a u-shape, featuring higher growth in low- and high-wage occupations. They link these patterns to the "routinization" hypothesis, i.e. that routine jobs of the income middle class have been increasingly automated, as in Autor, Levy, et al. (2003). Autor and Dorn (2013) argue that the relative rise in earnings and employment at the bottom of the occupational skill distribution in the US can be attributed to the rise of service occupations.

Using data from the PSID, Cortes (2016) finds that compared to routine workers who stayed in their occupation, those who switched to either abstract or manual occupations saw faster wage growth. I add to this empirical literature by showing that the presence of borrowing constraints and imperfect consumption smoothing have slowed down the reallocation of labor out of routine occupations. Furthermore, Cortes, Jaimovich, Nekarda, et al. (2020) find that a drop in the inflow rates into routine occupations explains a significant part of the decline in routine labor over recent decades, with young cohorts playing a disproportionate role.[2] Their study provides important empirical results, which I use as untargeted statistics to evaluate my model.

This paper is most closely related to the second strand of literature, which embeds labor market polarization into quantitative macroeconomic models. vom Lehn (2020) builds a model in which households are heterogeneous in skill type and endogenously sort into the three broad occupational groups. While in vom Lehn (2020) the household sector can be summarized by a representative agent, in my model workers face uninsurable idiosyncratic income risk (Aiyagari, 1994; Bewley, 1983; Huggett, 1993).[3] Importantly, I also add occupation-specific human capital, which makes occupational choice an investment decision.

Moll et al. (2022) add household heterogeneity in skills and dissipation shocks to wealth accumulation to the task-based framework developed in Acemoglu and Restrepo (2018). They simulate a trend in automation to study its implications for wealth inequality, and find that automation, by driving up the interest rate on capital, leads to higher wealth inequality. I differ from Moll et al. (2022) in building a model with uninsurable idiosyncratic income risk and occupation-specific human capital, and by focusing on the normative aspects of labor market polarization. The interest in policy analysis is shared by Jaimovich, Saporta-Eksten, et al. (2021). However, while they put the focus on la-

[2]This is also in line with the findings in Adão et al. (2020). They show that employment responses to technological innovations are to a large extent driven by new generations making different skill investment choices than older cohorts before entering the labor market.

[3]Kikuchi and Kitao (2020) study labor market polarization in an incomplete markets model, but in a partial equilibrium setting. General equilibrium effects will be important when I study labor market policies.

bor market frictions, I zoom in on the importance of borrowing constraints along the transition path.

In concurrent work, Beraja and Zorzi (2022) (BZ) study the optimal degree of automation in a model with a continuum of occupations. In the decentralized equilibrium of their economy automation can be inefficiently high, as firms do not take into account the borrowing constraints and costly reallocation process of displaced workers. My quantitative model differs in several ways from BZ, offering three important additional insights. First, following a large literature, I model labor market polarization as exogenous, routine-biased technological change which "hollows out" the middle of the income distribution. By modeling a continuum of worker skill types I can characterize the heterogeneous welfare consequences of the studied labor market policies along the income distribution, which BZ do not speak to. Second, in contrast to BZ, I explicitly model the accumulation of occupation-specific human capital.[4] This makes occupational choice an investment decision: borrowing-constrained workers are reluctant to enter occupations that promise high returns only in the future. This renders the allocation of workers across occupations inefficient even absent an endogenous automation decision made by firms, as in BZ.[5] Third, my model features a much richer structure of the household side, as I rely on the two-asset specification of Kaplan, Moll, et al. (2018). This enables me to show, for instance, that the highlighted mechanism is not only highly relevant for poor but also for wealthy hand-to-mouth households.

The third related strand of the literature models occupation-specific human capital and wealth accumulation simultaneously. That human capital is at least in part tied to a worker's specific occupation, or the tasks performed in them, has been documented in Cortes and Gallipoli (2018), Gathmann and Schönberg (2010), Kambourov and Manovskii (2009b), Sullivan (2010), and Traiberman (2019), several of which I use to calibrate the model. Attempts to study occupational choices and wealth accumulation jointly go back at least to Evans and Jovanovic (1989) and Galor and Zeira (1993). I integrate an interaction between wealth accumulation and occupation-specific human capital on the household side into a general equilibrium model of labor market polarization.

2 A Small Model of Dynamic Occupational Choice

In this section I illustrate the core mechanism at work in the full model of Section 4. I highlight that in a dynamic setting, in which relative wages between occupations change over time, a worker potentially makes differing occupational choices depending on whether she is at the borrowing constraint or not. A necessary ingredient to the model for this

[4]Switching occupations is costly in BZ because of exogenous, permanent productivity losses. Informed by my empirical analysis, I endogenize the distribution of wage changes in the immediate and long-run aftermath of a switch by explicitly modeling occupation-specific human capital.

[5]In a sense, the pace of technological change is controlled more by firms in BZ, and by households in my study. Seen from this perspective, the two studies complement each other.

channel to be active is that human capital is occupation-specific, as in this case occupational choice becomes an investment decision. A trade-off arises between building up human capital in the occupation whose wages are growing and the desire to smooth consumption.

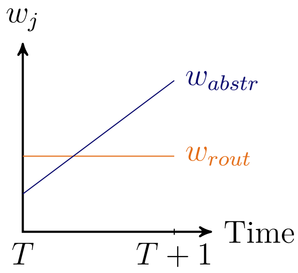

Figure 1: Time path of wages per efficiency unit of labor in routine and abstract occupation

The model has two time periods, T and $T+1$. There are two occupations, routine and abstract. The wage per efficiency unit of labor in the routine occupation is one in both periods, i.e. $w_{r,T} = w_{r,T+1} = 1$. The abstract wages are $w_{a,T} = \frac{1}{\omega}$ and $w_{a,T+1} = \omega$, with $\omega > 1$ (Figure 1).[6] Empirically of course, on average, abstract workers earn higher wages than routine workers, and have done so not only recently but also in the 1980s. However, for certain medium-skilled workers the potential wages in the two occupations have plausibly followed the pattern shown here. For instance, for some workers it paid more to have a job at an assembly line or to be a bookkeeper than to be a manager or a teacher in the 1980s, while in the 1990s or 2000s this ordering had reversed due to an increase in the wage premium of the abstract occupation.[7]

Consider a household who makes an occupational choice at the beginning of period T and again at the beginning of period $T+1$. Her income in every period is $y_t = w_{j,t} \cdot h_t$, where $h_t \in \{\underline{h}, \bar{h}\}$ is occupation-specific human capital, with $0 < \underline{h} < \bar{h}$. If the household works in the same occupation j in T and $T+1$, she is an experienced worker in occupation j in $T+1$ with certainty ($h_{T+1} = \bar{h}$). An occupational switch at the beginning of period t leads to full depreciation of human capital ($h_t = \underline{h}$). The household values consumption, with $u(c) = \ln(c)$. I assume that the household arrives with zero assets in T and that she discounts future utility by a factor $\beta \in (0, 1)$.

Suppose that at the beginning of period T the household has not yet gathered experience in either of the two occupations. What is her optimal occupational choice? Assuming first that the household can freely borrow against future income, her decision problem is:

[6]This symmetry is not crucial for the results but simplifies the algebra. Appendix B relaxes this assumption.

[7]In the quantitative model of Section 4, workers with skill type $s \in (\underline{s}_{\text{old}}, \bar{s}_{\text{old}})$ face the evolution of potential wages depicted in Figure 1 (see left panel of Figure 4).

$$\max_{c_T, c_{T+1}, j_T, j_{T+1}} \ln c_T + \beta \ln c_{T+1}$$
$$\text{s.t.: } c_T + \frac{c_{T+1}}{R} = y(j_T) + \frac{y(j_T, j_{T+1})}{R}$$

where R is the exogenous interest rate, c consumption, and j_t is the occupational choice at the beginning of period t. If instead the household is exogenously prevented from borrowing, it has to hold in addition that

$$c_T \leq y_T \ .$$

Given that she can choose between the two occupations at the beginning of each period, four possible combinations of occupational choice exist, which in turn determine labor income:

1. $\{j_T = r, j_{T+1} = r\} \rightarrow \{y_T = \underline{h}, y_{T+1} = \bar{h}\}$
2. $\{j_T = r, j_{T+1} = a\} \rightarrow \{y_T = \underline{h}, y_{T+1} = \omega \cdot \underline{h}\}$
3. $\{j_T = a, j_{T+1} = a\} \rightarrow \{y_T = \underline{h}/\omega, y_{T+1} = \omega \cdot \bar{h}\}$
4. $\{j_T = a, j_{T+1} = r\} \rightarrow \{y_T = \underline{h}/\omega, y_{T+1} = \underline{h}\}$

Proposition 1. *If not borrowing-constrained, the household chooses the abstract occupation in $t = T$ iff*

$$R \leq \omega(\bar{h}/\underline{h} - 1) \min \left\{ \frac{\bar{h}/\underline{h}}{\bar{h}/\underline{h} - 1}, \frac{\omega}{\omega - 1} \right\} .$$

In this case, she is a net borrower in $t = T$.
If borrowing-constrained, the household never chooses the abstract occupation in $t = T$.

The proof is relegated to Appendix A. The proposition shows that there exists a set of parameter combinations under which a household who is not borrowing-constrained optimally chooses the abstract occupation in period T, even though wages are still higher in the routine occupation. In this case, she borrows against future income in period T.[8]

The second part of Proposition 1 highlights the key inefficiency. Under no combination of parameters does the household work in the abstract occupation in T if she cannot borrow. The intuition is simple: foregoing high wages in the routine occupation today is

[8] The condition in Proposition 1 becomes more likely to hold when the interest rate R is low, such that borrowing against future income is cheap, and when the human capital spread $\bar{h}/\underline{h}$ is large, such that starting to gain experience in the abstract occupation today is valuable. Lastly, due to the non-linear way in which it affects earnings in the two periods in opposite directions, ω has an ambiguous effect on the occupational choice in T.

too costly, and if wages are very high in the abstract occupation in period $T+1$, she can still switch then. That the household always chooses the routine occupation in T when borrowing constraints bind is clearly inefficient: the first result of the proposition shows that for some parameters the long-term gains from switching, in form of discounted future profits, outweigh short-term costs. In these cases, choosing the abstract occupation in T is a profitable investment.

In Appendix A I show that a similar proposition holds for a worker who instead of being inexperienced in period T is an experienced routine worker, i.e. $h_T = \bar{h}$. Again, for some parameter combinations and when borrowing is allowed it is optimal to switch to the abstract occupation in T, even though this entails a short-run earnings loss. In case of binding borrowing constraints, however, experienced routine workers stay in the routine occupation in T and make the switch to abstract only in period $T+1$, if at all.

Discussion and extensions Appendix A.2 contains an extension of the simple model with time-varying aggregate productivity. This extended model can qualitatively account for the fact that a higher share of households exits routine occupations during a recession (because the opportunity cost of doing so is smaller than during a boom). This is in line with empirical evidence in Hershbein and Kahn (2018) and Jaimovich and Siu (2020).

Appendix B extends the simple model in two ways. It endogenizes wages and introduces a continuum of households who are heterogeneous with respect to their skill type. This extended set-up allows me to characterize analytically the socially optimal allocation of labor across the two occupations when the abstract wage grows over time relative to the routine wage. I show that, in line with the intuition conveyed above, in an economy in which households are hand-to-mouth, too little labor is supplied in the abstract occupation compared to the first-best. Hence, a policy that alleviates the borrowing constraint can raise output by improving the allocation of labor.

The mechanism laid out in the simple model does not depend on, but is similar to the existence of occupation-specific returns to tenure. For instance, returns to tenure might be higher in the abstract than in the routine occupation, in which case the ratio $\bar{h}_j/\underline{h}$ would be occupation-specific, with $\bar{h}_a/\underline{h} > \bar{h}_r/\underline{h}$ (e.g. a manager's occupational experience being more highly rewarded than that of a bookkeeper). Then, even if wages per efficiency unit in the two occupations stayed constant over time, individual income paths would resemble those depicted for wages in Figure 1, and borrowing-constrained households might end up inefficiently choosing the routine occupation in $t = T$. While I allow for heterogeneous tenure profiles in the full model in Section 4, the focus of this paper is technological change and the time-varying wages per efficiency unit it induces across occupations.[9]

[9]For a treatment of how returns to college and its cost shape the optimal design of student loan programs in the presence of borrowing constraints, see Lochner and Monge-Naranjo (2012, 2016). In Section 6 I show that the policies raise welfare significantly more along the transition path, which features time-varying relative wages between occupations, than they do in the steady state, in which occupation-

In the simple model I have assumed initial asset holdings to be zero. In reality, households can save in anticipation of future wage changes and occupational switches. The more sophisticated model of Section 4, which endogenizes the wealth distribution, is therefore necessary to judge whether the friction proposed here has had meaningful implications for aggregate variables. The full quantitative model also includes three instead of two occupations, speaking to the literature on labor market polarization. Before describing it, I present empirical evidence that supports the relevance of the just described mechanisms.

3 Empirical Evidence

3.1 Labor market polarization and broad occupational groups

To describe the phenomenon of labor market polarization, Autor and Dorn (2013) order 318 detailed occupations according to their skill level, which they proxy by the average hourly wage earned in the occupation in 1980. They show that between 1980 and 2005 occupations at the bottom and at the top of the skill distribution gained both in terms of employment shares, and in terms of wages relative to occupations found in the center of the distribution. Scrutinizing the task content of each occupation using the US Department of Labor's Dictionary of Occupational Titles, they divide occupations into six broad groups. For tractability, the literature often subsumes these further into three broad occupational groups: manual, routine and abstract (Jaimovich and Siu, 2020; vom Lehn, 2020).[10]

The first group of occupations are intensive in **manual** tasks, i.e. they require eye-hand-foot coordination, adapting to new surroundings often, and (non-trivial) interaction with other humans. These occupations can be found at the bottom of the wage distribution and are typically service occupations. Examples for manual occupations are health and nursing aides, workers in child and elderly care, bus drivers, waiters and waitresses, door-to-door/street sales, or janitors and gardeners.

The second group consists of occupations that require **routine** tasks to be performed, i.e. calculations, record-keeping, repetitive customer service, repetitive assembly, picking or sorting. Many occupations in the middle of the wage distribution belong to this group. Typical examples of routine occupations are bookkeepers, accounting clerks, secretaries, bank tellers, as well as machine operators and assemblers or butchers and meat cutters.[11]

Occupations of the third group require **abstract** tasks, i.e. cognitive thinking, form-

specific returns to tenure are present, but relative wages are constant.

[10]Following Jaimovich and Siu (2020), the services occupations are the only occupations I categorize as manual. See Appendix C for details. The assignment is complete and mutually exclusive: each of the detailed occupations is considered to be part of exactly one of the three broad groups.

[11]Some studies make a further distinction between routine manual and routine abstract occupations. I abstract from this further division for simplicity.

Table 1: Wage changes for routine workers, according to direction of switch

Change in real wages between year t and year ...	$t+1$	$t+2$	$t+4$	$t+10$
To abstract occupation	3.4%	5.9%	8.5%	16.3%
To manual occupation	−11.2%	−14.3%	−3.5%	11.5%

Notes: Change in real wages between year t and year $t+x$, compared to workers who stayed in routine occupations. Values are taken from Cortes (2016, Table 3).

ing/testing hypotheses, persuading, managing or organizing. These kind of jobs are found in the high-wage occupations, and typical examples are school teachers, managers, police and detectives, public service (e.g. city planners), or engineers.

The term "polarization" refers to the fact that the occupational wage and employment distributions have shifted towards their poles since the 1980s, while the middle of these distributions, where many of the routine occupations are found, has "hollowed out". The employment share in the routine occupations fell from 58.5% in 1980 to 46.2% in 2005, while it increased from 31.6% to 40.9% in the abstract, and from 9.9% to 12.9% in the manual occupations (Autor and Dorn, 2013). One commonly cited cause for the decline of the routine occupations is technological change that substitutes for routine labor (Autor, Levy, et al., 2003; Jaimovich, Saporta-Eksten, et al., 2021; vom Lehn, 2020). The fact that capital, most prominently ICT capital, has become much cheaper over the recent decades has led to a replacement of tasks formerly performed by humans with machines. Manual and abstract jobs are not so easily substituted by ICT capital, as they require either non-trivial interaction with humans or tasks such as managing and organizing, all of which machines struggle to excel at. Following the literature, a falling relative price of ICT capital drives technological change in the model of Section 4.

3.2 Wage paths and liquid asset holdings

3.2.1 Wage paths of routine workers: switchers vs. stayers

Using data from the PSID between 1976 and 2007, Cortes (2016) shows that compared to routine workers who stayed in their occupation, those who switched to manual or abstract occupations experienced faster wage growth after they had switched. For convenience, I reprint the baseline estimates from Cortes (2016, Table 3) in Table 1. He finds that wages of workers who switched to manual occupations were 11.2% lower after one year, but 11.5% higher after ten years, than wages of those who stayed. Wages of routine workers who switched to abstract occupations were on average 3.4% higher after one year compared to wages of those who stayed, and 16.3% higher after ten years. This pattern is consistent with a relative wage increase in manual and abstract relative to routine occupations, as in Figure 1. The quantitative model in the next section will account for these wage dynamics, with the wage change after one year (first column) being a target in calibration.

To take a closer look at the distribution of wage changes upon leaving routine occupations, I use PSID waves 1976 to 2017, following Cortes (2016) in the definition of variables and in sample selection. In particular, I focus on employed male household heads, aged 16–64. The only two differences in terms of the sample in my analysis are the extended time period and that, to be consistent throughout this paper, I only categorize low-skilled services occupations as manual occupations, while Cortes (2016) uses a slightly broader definition for his baseline results. I relegate all details to Appendix C.2.

I find that of all the workers who switched from routine to manual (abstract) occupations from one year to the next and for whom wages are observed in both years, 58% (42%) saw their wage decline upon switching. Hence, Cortes (2016)'s result that the one-year wage change of switchers to the abstract occupation was on average 3.4% higher than that of the stayers masks a lot of heterogeneity. While some moves from routine to abstract might have been due to career advancement, leading to wage gains, almost half of these switches have come with wage losses and are therefore less likely to represent career progression.[12]

The point here is not to claim that only leaving routine occupations can lead to (temporary) wage losses.[13] However, as Cortes (2016) shows, workers who switched from manual and abstract to routine occupations did not experience faster wage growth than stayers, as opposed to routine switchers (i.e. the analogues of Table 1 for manual and abstract workers switching to routine feature only negative or statistically insignificant values at a ten-year horizon). The takeaway here is therefore that it is predominantly for the group of routine workers that switching can be interpreted as an investment. In Appendix C.2 I document moreover that also the subgroup of routine switchers who faced initial wage losses eventually earned higher wages than routine stayers.

3.2.2 Hand-to-mouth shares

I have so far shown that the wage pattern depicted in Figure 1 has been relevant for many routine workers. But how many of them face binding liquidity constraints? To address this, I use liquid asset holdings to proxy for closeness to the borrowing constraint. Recent work by Kaplan, Violante, et al. (2014) has shown that although only about 10% of US households have zero or close to zero net worth ("poor hand-to-mouth"), another 20% hold only very few liquid assets, while possessing some illiquid assets, e.g. a house ("wealthy hand-to-mouth"). I extend these findings, splitting the data by the three broad occupations.

I use the SCF, instead of the PSID, to shed light on hand-to-mouth shares by occupation both because the PSID has started including detailed information on asset holdings

[12] Mukoyama et al. (2021) provide empirical evidence that in the U.S. almost none of the net reallocation of labor from routine into abstract and manual occupations was driven by within-firm switches.

[13] In my sample, 33% of workers leaving manual and 48% of workers leaving abstract occupations saw their wage decline year-on-year.

only in 1999 and because the focus of the SCF is acquiring accurate information on wealth. I use twelve waves, from 1989 to 2019. In terms of sample selection and classifying households as hand-to-mouth, I follow Kaplan, Violante, et al. (2014). In particular, I consider all households whose head is aged 22–79, and discard those who report negative labor income or whose only positive income stems from self-employment. I then relate each household's liquid assets to current income, and classify it as hand-to-mouth if liquid asset holdings are either zero (or positive but close to zero), or if liquid assets are close to an imputed borrowing constraint, equaling one times monthly income. Appendix C.3 lays out the details.

I find that, averaged across time, 35% of households whose head was currently working in routine occupations were hand-to-mouth. Hence, for a large fraction of routine workers binding borrowing constraints have potentially been an impediment to leaving their occupation, if such a switch entailed short-run wage losses. This might have caused them to stay in the routine occupations for a relatively long time, reminiscent of the behavior of the constrained household in the simple model of Section 2. Appendix C.3 depicts the time series as well as confidence intervals around the estimates. There, I also split up households into poor and wealthy hand-to-mouth, showing that routine workers are especially likely to be wealthy hand-to-mouth.

3.2.3 Liquid assets and switching behavior

In a last step, I ask whether being hand-to-mouth has had predictive power over the decision to leave the routine for the manual or abstract occupations, as the model of Section 2 suggests. To this end, I turn back to the PSID data, waves 1999 until 2017, because these provide information on assets (at the household level) and because, unlike the SCF, the PSID has a panel dimension and follows individuals over time. I estimate the following model:

$$\text{switch}_{i,t,t+2} = \beta \cdot HtM_{i,t} + \gamma \cdot X_{i,t} + u_{i,t} \ . \tag{1}$$

Here, $\text{switch}_{i,t,t+2}$ is a dummy variable which is equal to zero if worker i was employed in a routine occupation in year t and $t+2$ and equal to one if the worker was employed in a routine occupation in year t and a manual or abstract occupation in year $t+2$. I look at two-year differences as the PSID went to a bi-annual frequency in 1997. $HtM_{i,t}$ is a dummy variable indicating whether the household is hand-to-mouth in year t, and $X_{i,t}$ are control variables. $u_{i,t}$ is an exogenous error term with $\mathbb{E}[u_{i,t}] = 0$. I control for tenure in the broad occupation, a dummy indicating the region, age and its square, unionization status, married status, and a linear time trend. As in the quantitative model of the next section innate ability, or skill, will be an important determinant of switching behavior, I include in some specifications a dummy for whether individuals have received at least

Table 2: Switching decision and liquid asset holdings (data)

	(1)	(2)	(3)	(4)	(5)	(6)
HtM	-0.030***	-0.021*	-0.032***	-0.023**		
	(0.012)	(0.012)	(0.012)	(0.012)		
Occupational tenure	-0.014***	-0.014***	-0.021***	-0.020***	-0.021***	-0.020***
	(0.00098)	(0.00094)	(0.0018)	(0.0017)	(0.0018)	(0.0017)
Skill		0.090***		0.082***		0.082***
		(0.012)		(0.011)		(0.012)
Poor HtM					-0.046***	-0.030*
					(0.016)	(0.017)
Wealthy HtM					-0.025*	-0.020
					(0.013)	(0.013)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4904	4904	4904	4904	4904	4904
Model	OLS	OLS	Probit	Probit	Probit	Probit

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

Notes: Data are from the PSID, years 1999–2017. Sample selection is as in Cortes (2016), see also Appendix C.2. Dependent variable is whether or not individual leaves routine occ. between t and $t+2$. Definition of HtM status is as in Kaplan, Violante, et al. (2014). Skill is a dummy for whether the individual has received more than 12 years of education. Occ. tenure is years of uninterrupted tenure in broad occupation. Additional controls are: region dummies, age, age squared, unionization status, married status, year. Standard errors are clustered at the individual level. Columns with probit model show average marginal effect.

some years of college education.[14] In line with Cortes (2016), I only include males in the sample and cluster standard errors at the individual level.

Table 2 shows the results. The first row of columns 1 and 2 show the estimate of β. I find that hand-to-mouth agents are less likely to leave the routine occupation, compared to agents who hold a buffer of liquid assets. The likelihood of switching is 2.1 to 3.0 percentage points smaller for the former group than for the latter, everything else equal. This is in line with the mechanism laid out above, by which more borrowing-constrained households, for fear of temporary earnings losses, delay their move away from the routine occupations. Also, in line with what would be expected, more years of occupational tenure make switching less likely. Skill, as measured by education, has a positive impact on switching probabilities. Columns 3 and 4 show average marginal effects in a probit model, which are similar to the OLS estimates. In columns 5 and 6 I split up the explanatory variable into poor and wealthy hand-to-mouth households. Evidently, the negative correlation is driven by both subgroups, though the relationship is a bit stronger for the poor hand-to-mouth households. I extend the empirical model in a number of ways in Appendix C.2, showing, e.g., that there is no significant relationship between liquid assets and switching to the manual or abstract occupations.

Current liquid asset holdings and future switching decisions could be jointly deter-

[14]Proxying skill by the log real hourly wage or by raw years of education yields similar results.

mined, and in fact will be so in the quantitative model of the next section. In the data, as well as in the model, there exist workers who will never choose to leave the routine occupations, given their skills. Hence, they might hold low buffers of liquid savings, as they never plan to make a career change that would temporarily depress their earnings. As a result of this simultaneity, the estimate of β in equation (1) could be biased. I therefore view these estimates only as informative correlations that support the considerations from the small model above.[15] Also, I can use these empirical estimates later to compare them to the results from a synthetic panel, simulated from the quantitative model.

4 Quantitative Model

Taking into account the empirical findings, this section presents the full model. Time t is continuous and runs forever. The economy consists of a representative firm, heterogeneous households and a government. The representative firm operates under perfect competition and produces using labor from three occupations (manual, routine, abstract) and two types of capital (ICT and non-ICT). Households are subject to uninsurable idiosyncratic labor income risk and die stochastically. The government taxes households and distributes transfers to them. The analysis takes place in general equilibrium, i.e. all factor prices are endogenous. The exogenous driver of technological change is a falling price of ICT capital relative to the consumption good $\frac{1}{q_{ict}}$. I assume that the economy is initially in its steady state in 1980 with a constant q_{ict}. It is then hit by a shock that raises q_{ict} over many years to a new, higher level, until the economy reaches a new steady state. Agents have perfect foresight over the path of q_{ict} once it is revealed in 1980. There is no aggregate risk.

4.1 Representative firm

The final good in the economy Y_t is produced according to a multiply nested constant elasticity of substitution production function (vom Lehn, 2020):

$$Y_t = \underbrace{K_{s,t}^{\alpha}}_{\text{Non-ICT capital}} \left[\mu_m N_{m,t}^{\frac{\gamma_m-1}{\gamma_m}} + (1-\mu_m)\left[\mu_a N_{a,t}^{\frac{\gamma_a-1}{\gamma_a}} + (1-\mu_a) R_t^{\frac{\gamma_a-1}{\gamma_a}}\right]^{\frac{\gamma_a(\gamma_m-1)}{(\gamma_a-1)\gamma_m}}\right]^{\frac{\gamma_m(1-\alpha)}{\gamma_m-1}} \tag{2}$$

where

$$R_t = [(1-\mu_r)\underbrace{K_{ict,t}^{\frac{\gamma_r-1}{\gamma_r}}}_{\text{ICT capital}} + \mu_r N_{r,t}^{\frac{\gamma_r-1}{\gamma_r}}]^{\frac{\gamma_r}{(\gamma_r-1)}}$$

Here, $N_{j,t}$ denotes effective labor employed in occupation $j \in \{m, r, a\}$. $\{\gamma_m, \gamma_r, \gamma_a, \mu_m, \mu_r, \mu_a\}$ are parameters that govern the optimal factor input shares and the elasticities of substi-

[15] I experimented with using lagged hand-to-mouth status as an instrument for current hand-to-mouth status. The results were very similar to the ones shown here.

tution. There are two types of capital, ICT and non-ICT capital (e.g. structures). The laws of motion for the two types of capital are, respectively,

$$\dot{K}_{ict,t} = q_{ict,t} I_{ict,t} - \delta_{ict} K_{ict,t}$$
$$\dot{K}_{s,t} = q_{s,t} I_{s,t} - \delta_s K_{s,t} \ ,$$

where the parameters δ_x capture depreciation of the capital stock. $q_{x,t}$ denotes the amount of capital of type x that can be purchased for one unit of output at time t (Greenwood et al., 1997). The price of the final good is normalized to one. An increase in q_{ict}, i.e. a falling relative price of ICT capital, is the exogenous driving force behind the polarization of labor markets in the model. In line with Eden and Gaggl (2018), I set the relative price of non-ICT capital $\frac{1}{q_{s,t}}$ to one at all times for the remainder of this paper. All factor inputs are paid their marginal product and the firm makes zero profits because of the assumption of constant returns to scale.

4.2 Households

There exists a continuum of mass one of households who value consumption c and leisure $(1 - \ell)$. Let $u(c, \ell)$ denote the flow utility function, which is additively separable in consumption and leisure, monotonically increasing in c and monotonically decreasing in ℓ. Households discount the future at rate ρ and die at rate ζ, hence their effective discount rate is $\hat{\rho} \equiv \rho + \zeta$. I include a labor supply decision in the model to ensure that labor income taxation dampens labor supply. This is important when studying policies that are financed by raising labor taxes, as in Section 6.

In order for the model to generate a share of hand-to-mouth agents that is as high as in the data while simultaneously modeling a production economy, I follow Kaplan, Moll, et al. (2018) by using two assets that households can save in: a liquid asset m and an illiquid asset $\tilde{k}$. Like them, I assume that households who die are replaced by newborn households holding zero assets.[16] Households can borrow in the liquid asset up to a borrowing constraint $\underline{m}$. The liquid asset pays no interest (representing, for instance, money or low-yielding bonds), but if households borrow they have to pay an intermediation cost $\kappa > 0$. Households hold non-negative amounts of the illiquid asset, $\tilde{k} \geq 0$, which pays a return r_t. $\tilde{k}$ is subject to a portfolio adjustment cost $\chi(\tilde{k}, d)$, where a positive d denotes a deposit and a negative d a withdrawal of wealth from the illiquid account.

Labor income Households optimally choose to work in one of the three broad occupations at each instant of time t. Apart from losing occupation-specific human capital,

[16]The accidental bequests of dying households are passed on to all living households in proportion to their current assets (Kaplan, Moll, et al., 2018).

they can costlessly switch between occupations.[17] Denote the occupational choice by $j \in \{m, r, a\}$. Households' (pre-tax) labor income is

$$inc_j = w_j \cdot \ell \cdot y_j \ ,$$

where w_j denotes the wage per efficiency unit in occupation j, ℓ labor supply, and y_j labor productivity.

The log of labor productivity is in turn composed of three terms:

$$\ln(y_j) = a_j \cdot (\underbrace{s}_{\text{skill}} + \underbrace{\eta}_{\text{shock}}) + \underbrace{h_j}_{\text{specif. human cap.}} + \underbrace{\epsilon}_{\text{shock}} \tag{3}$$

Each household has a skill type s, which is fixed over the lifetime and distributed in the population according to some cumulative distribution function $F(s)$. The skill type is pre-multiplied by an occupation-specific slope parameter a_j, where I assume $0 = a_m < a_r < a_a$. These assumptions are borrowed from Cortes (2016), Jung and Mercenier (2014), and vom Lehn (2020) and imply a comparative advantage of low-(high-) skilled types in the manual (abstract) occupation. This gives rise to an endogenous sorting pattern of skill types into the three occupations.[18]

The left panel of Figure 2, which plots skill on the x-axis and potential earnings in each occupation on the y-axis, visualizes this. For an equilibrium with positive labor supply in each of the occupations to exist, wages per efficiency unit w_j must endogenously be ordered as can be seen on the y-axis.[19] The dashed extensions of the solid lines represent hypothetical earnings of households in all three occupations, and the slopes of the lines correspond to the parameters a_j. The cut-offs $\underline{s}$ and $\bar{s}$ separate the skill space into three regions. Hence, absent any other considerations, these cut-offs would sharply divide skill types into working in one of the three occupations in the steady state of the model. As I will discuss further below, I introduce the shock η to capture motives for occupational switches other than technological change. Note that, on average, manual (abstract) workers earn the lowest (highest) wages in the economy, with routine workers in between.

The right panel of Figure 2 depicts skills and potential earnings after polarization has taken place, i.e. in the new steady state. The exogenous fall in the price of ICT capital leads to an endogenous increase in the abstract and the manual wage relative to the routine wage. This shifts the skill cut-offs $\underline{s}$ and $\bar{s}$ inward, leading to a smaller set of skill types who choose the routine occupations in the new steady state. Hence, there are two margins of adjustment while the economy transitions to a smaller routine

[17] I discuss this assumption at the end of this subsection.

[18] Edin et al. (2021) refer to this structure as a hierarchical Roy model.

[19] For instance, if it were the case that $\ln(w_m) < \ln(w_r)$, no household would choose to work in the manual occupation. To simplify the exposition, the visualized ordering implicitly assumes that $s > 0$, which will not be the case in the calibrated model in which I assume that $s \sim N(0, 1)$. However, in that case, too, a necessary ordering of wages exists for there to be positive labor supply in each occupation.

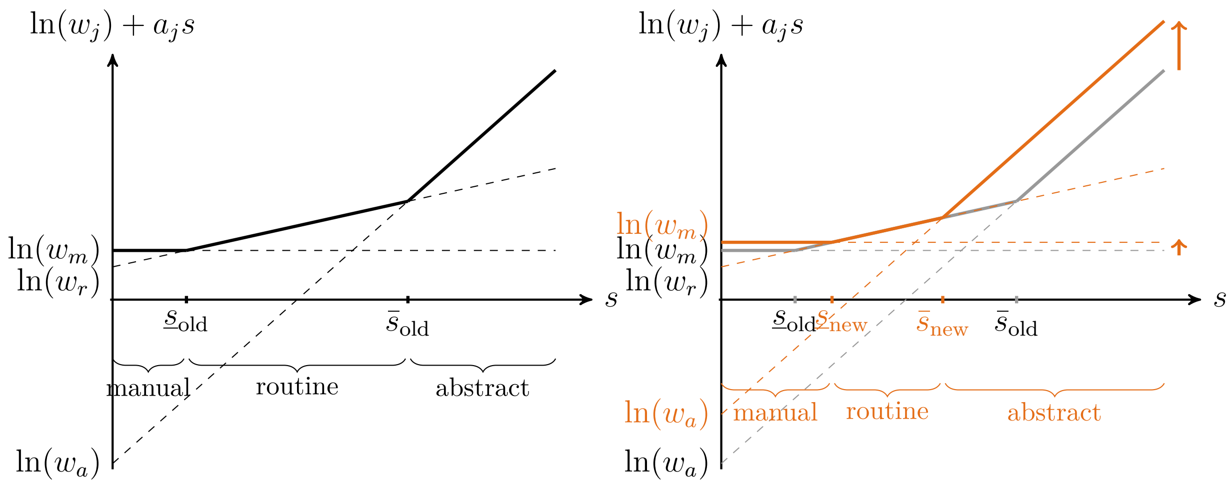

Figure 2: Wages for different skill types before (left) and after polarization (right)

employment share, i.e. when moving from the left to the right panel of Figure 2. First, there is occupational mobility, i.e. net flows of workers switching from the routine to the manual and abstract occupation. Second, some newborn workers choose to work in the manual and abstract instead of the routine occupation, unlike the households they have replaced. Both of these adjustments take place predominantly in the regions $[\underline{s}_{\text{old}}, \underline{s}_{\text{new}}]$ and $[\bar{s}_{\text{new}}, \bar{s}_{\text{old}}]$. I return to an illustrative discussion of the occupational choice of workers with skill type $\bar{s}_{\text{old}}$ at the beginning of Section 5.

Occupation-specific human capital in the current occupation is captured by h_j in equation (3). It can take on two values, capturing whether the worker is inexperienced ($h_j = \underline{h}$) or experienced ($h_j = \bar{h}_j$), with $\bar{h}^j > \underline{h}\ \forall j$. I allow the size of the spread $\bar{h}^j - \underline{h}$ to differ across occupations in the calibration. For tractability, I assume that households can only be experienced ($\bar{h}_j$) in their current occupation. Once a household leaves her current occupation and switches to another, h is set to $\underline{h}$. This implies that only human capital in the current occupation is a state variable, as human capital in the respectively other two occupations is always implicitly $\underline{h}$. It also implies that there is no recall of human capital if a worker ever returns to one of her previous occupations.[20] Inexperienced households become experienced with occupation-specific Poisson intensity λ_j^h, and experienced households never become inexperienced unless they switch the occupation.

I add two shocks, η and ϵ, to the log of productivity in equation (3). η is pre-multiplied by the slope parameters a_j, and hence introduces occupational mobility for reasons other than technologocial change into the model in a parsimonious way (Artuç et al., 2010).[21] Intuitively, a positive (negative) shock to η shifts households to the right (left) on the x-axis of Figure 2. A positive shock could be interpreted as a promotion, after which a household who formerly worked in the routine (manual) occupation now

[20]This is a common simplification (Kambourov and Manovskii, 2009a; Kikuchi and Kitao, 2020).

[21]This shock resembles idiosyncratic, occupation-specific shocks that are typical in the occupational choice literature, see for instance Traiberman (2019).

works in the abstract (routine) occupation. A negative shock could represent a job loss, after which a household is unable to find another job in the abstract (routine) occupation and therefore takes a routine (manual) job. The advantage of generating steady state occupational mobility in this way is that switches up the occupational ladder (i.e. from manual to routine and from routine to abstract) are contemporaneously correlated with wage gains, and switches down the ladder usually coincide with wage losses. This allows me to target the negative (positive) average wage change of switchers from routine to manual (abstract) documented by Cortes (2016) in the calibration (column 1 of Table 1).

The second shock, ϵ, also influences a worker's productivity, but unlike η, not her relative productivity across occupations. I include this shock to generate realistic amounts of earnings risk in the calibration. Each shock evolves according to some stochastic process

$$\dot{\eta}_t = \Phi_\eta(\eta_t), \; \dot{\epsilon}_t = \Phi_\epsilon(\epsilon_t) \; .$$

Newborn households are inexperienced ($\underline{h}$) and start their lives with a draw from the invariant stationary distributions of s, η and ϵ respectively.

Note that several types of costs resulting from occupational switching are not captured here for the sake of parsimony. Households might not only switch the broad occupation, but at the same time also the industry or the firm, which would entail losses of industry- or firm-specific human capital. There could also be fixed pecuniary costs associated with switching the occupation, such as obtaining a degree or a license, having to move to a new workplace, or buying new work clothes. These additional elements would arguably discourage especially households close to the borrowing constraint from switching. Omitting these costs is therefore conservative with respect to the proposed mechanism, as adding them would further increase the relevance of the friction and likely make the policies in Section 6 even more powerful.

Household problem Equation (4) shows the household problem.

$$V_T(i) = \max_{\{c_t,\ell_t,d_t\},\tau} \mathbb{E}_T \int_{t=T}^{\tau} \mathrm{e}^{-\hat{\rho}(t-T)} u(c_t,\ell_t)\, \mathrm{d}t + \mathrm{e}^{-\hat{\rho}(\tau-T)} \mathbb{E}_T V^*_\tau(i) \tag{4}$$

$$\begin{aligned}
\text{subj. to:} \quad & \dot{m}_t = (1-\tau_{l,t}) \cdot w_{j,t} \cdot \ell_t \cdot y_{j,t} + \mathbf{1}_{\{m_t<0\}} \cdot \kappa \cdot m_t - \chi(d_t, \tilde{k}_t) - d_t + T_t - c_t \\
& \dot{\tilde{k}}_t = r_t \tilde{k}_t + d_t \\
& m_t \geq -\underline{m}, \; \tilde{k}_t \geq 0 \\
& V^*_t(i) = \max_{\tilde{j}\in\{m,r,a\}} V_t(i_{-\{j,h\}}, \tilde{j}, \underline{h})
\end{aligned}$$

i indicates the household state, which collects idiosyncratic state variables ($\{s, \eta, \epsilon, j, h, m, \tilde{k}\}$) and includes information about aggregate variables implied by the distribution of households over the state space. $\mathbf{1}_{\{\cdot\}}$ denotes the indicator function. T_t is a lump-sum transfer from the government, $\tau_{l,t}$ a proportional labor income tax. $\tilde{k}_t \equiv \frac{k_{ict,t}}{q_{ict,t}} + k_{s,t}$ denotes capital in units of the final good. The interest rate r_t on $\tilde{k}$ and a no-arbitrage condition, which ensures that households are indifferent between holding either type of capital (ICT and non-ICT), are

$$r_t \equiv q_{ict,t} r_{ict,t} - (\delta_{ict} + \dot{q}_{ict,t}/q_{ict,t}) = r_{s,t} - \delta_s \ . \tag{5}$$

Note also the stopping-time nature of problem (4): households choose the time $\tau \in [T, \infty)$ at which they switch the occupation. Once they do, the continuation value of the household problem is $V^*(i)$, which is equal to $V(i)$, only that the occupation j is updated and human capital reset to $\underline{h}$, while all remaining state variables ($i_{-\{j,h\}}$) stay unchanged. The household problem gives rise to a Hamilton-Jacobi-Bellman equation, which is shown in Appendix D.2 for the specific processes of the exogenous productivity shocks used in the calibration.

4.3 Government

The government budget constraint holds at each instant of time:

$$G_t + T_t = \tau_{l,t} \int_i inc_i \, \mathrm{d}\Gamma_t(i) + \dot{M}_t^s \ . \tag{6}$$

Here, G_t denotes government spending and $\Gamma(i)$ the cumulative distribution function of households over the idiosyncratic state space. Fiscal policy sets M^s such that the liquid asset demand from households is met, i.e. I assume an infinitely elastic supply of M.

4.4 Equilibrium

An equilibrium is defined as paths for household decisions $\{\tilde{k}_t, m_t, d_t, c_t, \ell_t, j_t\}_{t\geq 0}$, input prices $\{w_{m,t}, w_{r,t}, w_{a,t}, r_{ict,t}, r_{s,t}\}_{t\geq 0}$, government taxes and transfers $\{\tau_{l,t}, T_t\}_{t\geq 0}$, distributions $\{\Gamma_t\}_{t\geq 0}$, and aggregate quantities such that, at every t:

1. Given prices, aggregate quantities, the distribution $\{\Gamma_t\}_{t\geq 0}$, and the stochastic processes for individual states, policy functions c_t^*, ℓ_t^*,d_t^*, m_t^*, $\tilde{k}_t^*$ and j_t^* solve the households' problem (4).

2. The representative firm optimizes, given input prices. The FOCs (12), (13), (14), (15), and (16) hold.

3. The government budget constraint (6) holds.

4. The labor markets clear, i.e. for $j \in \{m, r, a\}$:

$$N_{j,t} = \int_{i:j_t^*=j} y_{j,t} \ell_t^* \, \mathrm{d}\Gamma_t(i)$$

5. The no-arbitrage condition (5) holds and the capital market clears:

$$\frac{K_{ict,t}}{q_{ict,t}} + K_{s,t} = \int_i \tilde{k}_t^* \, \mathrm{d}\Gamma_t(i)$$

6. The liquid asset market clears:

$$M_t^s = \int_i m_t^* \, \mathrm{d}\Gamma_t(i)$$

7. The resource constraint holds:

$$Y_t = C_t + I_{s,t} + I_{ict,t} + G_t + \int_i \chi(\cdot) + \kappa \max\{-m_t^*, 0\} \, \mathrm{d}\Gamma_t(i)$$

   where C_t denotes aggregate consumption.

8. The sequence of distributions satisfies aggregate consistency conditions.

4.5 Calibration

Relative price of ICT capital The exogenous driving force of technological change in the model is a fall in the relative price of ICT capital $\frac{1}{q_{ict}}$. To calibrate its evolution over time, I use the estimates reported in Eden and Gaggl (2018), see Figure 19 in the appendix. During the last years covered by Eden and Gaggl (2018), i.e. up until 2013, the fall of $\frac{1}{q_{ict}}$ slows down markedly. I assume that the fall continues at the reduced rate of 1% annually between 2014 and 2025 and then stays at its value of 0.225 forever. Agents in the model have perfect foresight over the path of q_{ict}, once it is revealed in 1980.

Externally set parameters I set a first set of parameters as in Kaplan, Moll, et al. (2018). The utility function is

$$u(c, \ell) = \ln(c) - \varphi \frac{\ell^{1+\gamma}}{1+\gamma} \, ,$$

where γ is set to 1, and φ to 2.2. These choices ensure a Frisch elasticity of labor supply of one and an average labor supply of approximately 0.5.

Households die at rate $\zeta = \frac{1}{180}$, which implies an average life span of 45 years. The unsecured borrowing limit, $\underline{m}$, is set to the average quarterly income. The portfolio adjustment cost function for the illiquid asset $\tilde{k}$ is a convex adjustment cost function

$$\chi(d, \tilde{k}) = \chi_1 \left(\frac{|d|}{\tilde{k}} \right)^{\chi_2} \tilde{k} \, ,$$

Table 3: Externally calibrated parameters

Parameter	Value	Description	Source or Target
ζ	$1/(4 \cdot 45)$	death rate	avg. lifetime 45 years
φ	2.2	labor disutility	avg. labor time 8h/day
γ	1	elast. labor supply	Frisch elasticity of 1
$\underline{m}$	avg. qrtly. inc.	borr. constr.	Kaplan, Moll, et al. (2018)
τ_l	0.3	labor tax	Kaplan, Moll, et al. (2018)
T_t	$6\% \cdot Y_t$	lump-sum transfer	Kaplan, Moll, et al. (2018)
α	0.34	Non-ICT cap. share	Eden and Gaggl (2018)
δ_{ict}	0.175/4	deprec. ICT capital	Eden and Gaggl (2018)
δ_s	0.073/4	deprec. struct. capital	Eden and Gaggl (2018)
$[a_m, a_r, a_a]$	$[0, 0.18, 0.77]$	occ. prod. functions	vom Lehn (2020)
$F(s)$	$N(0,1)$	skill distrib.	vom Lehn (2020)

Notes: Rates are expressed as quarterly values.

where χ_1 and χ_2 are parameters.[22] The tax rate on labor income τ_l is set to 30%, and the lump-sum transfer from the government T amounts to 6% of total output Y_t.

The share of non-ICT capital α is set to 0.34 and the depreciation rates of capital to $\delta_{ict} = 0.175$ and $\delta_s = 0.073$ annually, which are average values reported in Eden and Gaggl (2018). For the parameters of the occupational production function I resort to the baseline values used by vom Lehn (2020). Normalizing $a_m = 0$, he estimates $a_r = 0.18$ and $a_a = 0.77$ using data on occupational choices and worker skills, proxied by wages, from the Current Population Survey (CPS). Like him, I assume that skills are standard normally distributed in the population, i.e. $s \sim N(0,1)$. Table 3 lists all externally calibrated parameters.

Occupation-specific human capital To calibrate the parameters of the human capital process $\{\bar{h}_m, \bar{h}_r, \bar{h}_a, \lambda^h_m, \lambda^h_r, \lambda^h_a\}$, I estimate returns to tenure in each occupation.[23] I follow the methodology outlined in Cortes (2016, Section VI C). In particular, using PSID data from 1981 to 2017, I estimate the following equation:

$$\mathcal{Y}_{it} = \sum_j D_{ijt} \left(\beta_{j1} Ten_{ijt} + \beta_{j2} Ten^2_{ijt} + \gamma_{ij} \right) + \delta X_{it} + u_{it}$$

where $\mathcal{Y}_{it}$ is the log real wage of individual i at time t, D_{ijt} is a dummy indicating whether the individual was working in occupation $j \in \{m, r, a\}$ at time t, Ten_{ijt} is occupational tenure, γ_{ij} is an occupation fixed effect for each individual, and X_{it} are controls. For details, see Appendix C.2.

[22] The adjustment cost function in Kaplan, Moll, et al. (2018) contains an additional parameter, χ_0. In a follow-up paper, Alves et al. (2020) use a more parsimonious function, leaving out this additional parameter. I follow this latter approach here.

[23] Having the common value $\underline{h} = 1$ for each occupation is a normalization. Only the gap $\bar{h}_j - \underline{h}$ is relevant in all that follows.

In line with previous literature (Sullivan, 2010), I find that returns to tenure are higher in the abstract than in the other two occupations. Moreover, I do not find statistically significant differences between β_{m1} and β_{r1}, nor between β_{m2} and β_{r2}. I therefore use the estimates of β_{j1} and β_{j2} and approximate the tenure profiles once for the abstract and once jointly for the routine and for the manual occupation. I choose the spreads $\bar{h}_j - \underline{h}$ and the intensities λ_h^j to minimize the mean squared deviations of the return profiles in the model from their empirical analogues over the first twenty years after entering an occupation. Figure 12 in the appendix plots these return profiles, for which I find $\bar{h}_a - \underline{h} = 0.29$ and $\bar{h}_{\{m,r\}} - \underline{h} = 0.15$ as well as $\lambda_a^h = 0.023$ and $\lambda_{\{m,r\}}^h = 0.033$ to provide the best fit. These return profiles are quantitatively in line with baseline values from Kambourov and Manovskii (2009b), who estimate returns to occupational tenure unconditionally, i.e. across all occupations.

Productivity shock process Φ_ϵ Following Kaplan, Moll, et al. (2018), I use the productivity shock ϵ to target moments of earnings changes, estimated in Guvenen et al. (2021). I assume that $\Phi_\epsilon(\epsilon_t)$ follows a jump-drift process, with jumps arriving at rate λ_ϵ. At all times, the process drifts toward its mean of zero at rate β_ϵ. Whenever there is a jump, a new log productivity state is drawn from a normal distribution, with $\epsilon_t' \sim N(0, \sigma_\epsilon^2)$. Hence we have

$$\mathrm{d}\epsilon_t = -\beta_\epsilon \epsilon_t + \mathrm{d}J_t \ ,$$

where $\mathrm{d}J_t$ captures the jumps in the process. The calibration targets are in Table 10 in the appendix. They imply that shocks arrive on average every five years ($\lambda_\epsilon = 0.05$), with a standard deviation σ_ϵ of 1.2 and a half-life of approximately 3 years ($\beta_\epsilon = 0.05$).

Supply side I calibrate the parameters of the aggregate production function (2) as is common in the literature (Jaimovich, Saporta-Eksten, et al., 2021; vom Lehn, 2020). I use the employment shares in the three occupational groups, as well as the share of income accruing to labor, both in 1980 and in 2020, to pin down the six share and elasticity parameters (μ_j, γ_j). For the 1980 employment shares I use the values reported in Autor and Dorn (2013), for the 2020 values I use my own estimates from the 2019 SCF (the most recent employment shares based on CPS data reported in Kikuchi and Kitao (2020) are very similar). For the labor share I take the values reported in Eden and Gaggl (2018) for both 1980 and 2020, assuming that the labor share does not fall further between their latest observation (2013) and 2020. vom Lehn (2020) shows that these six moments together identify the parameters of the production function.

The calibrated values of the production function parameters are as expected (Table 4). While routine labor and ICT capital are relatively easy to substitute ($\gamma_r > 1$), abstract labor is relatively complementary to the input provided by both routine labor and ICT capital ($\gamma_a < 1$). The substitution elasticity of manual labor with the nest composed of

Table 4: Internally calibrated parameters

Parameter	Value	Description	Target	Data (Model)
Supply side				
μ_m	0.13	PF share man.	1980 Empl. share rout.	58.5% (58.5%)
μ_r	0.94	PF share rout.	1980 Empl. share abstr.	31.6% (31.5%)
μ_a	0.69	PF share abstr.	1980 Labor share	64.0% (64.2%)
γ_m	1.67	PF elast. man.	2020 Empl. share rout.	45.0% (45.4%)
γ_r	2.47	PF elast. rout.	2020 Empl. share abstr.	42.3% (42.5%)
γ_a	0.27	PF elast. abstr.	2020 Labor share	57.0% (56.5%)
Demand side				
$\hat{\rho}$	0.018	discount rate	$\tilde{K}/Y$	2.92 (2.77)
κ	0.034	borr. wedge	M/Y	0.26 (0.30)
χ_1	0.87	portf. adj. cost	share poor HtM	0.10 (0.10)
χ_2	1.35	-	share wealthy HtM	0.20 (0.20)
Wage changes of routine switchers (1980-2020)				
$\eta_h - \eta_l$	0.78	spr. prod. grid	Avg. wage chng. switchers $r \to a$	3.4% (1.5%)
λ_η	0.02	λ prod. shock	Avg. wage chng. switchers $r \to m$	-11.2% (-10.9%)

Notes: Rates are expressed as quarterly values.

abstract labor and the routine input is again relatively high ($\gamma_m > 1$).[24]

Demand side Concerning the demand side of the economy, I need to calibrate four parameters that are also present in Kaplan, Moll, et al. (2018). I use the same targets as they do to pin them down. In particular, I calibrate the effective discount rate $\hat{\rho}$, the borrowing wedge κ and the parameters of the portfolio adjustment cost function $\chi(\cdot)$ using both the ratio of liquid and illiquid assets to output in the economy, and the shares of poor and wealthy hand-to-mouth households. I target these four statistics in the initial steady state of the model. I find very similar values for these parameters as Kaplan, Moll, et al. (2018), and hit the targets relatively well. Only κ, which indicates an annual borrowing wedge of 13.7%, is notably higher than in Kaplan, Moll, et al. (2018) (6.0%), but still well in line with empirical estimates of the price for unsecured borrowing (Dempsey and Ionescu, 2021).

Productivity shock process Φ_η The process Φ_η could be used either to target the average wage change of switchers or the level of occupational mobility. I opt for the former, as it is central for the proposed mechanism. I report (untargeted) statistics on occupational mobility below. More specifically, I use Φ_η to target the initial wage change of workers who leave the routine occupations relative to those who stay (first column of Table 1). To be as parsimonious as possible, I assume that η follows a two-state

[24] These values are similar to those used in the previous literature. For instance, Jaimovich, Saporta-Eksten, et al. (2021) calibrate $\gamma_m = 1$, $\gamma_r = 1.89$ and $\gamma_a = 0.32$. vom Lehn (2020) uses equipment instead of ICT capital, rendering his production function parameters less comparable to the ones here.

Poisson process with symmetric transition rate λ_η between the states. This yields two parameters to target the two statistics: the spread between the states, $\eta_h - \eta_l$, and the transition rate λ_η.[25] To obtain comparable statistics to Cortes (2016), I simulate a panel of 10,000 households along the transition path between 1980 and 2020 and perform the same regressions that he uses to produce his estimates. The calibrated shock hits the workers on average every twelve years and the impact of a standard deviation shock on log productivity is significantly smaller than that of a typical shock to the other productivity variable, ϵ.

4.6 Untargeted moments

Hand-to-mouth shares by occupation The calibration targets unconditional shares of hand-to-mouth households in the economy, but not the shares conditional on occupation. These moments are reported in Table 11 in the appendix for the initial steady state of the model as well as for the earliest available wave of the SCF (1989). Overall, the model provides a very good fit to the data in this regard.

The role of newborns in the decline of the routine employment share Cortes, Jaimovich, Nekarda, et al. (2020) provide empirical evidence highlighting that 34%–43% of the fall in routine employment has been due to a reduced propensity to enter these occupations from non-employment and unemployment.[26] They further show that the declining propensity of young workers (16–34 years) has been especially important in accounting for the drop in aggregate routine labor, explaining 17%-21% of the total fall in routine employment. While I do not model unemployment, one can interpret the entry of newborn households as entry from non-employment. I therefore conduct a counterfactual exercise to assess whether my model performs realistically in this regard.

Starting in the initial steady state, I use the optimal occupational policy functions j_t^* to decide which occupation new labor market entrants choose at the beginning of their life. Afterwards, I counterfactually assume that they never switch the occupation, i.e. I iterate forward the distribution of households over the state space assuming that households only make an occupational choice at the beginning of their lives. Hence, this is an out-of-equilibrium exercise that abstracts from general equilibrium effects on

[25] A larger spread $\eta_h - \eta_l$ leads to the same (absolute) increase in the average wage change for both switching directions. If shocks hit frequently (a high λ_η), households ignore them in their occupational choice, focussing on accumulating occupation-specific human capital in one occupation. In this case, switching due to technological change becomes the prominent driver of occupational mobility. Since technological change affects the evolution of relative wages w_a/w_r and w_m/w_r differently (see below) the two parameters identify the two targeted statistics.

[26] They find that outflows to non- and unemployment are not important for explaining the decline. Also, the authors note that 54–60% of the drop in routine employment cannot be explained by changed exit and entry to non- and unemployment, and is therefore due to job-to-job transitions and other transitions not covered by their decomposition. In my model, job-to-job transitions and reduced inflows from new labor market entrants are the sole drivers of the decline in routine employment.

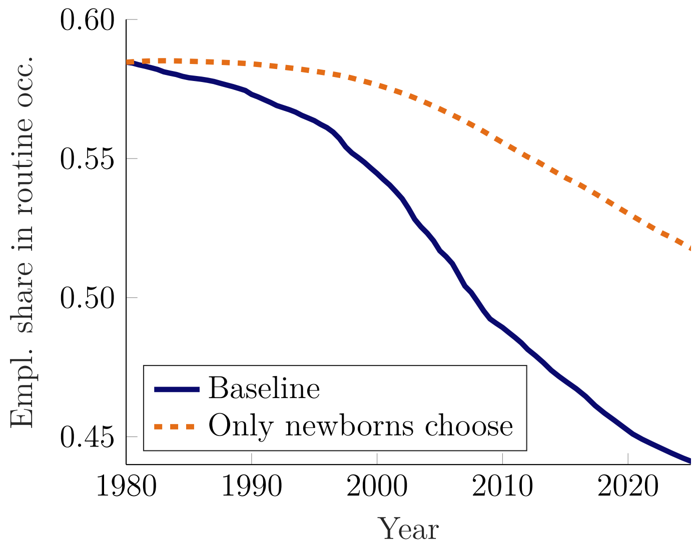

Figure 3: Employment share in the routine occupation

Notes: Blue solid: baseline transition. Orange dashed: counterfactual with initial occupational choices made permanent for rest of life.

initial occupational choices and on wages, just as in Cortes, Jaimovich, Nekarda, et al. (2020). Details on how I construct this and all following counterfactuals are relegated to Appendix D.3.

The orange dashed line in Figure 3 depicts the resulting mass of routine workers in the economy. It falls much more slowly compared to the baseline transition (blue solid), which implies that some of the fall in routine labor in the model is due to net occupational switching. Consistent with Cortes, Jaimovich, Nekarda, et al. (2020), in 2020 41% of the fall in routine employment since 1980 is accounted for in the model by the reduced propensities of new labor market participants to enter the routine occupations.

Timing of the fall in routine employment The magnitude of the decline of routine employment from 58.5% in 1980 to 45.0% in 2020 was targeted in the calibration. The dynamics of the fall, though untargeted, are however well in line with empirical evidence in Cortes, Jaimovich, and Siu (2017), Jaimovich and Siu (2020), and Kikuchi and Kitao (2020): Routine employment declines gradually prior to the 2000s and faster afterwards.

Occupational mobility Mobility across the three broad occupations averages 1.0% annually along the transition in the model. This is lower than mobility in the PSID, which between 1979 and 1997 was 5.0% for males. However, it is well-known that due to measurement errors estimates of occupational mobility in the PSID are inflated (Kambourov and Manovskii, 2008). Using CPS data, Kikuchi and Kitao (2020) estimate occupational mobility of 1.3% for abstract, 1.4% for routine and 5.6% for manual workers, closer to the average value in my model.[27]

[27] These numbers correspond to the high-skilled group in the case of abstract and to the low-skilled group in the case of routine and manual workers reported in Kikuchi and Kitao (2020). These groups

Relative wages and interest rate over time While I target the change in employment shares in the calibration, the evolution over time of relative wages per efficiency unit is untargeted. Cortes (2016) estimates that the log of w_a/w_r rose by about 25% between 1980 and 2007, and the log of w_m/w_r by 10 to 15%.[28] The model produces a nearly identical rise in the log of w_a/w_r (23%), though a somewhat smaller increase in the log of w_m/w_r (4%). This indicates that the model captures very well the incentives over time for relatively high-skilled routine workers to switch to the abstract occupation. The incentives for low-skilled routine workers to switch to the manual occupation is a bit smaller in the model than in the data. If anything, this could lead me to underestimate the benefits of policies targeted at switchers to the manual occupation.

Figure 20 in the appendix further plots the evolution of the interest rate. Since firms demand more capital when its relative price falls, the interest rate rises over time. This is in line with empirical evidence discussed in Moll et al. (2022).

Wage changes upon occupational switch In the calibration I target the average wage change of workers leaving the routine for either the manual or the abstract occupation, compared to workers who stayed in the routine occupation. Remembering Table 1, Cortes (2016) also compares wages over longer horizons than one year, documenting faster wage growth for switchers than for stayers. I visualize his estimates, i.e. the values from Table 1, and the corresponding statistics from the simulated panel of my model in Figure 11 in the appendix. Overall, I am able to capture the differential wage paths of switchers compared to stayers quite well, though for both directions of the switch (abstract/manual) long-run wage growth is a bit less pronounced in the model than in the data. In the case of switches to the manual occupation, this owes in part to the somewhat smaller than empirically observed increase in $\ln(w_m/w_r)$ mentioned in the previous paragraph.

5 Transition Path

This section studies the transition between the two steady states. The focus lies on demonstrating that the existence of a large share of households who hold few liquid assets, i.e. who are close to the borrowing constraint, causes a lag in the reallocation of labor into the abstract and manual occupation.

5.1 Individual choices

To illustrate this point, I first analyze the switching decisions of a particular set of formerly routine workers whose optimal occupational choice is clearly affected by technological

respectively account for the largest portion of employment in each occupation.

[28] These numbers correspond to the lower left panel of Cortes (2016, Figure 6), as in that specification he allows for occupation-specific tenure profiles, as I do in my model.

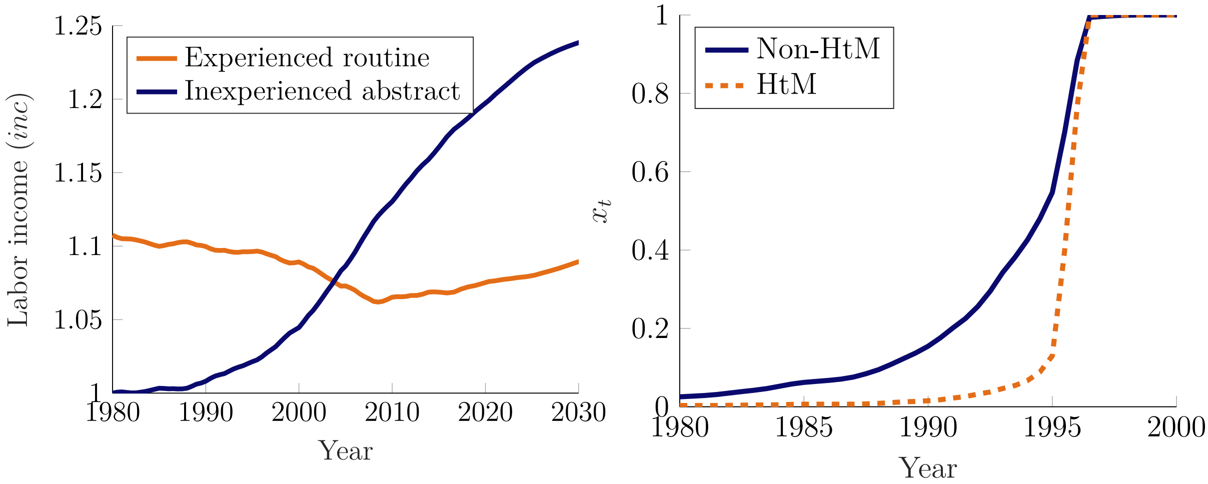

Figure 4: Experienced routine workers with skill type $s = \bar{s}_{\text{old}}$: Potential labor income (left) and likelihood of switching to the abstract occupation (right)

Notes: The left panel shows labor income inc for workers of skill type $s = \bar{s}_{\text{old}}$ in productivity states $\eta = \eta_h$ and $\epsilon = \mathbb{E}[\epsilon] = 0$. The red line indicates income of experienced routine workers ($w = w_{r,t}$, $h = \bar{h}_r$), the blue line income of inexperienced abstract workers ($w = w_{a,t}$, $h = \underline{h}$). The right panel shows the binary choice x_t of entering the abstract occupation for the same workers, averaged across wealth (m and $\tilde{k}$) using the stationary distribution of households in the initial steady state $\Gamma(i)$. The dashed red line depicts the case when averaging only over individuals with $m = 0$ or $m = -\underline{m}$, the solid blue line when averaging over all remaining individuals.

change. Specifically, I consider the occupational policy functions j_t^* of experienced routine workers ($\bar{h}_r$) of skill type $s = \bar{s}_{\text{old}}$, and ask at what point in time they decide to leave the routine for the abstract occupation.[29] Workers of this skill type predominantly work in the routine occupations before and in the abstract occupations after polarization has shifted relative wages in favor of performing abstract work (see Figure 2).

The left panel of Figure 4 plots the labor income that these workers can earn either as an experienced routine worker (red) or as an inexperienced abstract worker (blue). While being an experienced routine worker clearly dominates being an inexperienced abstract worker in the 1980s, this relationship reverses in the early 2000s. The dynamic occupational choice therefore resembles the one studied in the two-period model of Section 2 (compare Figure 1). Note that when making their decision, workers realize that once they start working in the abstract occupation, they build up human capital there. Income of experienced abstract workers over time would in turn be represented by an upward shift of the blue line.

The right panel of Figure 4 visualizes the switching choice over time, once for the households that are hand-to-mouth, and once for those that are not. It plots the binary choice x_t of entering the abstract (and hence leaving the routine) occupation of skill type $s = \bar{s}_{\text{old}}$, averaged across the wealth dimensions (m and $\tilde{k}$) using the stationary

[29] I further condition on workers being in exogenous productivity states $\eta = \eta_h$ and $\epsilon = \mathbb{E}[\epsilon] = 0$.

distribution of households in the initial steady state $\Gamma(i)$, i.e.

$$x_t = \frac{\int_{i:\mathcal{I}} \mathbf{1}_{\{j_t^*=a\}} \mathrm{d}\Gamma(i)}{\int_{i:\mathcal{I}} \mathrm{d}\Gamma(i)} \ , \tag{7}$$

where $i : \mathcal{I}$ indicates that individual i belongs to the set $\mathcal{I} = \{s = \bar{s}_{\text{old}}, j_{1980}^* = r, h = \bar{h}_r, \eta = \eta_h, \epsilon = 0\}$. For the orange dashed line, corresponding to choices of hand-to-mouth households I replace $\Gamma(i)$ in (7) with

$$\Gamma(i) \cdot \mathbf{1}_{i:\{m=0 \vee m=-\underline{m}\}}$$

and I replace it with

$$\Gamma(i) \cdot \mathbf{1}_{i:\{m\neq 0 \wedge m\neq -\underline{m}\}}$$

for the blue solid line that corresponds to occupational choices of non-hand-to-mouth households. A value of $x_t = 0$ indicates that the mass of workers from the set $\mathcal{I}$ who would leave the routine for the abstract occupation at time t equals zero, while $x_t = 1$ implies that all of these workers would make the switch if they found themselves working in the routine occupation at time t.

Figure 4 can be interpreted as follows. As the relative wage in the abstract relative to the routine occupation rises over time, an increasing share of experienced routine workers with skill type $s = \bar{s}_{\text{old}}$ finds it optimal to switch the occupation. However, while the share of non-hand-to-mouth workers wanting to switch rises quickly, almost none of the hand-to-mouth households prefer a switch up until the mid-1990s. This shows how being close to the borrowing constraint delays investment into future earnings growth, just as it did in the tractable model of Section 2.

5.2 Aggregate implications

Figure 4 has shown the differential switching behavior of workers who are at a particular, exemplary, point of the state space. To assess whether the distortions at the individual level have had an impact on aggregate employment shares in the abstract and manual occupations, I simulate a counterfactual transition in which all households choose their occupation like those that are rich in liquid assets and hence far away from the borrowing constraint.

Specifically, I start with the actual employment share in occupation j in the initial steady state. I then iterate this share forward in time using the following procedure. For a given point in time t, I consider all households with liquid assets m_t exceeding the 70th (90th) percentile of the liquid wealth distribution. I then ask what share of these households optimally chooses to work in occupation j, using the policy functions from the baseline transition. I use this probability to iterate forward the employment share and

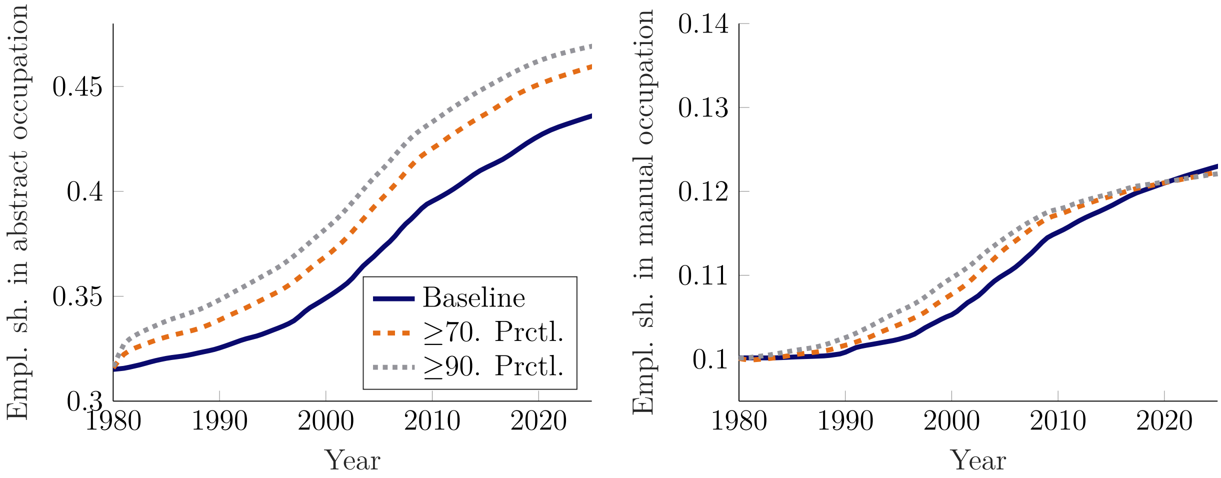

Figure 5: Baseline and counterfactual employment share in abstract (left) and manual (right) occupation

Notes: "≥70. Prctl." ("≥90. Prctl.") corresponds to counterfactual simulation in which all households choose occupations like households with liquid assets m_t greater or equal to the 70th (90th) percentile of the liquid wealth distribution.

then redo the procedure for the next point in time.[30] At each step, I correct for the fact that liquidity-rich households systematically differ in terms of exogenous productivity (η and ϵ) from the unconditional distribution by reweighting accordingly. Appendix D.3 explains the details. Note that this is not an equilibrium exercise, in contrast to the policy experiments in Section 6. Here, I neither specify where the additional liquid assets come from, nor do aggregate quantities respond to the changed behavior of households.

Figure 5 shows the results. Had all households acted as if they were far away from the borrowing constraint, both the manual and the abstract employment share would have been significantly higher during the transition. For instance, between 1980 and 2020 the employment share in the abstract occupation would have been on average two (three) percentage points higher than in the baseline transition. The effect is also present for the manual employment share, though overall movements are much smaller.[31]

Another way to show that individual changes in behavior become visible at the aggregate level, is to rerun the regressions from the end of Section 3 (equation (1)). This time, instead of using data from the PSID, I use the synthetic panel of 10,000 households described in the calibration. Mimicking the empirical implementation, I regress a dummy for whether a household switches between year t and $t + 2$ on a dummy for whether a household is hand-to-mouth. I use the same controls as in the empirical specification (as

[30] When solving for the transition path I discretize time into periods (Kaplan, Moll, et al., 2018).

[31] The counterfactual abstract employment shares stay elevated for several decades and then slowly approach the baseline. They stay elevated by about 0.5 percentage points even far into the future, however. This is because of the occupation-specific tenure profiles, which are relatively steep in the abstract occupation. This leads to some households inefficiently working in the routine occupation if they do not have enough liquid assets to make the investment of starting a career in the abstract occupation which promises higher wages only in the future. See discussion below on introducing policies in steady state.

Table 5: Switching decision and liquid asset holdings (model).

	(1)	(2)	(3)	(4)	(5)	(6)
HtM	-0.0063***	-0.0076***	-0.0060***	-0.0084***		
	(0.0013)	(0.0013)	(0.0013)	(0.0012)		
Occupational tenure	-0.055***	-0.048***	-0.039***	-0.033***	-0.039***	-0.033***
	(0.0032)	(0.0030)	(0.0019)	(0.0016)	(0.0019)	(0.0017)
Skill		0.068***		0.064***		0.064***
		(0.0020)		(0.0020)		(0.0020)
Poor HtM					-0.0034	-0.0091***
					(0.0028)	(0.0025)
Wealthy HtM					-0.0066***	-0.0082***
					(0.0015)	(0.0013)
Time trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	99491	99491	99491	99491	99491	99491
Model	OLS	OLS	Probit	Probit	Probit	Probit

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

Notes: Data are from a synthetic panel of 10,000 households, simulated from the model at annual frequency between 1980 and 2020. Dependent variable is whether or not individual leaves routine occ. between t and $t + 2$. Occ. tenure is a dummy for whether or not worker is experienced. Skill is s. I only use observations in or after 1999. Standard errors are clustered at the individual level. Columns with probit model show average marginal effect.

far as they exist in the model), and use observations in or after 1999. Table 5 shows the results. The same negative association between current liquid asset holdings and future switching decision found in the data also prevails in the model.[32] Also as in the data, the correlation is negative both for poor and for wealthy hand-to-mouth households.

6 Policy Analysis

The fundamental cause of the protracted labor market transition highlighted so far is the borrowing constraint. It causes households with few liquid assets to underinvest in future earnings growth and to stay in the declining routine occupation for a relatively long time. In this section, I ask what the policymaker can do in order to alleviate this friction. In particular, I study the consequences for social welfare and output of two policies, which I introduce into the model one at a time. The first is a government loan program, the second a recurrent transfer—or wage replacement—program. Both policies aim to alleviate the borrowing constraint for workers leaving the routine occupation.

[32] The point estimates are smaller (in absolute terms) than their empirical counterparts in Table 2. This owes to the somewhat lower level of occupational mobility in the model compared to the PSID (see discussion in Section 4.6): as the overall level of mobility is lower in the model, so are the marginal effects. However, despite the marginal effects being closer to zero, all of them are statistically significant.

6.1 Design of the policies

The policies are supposed to target those routine workers for whom switching to the manual or abstract occupation is costly in the short run, but profitable in the long run. Therefore, ideally, I would condition on households experiencing a wage loss upon switching. This would, however, require making past wages an additional state variable in the model, which would greatly increase the computational burden of solving it. Instead, I proxy for this condition, which could easily be implemented in practice, in two ways. First, only *experienced* routine workers ($\bar{h}_r$) who leave the occupation become entitled to the programs, as they are most likely to suffer from temporary earnings losses due to the depreciation of occupation-specific human capital. Second, to avoid offering the program to households for whom a switch to the abstract occupation reflects career progression, at every instant eligibility is limited to those skill types (s) among which the majority of households is currently employed in the routine occupation.[33]

All households begin their lives as non-eligible, and only experienced routine workers who switch to the abstract or manual occupation become eligible, provided that their skill type is qualified to receive the treatment. Households are never restricted in their occupational choice after they have selected into treatment, i.e. they can move back to the routine occupation at a later point if they find this optimal. Note, however, that because previous human capital cannot be recalled, they are inexperienced ($\underline{h}$) routine workers if they do so.

Under the loan program, eligible workers receive a loan of size L in liquid assets from the government upon leaving the routine occupation. After having received the loan, they pay it back at a constant rate $\zeta \cdot L$ until they die. This ensures that in expectation the government breaks even on each individual loan, even though on aggregate it might face temporary deficits (surpluses) from the program if at a given time many workers are taking out (paying back) a loan.

The wage replacement program aims to replace part of the lost earnings that arise due to the occupational switch, and I model it as a transfer payment to the eligible households. This policy is motivated by the Reemployment Trade Adjustment Assistance (RTAA) program currently in place in the U.S., under which wage replacements are paid to workers who lost their job because of foreign trade and found reemployment at a lower wage than before. In the model, I assume that once a worker becomes eligible (i.e. once an experienced routine worker leaves the occupation), she collects a type-independent

[33] This condition rules out relatively high-skilled households from becoming eligible. These are households who only work in the routine occupation (if at all) in case they receive a low productivity draw η_l. Once they receive a high draw (e.g. a promotion), they switch to the abstract occupation, usually incurring a wage gain. While this pattern in principle holds for every skill type, the further to the right of the skill distribution, the higher the comparative advantage from working in the abstract occupation and hence the higher the average wage gain from switching there (Figure 2). I do not include such a condition on skill type for switchers to the manual occupation, as here immediate wage gains occur much less often.

monthly benefit of R. Workers lose eligibility, and hence leave the program, at a quarterly rate of λ_I. I choose λ_I to coincide with the average quarterly rate at which inexperienced workers become experienced in the economy of 0.03, which leads to an average duration in the program of about eight years.

There are two key differences in the design of the wage replacement and the loan program. First, workers never have to pay back the wage replacements. Second, in the spirit of RTAA, payments are conditioned on working in the new (abstract or manual) occupation. If a worker decides to switch back to the routine occupation, she stays entitled but does not receive the benefit R unless she again returns to the manual or abstract occupation.

To balance its budget, the government adjusts the labor income tax $\tau_{l,t}$, while government expenditures G_t and lump-sum transfers to the households T_t stay unchanged compared to the baseline transition. The policies start in 1980 and workers can enter the programs until 2025. All payments are stopped in 2070, an average lifetime after the last workers were allowed into the program.[34]

6.2 Results

I now study the introduction of the two policies in turn. I separately consider making the policy only available to switchers to the abstract and only to switchers to the manual occupation, as I find that the implications of the policies differ by the direction of switch. Since the increase in employment in the abstract occupation has been quantitatively much more important than that in the manual occupation since the 1980s, I focus here on implementing the program solely for workers who switch to the abstract occupation. Targeting the policies at exits to the manual occupation is relegated to Appendix E.

6.2.1 Welfare comparison

To evaluate the policies, I measure welfare changes in consumption-equivalent units. I proceed in two steps. First, for each t, I compute the consumption-equivalent welfare change ϕ_t that makes individuals currently alive in the economy on average indifferent between living in the baseline economy (without the loan or wage replacement program) and the economy with the program:

$$\int_i u(\phi_t \cdot c_t^{basel}, \ell_t^{basel}) \, \mathrm{d}\Gamma_t^{basel}(i) = \int_i u(c_t^{pol}, \ell_t^{pol}) \, \mathrm{d}\Gamma_t^{pol}(i) \, . \tag{8}$$

Second, I compute the average of ϕ_t between $t = 1980$, when the policies are introduced, and $t = 2070$, when the last payments are stopped.

[34] I phase out the programs so that the economy transitions back to the same steady state under the policy as in the baseline without policies.

An alternative way to evaluate welfare would be to first compute the expected lifetime consumption-equivalent welfare change $\bar{\phi}_{\tilde{T}}$ for a cohort entering the labor market in $\tilde{T}$,

$$\int_i \mathbb{E}\left[\int_{t=\tilde{T}}^{\infty} \mathrm{e}^{-\hat{\rho}(t-\tilde{T})} u\left(\bar{\phi}_{\tilde{T}} \cdot c_t^{\text{basel}}, \ell_t^{\text{basel}}\right) \mathrm{d}t\right] \mathrm{d}\bar{\Gamma}_{\tilde{T}}^{\text{basel}}(i) = \int_i \mathbb{E}\left[\int_{t=\tilde{T}}^{\infty} \mathrm{e}^{-\hat{\rho}(t-\tilde{T})} u\left(c_t^{\text{pol}}, \ell_t^{\text{pol}}\right) \mathrm{d}t\right] \mathrm{d}\bar{\Gamma}_{\tilde{T}}^{\text{pol}}(i) \tag{9}$$

where $\bar{\Gamma}_{\tilde{T}}(i)$ is the distribution of workers in $\tilde{T}$ conditional on being an entrant to the labor market.[35] Second, one would then average $\bar{\phi}_{\tilde{T}}$ across different cohorts $\tilde{T}$. Evaluating this is computationally infeasible, however, since the cohort is not a state variable and thus the expression inside the expectations operator is time-consuming to compute even for a single cohort. Hence, I use equation (8) as the basis for welfare comparisons. That said, below I also show expected lifetime consumption-equivalent welfare changes according to (9) for two exemplary cohorts $\tilde{T}$, to zoom in on welfare changes across the skill distribution.

Results The blue solid lines in Figure 6 show consumption-equivalent welfare changes according to (8) averaged over time for different values of L (left panel) and R (right panel). In both cases, welfare differences are inversely u-shaped in the size of the policy, with the optimal loan being 10,000$ and the optimal monthly wage replacement 420$.[36] Furthermore, the optimal wage replacement leads to a larger increase in welfare than the optimal loan. The former achieves an average increase in consumption of 0.15%. This masks significant variation across cohorts and especially across skills, though, as I demonstrate below.

There are several reasons why the policies can increase welfare vis-à-vis the baseline. First, they provide insurance for eligible households and therefore improve their ability to smooth consumption. Second, at least in the case of the wage replacements, income is redistributed from tax payers to the recipients of the transfers. Third, by loosening the borrowing constraint for eligible households, the programs potentially lead to a more efficient allocation across occupations. This can cause important general equilibrium effects in the form of higher output and wages. I attempt to disentangle these different channels by 1) implementing the policies in the steady state of the model (instead of along the transition) and by 2) dissecting the general equilibrium effects below. Both approaches show that the general equilibrium effects generated by efficiency gains are quantitatively important.

The policies also have some clearly negative effects, which outweigh once the loan (wage replacement) becomes very large. First, both policies are financed by distortionary labor taxes. Even in the case of the loan program, where the government breaks even

[35] Productivities η, ϵ and skill s drawn from their invariant distributions in $t = \tilde{T}$, human capital $h = \underline{h}$, assets $m = \tilde{k} = 0$ and occupation j chosen optimally.

[36] Conditional on observing a year-on-year earnings loss when switching from the routine to the abstract occupation, the median monthly earnings loss in the synthetic panel simulated from the model is 680$. Hence, the optimal wage replacement program replaces about 60% of the median earnings loss.

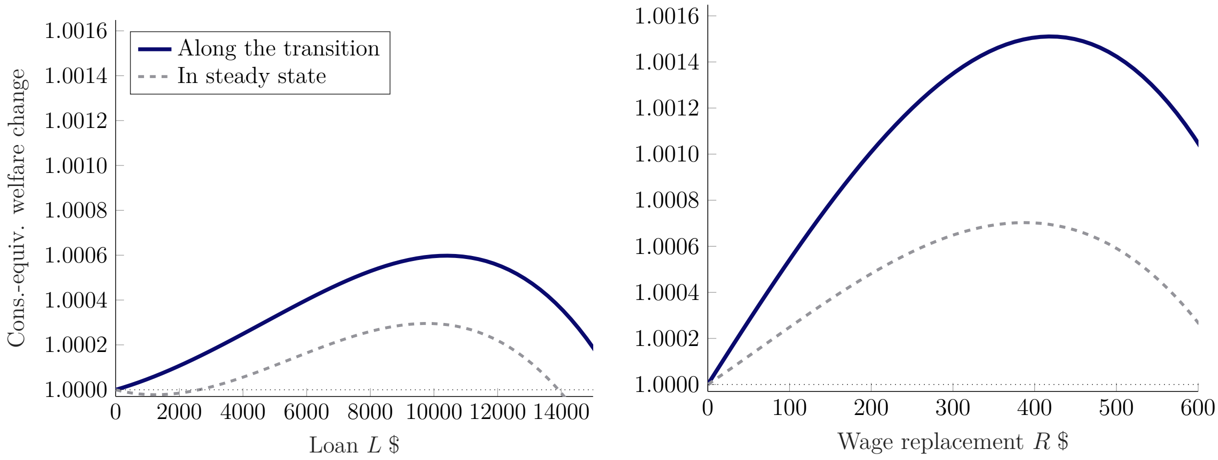

Figure 6: Average change in welfare under different policies compared to the baseline
Notes: Cons.-equiv. welfare change ϕ_t (defined in equation (8)), averaged between $t = 1980$ and $t = 2070$. "Transition": baseline transition path including technological change ($q_{ict,t}$ rises). "Steady state": transition during which no technological change occurs ($q_{ict,t}$ stays constant at its 1980 level). Nominal quantities are expressed in 2017 US dollars.

in expectation on each individual loan, it has to raise taxes whenever the paybacks from earlier loan recipients are not high enough to cover the initiation of new loans.[37] Second, every time an experienced routine worker switches to the abstract occupation, occupation-specific human capital gets destroyed. Hence, every additional switch induced by the policies entails at least a temporary resource cost. For some workers it might be efficient to incur this short-term cost, as switching to the abstract occupation can lead to higher income in the future (Section 2). However, some households might opt into the program only in order to pick up the loan (wage replacement) and be able to smooth current consumption, without any intent of staying in the abstract occupation in the long run.

This helps explain why, by design, the loan program obtains smaller welfare gains than the wage replacement program. Under the loan program there is no disadvantage for the individual worker to switching back to the routine occupation after having obtained the loan. Hence there exist many experienced routine workers who, when hit by an adverse income shock, opt into the program to collect the loan and then switch back to the routine occupation relatively quickly. While this can raise (short-term) utility of the individual worker, once the loaned money has been spent the worker is left with lower human capital and hence lower medium- to long-run earnings than if the policy had not been offered.[38] In contrast to this, under the wage replacement program payments are stretched out over a longer time horizon and conditioned on working in the abstract occupation (in the spirit of the RTAA program). Hence, the workers who opt into this program are those

[37] The labor taxes needed to finance the optimal programs are shown in Figure 22 in the Appendix.

[38] The fact that some experienced workers in the model leave their occupation only for an infinitesimal short period of time and still return as an inexperienced worker is clearly an abstraction that owes to the assumption of no recall of previous human capital. This assumption is necessary to keep the model computationally tractable. More realistically, labor market frictions might prevent households from switching back and forth between occupations at great speed, causing a gradual depreciation of occupation-specific human capital.

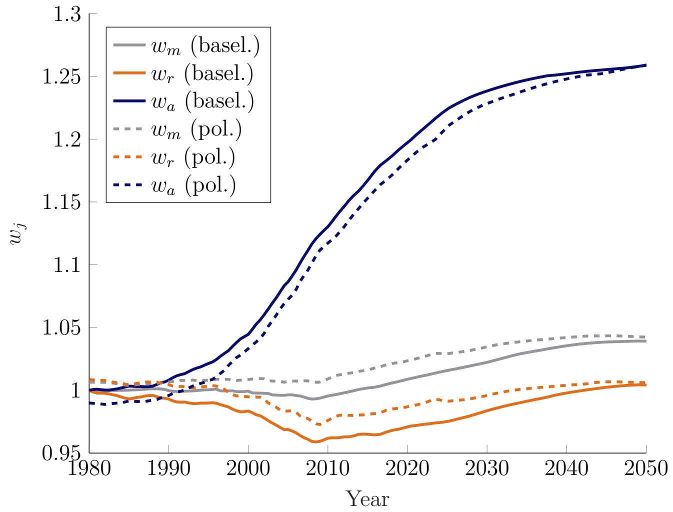

Figure 7: Wages per efficiency unit of labor

Notes: Solid lines: Baseline transition. Dashed lines: Transition with optimal wage replacement program.

who have an interest in becoming abstract workers and leaving the routine occupation for good. In short, the wage replacement program is more successful in incentivizing the right workers to leave the routine occupation than the loan program.[39]

6.2.2 General equilibrium effects under optimal policies

The fact that more routine workers find it optimal to switch to the abstract occupation when the policies are in place puts upward (downward) pressure on the routine (abstract) wage. This is illustrated in Figure 7, which plots wages in the three broad occupations both along the baseline transition (solid lines) and along the transition that implements the optimal wage replacement program (dashed lines). The figure also reveals that, as some low-skilled workers switch from the manual to the routine occupation because of the now higher wages there, manual wages rise as well due to lower supply of manual labor. In sum, wages rise for a majority of the population (routine and manual workers) and fall for the minority of abstract workers.

Figure 8 shows the effect of the optimal policies on output, ICT capital and labor productivity. The left panel plots relative deviations of output Y_t under the policies from its values in the baseline transition. During the first years, especially under the wage replacement program, effects on output are slightly negative. This owes to higher labor taxes and additional switching of experienced workers which destroys human capital in the short term. After 2000, both policies have positive effects on output which persist far into the future. Averaged over the years 1980 to 2050, both policies cause output to rise

[39]To illustrate this, I compute the share of program participants who have returned to working in the routine occupation among all currently entitled households at time t. Averaged across the years 1980 to 2025 this share is 33% under the optimal loan program and only 11% under the wage replacement (see Figure 21 in the appendix). This indicates a significant resource cost of the loan program, caused by workers who switch to the abstract occupation despite having no intent of working there in the long run.

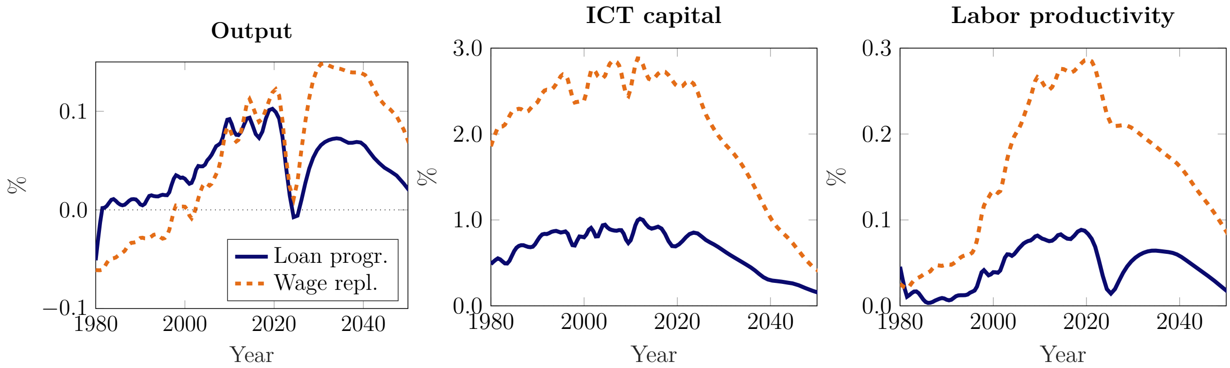

Figure 8: Deviations of variables under optimal policies relative to baseline transition
Notes: Left: Output Y_t. Middle: ICT capital $K_{ict,t}$. Right: Labor prod. $Y_t / \left(\int_i \ell_t^* \, d\Gamma_t(i) \right)$.

by about 0.05% compared to the baseline, with a peak of about 0.1% during the later years of the transition.[40] This is in line with the results from the extended simple model discussed at the end of Section 2. Alleviating the borrowing constraints leads to a more efficient allocation of labor across occupations and therefore benefits output.

The middle panel shows that the optimal policies lead to a crowding in of ICT capital of up to 1% (3%). As there is less supply of routine work, which is a substitute to ICT capital, and more supply of abstract work, which is a complement, firms optimally react by using more ICT capital in production when the policies are in place. Finally, as the right panel shows, the policies have a positive impact on labor productivity, as measured by output divided by hours worked. This is driven by the increase in ICT capital as well as the improved allocation of workers across occupations, i.e. more abstract and less routine labor. These two factors are intimately linked, given the complementarities inherent to the aggregate production function (2): the reallocation of labor towards the abstract occupation only leads to productivity gains if accompanied by an increase in ICT capital.[41]

6.2.3 Implementing the policies in the steady state

The grey dashed lines in Figure 6 show the welfare implications of introducing the policies in the initial steady state of the model.[42] About half of the welfare gains obtained along the actual transition path are also realized in the steady state. There are two main reasons for this. First, the policies provide insurance to eligible workers and redistribute across

[40] The dip in 2025 is explained by the fact that the programs are phased out in that year (see design of the policies). This causes some last workers to take advantage of the policies, leading to a spike in labor taxes to finance this (see Figure 22 in the appendix).

[41] When fixing the capital stock at its values under the baseline transition and only letting labor inputs $N_{j,t}$ adjust to their new values under the policies, the effect on output is negative (not shown). Only in conjunction with the increase in ICT capital do the policies cause output gains.

[42] Technically, I still simulate a transition to compute the welfare criterion, but one in which q_{ict} stays constant at its 1980 level. I then phase out the policies between 2025 and 2070, which makes the results comparable to the policy analysis along the actual transition path with a falling relative price of ICT capital.

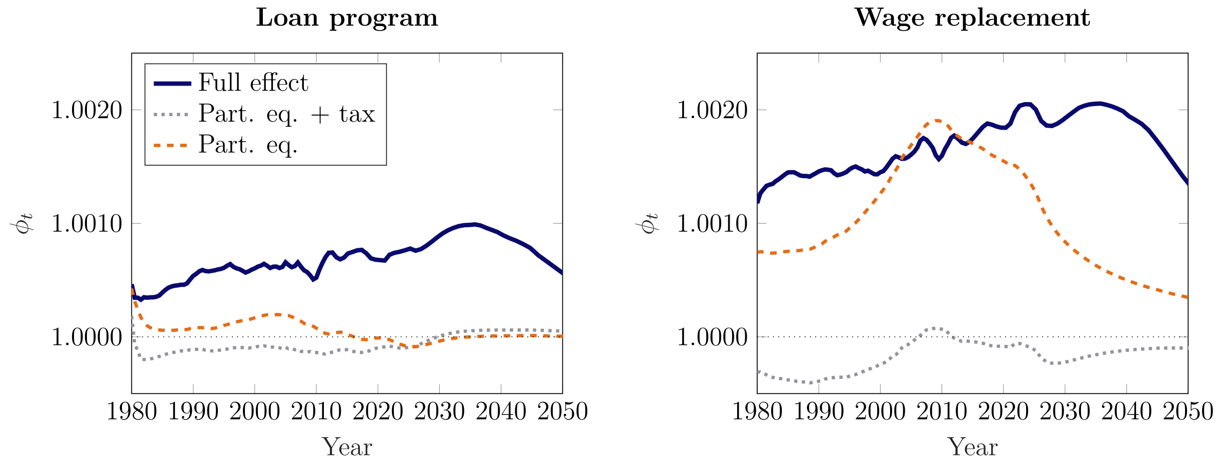

Figure 9: Consumption-equivalent welfare change under optimal policies compared to baseline over time

Notes: Left: optimal loan program. Right: optimal wage replacement. ϕ_t is s.t. $\int_i u(\phi_t \cdot c_t^{basel}, \ell_t^{basel})\, \mathrm{d}\Gamma_t^{basel}(i) = \int_i u(c_t^{pol}, \ell_t^{pol})\, \mathrm{d}\Gamma_t^{pol}(i)$ holds. "Part. eq." holds fixed taxes $\tau_{l,t}$ and factor prices at their values from the baseline transition without policy. "Part. eq. + tax" holds fixed factor prices only. "Full effect" is the full general equilibrium effect.

households just like they do when implemented along the transition. Second, there can be some efficiency gains even in steady state: while wages are constant in steady state, returns to tenure $(\bar{h}_j - \underline{h})$ are higher and hence earnings paths steeper in the abstract than in the routine occupation. Therefore, even in steady state the borrowing constraint prevents some workers from optimally borrowing against high future income and choosing the abstract instead of the routine occupation.

In sum, however, the welfare gains are only half of those obtained when implementing the policies along the transition path. In addition, unlike along the transition, the policies' effect on output is negative in steady state (graph not shown). This points to an important role of efficiency gains causing the welfare improvements along the transition.

6.2.4 Welfare over time and dissection of channels

How are the welfare gains from implementing the optimal loan (wage replacement) program along the transition distributed over time? To answer this question, Figure 9 plots the change in welfare in terms of consumption-equivalent units from equation (8). The blue solid line shows that both programs lead to welfare improvements along the entire transition path.

To shed further light on the discussed channels that can cause welfare improvements, I further dissect the total general equilibrium effect of the policy. The orange dashed line in Figure 9 plots ϕ_t when keeping the labor tax as well as all factor prices, i.e. wages and the interest rate, constant at their values from the baseline transition without policy. The only change compared to the baseline is that the policies are implemented (without being funded). As can be seen, this partial equilibrium effect raises welfare at most (all) horizons under the loan (wage replacement) program. Households benefit from the loans

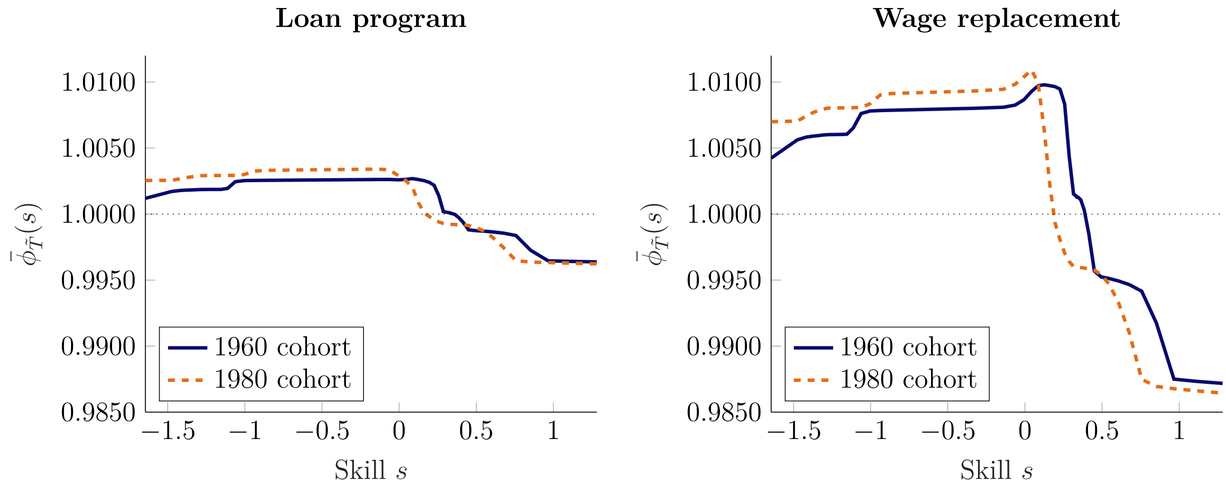

Figure 10: Expected lifetime consumption-equivalent welfare change of newborn households under optimal policies compared to the baseline

Notes: Left: optimal loan program. Right: optimal wage replacement. $\bar{\phi}_{\tilde{T}}(s)$ is such that $\int_i \mathbb{E}_{\tilde{T}}\left[\int_{t=\tilde{T}}^{\infty} \mathrm{e}^{-\hat{\rho}(t-\tilde{T})} u(\bar{\phi}_{\tilde{T}}(s) \cdot c_t^{\text{basel}}, \ell_t^{\text{basel}}) \mathrm{d}t\right] \mathrm{d}\bar{\Gamma}_{\tilde{T}}^{\text{basel}}(i) = \int_i \mathbb{E}_{\tilde{T}}\left[\int_{t=\tilde{T}}^{\infty} \mathrm{e}^{-\hat{\rho}(t-\tilde{T})} u(c_t^{\text{pol}}, \ell_t^{\text{pol}}) \mathrm{d}t\right] \mathrm{d}\bar{\Gamma}_{\tilde{T}}^{\text{pol}}(i)$ holds for $\tilde{T} = [1960, 1980] + 20$.

(wage replacement payments) and increase consumption and leisure. Only at later stages of the loan program, when no new households become eligible and earlier recipients have to pay back the loan they received, the welfare effect turns slightly negative.

On top of this partial equilibrium effect, the grey dotted line further lets the labor income tax $\tau_{l,t}$ adjust to the level needed to finance the payments. This takes away from the welfare gains obtained initially, and the overall effect becomes slightly negative at most horizons. This clearly demonstrates that the higher insurance as well as the redistribution channel are not the key drivers of the aggregate welfare gains obtained from implementing the optimal policies. The blue solid line plots the full general equilibrium effect, i.e. after wages and the interest rate have adjusted to clear the factor markets. This effect is positive and quantitatively the most important one at almost all horizons of both programs.

6.2.5 Welfare across cohorts and skill types

The total effect of the policies on welfare masks substantial heterogeneity both across birth cohorts and especially across skill types. To demonstrate this, Figure 10 depicts welfare changes of newborn workers by year of birth and skill type, for the optimal loan program (left panel) and the optimal wage replacement (right panel). The graphs plot the expected consumption-equivalent welfare gain according to equation (9) of a worker of skill type s who joins the labor market in $\tilde{T} = 1980$ and 2000, and was therefore born around 1960 and 1980, respectively.

While the heterogeneity across birth cohorts is of minor importance, the heterogeneity across skill types is quite significant. On the one hand, low- and medium-skilled workers gain from the policies. This is both because they directly benefit from the programs by collecting the loans (wage replacements) in case they switch to the abstract occupation, and because of the advantageous general equilibrium effects on routine and manual wages discussed above. Quantitatively, welfare gains for medium-skilled types born in 1980 are equivalent to a 0.3% (1.0%) increase in expected lifetime consumption under the optimal loan (wage replacement) program. High-skilled workers, on the other hand, lose in terms of welfare. They usually work in the abstract occupation their entire life and hence never directly benefit from the policies. However, they have to pay higher labor taxes (as everyone else in the economy) and they are harmed by the lower abstract wage.

7 Conclusion

The US labor market has undergone profound structural change in recent decades. Caused by a falling price of ICT capital, jobs intensive in routine tasks have become automated and wages for routine labor have fallen. As a result, a large fraction of the US workforce has reallocated into occupations that perform work complementary to ICT capital.

I demonstrated that borrowing constraints are important to understand the output and welfare consequences of this labor market adjustment. In a simplified model, occupational choices are distorted towards staying in today's attractive occupations when households are constrained in borrowing against future income. Empirically, I documented three facts. First, while routine workers who switched to the manual or abstract occupations saw faster wage growth on average than those who stayed in the routine occupations, a large share of them faced initial wage losses. Second, at least a third of routine workers is hand-to-mouth, i.e. possesses very few liquid assets to smooth consumption. Third, being hand-to-mouth has been predictive of staying in routine occupations.

Building on these findings, I developed a general equilibrium model with incomplete markets and occupation-specific human capital. Along a transition during which relative wages in the routine occupation decline, households close to the borrowing constraint are more reluctant to leave the routine occupation and start over new in the manual or abstract occupation than households with many liquid assets. This causes employment shares to be subdued in the baseline economy compared to a counterfactual scenario in which all households behave like the liquidity-rich.

I used the model to study two policies: a loan and a transfer program. Both programs alleviate the borrowing constraint of experienced routine workers who leave their former occupation. These workers lose occupation-specific human capital and hence often incur wage losses upon switching while enjoying wage gains only in the long run. When targeted towards workers who switch to the abstract occupation, both policies have positive effects on social welfare. This owes in large part to general equilibrium effects, as wages of low-income households rise, and additional ICT capital and an improved allocation of labor raise output. My results indicate that handing out a recurrent transfer is preferable to a loan, since the former better targets those routine workers who have a long-run interest in staying in the abstract occupation.

I made a number of simplifications to keep the analysis tractable. All agents in the model have perfect foresight over future technological growth and therefore wage paths in all occupations. Assuming some degree of uncertainty over future wages or even myopia when it comes to occupational choices might be more realistic. Also, it could be interesting to study the incentives of firms more closely. Some firms might retrain routine workers for new tasks instead of firing them once they are replaced by machines (Dauth et al., 2021). This seems to be especially relevant for understanding the transition process in European countries, though not as much in the US where firing costs are low (Mukoyama et al., 2021). I captured moves along the occupational ladder in a reduced-form, exogenous way by adding a shock (η) to the productivity process of workers. In general, I abstracted from explicitly modeling labor market frictions to focus on the role of borrowing constraints in the labor market transition. All this is left for future work.

In the future, more jobs will likely become automated that so far have been performed by machines (Edin et al., 2021). Moreover, Albanesi and Kim (2021) and Chernoff and Warman (2020) argue that the Covid-19 pandemic might accelerate the trend in automation. Machines are not susceptible to falling ill due to a virus, and safeguarding the workplace against the spread of diseases further adds to the cost of employing labor relative to machines. This could spur investment in labor-saving technology. Also, while in the past a separation of occupations into routine and non-routine has been important to understand wage and employment growth, the pandemic could make on-the-job contact to other human beings as well as flexibility to work remotely relevant task dimensions. Increasing demand for workers in low-contact, flexible jobs could increase wages in these kinds of activities. Kaplan, Moll, et al. (2020) document that workers in social-intensive, low-flexibility occupations tend to hold few liquid assets. This suggests that the same mechanism I highlighted in this paper will slow down the reallocation of labor into less contact-intensive and more flexible occupations.

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A Proofs for Simple Model

Note that the model of Section 2 can be more generally described as a model where the household arrives in T either with some prior occupation $j_{T-1} \in \{r, a\}$ or as a newborn with no prior occupation, $j_{T-1} = \emptyset$. The prior occupation is then the only relevant state variable of the household. If she works in the same occupation for two consecutive periods, she is an experienced household ($\bar{h}$). If she switches the occupation or if she has no prior occupation (e.g. because she newly arrived to the labor market) she is inexperienced ($\underline{h}$). Therefore, $h_t = \bar{h} \cdot \mathbf{1}_{\{j_t = j_{t-1}\}} + \underline{h} \cdot \mathbf{1}_{\{j_t \neq j_{t-1}\}}$.

Experienced routine worker Let me first state the proposition regarding the occupational choice of a worker who was priorly employed in the routine occupation, i.e. with $j_{T-1} = r$. The potential occupational choices are:

1. $\{j_T = r, j_{T+1} = r\} \rightarrow \{y_T = \bar{h}, y_{T+1} = \bar{h}\}$
2. $\{j_T = r, j_{T+1} = a\} \rightarrow \{y_T = \bar{h}, y_{T+1} = \omega \cdot \underline{h}\}$
3. $\{j_T = a, j_{T+1} = a\} \rightarrow \{y_T = \underline{h}/\omega, y_{T+1} = \omega \cdot \bar{h}\}$
4. $\{j_T = a, j_{T+1} = r\} \rightarrow \{y_T = \underline{h}/\omega, y_{T+1} = \underline{h}\}$

Proposition 2. *If not borrowing-constrained, the household switches to the abstract occupation in $t = T$ iff*

$$R \leq \omega - \frac{\max\left\{\omega, \bar{h}/\underline{h}\right\} - 1}{\bar{h}/\underline{h} - 1/\omega}$$

In this case, she is a net borrower in $t = T$.
If borrowing-constrained, the household never switches to the abstract occupation in $t = T$.

The result resembles the one for the inexperienced worker in Section 2. This was to be expected: the only difference in the case of the experienced routine worker is that choosing the abstract occupation in period T is even more costly because of the already accumulated occupation-specific human capital. This also explains why a growing human capital spread $\bar{h}/\underline{h}$ does not unambiguously make the condition in Proposition 2 more likely to hold (like it did in Proposition 1), as it further raises the cost of leaving the routine occupation. As was the case for inexperienced workers, experienced workers who are borrowing-constrained never choose the abstract occupation in T.

A.1 Proofs of Propositions 1 and 2

Unconstrained households I first prove the result regarding the unconstrained household of Proposition 1 in the main text.

For the household to choose the abstract occupation in period T, it must hold that option 3 yields higher lifetime income than the maximum of options 1 and 2, i.e.

$$\underline{h} + \frac{1}{R}\max\{\bar{h}, \omega\underline{h}\} \leq \underline{h}/\omega + \frac{\omega}{R}\bar{h}$$

Case 1: $\bar{h}/\underline{h} \geq \omega$

$$\begin{aligned}
\underline{h} + \frac{1}{R}\bar{h} &\leq \underline{h}/\omega + \frac{\omega}{R}\bar{h} \\
R\left(1 - \frac{1}{\omega}\right) &\leq (\omega - 1)\bar{h}/\underline{h} \\
R &\leq \frac{\omega - 1}{1 - \frac{1}{\omega}}\bar{h}/\underline{h} = \omega\bar{h}/\underline{h} = \omega(\bar{h}/\underline{h} - 1)\frac{\bar{h}/\underline{h}}{\bar{h}/\underline{h} - 1}
\end{aligned}$$

Case 2: $\bar{h}/\underline{h} < \omega$

$$\begin{aligned}
\underline{h} + \frac{\omega}{R}\underline{h} &\leq \underline{h}/\omega + \frac{\omega}{R}\bar{h} \\
R\left(1 - \frac{1}{\omega}\right) &\leq \omega(\bar{h}/\underline{h} - 1) \\
R &\leq \omega\frac{\bar{h}/\underline{h} - 1}{1 - \frac{1}{\omega}} = \omega(\bar{h}/\underline{h} - 1)\frac{\omega}{\omega - 1}
\end{aligned}$$

Rearranging yields the desired result, which I reprint here for convenience:

$$R \leq \omega(\bar{h}/\underline{h} - 1)\min\left\{\frac{\bar{h}/\underline{h}}{\bar{h}/\underline{h} - 1}, \frac{\omega}{\omega - 1}\right\}.$$

The proof of Proposition 2 regarding the unconstrained households follows analogously.

It is also straightforward to verify that whenever the unconstrained household chooses option 3, she borrows against future income. Too see this, note that consumption in period T is $c_T = \frac{1}{1+\beta}\left(\underline{h}/\omega + \frac{\omega}{R}\bar{h}\right)$, and hence savings in period T are $s = \frac{1}{1+\beta}\left(\beta\underline{h}/\omega - \frac{\omega}{R}\bar{h}\right)$. Assume for a contradiction that savings in T are positive

Case 1: $\bar{h}/\underline{h} \geq \omega$

$$\begin{aligned}
& \beta\underline{h}/\omega > \frac{\omega}{R}\bar{h} \\
\Rightarrow \quad & \underline{h}/\omega > \frac{\omega}{R}\bar{h} \\
\Rightarrow \quad & R > \omega^2\bar{h}/\underline{h} > \omega\bar{h}/\underline{h} \quad ↯
\end{aligned}$$

Case 2: $\bar{h}/\underline{h} < \omega$

$$\begin{aligned} & \beta \underline{h}/\omega > \frac{\omega}{R}\bar{h} \\ \Rightarrow\quad & \underline{h}/\omega > \frac{\omega}{R}\bar{h} \\ \Rightarrow\quad & R > \omega^2 \bar{h}/\underline{h} > \omega^2 \frac{\bar{h}/\underline{h} - 1}{\omega - 1} = \omega \frac{\bar{h}/\underline{h} - 1}{1 - \frac{1}{\omega}} \quad ↯ \end{aligned}$$

Both contradictions arise from the conditions derived in the first part of the proof.

Constrained households Next I prove that if the household is prevented from borrowing, she never chooses option 3.

Suppose first that in the optimal solution the borrowing constraint is not binding. In this case, the problem of the constrained household is identical to that of the unconstrained household, whose solution I have just derived. We know, however, that if parameters are such that option 3 (choosing abstract in $t = T$) is optimal she is a net borrower, a contradiction to the assumption that the constraint is not binding.

Now suppose the borrowing constraint is binding and the constrained household consumes her current income in both periods. For her to find it optimal to choose option 3 it must hold that

$$\ln(\underline{h}) + \beta \max\left\{\ln\left(\bar{h}\right), \ln(\omega \underline{h})\right\} \leq \ln(\underline{h}/\omega) + \beta \ln\left(\omega \bar{h}\right)$$

Case 1: $\bar{h}/\underline{h} \geq \omega$

$$\begin{aligned} \ln(\underline{h}) + \beta \ln\left(\bar{h}\right) &\leq \ln(\underline{h}) - \ln(\omega) + \beta \ln(\omega) + \beta \ln\left(\bar{h}\right) \\ 0 &\leq \beta - 1 \quad ↯ \end{aligned}$$

The contradiction follows from the fact that I have assumed (strict) discounting, i.e. $\beta < 1$.
Case 2: $\bar{h}/\underline{h} < \omega$

$$\begin{aligned} \ln(\underline{h}) + \beta \ln(\omega) + \beta \ln(\underline{h}) &\leq \ln(\underline{h}) - \ln(\omega) + \beta \ln(\omega) + \beta \ln\left(\bar{h}\right) \\ \ln(\omega) &\leq \beta \ln\left(\bar{h}/\underline{h}\right) \\ \omega &\leq (\bar{h}/\underline{h})^\beta \quad ↯ \end{aligned}$$

The proof of Proposition 2 regarding the constrained households follows analogously.

A.2 Time-varying aggregate productivity

Consider now the introduction of an additional variable $Z > 1$ that augments all wages in period $T + 1$, i.e.

$$w_{r,T} = 1, \qquad w_{r,T+1} = Z$$
$$w_{a,T} = \frac{1}{\omega}, \qquad w_{a,T+1} = Z\omega$$

The following proposition holds regarding the occupational choice of an inexperienced household, and can be proved analogously to Proposition 1 above.

Proposition 3. *If not borrowing-constrained, the household chooses the abstract occupation in $t = T$ iff*

$$\frac{R}{Z} \leq \omega(\bar{h}/\underline{h} - 1) \min\left\{\frac{\bar{h}/\underline{h}}{\bar{h}/\underline{h} - 1}, \frac{\omega}{\omega - 1}\right\}.$$

In this case, she is a net borrower in $t = T$.
If borrowing-constrained, the household never chooses the abstract occupation in $t = T$.

This result is identical to Proposition 1, except for the fact that the gross interest rate R is dampened by the factor Z. Put differently, a higher Z makes choosing the abstract occupation today more likely. Intuitively, if wages today are relatively low compared to tomorrow, the opportunity cost of choosing the abstract occupation today is also relatively low. This is in line with empirical evidence on the business cycle patters of the aggregate decline in routine labor (Hershbein and Kahn, 2018; Jaimovich and Siu, 2020).[43]

B Simple Model with Endogenous Wages and Skill Distribution

In the following I extend the simple model of Section 2 in two ways. First, I endogenize wages. Second, I allow for a continuum of households with heterogeneous skill type. The extended environment allows me to characterize the efficient allocation of labor across occupations when there is relative wage growth in the abstract relative to the routine occupation. I then study the allocation in the decentralized equilibrium, once when households can freely borrow against future income and once when everyone is hand-to-mouth. In the former case, the allocation of labor coincides with that chosen by the planner. In the latter, relative to the first-best, too few households work in the abstract and too many in the routine occupation.

[43] The cyclical patterns of the hand-to-mouth share have so far, to the best of my knowledge, not been studied in detail. Note, however, that the share of hand-to-mouth households in the US economy depicted in Figure 14 or in Kaplan, Violante, et al. (2014) does not display any notable pro- or countercyclical pattern.

B.1 Environment

Time t is discrete and runs until period $T+1$.[44] There exists a representative firm that uses two inputs, routine labor N_r and abstract labor N_a. It produces output according to the production function $F(N_r, N_a; q)$ where q is the exogenous level of technology.

There exists a continuum of measure one of households. Households derive utility from consumption $u(c)$ and provide one unit of labor inelastically in one of the two occupations. A household is characterized by her fixed skill type s and her previous period's occupation j_{t-1}. Households face a constant probability of dying $\pi \in (0,1)$. A dead household is replaced by a newborn who has no previous occupation, $j_{t-1} = \emptyset$. All households die with certainty after period $T+1$. Conditional on survival, households discount future utility by a factor $\beta \in (0, \frac{1}{1-\pi})$. Denote the effective discount rate of households $\hat{\beta} \equiv \beta \cdot (1-\pi)$, and hence $\hat{\beta} \in (0,1)$.

Skill is distributed in the population according to some probability distribution function $s \sim g(s)$. Households accumulate occupation-specific human capital $h \in \{\underline{h}, \bar{h}\}$, with $0 < \underline{h} < \bar{h}$. If a household stays in the same occupation in two consecutive periods, i.e. $j_t = j_{t-1}$ she is an experienced worker in period t ($h_t = \bar{h}$). If she switches occupations or if she is a newborn with no prior occupation, she is inexperienced ($h_t = \underline{h}$), as $j_t \neq j_{t-1}$. The functions $\phi_j(s)$ with $j \in \{r, a\}$ map skill into productivity in the respective occupation. Hence if a household works in occupation j at time t, her labor supply is $\phi_j(s) \cdot h_t$. I make the following assumptions:

Assumptions 1.

- $F(\cdot)$ *is continuously differentiable, with* $F_{N_j} > 0$ *for* $j = r, a$
- *Conditional on factor inputs* N_j*,* q *raises the marginal product of abstract labor relative to that of routine labor,* $\frac{\partial \frac{F_{N_a}}{F_{N_r}}}{\partial q} > 0$
- $u(\cdot)$ *is twice continuously differentiable, with* $u_c > 0$*,* $u_{cc} < 0$
- $g(s)$ *has positive mass on the whole real line:* $\forall s \in \mathbb{R}, g(s) > 0$
- $\phi(s) \equiv \frac{\phi_a(s)}{\phi_r(s)}$ *is continuously differentiable, with* $\phi'(s) > 0$

The last assumption implies that high-skilled types have a comparative advantage in the abstract occupation, low-skilled types in the routine occupation.[45]

[44] The framework could be extended to an infinite time horizon. Ending in $T+1$, however, makes the problem below a more tractable two-period problem (T and $T+1$), which greatly simplifies the exposition and algebra.

[45] This assumption is common in the literature (Cortes, 2016; vom Lehn, 2020) and it is met in the full model of the main text, where I calibrate $\phi_j(s) = \exp(a_j s)$ with $0 = a_m < a_r < a_a$.

B.2 Social planner

I begin by studying the first-best allocation of labor that arises as the solution to a social planner's problem. I have abstracted from physical capital as it is not crucial for the analysis. Instead, I assume that the economy can transfer resources on aggregate to the next period by lending and borrowing from the rest of the world at rate $R \leq 1/\beta$. Denote aggregate holdings of the foreign asset at time t by B_t. All debt has to be repaid at the end of period $T+1$.

B.2.1 No technological change

Assume first that there is no technological change: $\forall t, q_t = q$. In period T, the planner needs to allocate consumption and an occupation to each household for the remaining two periods T and $T+1$. Note first that since I have assumed concave utility, the planner assigns the same level of consumption C_t to each household. Second, the assumption on the productivity functions $\phi_j(s)$ and the fact that marginal products of labor are constant imply that there is no occupational mobility and that there exists a cut-off S that separates the skill space into low-skilled (who work in the routine occupation their entire life) and high-skilled (abstract occupation).

$$\begin{aligned}
\max_{S, C_T, C_{T+1}} \; & u(C_T) + \beta \cdot u(C_{T+1}) \\
& \text{subject to:} \\
& C_T + \frac{C_{T+1}}{R} = Y_T + \frac{Y_{T+1}}{R} + B_T \\
& \text{and for } t = T, T+1: \\
& Y_t = Y = F(N_r, N_a; q) \\
& N_r = \int_{-\infty}^{S} \left[\pi \cdot (\phi_r(s) \cdot \underline{h}) + (1-\pi) \cdot (\phi_r(s) \cdot \bar{h}) \right] g(s) \mathrm{d}s \\
& N_a = \int_{S}^{\infty} \left[\pi \cdot (\phi_a(s) \cdot \underline{h}) + (1-\pi) \cdot (\phi_a(s) \cdot \bar{h}) \right] g(s) \mathrm{d}s
\end{aligned}$$

The optimal skill cut-off, which maximizes output, is characterized by:

$$\begin{aligned}
F_{N_r} \cdot \phi_r(S) &= F_{N_a} \cdot \phi_a(S) \\
\Leftrightarrow F_{N_r} &= F_{N_a} \cdot \phi(S) \qquad (10)
\end{aligned}$$

Intuitively, this condition ensures that the worker with skill type $s = S$ is equally productive in both occupations.

B.2.2 Technological change

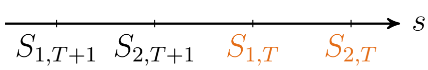
Now assume that technology is constant up until time T. In period T, however, it becomes known that $q_{T+1} > q_T$ and hence the marginal product of abstract labor relative to that of routine labor grows. It is thus optimal to reallocate workers to the abstract occupation, i.e. even those with skill below the optimal skill cut-off absent technological change S. Moreover, it might be optimal to start doing so already in period T such that workers can start building up occupation-specific human capital.

The planner now needs to choose four cut-off levels, one for each combination of human capital and time period. For $t = T, T+1$, she needs to decide up to which skill level $S_{1,t}$ inexperienced workers work in the routine occupation. She also needs to decide up to which level $S_{2,t}$ experienced routine workers keep working in the routine occupation. Note that in any optimal allocation it must hold that $S_{1,t} \leq S_{2,t}$. In words, young workers are at least as likely to enter the abstract occupation as experienced routine workers, since the latter have already accumulated occupation-specific human capital.[46]

$$\begin{aligned}
\max_{\{S_{1,t}, S_{2,t}, C_t\}_{t=T,T+1}} \quad & u(C_T) + \beta \cdot u(C_{T+1}) \\
& \text{subject to:} \\
& C_T + \frac{C_{T+1}}{R} = Y_T + \frac{Y_{T+1}}{R} \\
& Y_t = F(N_{r,t}, N_{a,t}; q_t), \text{ for } t = T, T+1 \\
& N_{r,T} = \pi \int_{-\infty}^{S_{1,T}} (\phi_r(s)\underline{h}) g(s) \mathrm{d}s + (1-\pi) \int_{-\infty}^{S_{2,T}} (\phi_r(s)\bar{h}) g(s) \mathrm{d}s \\
& N_{a,T} = \pi \int_{S_{1,T}}^{\infty} (\phi_a(s)\underline{h}) g(s) \mathrm{d}s + (1-\pi) \left[\int_{S}^{\infty} (\phi_a(s)\bar{h}) g(s) \mathrm{d}s + \int_{S_{2,T}}^{S} (\phi_a(s)\underline{h}) g(s) \mathrm{d}s \right]
\end{aligned}$$

and subject to labor market clearing in $T+1$, for which one needs to differentiate three cases, depending on the ordering of $S_{1,T}$, $S_{2,T}$ and $S_{2,T+1}$:[47]

Case 1:



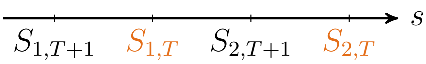
[46] This is easy to prove by contradiction. Assume that $S_{1,t} > S_{2,t}$. But then one can move the cut-offs closer together, achieving the same amount of abstract labor supply but more routine labor supply. This will become evident formally when I derive the optimal cut-offs below.

[47] The position of $S_{1,T+1}$ relative to $S_{1,T}$ and $S_{2,T}$ does not affect the labor market clearing conditions.

$$
N_{r,T+1} = \pi \int_{-\infty}^{S_{1,T+1}} (\phi_r(s)\underline{h})g(s)\mathrm{d}s + (1-\pi) \int_{-\infty}^{S_{2,T+1}} (\phi_r(s)\bar{h})g(s)\mathrm{d}s
$$

$$
\begin{aligned}
N_{a,T+1} = \pi \int_{S_{1,T+1}}^{\infty} (\phi_a(s)\underline{h})g(s)\mathrm{d}s + (1-\pi)\Bigg[\pi \int_{S_{2,T+1}}^{S_{1,T}} (\phi_a(s)\underline{h})g(s)\mathrm{d}s + (1-\pi) \int_{S_{2,T+1}}^{S_{2,T}} (\phi_a(s)\underline{h})g(s)\mathrm{d}s \\
+ (1-\pi) \int_{S_{2,T}}^{\infty} (\phi_a(s)\bar{h})g(s)\mathrm{d}s + \pi \int_{S_{1,T}}^{\infty} (\phi_a(s)\bar{h})g(s)\mathrm{d}s\Bigg]
\end{aligned}
$$

Case 2:



$$
N_{r,T+1} = \pi \int_{-\infty}^{S_{1,T+1}} (\phi_r(s)\underline{h})g(s)\mathrm{d}s + (1-\pi)\left[(1-\pi) \int_{-\infty}^{S_{2,T+1}} (\phi_r(s)\bar{h})g(s)\mathrm{d}s + \pi \int_{-\infty}^{S_{1,T}} (\phi_r(s)\bar{h})g(s)\mathrm{d}s\right]
$$

$$
\begin{aligned}
N_{a,T+1} = \pi \int_{S_{1,T+1}}^{\infty} (\phi_a(s)\underline{h})g(s)\mathrm{d}s + (1-\pi)\Bigg[(1-\pi) \int_{S_{2,T+1}}^{S_{2,T}} (\phi_a(s)\underline{h})g(s)\mathrm{d}s \\
+ (1-\pi) \int_{S_{2,T}}^{\infty} (\phi_a(s)\bar{h})g(s)\mathrm{d}s + \pi \int_{S_{1,T}}^{\infty} (\phi_a(s)\bar{h})g(s)\mathrm{d}s\Bigg]
\end{aligned}
$$

Case 3:

$$
N_{r,T+1} = \pi \int_{-\infty}^{S_{1,T+1}} (\phi_r(s)\underline{h})g(s)\mathrm{d}s + (1-\pi)\left[(1-\pi) \int_{-\infty}^{S_{2,T}} (\phi_r(s)\bar{h})g(s)\mathrm{d}s + \pi \int_{-\infty}^{S_{1,T}} (\phi_r(s)\bar{h})g(s)\mathrm{d}s\right]
$$

$$
N_{a,T+1} = \pi \int_{S_{1,T+1}}^{\infty} (\phi_a(s)\underline{h})g(s)\mathrm{d}s + (1-\pi)\left[(1-\pi) \int_{S_{2,T}}^{\infty} (\phi_a(s)\bar{h})g(s)\mathrm{d}s + \pi \int_{S_{1,T}}^{\infty} (\phi_a(s)\bar{h})g(s)\mathrm{d}s\right]
$$

For Case 1, this yields the following optimality conditions that implicitly characterize the cut-off levels:

$$
\begin{aligned}
[S_{1,T}]: &\ \frac{(1-\pi)\cdot F_{N_{a,T+1}}\cdot\phi(S_{1,T})\cdot(\bar{h}/\underline{h}-1)}{F_{N_{r,T}}-F_{N_{a,T}}\cdot\phi(S_{1,T})}=R\\
[S_{2,T}]: &\ \frac{(1-\pi)\cdot F_{N_{a,T+1}}\cdot\phi(\tilde{S}_{2,T})\cdot(\bar{h}/\underline{h}-1)}{F_{N_{r,T}}\cdot(\bar{h}/\underline{h})-F_{N_{a,T}}\cdot\phi(\tilde{S}_{2,T})}=R,\quad S_{2,T}=\min\{\tilde{S}_{2,T},S\}\\
[S_{1,T+1}]: &\ F_{N_{r,T+1}}=F_{N_{a,T+1}}\cdot\phi(S_{1,T+1})\\
[S_{2,T+1}]: &\ F_{N_{r,T+1}}\cdot(\bar{h}/\underline{h})=F_{N_{a,T+1}}\cdot\phi(\tilde{S}_{2,T+1}),\quad S_{2,T+1}=\min\{\tilde{S}_{2,T+1},S\}
\end{aligned}
$$

Focus on the first condition, i.e. for $S_{1,T}$. Intuitively, choosing the optimal cut-offs in period T is an investment decision. Putting an additional household to work in the abstract occupation reduces output today, a cost which appears in the denominator (remember that the denominator would be zero for $\phi(S)$ and becomes positive for $S_{1,T} < S$, see equation (10)). This cost must be worth the benefit of having an additional abstract worker in period $T+1$, which appears in the numerator.

It is easy to see that the skill cut-off for inexperienced workers in period T is smaller than it was absent technological change, i.e. $S_{1,T} < S$, since $\phi(s)$ is continuous and monotone in s and

$$
\begin{aligned}
\lim_{S_{1,T}\to-\infty}\frac{(1-\pi)\cdot F_{N_{a,T+1}}\cdot\phi(S_{1,T})\cdot(\bar{h}/\underline{h}-1)}{F_{N_{r,T}}-F_{N_{a,T}}\cdot\phi(S_{1,T})}&=0\\
\lim_{S_{1,T}\to S^-}\frac{(1-\pi)\cdot F_{N_{a,T+1}}\cdot\phi(S_{1,T})\cdot(\bar{h}/\underline{h}-1)}{F_{N_{r,T}}-F_{N_{a,T}}\cdot\phi(S_{1,T})}&=+\infty\ .
\end{aligned}
$$

For completeness, in Case 2, $S_{1,T}$ is instead characterized by

$$
[S_{1,T}]:\ \frac{(1-\pi)\cdot(F_{N_{a,T+1}}\cdot\phi(S_{1,T})-F_{N_{r,T+1}})\cdot(\bar{h}/\underline{h})}{F_{N_{r,T}}-F_{N_{a,T}}\cdot\phi(S_{1,T})}=R
$$

while the remaining cut-offs are as in Case 1. In Case 3, $S_{2,T}$ is instead characterized by

$$
[S_{2,T}]:\ \frac{(1-\pi)\cdot(F_{N_{a,T+1}}\cdot\phi(\tilde{S}_{2,T})-F_{N_{r,T+1}})\cdot(\bar{h}/\underline{h})}{F_{N_{r,T}}\cdot(\bar{h}/\underline{h})-F_{N_{a,T}}\cdot\phi(\tilde{S}_{2,T})}=R,\quad S_{2,T}=\min\{\tilde{S}_{2,T},S\}
$$

while the remaining cut-offs are as in Case 2.

B.3 Competitive equilibrium

Next I show that the same cut-off skill levels that I have just derived as the optimal solution to the planner's problem arise from a decentralized equilibrium in which households can freely borrow against future income and in which the representative firm maximizes profits. Suppose first that $\forall t, q_t = q$ such that both wages are constant over time. In this case, it is optimal for households to choose the occupation in which they are most productive and work there their entire life. Hence, absent wage growth the cut-off S from the planner's problem again separates the skill space into routine and abstract workers and the allocation of labor is efficient.

Let me therefore turn to the more interesting case of solving the problem with technological change, $q_{T+1} > q_T$. Let b_t denote the amount of assets a household currently holds. Denoting by $w_{j,t}$ the wage a household earns when working in occupation j, a household of type (s, j_{T-1}, b_T) solves:[48]

$$\max_{\{j_t, c_t\}_{t=T,T+1}} u(c_T) + \hat{\beta} \cdot u(c_{T+1})$$

$$\text{subject to:}$$

$$c_T + \frac{c_{T+1}}{R/(1-\pi)} = y(s, j_{T-1}, j_T) + \frac{y(s, j_T, j_{T+1})}{R/(1-\pi)} + b_T$$

Focus first on an inexperienced household, $j_{T-1} = \emptyset$. Her lifetime income is

$$y_T + \frac{y_{T+1}}{R/(1-\pi)} = \begin{cases} \underline{h} \cdot \phi_r(s) \cdot w_{r,T} + \frac{\bar{h} \cdot \phi_r(s) \cdot w_{r,T+1}}{R/(1-\pi)} & \text{if } j_T = r, j_{T+1} = r \\ \underline{h} \cdot \phi_r(s) \cdot w_{r,T} + \frac{\underline{h} \cdot \phi_a(s) \cdot w_{a,T+1}}{R/(1-\pi)} & \text{if } j_T = r, j_{T+1} = a \\ \underline{h} \cdot \phi_a(s) \cdot w_{a,T} + \frac{\bar{h} \cdot \phi_a(s) \cdot w_{a,T+1}}{R(1-\pi)} & \text{if } j_T = a, j_{T+1} = a \end{cases} \tag{11}$$

I want to determine the skill type $S^*_{1,T}$ that is exactly indifferent between working in the routine and the abstract occupation in period T.

Case A: (corresponds to Case 1 of the planner)

$$\bar{h} \cdot \phi_r(S^*_{1,T}) \cdot w_{r,T+1} \leq \underline{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T+1}$$

In this case, the skill type $S^*_{1,T}$ is determined by the following equation:

$$\underline{h} \cdot \phi_r(S^*_{1,T}) \cdot w_{r,T} + \frac{\underline{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T+1}}{R/(1-\pi)} = \underline{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T} + \frac{\bar{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T+1}}{R/(1-\pi)}$$

$$\Rightarrow \quad \frac{(1-\pi) \cdot w_{a,T+1} \cdot \phi(S^*_{1,T}) \cdot (\bar{h}/\underline{h} - 1)}{w_{r,T} - \phi(S^*_{1,T}) \cdot w_{a,T}} = R$$

Case B: (corresponds to Cases 2 and 3 of the planner)

$$\bar{h} \cdot \phi_r(S^*_{1,T}) \cdot w_{r,T+1} > \underline{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T+1}$$

[48] I assume that households may die with positive or negative asset holdings. The foreign creditor realizes this and augments the gross interest rate households have to pay by a factor $\frac{1}{1-\pi}$. This way, aggregate debt can be honored in the last period since $R \int s_T = (1-\pi) \int (c_{T+1} - w_{T+1})$, where $s_T = w_T - c_T$.

In this case, the skill type $S^*_{1,T}$ is determined by:

$$
\begin{aligned}
& \underline{h} \cdot \phi_r(S^*_{1,T}) \cdot w_{r,T} + \frac{\bar{h} \cdot \phi_r(S^*_{1,T}) \cdot w_{r,T+1}}{R/(1-\pi)} = \underline{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T} + \frac{\bar{h} \cdot \phi_a(S^*_{1,T}) \cdot w_{a,T+1}}{R/(1-\pi)} \\
\Rightarrow \quad & \frac{(1-\pi) \cdot (w_{a,T+1} \cdot \phi(S^*_{1,T}) - w_{r,T+1}) \cdot (\bar{h}/\underline{h})}{w_{r,T} - \phi(S^*_{1,T}) \cdot w_{a,T}} = R
\end{aligned}
$$

Since the optimal behavior of the representative firm ensures that wages equal the marginal product of labor, $w_{j,t} = F_{N_{j,t}}$, the condition that characterizes $S^*_{1,T}$ coincides with that for $S_{1,T}$ derived in the planner's problem, so the two cut-offs are equal. The same property can be shown in an analogous fashion for the cut-off $S_{1,T+1}$ as well as for the cut-offs $S_{2,T}$ and $S_{2,T+1}$ when analyzing the problem of experienced routine workers with $j_{T-1} = r$. Hence, the allocation of labor in the decentralized economy is efficient.

For future reference, let me define wage growth in occupation j as

$$\omega_j \equiv \frac{w_{j,T+1}}{w_{j,T}}$$

and let me explicitly solve for $\phi(S_{1,T})$:

Case A:

$$\phi(S_{1,T}) = \frac{w_{r,T}}{w_{a,T}} \cdot \frac{1}{1 + \frac{1-\pi}{R} \cdot \omega_a \cdot (\bar{h}/\underline{h} - 1)}$$

Case B:

$$\phi(S_{1,T}) = \frac{w_{r,T}}{w_{a,T}} \cdot \frac{1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r}{1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_a}$$

B.4 Competitive equilibrium with hand-to-mouth households

I now analyze the equilibrium allocation when all households in the economy are hand-to-mouth, i.e. they consume their current income in both periods. Consuming current income would endogenously arise as the optimal choice of all households if wages grew over time in both occupations and households held zero assets and were exogenously prevented from borrowing against future income.[49]

Suppose first that $\forall t, q_t = q$ such that both wages are constant over time. In this case, it is optimal for hand-to-mouth households to choose the occupation in which they are most productive and work there their entire life. Hence, absent wage growth the cut-off S from the planner's problem again separates the skill space into routine and abstract workers and the allocation of labor is efficient, as in the case without borrowing constraints. I therefore turn to analyzing the problem with technological change, i.e.

[49] Under these assumptions, the proof of this is analogous to the one provided in Appendix A.1 for the simpler model.

$q_{T+1} > q_T$. The problem of a household with type (s, j_{T-1}) is:

$$\max_{j_T, j_{T+1}} u(y_T) + \hat{\beta} \cdot u(y_{T+1})$$

Note that occupational choices lead to the same implications for income y_t as shown in (11). To make progress, I make the following assumptions in what follows:

Assumptions 2.

- $u(c) = \ln(c)$
- $\omega_a \geq 1$
- $\omega_a > \omega_r$

The last two assumptions are fairly weak. $\omega_a \geq 1$ implies that abstract wages grow (weakly). This provides an incentive to borrow against future income which households in this subsection cannot do, leading to an inefficiency.[50] $\omega_a > \omega_r$ indicates that wage growth is stronger in the abstract than in the routine occupation. Note that this requirement is a bit stronger than the second bullet point of Assumptions 1, which only implied that *conditional on fixed factor inputs* the marginal product of abstract labor grows in comparison to that of routine labor. Essentially, $\omega_a > \omega_r$ requires that the reduction of labor supply in the routine occupation (increase of labor supply in the abstract occupation) does not overturn the growth in relative abstract wages that results from technological change.

As before, focus on the decision of an inexperienced household, i.e. with $j_{T-1} = \emptyset$.
<u>Case A:</u>

$$\bar{h} \cdot \phi_r(S^+_{1,T}) \cdot w_{r,T+1} \leq \underline{h} \cdot \phi_a(S^+_{1,T}) \cdot w_{a,T+1}$$

In this case, the skill type $S^+_{1,T}$ that is indifferent between working in the routine and the abstract occupation in period T is determined by:

$$\begin{aligned}
\ln\Big(\phi_r(S^+_{1,T}) \cdot w_{r,T} \cdot \underline{h}\Big) + \hat{\beta} \cdot \ln\Big(\phi_a(S^+_{1,T}) \cdot w_{a,T+1} \cdot \underline{h}\Big) \\
= \ln\Big(\phi_a(S^+_{1,T}) \cdot w_{a,T} \cdot \underline{h}\Big) \\
+ \hat{\beta} \cdot \ln\Big(\phi_a(S^+_{1,T}) \cdot w_{a,T+1} \cdot \bar{h}\Big) \\
(\phi_r(S^+_{1,T}) \cdot w_{r,T} \cdot \underline{h}) \cdot (\phi_a(S^+_{1,T}) \cdot w_{a,T+1} \cdot \underline{h})^{\hat{\beta}} = (\phi_a(S^+_{1,T}) \cdot w_{a,T} \cdot \underline{h}) \cdot (\phi_a(S^+_{1,T}) \cdot w_{a,T+1} \cdot \bar{h})^{\hat{\beta}} \\
\phi(S^+_{1,T}) = \frac{w_{r,T}}{w_{a,T}} \cdot (\bar{h}/\underline{h})^{-\hat{\beta}}
\end{aligned}$$

<u>Case B:</u>

$$\bar{h} \cdot \phi_r(S^+_{1,T}) \cdot w_{r,T+1} > \underline{h} \cdot \phi_a(S^+_{1,T}) \cdot w_{a,T+1}$$

[50] In fact, all results that follow hold also under the weaker condition $\omega_a \geq \beta \cdot R$.

In this case, $S^+_{1,T}$ is determined by:

$$(\phi_r(S^+_{1,T}) \cdot w_{r,T} \cdot \underline{h}) \cdot (\phi_r(S^+_{1,T}) \cdot w_{r,T+1} \cdot \bar{h})^{\hat{\beta}} = (\phi_a(S^+_{1,T}) \cdot w_{a,T} \cdot \underline{h}) \cdot (\phi_a(S^+_{1,T}) \cdot w_{a,T+1} \cdot \bar{h})^{\hat{\beta}}$$

$$\phi(S^+_{1,T}) = \frac{w_{r,T}}{w_{a,T}} \cdot \left(\frac{\omega_r}{\omega_a}\right)^{\frac{\hat{\beta}}{1+\hat{\beta}}}$$

To show that fewer workers choose to work in the abstract occupation in T when borrowing constraints bind than when borrowing is unrestricted I next prove that $\phi(S^+_{1,T}) > \phi(S^*_{1,T})$, which by monotonicity of $\phi(s)$ implies $S^+_{1,T} > S^*_{1,T}$.

<u>Case A:</u>

$$\phi(S^*_{1,T}) < \phi(S^+_{1,T})$$

$$\frac{1}{1 + \frac{1-\pi}{R} \cdot \omega_a \cdot (\bar{h}/\underline{h} - 1)} < (\bar{h}/\underline{h})^{-\hat{\beta}}$$

$$0 < \underbrace{1 + \frac{1-\pi}{R} \cdot \omega_a \cdot (\bar{h}/\underline{h} - 1) - (\bar{h}/\underline{h})^{\hat{\beta}}}_{\Lambda(\bar{h}/\underline{h})}$$

For this inequality to be fulfilled it needs to hold that $\forall(\bar{h}/\underline{h}) > 1, \Lambda(\bar{h}/\underline{h}) > 0$. Note that $\Lambda(1) = 0$. Hence it suffices to show that $\forall(\bar{h}/\underline{h}) \geq 1, \Lambda'(\bar{h}/\underline{h}) > 0$.

$$\Lambda'(\bar{h}/\underline{h}) = \frac{1-\pi}{R} \cdot \omega_a - \hat{\beta}(\bar{h}/\underline{h})^{\hat{\beta}-1} > 0$$

$$\underbrace{\omega_a}_{\geq 1} > \underbrace{\beta \cdot R}_{\leq 1} \cdot \underbrace{(\bar{h}/\underline{h})^{\hat{\beta}-1}}_{<1}$$

<u>Case B:</u>

$$\phi(S^*_{1,T}) < \phi(S^+_{1,T})$$

$$\frac{1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r}{1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_a} < \left(\frac{\omega_r}{\omega_a}\right)^{\frac{\hat{\beta}}{1+\hat{\beta}}}$$

Define $x \equiv \frac{\omega_a}{\omega_r}$ and take the log on both sides.

$$0 < \underbrace{\ln\left(1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r \cdot x\right) - \ln\left(1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r\right) - \frac{\hat{\beta}}{1+\hat{\beta}} \ln(x)}_{H(x)}$$

For this inequality to be fulfilled it needs to hold that $\forall x > 1, H(x) > 0$. Note that

$H(1) = 0$. Hence it suffices to show that $\forall x \geq 1, H'(x) > 0$.

$$
\begin{aligned}
H'(x) = \frac{\frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r}{1 + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r \cdot x} - \frac{\hat{\beta}}{1+\hat{\beta}} \frac{1}{x} &> 0 \\
\frac{\frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r}{\frac{1}{x} + \frac{1-\pi}{R} \cdot (\bar{h}/\underline{h}) \cdot \omega_r} &> \frac{\hat{\beta}}{1+\hat{\beta}} \\
\frac{1+\hat{\beta}}{\hat{\beta}} &> 1 + \frac{1}{x \cdot (\bar{h}/\underline{h}) \cdot \frac{1-\pi}{R} \cdot \omega_r} \\
1 &> \frac{\hat{\beta}}{x \cdot (\bar{h}/\underline{h}) \cdot \frac{1-\pi}{R} \cdot \omega_r} \\
\underbrace{\omega_a \cdot (\bar{h}/\underline{h})}_{>1} &> \underbrace{\beta \cdot R}_{\leq 1}
\end{aligned}
$$

This completes the proof that $S^{+}_{1,T} > S^{*}_{1,T} = S_{1,T}$ and a similar result can be shown to hold for the cut-off $S_{2,T}$ when analyzing the problem of an experienced routine worker. Hence, fewer skill types work in the abstract occupation in T when households are hand-to-mouth than is optimal. This in turn leads to a shortage of experienced abstract workers in period $T + 1$.

C Data Sources and Measurement

C.1 Broad occupational groups

Based on earlier work by Dorn (2009), Autor and Dorn (2013) map Census Occupation Codes from 1950 to 2005 into a time-consistent set of occupations. They then form six broad occupational groups, based on the task content in each occupation which they in turn derive from the US Department of Labor's Document of Occupational Titles. Throughout this paper, I use the following categorization of these six groups into manual, routine and abstract occupations, which coincides with the concepts used in Jaimovich and Siu (2020) and in the appendix of vom Lehn (2020):

- Abstract:
  - management/professional/technical/financial sales/public security occupations
- Routine:
  - administrative support and retail sales occupations
  - precision production and craft occupations
  - machine operators, assemblers and inspectors

    – transportation/construction/mechanics/mining/agricultural occupations

- Manual:

    – low-skill services

C.2 PSID

C.2.1 Sample selection

I use waves 1976 to 2017 of the PSID and I follow Cortes (2016) in terms of sample selection and when defining variables. In particular, Cortes (2016) uses only the core PSID sample, drops all individuals who have never been a household head or a wife and only keeps observations aged 16–64. Note that while Cortes (2016) uses data only up until 2007, I include data until 2017, i.e. five more waves of the PSID. Whenever using real wages (or changes thereof) in the analysis, I follow Cortes (2016) in excluding observations with log hourly real wages below 1.10$ or above 54.60$ in terms of 1979 dollars (3.87$ and 192.30$ in terms of 2019 dollars). This is relevant for the results in Section 3.2.1 and when estimating returns to tenure in the calibration. Like Cortes (2016), I use the Consumer Price Index for All Urban Consumers: All Items in U.S. City Average (CPIAUCSL, downloaded from the Federal Reserve Economic Database) to deflate nominal quantities. The empirical analysis in Section 3.2 further only uses male observations to make the results comparable to Cortes (2016)'s.

As mentioned in the main text, in order to be consistent throughout this paper I marginally deviate from Cortes (2016) when assigning the broad occupation to individuals. While Cortes (2016) groups occupations according to the classification given in Acemoglu and Autor (2011), I form groups from the six broad groups listed in Autor and Dorn (2013) as described above. The two concepts yield very similar results, and Cortes (2016) shows in his appendix that using a classification that is closer to the one used by Autor and Dorn (2013) leads to very similar results as his baseline.

C.2.2 Wage changes of switchers vs stayers

To obtain estimates of how wages of switchers from routine to abstract and manual occupations evolved relative to routine stayers at horizon h, Cortes (2016) performs the following regression

$$\Delta_h \ln(wage_{it}) = \beta_m^h \cdot D_{imt} + \beta_a^h \cdot D_{iat} + \gamma_t^h + u_{iht}$$

where $\Delta_h \ln(wage_{it})$ is the change in the log real hourly wage of individual i between years t and $t+h$, D_{ijt} is a dummy variable equal to zero if the individual was working in the routine occupation in both t and $t+1$ (or t and $t+2$ for $h \geq 2$) and one if she switched from the routine occupation to occupation j, γ_t captures time fixed effects, and

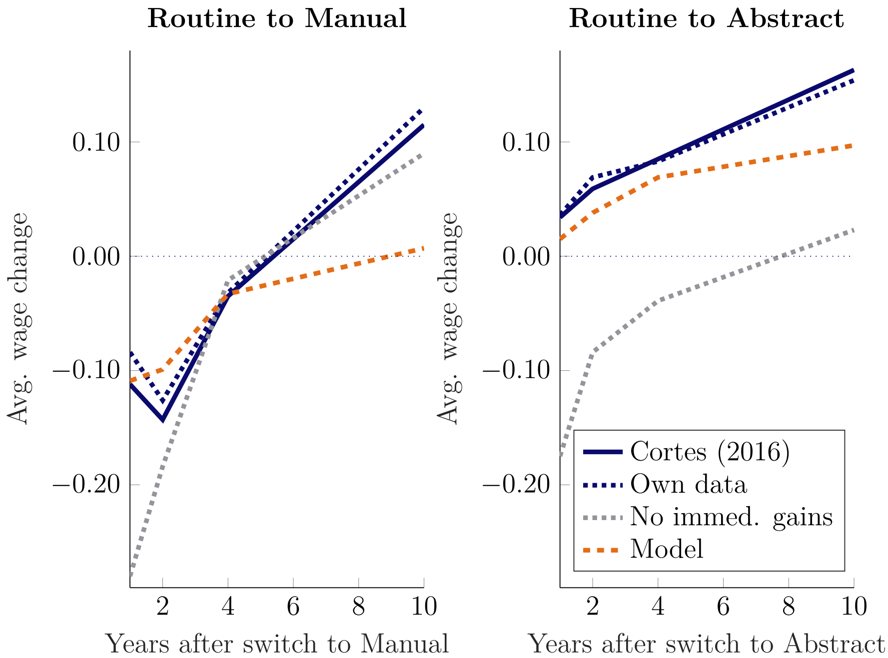


Figure 11: Average log hourly real wages of switchers from routine to manual (left) and to abstract (right) compared to routine stayers.

Notes: Blue solid lines are the estimates from Cortes (2016, Table 3). "Own data" replicates his analysis. "No immed. gains" excludes all individuals from the sample who saw positive wage changes from leaving the routine occupation on impact. For obtaining the model values I perform the same regression as Cortes (2016), only using data from a synthetic panel of 10,000 households, simulated between 1980 and 2020 from the full model of Section 4.

u_{iht} is a mean zero error term. The solid blue lines in Figure 11 visualize his estimates of β_m^h (left panel) and β_a^h (right panel), which I already printed in Table 1 in the main text. The dotted blue lines show my own estimates, which employ the slightly different occupational groups as well as the additional five waves of the PSID. As can be seen, the estimates are nearly identical to Cortes (2016)'s.

The grey dotted lines show the estimates when deleting all observations from the sample who see immediate wage gains (i.e. between t to $t+1$) when leaving the routine occupation. Since the PSID went to bi-annual frequency after 1997, so that I do not observe year-on-year wage changes in the later waves, I restrict the sample to observations prior to 1997 for computing these estimates. Estimating the wage effects only on workers who see initial wage losses when leaving the routine occupations obviously lowers the average wage gains obtained from switching, but, as can be seen, even this subset of workers saw faster wage growth than the stayers. The dashed red lines show the estimates from the synthetic panel simulated from the full model of Section 4. While the initial average wage change (i.e. after year 1) is targeted in the calibration, the remaining horizons are untargeted, and still provide a relatively good fit to Cortes (2016)'s estimates. Long-run wage growth of switchers is, however, somewhat lower in the model than in the data, especially for switches to the manual occupation (see discussion in Section 4.6).

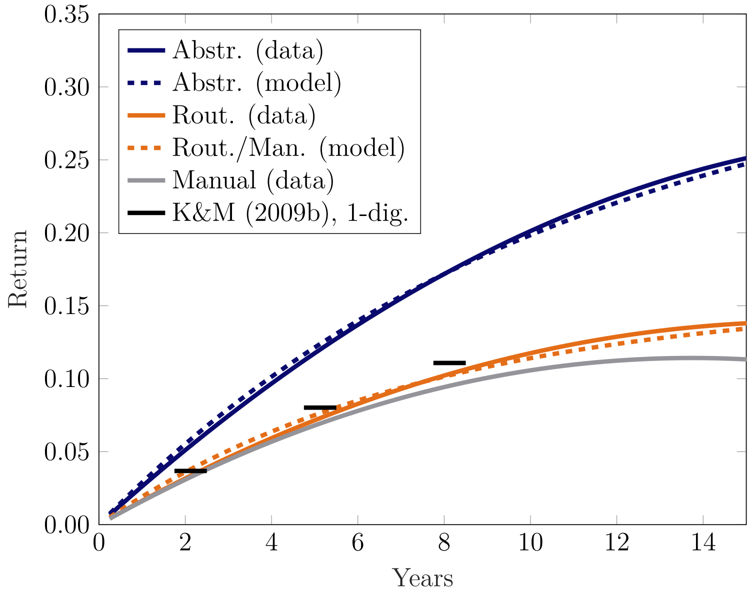


Figure 12: Returns to occupational tenure, estimated from PSID data (1981-2017).

Notes: I estimate $\mathcal{Y}_{it} = \sum_j D_{ijt}\left(\beta_{j1}Ten_{ijt} + \beta_{j2}Ten^2_{ijt} + \gamma_{ij}\right) + \delta X_{it} + u_{it}$, where $\mathcal{Y}_{it}$ is the log real wage of individual i at time t, D_{ijt} is a dummy indicating whether the individual was working in occupation $j \in \{m, r, a\}$ at time t, Ten_{ijt} is occupational tenure, γ_{ij} is an occupation fixed effect for each individual, and X_{it} are controls (unionization and marital status, region of residence, year dummies and year-occupation dummies). I then calibrate the parameters of the Poisson process in the model $(\bar{h}_j - \underline{h})$ and λ^h_j to obtain the closest fit (in a mean squared sense) to the data over the first 20 years.

C.2.3 Returns to tenure

As specified in the main text, when estimating returns to tenure in the calibration, I follow the procedure outlined in Cortes (2016, Section VI C), using years 1981 to 2017 only (see Figure 12). I only deviate from him by leaving females in the sample (as employment shares used in the calibration also relate to both males and females (Autor and Dorn, 2013)), and by only assigning a value for broad occupational tenure to individuals once I have observed them making an occupational switch. Following Kambourov and Manovskii (2009b), every time a person indicates working in a different occupational group than in her most previous report, Cortes (2016) considers the person to have made a switch and occupational tenure is reset. For individuals who are observed for the first time in the survey, Cortes (2016) constructs estimates of occupational tenure by setting it equal to the person's stated tenure at her employer or in her current position. This is of course an imperfect estimate of tenure in the broad occupation and adds significant measurement error to the variable. As I have many additional observations in comparison to Cortes (2016) because of the five more waves of the PSID that I use, I choose to limit myself to individuals whom I have observed to make a switch and for whom I can therefore construct the measure relatively cleanly.

Table 6: Switching decision, estimated with interaction terms.

	(1)	(2)	(3)	(4)
HtM=0 × wage_gain=1	0.025	0.026*	0.098	0.11*
	(0.016)	(0.016)	(0.061)	(0.062)
HtM=1 × wage_gain=0	-0.040**	-0.032	-0.17*	-0.14
	(0.020)	(0.020)	(0.087)	(0.088)
HtM=1 × wage_gain=1	-0.0025	0.0083	-0.015	0.028
	(0.017)	(0.017)	(0.066)	(0.067)
Occupational tenure	-0.014***	-0.014***	-0.083***	-0.079***
	(0.00098)	(0.00095)	(0.0072)	(0.0071)
Skill		0.090***		0.33***
		(0.012)		(0.045)
Controls	Yes	Yes	Yes	Yes
Observations	4904	4904	4904	4904
Incl. females				
Model	OLS	OLS	Probit	Probit

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

Notes: Data are from the PSID, years 1999–2017. Sample selection is as in Cortes (2016). Definition of HtM status is as in Kaplan, Violante, et al. (2014). Dependent variable is whether or not individual leaves routine for the manual occ. between t and $t + 2$. Skill is a dummy for whether the individual has received more than 12 years of education. Occ. tenure is years of uninterrupted tenure in broad occupation. Additional controls are: region dummies, age, age squared, unionization status, married status, year. Standard errors are clustered at the individual level. Columns with probit model show probit coefficient.

C.2.4 Extensions for Section 3.2.3

In Table 6 I split up the independent variable "HtM" into an interaction term between being hand-to-mouth and experiencing wage gains upon switching. Consistent with the intuition from the quantitative model it is especially those switches that entail wage losses (second row) that hand-to-mouth agents are especially likely to avoid. Note that since average marginal effects are not well-defined for levels of interaction terms, I display the coefficients of the probit model in this case.

Next, I ask whether being hand-to-mouth also predicts switches out of abstract (Table 7) and out of manual (Table 8) occupations. None of the estimated coefficients on the hand-to-mouth dummy are statistically different from zero. This is in line with the quantitative model of Section 4, in which liquid assets are an especially strong determinant of switching behavior only among routine workers.

C.2.5 Definition of being hand-to-mouth

In classifying households as either being hand-to-mouth or not I follow Kaplan, Violante, et al. (2014). For a detailed record of how they define income, liquid and illiquid wealth,

Table 7: Switching decision, exit from abstract occupations.

	(1)	(2)	(3)	(4)
HtM	0.0021	-0.0018	0.00059	-0.0033
	(0.012)	(0.012)	(0.011)	(0.011)
Occupational tenure	-0.011***	-0.0098***	-0.013***	-0.012***
	(0.00072)	(0.00072)	(0.0011)	(0.0011)
Skill		-0.11***		-0.086***
		(0.015)		(0.012)
Controls	Yes	Yes	Yes	Yes
Observations	5567	5567	5567	5567
Model	OLS	OLS	Probit	Probit

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

Notes: Data are from the PSID, years 1999–2017. Sample selection is as in Cortes (2016). Definition of HtM status is as in Kaplan, Violante, et al. (2014). Dependent variable is whether or not individual leaves abstract occ. between t and $t + 2$. Skill is a dummy for whether the individual has received more than 12 years of education. Occ. tenure is years of uninterrupted tenure in broad occupation. Additional controls are: region dummies, age, age squared, unionization status, married status, year. Standard errors are clustered at the individual level. Columns with probit model show average marginal effect.

Table 8: Switching decision, exit from manual occupations.

	(1)	(2)	(3)	(4)
HtM	0.012	0.011	0.0087	0.0082
	(0.030)	(0.030)	(0.029)	(0.029)
Occupational tenure	-0.018***	-0.018***	-0.022***	-0.022***
	(0.0031)	(0.0032)	(0.0043)	(0.0043)
Skill		-0.0044		-0.0042
		(0.029)		(0.029)
Controls	Yes	Yes	Yes	Yes
Observations	1136	1136	1136	1136
Model	OLS	OLS	Probit	Probit

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

Notes: Data are from the PSID, years 1999–2017. Sample selection is as in Cortes (2016). Definition of HtM status is as in Kaplan, Violante, et al. (2014). Dependent variable is whether or not individual leaves manual occ. between t and $t + 2$. Skill is a dummy for whether the individual has received more than 12 years of education. Occ. tenure is years of uninterrupted tenure in broad occupation. Additional controls are: region dummies, age, age squared, unionization status, married status, year. Standard errors are clustered at the individual level. Columns with probit model show average marginal effect.

see pages 122-3 in Kaplan, Violante, et al. (2014). I use information on income and wealth on determining whether a household is hand-to-mouth as they do and I detail this procedure in the next subsection.

C.3 SCF

I use waves 1989 to 2019 of the SCF and I follow Kaplan, Violante, et al. (2014) in terms of sample selection and when defining variables. In particular, I consider all households whose head is aged 22–79, and discard those who report negative labor income, and those whose only positive income stems from self-employment. I refer the reader to Kaplan, Violante, et al. (2014) for further details.

C.3.1 Definition of being hand-to-mouth

I define the liquid asset holdings of a household m_{it} as the sum of cash, money market accounts, checking/savings/call accounts, prepaid cards, directly held stocks, bonds, non-money-market mutual funds, minus revolving consumer debt. Income y_{it} collects labor earnings, regular private transfers (e.g. child support, alimony), and public transfers (e.g. unemployment benefits, food stamps, Social Security Income). Income y_{it} corresponds to bi-weekly income, as this is the most common frequency of payment in the US (Kaplan, Violante, et al., 2014).

Households are considered hand-to-mouth if and only if one of the following two conditions is true:

$$0 \leq m_{it} \leq \frac{y_{it}}{2}$$

or

$$m_{it} \leq \frac{y_{it}}{2} - \underline{m}_{it} \ ,$$

where $\underline{m}_{it}$ corresponds to a household's borrowing constraint, which, in line with Kaplan, Violante, et al. (2014)'s baseline definition, I assume to be one times monthly income.

C.3.2 Mapping of occupations

From 1989 until 2001, the SCF used the 3-digit 1980 and 1990 Census occupation codes, which were both very similar. The public-use files contain identifiers for whether the household head worked in one of six broad occupational groups. I map these six groups as closely as possible to the three groups used throughout this paper (manual, routine, abstract) using the consistent occupation-classification scheme proposed in the data appendix of Dorn (2009) (*Occ1990dd*).

Table 9 lists the assignment of SCF groups to the three broad occupational groups. While the overlap is very large and the assignment therefore unambiguous for the SCF groups 1 and 3 to 6, group 2 contains some abstract and some routine occupations (codes 203–389 of the 1980 Census classification). I therefore further look at the employment

Table 9: Mapping of SCF occupation dummies into broad occupational groups.

Broad Group	Manual	Routine	Abstract
SCF occupation dummies	3	2, 4, 5, 6	1

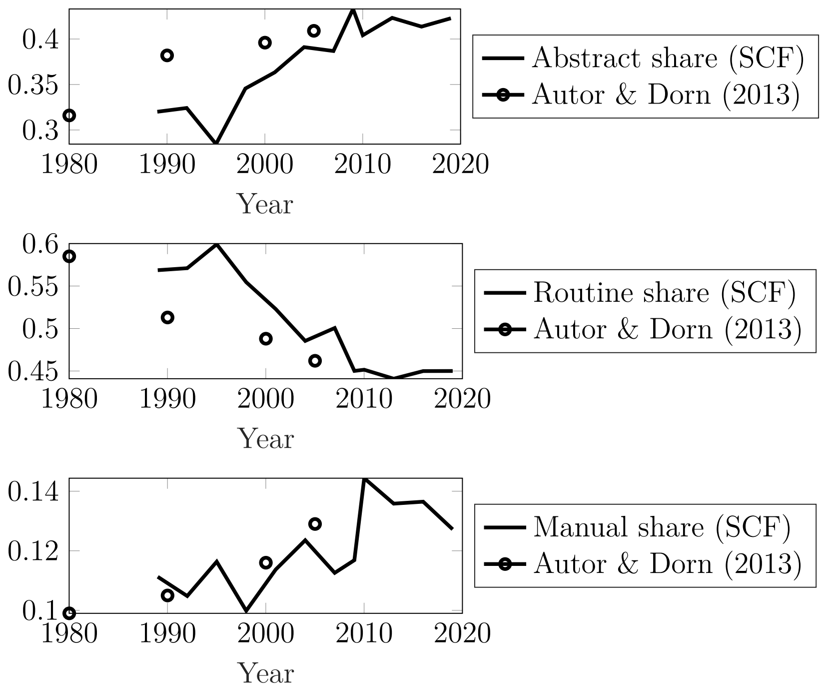


Figure 13: Employment shares in the SCF and in Autor and Dorn (2013).

shares in each of these occupations provided by Autor and Dorn (2013) for the years 1990 and 2000. A significantly smaller fraction of workers in this group was employed in abstract occupations (8-9%, codes 203–258) than in routine occupations (21–22%, codes 274–389). Hence, I classify all workers of group 2 as routine, which also explains why I slightly overestimate the routine employment share in Figure 13 in the first years.

From 2004 onward, the SCF used the 2000 and 2010 Census codes, which were very similar to each other but quite distinct from the earlier Census codes. The SCF then assigned households again into six broad groups. While the overlap between the three broad occupational groups and the six SCF groups is somewhat weaker than prior to 2004, I still find that the assignment displayed in Table 9 yields the closest mapping.

To demonstrate that my classification of occupations is close to that of Autor and Dorn (2013), Figure 13 plots the self-constructed shares of employment obtained from the SCF next to those in Autor and Dorn (2013). While I am overestimating (underestimating) slightly the share of workers employed in routine (abstract) occupations in the early 1990s, the time series are relatively closely aligned towards the early 2000s.

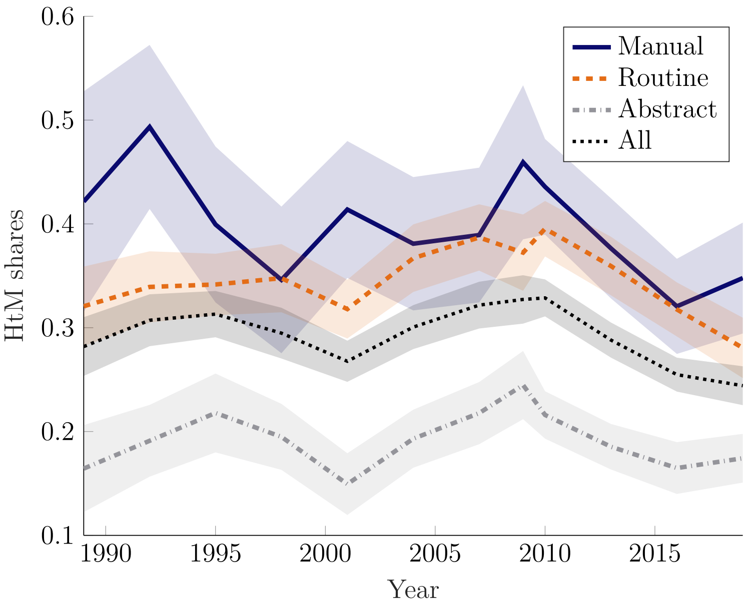


Figure 14: Hand-to-mouth shares in the three broad occupational groups.
Notes: Confidence intervals are at the 95% level. "All" refers to households whose head works in either of the three occupations, i.e. is employed.

C.3.3 Time series of hand-to-mouth shares

Figure 14 plots the shares of households that I classify as being hand-to-mouth separately for each broad occupational group as well as unconditionally for all households. Two results stand out. First, there is a clear ordering of hand-to-mouth shares by occupational group, with workers in the manual occupations most likely to be hand-to-mouth, and abstract workers least likely. This is perhaps not surprising, given that abstract workers are usually the ones earning the highest incomes, manual workers earning the lowest incomes, and routine workers in between.

Second, routine workers, while not as likely as manual workers to be hand-to-mouth, are still more likely to be so than the average US household. Across all years, the probability of routine workers to be hand-to-mouth was on average 35%, higher than the average probability across all households of 29%. At each single point in time, the two series differ by three to seven percentage points.

Figures 15 and 16 further document that the high share of hand-to-mouth households among the routine workers is driven to a large extent by the high prevalence of wealthy hand-to-mouth households among them. These are households who are by definition hand-to-mouth, but own positive illiquid wealth such as equity in houses or indirect stock holdings (Kaplan, Violante, et al., 2014). In all years between 1995 and 2016, routine workers were more likely to be wealthy hand-to-mouth than either abstract or manual workers.

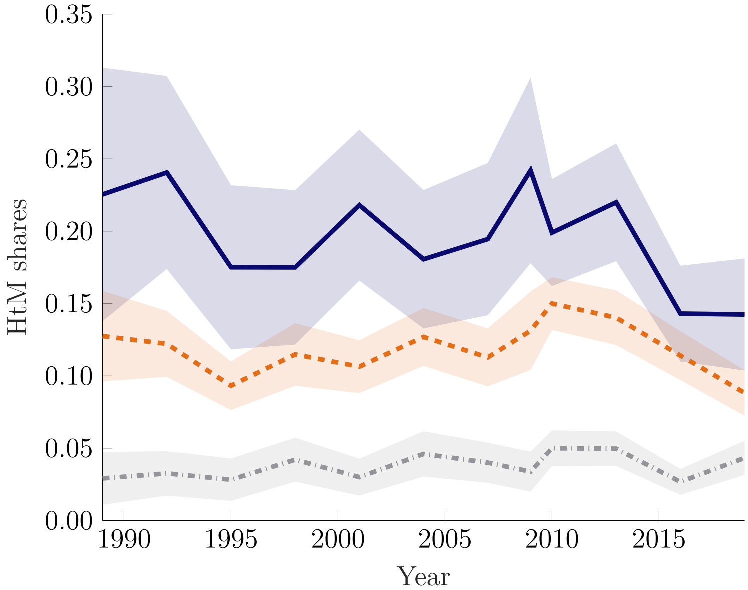


Figure 15: Poor hand-to-mouth shares in the three broad occupational groups.
Notes: Confidence intervals are at the 95% level.

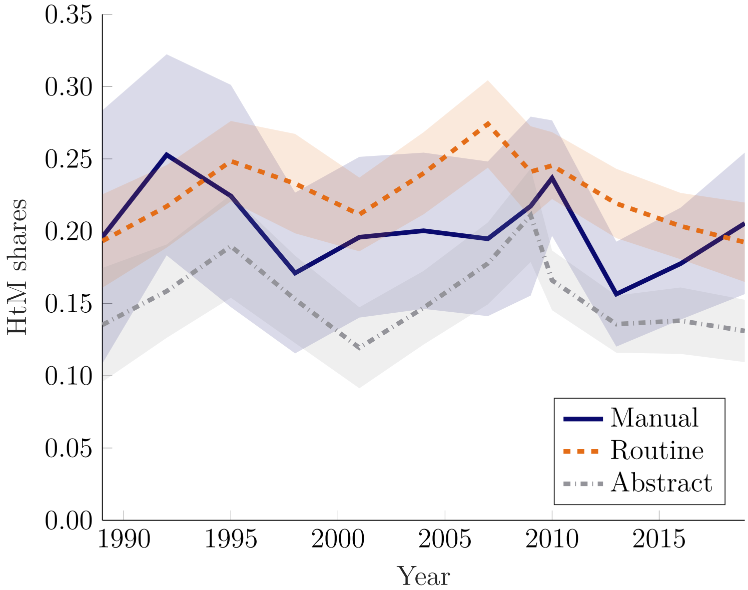


Figure 16: Wealthy hand-to-mouth shares in the three broad occupational groups.
Notes: Confidence intervals are at the 95% level.

D Details of the Full Model

D.1 FOCs of the representative firm

$$w_m = K_s^{\alpha}(1-\alpha)\tilde{Y}^{-\alpha}\mu_m\left(\frac{\tilde{Y}}{N_m}\right)^{\frac{1}{\gamma_m}} \tag{12}$$

$$w_r = \Omega(1-\mu_a)R^{\frac{\gamma_a-\gamma_r}{\gamma_a\gamma_r}}\mu_r N_r^{\frac{-1}{\gamma_r}} \tag{13}$$

$$w_a = \Omega\mu_a N_a^{\frac{-1}{\gamma_a}} \tag{14}$$

$$r_{ict} = \Omega(1-\mu_a)R^{\frac{\gamma_a-\gamma_r}{\gamma_a\gamma_r}}(1-\mu_r)K_{ict}^{\frac{-1}{\gamma_r}} \tag{15}$$

$$r_s = \alpha K_s^{\alpha-1}\tilde{Y}^{1-\alpha} \tag{16}$$

where

$$\Omega = K_s^{\alpha}(1-\alpha)\tilde{Y}^{\frac{-\alpha}{\gamma_m}}(1-\mu_m)\left(\mu_a N_a^{\frac{\gamma_a-1}{\gamma_a}} + (1-\mu_a)R^{\frac{\gamma_a-1}{\gamma_a}}\right)^{\frac{\gamma_m-\gamma_a}{(\gamma_a-1)\gamma_m}}$$

$$\tilde{Y} = \left[\mu_m N_m^{\frac{\gamma_m-1}{\gamma_m}} + (1-\mu_m)\left[\mu_a N_a^{\frac{\gamma_a-1}{\gamma_a}} + (1-\mu_a)R^{\frac{\gamma_a-1}{\gamma_a}}\right]^{\frac{\gamma_a(\gamma_m-1)}{(\gamma_a-1)\gamma_m}}\right]^{\frac{\gamma_m}{\gamma_m-1}}$$

D.2 Hamilton-Jacobi-Bellman equation

The solution to the problem of a household with state η_k is characterized by

$$\begin{aligned}
\hat{\rho}V_t(s,\eta_k,\epsilon,h,j,m,\tilde{k}) = &\max_{c,\ell,d} u(c,\ell) \\
&+V_{m,t}(s,\eta_k,\epsilon,h,j,m,\tilde{k})\left[(1-\tau)w_j\ell y + \mathbf{1}_{m<0}\kappa m + T - d - \chi(d,\tilde{k}) - c\right] \\
&+V_{\tilde{k},t}(s,\eta_k,\epsilon,h,j,m,\tilde{k})(r\tilde{k}+d) \\
&+\lambda_\eta\left[V_t(s,\eta_{-k},\epsilon,h,j,m,\tilde{k}) - V_t(s,\eta_k,\epsilon,h,j,m,\tilde{k})\right] \\
&+V_{\epsilon,t}(s,\eta_k,\epsilon,h,j,m,\tilde{k})(-\beta_\epsilon\epsilon) \\
&+\lambda_\epsilon\int_{-\infty}^{\infty}\left[V_t(s,\eta_k,x,h,j,m,\tilde{k}) - V_t(s,\eta_k,\epsilon,h,j,m,\tilde{k})\right]\phi(x)\,\mathrm{d}x \\
&+\dot{V}_t(s,\eta_k,\epsilon,h,j,m,\tilde{k}) \\
&\quad\text{such that:} \\
&\quad V_t(s,\eta_k,\epsilon,h,j,m,\tilde{k}) \geq \max_{\tilde{j}\in\{m,r,a\}} V_t(s,\eta_k,\epsilon,\underline{h},\tilde{j},m,\tilde{k})
\end{aligned}$$

and symmetrically for households with state η_{-k}. $\phi(\cdot)$ denotes the pdf of a normal distribution with standard deviation σ_ϵ. I employ the methods outlined in Achdou et al.

(2020) to solve this household problem.[51]

D.3 Computation of counterfactual densities

To compute the counterfactual densities in Section 4 I proceed as follows. I start with the distribution of households over the state space in 1980 $\Gamma_{1980}(i)$. Denote the mass of workers of skill type $\tilde{s}$ in occupation j in 1980 as follows:

$$
\begin{aligned}
g_{1980,in,j,\tilde{s}} &= \int_{i:\{h=\underline{h} \wedge s=\tilde{s}\}} \mathbf{1}_{\{j^*_{1980}(i)=j\}} \mathrm{d}\Gamma_{1980}(i) \\
g_{1980,ex,j,\tilde{s}} &= \int_{i:\{h=\bar{h}_j \wedge s=\tilde{s}\}} \mathbf{1}_{\{j^*_{1980}(i)=j\}} \mathrm{d}\Gamma_{1980}(i)
\end{aligned}
$$

where $j^*_{1980}(i)$ denotes optimal occupational choices in 1980, and in and ex in the index of the densities abbreviates "inexperienced" and "experienced", respectively.

Note that when solving for the transition path I discretize time into periods (Kaplan, Moll, et al., 2018). For each point t on the discretized time grid I compute for each skill type $\tilde{s}$ the average probability across all inexperienced households to choose a certain occupation j, and denote this probability by $p_{t,\tilde{s},j}$, i.e.

$$
p_{t,\tilde{s},j} = \frac{\int_{i:\{h=\underline{h} \wedge s=\tilde{s}\}} \mathbf{1}_{\{j^*_t=j\}} \mathrm{d}\Gamma_t(i)}{\int_{i:\{h=\underline{h} \wedge s=\tilde{s}\}} \mathrm{d}\Gamma_t(i)} \tag{17}
$$

This effectively averages over the wealth (m and $\tilde{k}$) and idiosyncratic productivity (η and ϵ) dimensions, while conditioning on human capital and skill type. Γ_t refers to the distribution at time t during the baseline transition. Similarly, for $j \in \{m, r, a\}$, I compute the average probability $x_{t,\tilde{s},j}$ that experienced households exit their current occupation j and become inexperienced households

$$
x_{t,\tilde{s},j} = \frac{\int_{i:\{j^*_{t-1}=j \wedge h=\bar{h}_j \wedge s=\tilde{s}\}} \mathbf{1}_{\{j^*_t \neq j\}} \mathrm{d}\Gamma_t(i)}{\int_{i:\{j^*_{t-1}=j \wedge h=\bar{h}_j \wedge s=\tilde{s}\}} \mathrm{d}\Gamma_t(i)} \tag{18}
$$

I then use these probabilities to iterate forward the densities of skill type $\tilde{s}$ in the following

[51] To deal with the stopping-time nature of the problem I further rely on the note "Liquid and Illiquid Assets with Fixed Adjustment Costs" by Greg Kaplan, Peter Maxted and Benjamin Moll, accessed on November 6, 2021, at https://benjaminmoll.com/wp-content/uploads/2020/06/liquid_illiquid_numerical.pdf.

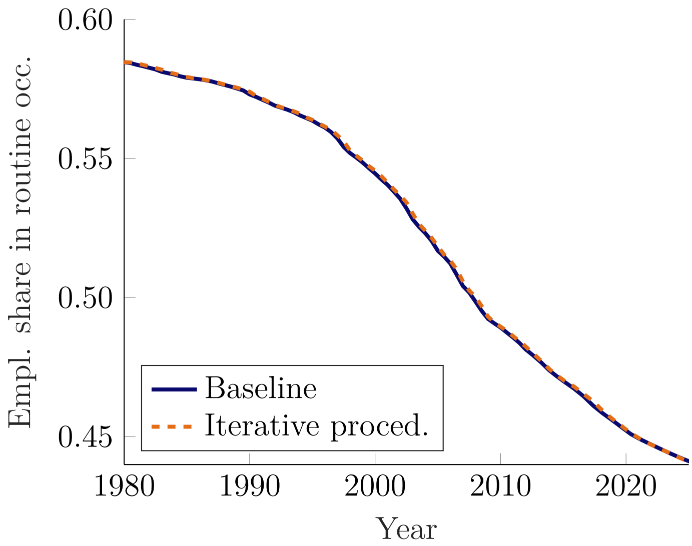


Figure 17: Employment share in the routine occupation.
Notes: Blue solid: true employment share during the transition ($\int_{i:j_t^*=r} \mathrm{d}\Gamma_t(i)$). Orange dashed: employment share constructed from iterative procedure ($\sum_s g_{t,in,r,s} + g_{t,ex,r,s}$).

way. For inexperienced households in occupation j:

$$g_{t+1,in,j,\tilde{s}} = p_{t,\tilde{s},j}\Bigg\{ \underbrace{\sum_{k\in\{m,r,a\}} \mathrm{e}^{-\lambda_h^k\cdot \mathrm{dt}} g_{t,in,k,\tilde{s}}}_{\text{inexp. HHs who do not become experienced}} + \underbrace{\sum_{k\in\{m,r,a\}} \Big[x_{t,\tilde{s},k}\Big(\mathrm{e}^{-\zeta\cdot\mathrm{dt}} g_{t,ex,k,\tilde{s}} + (1-\mathrm{e}^{-\lambda_h^k\cdot\mathrm{dt}}) g_{t,in,k,\tilde{s}}\Big)\Big]}_{\text{exp. HHs who exit their occ.}} + \underbrace{(1-\mathrm{e}^{-\zeta\cdot\mathrm{dt}}) \sum_{k\in\{m,r,a\}} g_{t,ex,k,\tilde{s}}}_{\text{dead exp. HHs}} \Bigg\} \tag{19}$$

And for experienced households in occupation j:

$$g_{t+1,ex,j,\tilde{s}} = (1-x_{t,\tilde{s},j})\Big\{\mathrm{e}^{-\zeta\cdot\mathrm{dt}} g_{t,ex,j,\tilde{s}} + (1-\mathrm{e}^{-\lambda_h^j\cdot\mathrm{dt}}) g_{t,in,j,\tilde{s}}\Big\} \tag{20}$$

The last step is to aggregate these densities across all skill types s.

Figure 17 plots both the actual mass of households in the routine occupations (i.e. using Γ_t), as well as the one obtained from the iterative procedure described here. It reveals that by using the iterative procedure I recover the actual employment share during the transition very well.

Figure 3 For this counterfactual, in which I assume that only newborns can make occupational choices, I first set all exit probabilities $x_{t,s,j} = 0$ in (19) and (20). Furthermore, only newborns can choose a new occupation, i.e. (19) becomes

$$\begin{aligned} g_{t+1,in,j,\tilde{s}} &= \mathrm{e}^{-\zeta\cdot\mathrm{d}t}\mathrm{e}^{-\lambda_h^j\cdot\mathrm{d}t}g_{t,in,j,\tilde{s}} \\ &\quad + p_{t,\tilde{s},j}(1-\mathrm{e}^{-\zeta\cdot\mathrm{d}t})\sum_{k\in\{m,r,a\}}\left[g_{t,ex,k,\tilde{s}}+\mathrm{e}^{-\lambda_h^k\cdot\mathrm{d}t}g_{t,in,k,\tilde{s}}\right] \ . \end{aligned}$$

Figure 5 To arrive at the counterfactual employment shares that use policy functions of the liquid-wealthy households only, I replace $\Gamma_t(i)$ in (17) and (18) with

$$\Gamma_t(i)\cdot\mathbf{1}_{i:\{m\geq 70.(90.)\text{ prctl.}\}} \ .$$

Given that households with high liquid assets have systematically different (i.e. higher) productivity draws than the average population, I correct for this as follows. For each t, I compute (17) and (18) for each point on the discretized grids of the two productivity processes. I then weight these probabilities according to their occurrence in the whole population (i.e. I use the invariant stationary distribution for weighting) to arrive at aggregate values for $p_{t,\tilde{s},j}$ and $x_{t,\tilde{s},j}$. I then iterate on (19) and (20) as described above.

E Policies Targeted at Switchers to Manual Occupation

In Section 6 the policies were targeted only at experienced routine workers who switched to the abstract occupation. In this section, I assume instead that experienced workers switching to the manual occupation become eligible to the loan (wage replacement).

Figure 18 plots average welfare gains from introducing the policies. Evidently, implementing the programs for switchers to manual does not increase welfare. Decomposing welfare changes as in the main text, for $L = 10,000\$$ and $R = 420\$$, reveals why this is the case. While at least in the case of the wage replacement program the partial equilibrium effect on welfare is positive (graphs not shown), the general equilibrium effects of both programs on welfare are negative.

There are several reasons for small welfare and efficiency gains when incentivizing experienced routine workers to switch to the manual occupation. First, the manual wage has risen only marginally relative to the routine wage since the 1980s, especially when one contrasts this to the rise in the abstract to routine wage. It is therefore rarely the case that foregoing their occupation-specific human capital in the routine occupation by switching to the manual occupation is optimal for experienced routine workers. Second, the calibrated occupation-specific slopes a_j in Figure 2 imply that many medium-skilled workers bear much lower wage losses when switching to the manual than when switching to the abstract occupation ($a_r - a_m < a_a - a_r$). The elasticity of the manual labor supply with respect to the routine wage is therefore much higher than that of the abstract labor

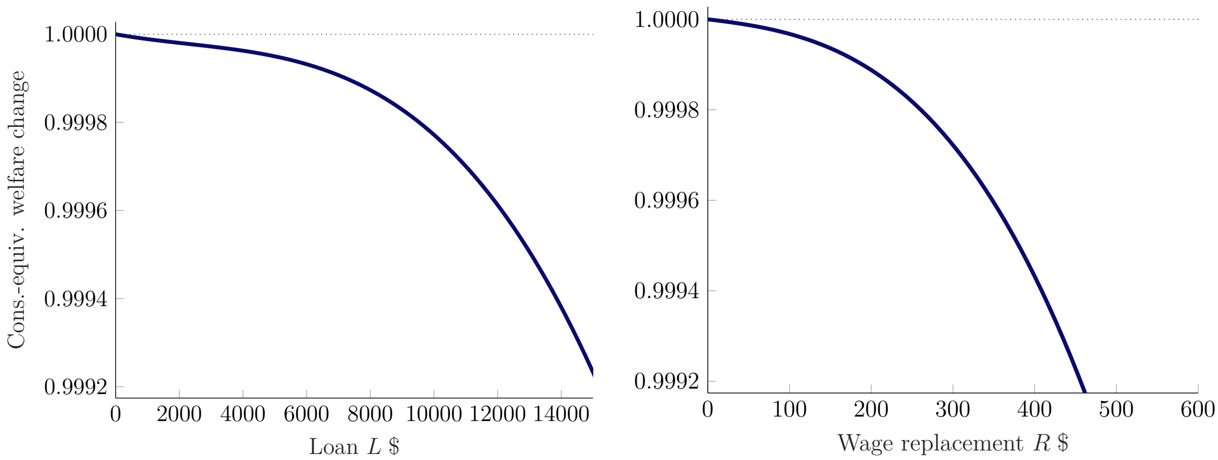


Figure 18: Average change in welfare under different policies (targeted at switchers from routine to manual) compared to the baseline.
Notes: Cons.-equiv. welfare change ϕ_t (defined in equation (8)), averaged between $t = 1980$ and $t = 2070$. Nominal quantities are expressed in 2017 US dollars.

supply.

For both of these reasons, the increase in the manual employment share, which is quantitatively small in any case, mostly runs via newborn or inexperienced households moving into manual occupations and less via experienced routine workers switching there in the baseline transition. Hence, the introduction of the policies mostly causes inefficient switching of the kind discussed in Subsection 6.2.1. Indeed, output does not increase on average under policies (graph not shown), in contrast to the case where policies where targeted at switchers to the abstract occupation.

Lastly note, however, that the model understates somewhat the overall rise in the manual relative to the routine wage over time (see discussion in Section 4.6). This biases my results against finding significant welfare effects for policies that target switchers to the manual occupation.

F Additional Graphs and Tables

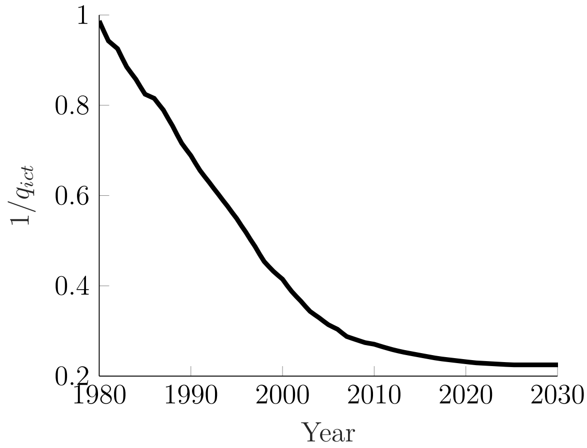


Figure 19: Relative price of ICT capital.

Notes: Data from 1980 to 2013 are taken from Eden and Gaggl (2018). I assume that $\frac{1}{q_{ict}}$ continues its fall at an average rate of 1% between 2013 and 2025, and stays constant thereafter.

Table 10: Parameters and targets for the calibration of Φ_ϵ.

Moment	Data	Model
Variance: ann. log earnings	0.70	0.70
Variance: 1-year change	0.26	0.26
Kurtosis: 1-year change	14.9	15.0
Fraction 1-year log change < 0.2	66.5%	70.2%
Fraction 1-year log change > 1.0	6.6%	6.6%

Notes: Empirical moments (Data) are taken from Guvenen et al. (2021), except for the variance of annual log earnings, which is not reported there. Instead, I use the value reported in Kaplan, Moll, et al. (2018).

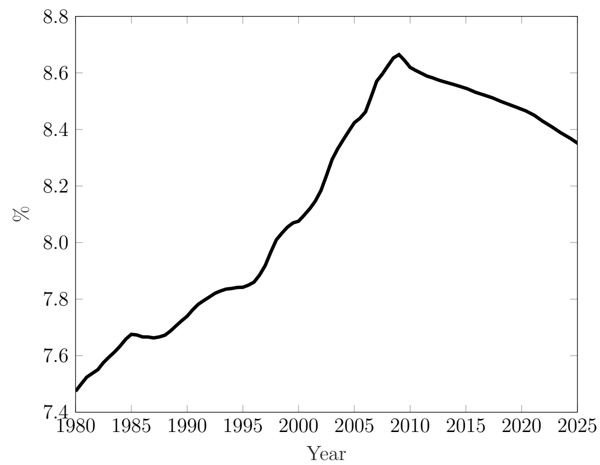


Figure 20: Model-implied (annual) interest rate r (in %).

Table 11: Hand-to-mouth shares by occupation.

	SCF (1989)			Model (init. steady state)		
	HtM	wealthy HtM	poor HtM	HtM	wealthy HtM	poor HtM
Manual	42%	20%	22%	41%	26%	15%
Routine	32%	20%	13%	34%	23%	11%
Abstract	16%	13%	3%	17%	12%	6%

Notes: Wealthy HtM are hand-to-mouth households with positive illiquid assets, poor HtM are those with zero illiquid assets.

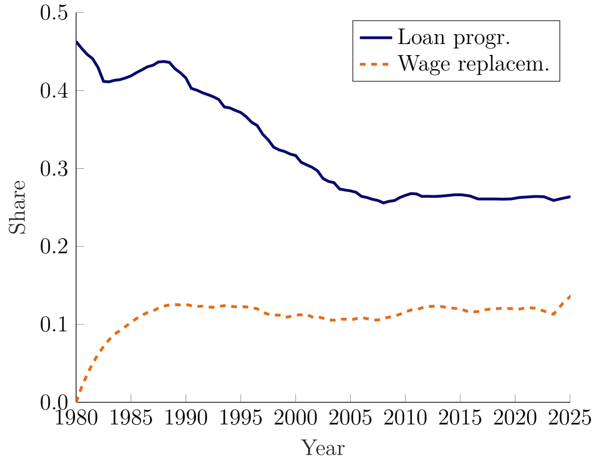


Figure 21: Share of eligible workers who work in the routine occupation under optimal programs.

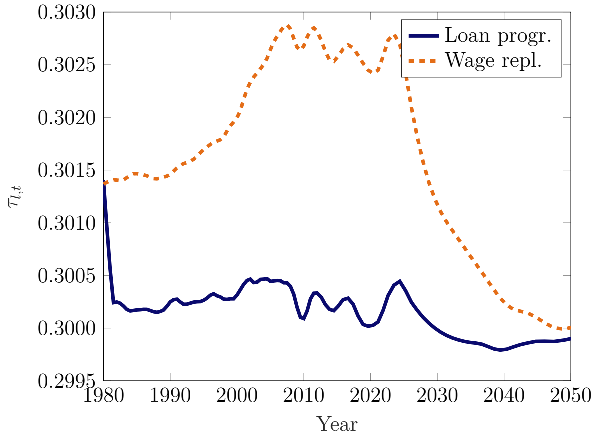


Figure 22: Labor income tax $\tau_{l,t}$ necessary to finance the policies.